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Sir John Murray K.C.B., F.R.S., Etc.

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ON THE DEPOSITS OF THE BLACK SEA.

By Sir John Murray, K.C.B., F.R.S., Etc.

Through the kindness of Professor N. Andrussow, of Juriew (Dorpat), we have received a series of the deposit-samples collected in the Black Sea during the Russian explorations in 1890 and 1891 in the steamships *Tschernomoretz*, *Zaporojetz*, and *Donetz*. We have submitted these deposits to careful microscopical examination and chemical analysis, and in this paper we propose to give the general results and detailed descriptions; but, before proceeding to do so, it will be advisable to describe briefly the general physical conditions in the Black Sea, and this involves a reference to the whole Mediterranean region.

The Mediterranean is filled with water having a very high salinity (3·85 per cent.), and the evaporation from its surface is enormous, for not only does it receive a large amount of fresh water from rivers, but it also exchanges denser water for fresher water with the North Atlantic Ocean and with the Black Sea. Dense Mediterranean water flows out at the bottom of the Straits of Gibraltar into the Atlantic, and has a great effect upon the salinity, as well as upon the temperature, of a large part of the North Atlantic basin, while fresher water flows into the Mediterranean at the surface. It has been estimated that for every 10,000 parts of Atlantic water entering the Mediterranean, 9334 parts of Mediterranean water must go out, leaving 666 for the water evaporated, and that the annual inflow of Atlantic water is equal to about 5000 cubic miles, while the annual outflow of Mediterranean water is equal to about 4667 cubic miles.[1] The mean specific gravity of the inflowing

[1] See Buchanan, "On the Distribution of Salt in the Ocean, as indicated by the specific gravity of its waters."—*Journ. Roy. Geogr. Soc.*, vol. xlvii. p. 72, 1877.

Atlantic water is about 1·027 (3·6 per cent.), and that of the outflowing Mediterranean water is about 1·029 (3·9 per cent.).

A somewhat similar interchange of waters takes place between the Mediterranean and the Black Sea, through the Dardanelles, Sea of Marmara, and the Bosphorus, the dense Mediterranean water flowing into the Black Sea as an under-current through the Bosphorus, and the fresh Black Sea water flowing out as a surface-current. These two currents, and the manner in which they are to be accounted for, have given rise to some discussion and difference of opinion.

Admiral Makaroff writes:—

"The Strait of Bosphorus joins the Black Sea and the Marmora Sea. The Black Sea water has in it—roughly speaking—half the quantity of salt found in the water of the Mediterranean. The water of the lower strata of the Marmora Sea has the same composition as the water of the Mediterranean. The upper strata, say from 10 fathoms upwards, contain water of intermediate salinity between the water of the Mediterranean and the water of the Black Sea. This difference in the salinity of the water is the chief reason of the enormous double current of the Bosphorus. Let us imagine that at a certain given moment the level of both seas is at the same height. The pressure of the column of water in the Marmora Sea will be greater than that in the Black Sea; the difference would increase with the depth, and it would disappear at the surface. For this reason the water in the lower strata of the Marmora Sea rushes into the Black Sea, keeping close to the bottom. That rush of water after a certain time will raise the level of the Black Sea, producing a difference in the level of the two seas, which causes a superficial current to flow out of the Black Sea in the opposite direction to the under-current. Here we see distinctly that the principal reason for the double current is the difference in the salinity of the water, and should that difference in salinity cease the double current would be discontinued. The fact is that in the Black Sea evaporation does not exceed the quantity of water supplied by rains and streams, and this excess of fresh water maintains the difference of salinity in the water of the Black Sea and Mediterranean. The existence of double currents in the Bosphorus was known long ago, and Marsilli in 1681, in his letter to Queen Christina of Sweden, has described them. Later, they were somehow forgotten, and some interesting papers have been published, in which the authors try to prove that the double current was legendary. Rear-Admiral Sir W. J. L. Wharton, of your Navy (who is now at the head of the Hydrographic Office), was the first to show by direct observations that a double current existed in the Bosphorus. I was there a few years after him, commanding the stationary steamer *Taman*. I began to take observations of the specific gravity of the water at different depths, and I found out that the water forming the lower strata contained twice as much salt as the water of the upper strata; after this a double current was quite evident to me. In order to measure the velocity of both currents, I invented an instrument which consists of a propeller revolving on a horizontal spindle. A bell is attached to the propeller, the tongue of which is arranged to move on an axle in one direction; at every revolution of the propeller it strikes twice, and, as water is a very good conductor of sound, the number of revolutions could be counted through the bottom of the ship (provided the ship is not sheathed with wood) at all depths to which the instrument was lowered (40 fathoms). To this instrument I gave the name of fluctometer, and I used it during the whole year, lowering it on a wire rope with ballast of eighty pounds of lead attached below. Observations were made every two hours, and the specific gravity of water from every depth was taken at the same time when the velocity of the current was observed. The lower current is similar in many details to an ordinary river, while, on the contrary, the upper current differs much from an ordinary river, probably from the reason that, while the surface of it is falling gradually down, the bottom rises constantly. The difference of level of the Black Sea and Marmora Sea, calculated from the difference in the specific gravity of the water, I found for the month of July 1882 to be 1·396 feet."[1]

Admiral Sir W. J. L. Wharton writes:—

"In *Nature* for July 13, p. 261, is given an abstract of a paper lately read by Admiral Makaroff, of the Imperial Russian Navy, before the Royal Society of Edinburgh, on the subject of double currents, *i.e.* of currents in reverse directions in different strata of water in certain straits. Admiral Makaroff gives his opinion on the causes of these reverse currents, and as they are diametrically opposed to those that I hold, I think that it may not be uninteresting to give my reasons for differing from him. Admiral Makaroff considers that difference of density of the water is the primary and, indeed I gather he thinks, the only cause of these opposing currents; but he brings no evidence beyond theoretical considerations in support of his belief. Let us consider his instance of the Bosporus. In 1872, as Admiral Makaroff very kindly mentions, I made a series of observations on the under-currents in this Strait and in the Dardanelles, and showed that when the surface-water, of a very low specific gravity, was flowing from the Black Sea to the Mediterranean, the water in the lower strata of the Straits, of a high specific gravity, was running strong in the opposite direction. But the surface-current does not always flow in this direction. It is sometimes almost still, and on occasions the movement is towards the Black Sea. The lower strata respond, and are either also still, or move in the opposite direction. It is evident that as the Mediterranean water is always of a high specific gravity, and the Black Sea surface-water always of a low specific gravity, if the difference between them is the primary cause of the opposing currents, the latter would always flow in the same direction, and that as they do not in fact behave in this manner, there must be some other force at work. My observations soon led me to conclude that this force is the wind. The prevailing wind in the summer and autumn, in which I made my observations, is from the north-east. When it blew from this direction, the surface-current ran

[1] *Proc. Roy. Soc. Edin.*, vol. xxii. pp. 393, 394, 1899; quoted in *Nature*, vol. lx. pp. 261-263, 1899.

towards the Mediterranean. When it was calm the water was in the Dardanelles, ordinarily, still, and in the Bosporus often so. When the wind came from the westward, the currents were reversed. I do not know how the deduction from these facts can be got over. I am quite ready to admit that the difference in specific gravity will cause a slow circulation in the direction in which the two currents ordinarily run, but in the face of their undoubted reversal under the circumstances which I have related, it appears to me that there can only be one conclusion. Admiral Makaroff is a close and indefatigable observer, and oceanography owes him much, but I cannot help thinking that in this instance his enthusiasm for densities has led him away. However, I shall be glad to hear reasons to the contrary, as I only desire the truth."[1]

Admiral Makaroff replied as follows:—

"In *Nature* of August 3, page 316, is given a letter from Rear-Admiral Sir William Wharton, in which he states that he is diametrically opposed to my opinion about the double currents in the straits. He says that 'Admiral Makaroff considers that difference of density of the water is the primary and, indeed I gather he thinks, the only cause of these opposing currents; but he brings no evidence beyond theoretical considerations in support of his belief'; further, in his letter, Admiral Wharton refers particularly to the double current of the Bosporus, of which I spoke in my lecture at the Royal Society of Edinburgh. I cannot leave unnoticed remarks from so distinguished a hydrographer, who, during his long work, has contributed so much to the advance of science. My researches about the Bosporus are published only in Russian, in a book named *On Exchange of Water between Black Sea and Mediterranean* (St. Petersburg, 1885). Should Admiral Wharton know my language, he would easily come to the conclusion that my opinion about double currents in the Bosporus is based upon the observations made in 1881 and 1882. I then invented an instrument for measuring the current at different depths [already described]. I am sorry that the limits of this paper do not allow me to give particulars of my observations, but I believe some of my deductions, worked out from direct observations, would be interesting to English readers. Mean velocity of the upper current, $3\frac{1}{4}$ feet per second. It varies from 0 to 10 feet per second in certain places. Velocity of the upper current diminishes with every fathom of depth. Limit between two currents close to the Marmora Sea is at 11 fathoms. It gradually goes down to 27 fathoms close to the Black Sea. Limit between two currents is influenced by winds and by barometrical pressure, but not very much. Lower current has close resemblance with the river. Its velocity does not vary very much. We never found anywhere lower current less than 1·84 and more than 3·22 feet per second. Mean velocity of the under current was 2·32. The upper current does not everywhere occupy the full breadth of the strait. It flows in some places under the north coast of the strait, and in other places under the south coast. Lower current also does not flow over the whole breadth, and occupies a certain part of

[1] *Nature*, vol. lx. p. 316.

the bed of the strait. In my book I give a chart of the Bosporus, where I show direction of the upper and lower currents. A glance at that chart will show that there are places where both currents can be found, and there are places where the instrument will show the existence of only one of them, and in some places the explorer will not find either upper direct current or under current. Mean specific gravity of water entering from the Black Sea into the Bosporus is 1·0140. Mean specific gravity of water entering from the Marmora into the Bosporus is 1·0283. By upper current pass 370,000 cubic feet per second. By lower current pass 200,000 feet per second. Difference between these two figures being 170,000 feet per second is due to the excess of fresh water in the Black Sea. I hope that after reading these figures and deductions Admiral Wharton will change his opinion, and come to the conclusion that my idea about double current in the Bosporus is based, not only on theoretical considerations, but also upon direct measurement. Nobody can deny that the wind has a great influence upon the movement of surface water; but I hope that Admiral Wharton will agree with me that differences of specific gravity have also some influence upon the circulation of water in the seas generally and in the straits particularly."[1]

E. von. Maydell,[2] in discussing this question, says the upper current is caused by the difference between the levels of the two seas, which, though not established by direct measurement, is inferred to exist in consequence of the difference between the densities of the two masses of water. Since the Black Sea receives annually from the large rivers which flow into it a greater quantity of water than is evaporated during the course of the year, it results that there is an absolute augmentation in its mass, causing a difference between its level and that of the Sea of Marmara, and so giving rise to the surface current. The under current is originated as a consequence of the difference in pressure—the more saline and heavier waters of the Sea of Marmara exercising, in comparison with the waters of the Black Sea, a greater pressure, bulk for bulk, than those of the Black Sea.

In the paper referred to, von Maydell also discusses the variations in the level of the Black Sea, based upon observations made at eight stations on the north and east coasts, spread over a period of eight to ten years. He concludes that there is not only a series of regular annual fluctuations, but also variations of a somewhat more permanent character, making themselves felt at irregular intervals, which last stand in intimate relation to the variations in the amount of precipitation in the countries drained by the river-feeders of the sea. As regards the regular annual fluctuations, the maximum is attained in the middle of May at the mouths of the great rivers, and in June at other places. The maximum rise is equal to from 3½ to nearly 7 inches above the mean level of the year, which is observed in July and August. There are two minimum levels

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1 *Nature*, vol. lx. pp. 544, 545.

2 *Ann. d. Hydrographie u. marit. Meteorologie*, 1886, Theil. xii. (summarised in *Scott. Geogr. Mag.*, vol. iii. p. 77. 1887).

in the year, in October and in February, when the surface falls from $2\frac{1}{2}$ to 4 inches below the mean annual level, separated by a secondary maximum in December, which, however, fails to reach the mean of the year. In the case of the greater non-periodical fluctuations, it seems that from 1874 to 1879 the surface rose permanently to the extent of $7\frac{1}{2}$ to over 14 inches. In 1880 it sank, rising again in 1881, and falling again in 1882. In 1878 a small secondary minimum was observed at the mouths of the Dniester and Dnieper, and in the Sea of Azov and the Straits of Kertch. These fluctuations correspond exactly with the fluctuations in the amount of precipitation on the drainage-basins of the Russian rivers, a heavy precipitation being followed by a rise in the level of the Black Sea, and a light precipitation by a sinking of its level.

It will thus be seen that the physical and biological conditions in the Black Sea are most peculiar, a large body of dense water being introduced into the deeper parts of the sea, and remaining there in an almost stagnant condition, the vertical circulation being limited to the upper strata of comparatively fresh water. The result is that life, except perhaps in its lowest forms, is entirely absent throughout the greater depths, where there is an abundant formation of sulphuretted hydrogen, and, in the deposits on the floor of the Black Sea, chemical precipitations of calcium carbonate and of sulphide of iron take place. Several papers[1] have been published, mostly in Russian, dealing with the results of the Russian investigations, and it will be interesting here to collect the information as to the temperature and salinity of the water, and to give the views expressed regarding the past condition of the Black Sea.

Generally speaking, the Black Sea forms a basin with steep sides and flat bottom, attaining a maximum depth of 1227 fathoms in the centre of the basin where the coasts of Asia Minor and the Crimea approach each other. Below the 100-fathoms line the slopes are generally steep, the most rapid descent being usually found between 700 and 800 fathoms, beyond which, down to the greatest depths, the slopes become very gentle. The 100-fathoms line is found at a con-

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[1] Spindler and Wrangel, *Résumé des observations hydrologiques faites dans la mer Noire et la mer d'Azof pendant les expeditions de* 1890 *et* 1891. St. Petersburg, 1899.

Skalovsky, "Des conditions physico-géographiques du bassin de la Mer Noire sous l'influence du Bosphore" (in Russian, title only in French): *Mém. Soc. Technique Imp. Russ. à Sébastopol.* St. Petersburg, 1897.

Collection of hydro-meteorological observations in various seas, including the Black Sea and Sea of Azov in 1897 *and* 1898 (in Russian). St. Petersburg, 1900.

Andrussow, three papers in Russian published by the Imp. Russ. Geogr. Soc., St. Petersburg, tom. xxvi. and xxviii.: "On the necessity for deep-sea investigations in the Black Sea"; "Preliminary account of deep-sea soundings in the Black Sea, 1890"; "Some results of the Tschernomoretz Expedition: on the origin of sulphuretted hydrogen in the waters of the Black Sea."

Andrussow, "Einige Resultate der Tiefseeuntersuchungen im Schwarzen Meere": *Mittheil. d. k.k. geogr. Ges.*, 1893, p. 373.

Andrussow, "La mer noire": papers of the International Geological Congress, St. Petersburg, 1897.

Marmora Sea: Expedition of the Imp. Russ. Geogr. Society in 1894, containing papers by Spindler, Andrussow, and Ostroumow, with *résumé* of the hydrological researches (in French) by Spindler, St. Petersburg, published by the Society (tom. xxxiii. No. 2), 1896.

siderable distance from the coast opposite the Straits of Kertch, and in the north-western part of the sea, where the rivers pour out large quantities of fresh water charged with sediment, the Danube being the most important in this respect.

The waters of the Black Sea cover an area of about 119,000 square geographical miles (or, according to Andrussow, 360,850 square kilometres), and the area of land draining into it is about 692,000 square geographical miles, or together 811,000 square geographical miles. The contour-lines of depth (as shown in the accompanying map), based upon the latest information available, were transferred to an equal-surface projection map, and the intervals between the contour-lines were measured by the planimeter, with the following results:—

0 to 100 fathoms,	41,000	sq. g. m. or	35	per cent.
100 „ 500 „	11,000	„	9	„
500 „ 1000 „	23,000	„	19	„
1000 „ 1200 „	38,000	„	32	„
over 1200 „	6,000	„	5	„
	119,000	„	100	„

From these figures we have calculated the cubic mass of water contained in the Black Sea and Sea of Azov to be about 108,000 cubic miles, and the mean depth works out at about 600 fathoms (3599 feet).[1]

The Russian observations in the Black Sea were made in 1890 from 27th June to 23rd July, and in 1891 from 17th May to 11th June, and again from 4th to 27th August, so that by combining the results obtained in the two years we may form a good idea of the physical conditions during the summer season.

Temperature.—The temperature observations show that in summer the temperature falls rapidly from the surface of the sea down to a certain depth, which varies from 25 to 50 fathoms; the minimum temperature is generally found nearer the surface in the central parts of the sea than near the coasts or on the submarine slopes. Below this layer of minimum temperature, the temperature increases very slowly. At a depth of 100 fathoms the mean temperature is 47·7° F., the maximum being 48·2° and the minimum 46·2° F. At a depth of 200 fathoms the mean temperature is 48° F., the variations not exceeding 0·5° F. At still greater depths the temperature is nearly uniform at 48·2° F., with a maximum of 48·7° observed at 1100 to 1200 fathoms in the western basin of the sea.

We have prepared the accompanying diagram, showing the distribution of temperature in the waters of the Black Sea, from the observations made in the month of July 1890, and we give in the following table the observations upon which the diagram is based, the Stations being arranged in geographical order from west to east:—

[1] In 1887 we estimated the mean depth of the Black Sea and Sea of Azov at 412 fathoms (*Scott. Geogr. Mag.*, vol. iv. p. 32), but since then deeper soundings have been taken. The Russians have computed the mean depth of the Black Sea at 654 fathoms (1197 metres).

SERIAL TEMPERATURE OBSERVATIONS taken by ss. *Tschernomoretz* in the Black Sea in the month of July 1890 (shown graphically in the accompanying diagram).

The longitudes are referred to St. Petersburg.

Depth in Fathoms.	No. 49, July 21, 1890 43° 17′ N., 1° 15′ W. 47 fathoms.	No. 50, July 21, 1890. 43° 32′ N., 0° 45′ W. 47 fathoms.	No. 47, July 20, 1890. 43° 51′ N., 0° 16′ E. 501 fathoms.	No. 46, July 20, 1890. 43° 53′ N., 0° 58′ E. 748 fathoms.	No. 45, July 20, 1890. 44° 15′ N., 1° 58′ E. 817 fathoms.	No. 44, July 16, 1890. 43° 57′ N., 3° 36′ E. 1177 fathoms.	No. 25, July 10, 1890. 43° 37′ N., 4° 19′ E. 1226 fathoms.	No. 26, July 10, 1890. 43° 14′ N., 5° 12′ E. 1219 fathoms.	No. 27, July 10, 1890. 43° 15′ N., 5° 59′ E. 1203 fathoms.	No. 28, July 11, 1890. 43° 10′ N., 7° 43′ E. 1178 fathoms.	No. 29, July 11, 1890. 43° 12′ N., 8° 32′ E. 1157 fathoms.	No. 30, July 11, 1890. 43° 12′ N., 9° 6′ E. 1009 fathoms.	No. 31, July 11, 1890. 43° 11′ N., 9° 40′ E. 650 fathoms.
	F.°	F.°	F.°	F.°	F.°	F.°	F.°	F.°	F.°	F.°	F.°	F.°	F.°
0	75·7	78·6	76·8	76·1	73·9	73·2	71·4	72·3	73·6	74·3	76·1	76·3	75·9
2	...	...	...	...	...	...	...	...	...	...	...	76·1	...
4	...	...	...	...	...	...	...	...	...	...	...	75·9	...
5	72·3	71·6	71·8	73·6	72·1	71·8	71·4	72·0	73·6	73·6	75·9	64·4	65·7
6	...	...	...	...	...	...	...	...	...	...	...	57·2	...
7	...	...	...	...	...	...	...	...	...	...	...	...	58·6
8	...	...	...	...	...	...	...	...	...	...	...	51·1	...
10	63·7	63·3	65·3	65·7	60·1	60·1	64·6	48·9	53·4	57·2	53·6	49·3	51·3
12	...	...	...	...	...	...	59·0	47·5	51·4	...	48·7	48·2	50·0
15	53·4	51·1	49·8	57·2	48·7	49·6	50·7	46·0	48·4	51·4	46·6	46·8	47·5
17	...	...	...	...	...	...	...	...	...	...	...	...	46·4
20	47·3	47·8	...	48·9	46·6	47·7	48·6	44·6	46·2	48·4	45·3	45·3	45·1
25	46·0	45·1	44·6	45·3	45·3	45·9	45·9	44·1	45·7	45·7	44·2	44·4	44·2
30	45·3	44·1	45·3	44·8	44·6	44·8	45·0	44·4	46·2	44·4	...	44·1	44·1
35	44·6	44·4	46·2	44·4	44·6	45·0	44·8	...	46·6	44·2	45·1	...	43·9
40	44·6	45·3	46·6	43·9	45·7	...	46·2	...	...	...	...	...	43·7
45	45·7	46·4	46·6	44·1	46·0	...	...	...	...	...	...	...	...
50	...	...	46·8	44·8	46·4	46·0	46·9	46·6	46·9	46·0	46·4	46·2	44·4
60	...	...	...	46·4	47·3	...	47·3	46·9	...	...	...	...	...
65	...	...	...	46·4	47·3	...	...	...	...	...	...	...	...
70	...	...	47·8	46·8	47·5	...	...	...	...	...	...	...	...
75	...	...	...	...	...	...	...	...	...	...	...	47·7	...
80	...	...	...	46·9	...	...	...	...	...	...	...	...	...
95	...	...	...	...	...	...	...	...	48·2	...	...	...	...
100	...	...	47·8	47·7	47·7	47·7	47·7	47·7	48·2	48·0	48·2	48·2	47·7
175	...	...	...	...	...	...	48·0	...	...	...	...	...	...
200	...	...	48·0	48·0	48·0	47·8	48·2	48·0	48·2	48·2	48·2	48·2	48·2
300	...	...	...	...	...	...	...	48·2	...	...	48·2	...	...
400	...	...	...	...	...	...	...	...	...	...	...	48·2	...
600	...	...	...	48·2	...	...	...	...	...	...	...	...	...

An examination of this table and diagram shows that during the summer season a stratum of colder water is sandwiched between warmer water above and below. This stratum is covered by a very thin layer of warm water, while the temperature of the underlying water increases very slowly down to the bottom. This peculiar thermal distribution is due to the influence of the under-current from the Bosphorus, which furnishes the deeper parts of the Black Sea with water of a higher salinity than that of the water cooled in winter at its surface.

The temperature of the surface-water was found to increase from 55·4° F. in May to 78·8° F. in August. Abrupt changes of temperature were sometimes observed near the coasts, but there was no evidence of any diurnal march of temperature in the open sea. On proceeding from the open sea towards the coasts the temperature was usually observed to rise, which seems to prove that in summer the re-heating of the water takes place principally in the shallow waters, and through the influence of the fresh water derived from the land.

Salinity.—The mean salinity of the surface-waters in the central parts of the sea was 1·83 per cent.; in August 1891 it was a little higher (1·85 per cent.) than in July 1890. Opposite the mouths of the rivers, notably of the Danube, the water is not so salt, and this is especially the case at the commencement of summer: in these positions the salinity increases rapidly from the surface to a depth of 15 fathoms, but in the open sea the salinity of this superficial layer varies very little. At a depth of 15 fathoms the maximum salinity (1·85 per cent.) was observed in the middle of the sea, and the minimum (1·78 per cent.) in the north-west part of the basin. At 25 fathoms the mean salinity was 1·83 per cent., but the maximum rises to 1·9 per cent. (in the middle of the sea), the minimum being 1·79 per cent. (in the north-west angle of the sea); thus the range is greater at 25 fathoms than at 15 fathoms. At 50 fathoms the mean of thirty-three observations taken in May and June 1891 was 1·97 per cent., the mean of thirty-nine observations taken in July 1890 was 2·03 per cent., and the mean of thirty-three observations taken in August 1891 was also 2·03 per cent.; the maximum was 2·08 per cent. in the centre of the sea, with a minimum of 1·85 per cent. near the coasts of the Crimea and Asia Minor, falling to 1·81 per cent. near Novorossiisk in the north-eastern part of the sea. At 100 fathoms the salinity in the central parts ranged from 2·14 to 2·16 per cent.; near the coasts and on the submarine slopes it was less, falling in some places to 2·06 per cent. At 200 fathoms the salinity varied from 2·19 to 2·21 per cent. in the deep parts of the sea, while at certain stations near the coasts, and especially opposite the Straits of Kertch, it was lower. At greater depths, from 400 to 1100 fathoms, the salinity varied only from 2·23 to 2·25 per cent, so that it may be said to be practically uniform at these depths.

The observations taken in the vicinity of the Bosphorus show that the salinity of the surface-water varied from 1·7 to 1·82 per cent., while at 25 fathoms the limits were 1·81 and 1·83 per cent., although the observations were made in different months and in different years. At the bottom in this locality, on the contrary, the salinity was very variable, depending evidently on the proximity of the wedge of salt water forming the submarine current from the Bosphorus, which appears to follow the submarine valleys leading from the bottom of the Bosphorus to the greater depths of the Black Sea. This is corroborated by the observations made at one station situated five miles from the Strait, and seven and a half miles from the place where the 100-fathoms line approaches nearest to the Bosphorus. Here during the half-hour occupied in taking the observations the ship drifted under the influence of wind and current from 29 fathoms into 45 fathoms of water; at 29 fathoms the salinity near the bottom was 2·04 per cent., at 35 fathoms 2·41 per cent., and at 38 fathoms 3·38 per cent.—the highest salinity recorded in the Black Sea, and almost identical with that found by Admiral Makaroff in the undercurrent near Bujuk-Dere. Probably the under-current, on leaving the Strait for the open sea, is divided into several branches, forming a kind of submarine delta, its salt waters being mixed very slowly with the surrounding fresh water. All the observations obtained in the summers of 1890 and 1891 indicated that the velocity and thickness of the submarine current were not very great; probably its mass and its velocity are more considerable in winter than in summer, especially after a spell of west winds, and that it maintains longer its velocity and level, losing itself gradually in the circumambient water, the temperature and salinity of which it raises.

Temperature and Salinity of the Sea of Marmara.—A brief summary of the results obtained by the Russian exploration of the Sea of Marmara in 1894 will not be out of place here, since no account of the Black Sea can be complete without reference to this "go-between" connecting the Black Sea and the Mediterranean. We have extracted the following particulars from the report published by the Imperial Russian Geographical Society of St. Petersburg in 1896.[1]

The bottom of the Sea of Marmara is more diversified than that of the Black Sea, presenting three hollows or basins attaining depths exceeding 600 fathoms, of which two are found in the western part of the sea, separated by a submarine elevation covered by 300 to 400 fathoms of water, the maximum depth in the one being 630 fathoms, and in the other 688 fathoms; while the third depression is situated in the eastern part of the sea, and exceeds 700 fathoms in depth, the maximum depth being 767 fathoms—the greatest depth observed in the sea. The mean depth of the Sea of Marmara has been calculated by the Russians at 158 fathoms (289 metres).

The mean temperature of the surface-waters during the period of observation (19th September to 20th October) was 67·1° F. (19·48° C.), while the salinity was found to increase in going from the Bosphorus to the Dardanelles. The freshest water is that bathing the vicinity of the Bosphorus: this must, without doubt, be attributed to the influence of the surface-current coming from the Black Sea, which after leaving the Bosphorus is split up, one branch flowing towards the northern coasts, the central branch being directed almost in a straight line from the Bosphorus

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[1] See last item in footnote, p. 678.

to Kalelimno Island, sending on the way a branch towards the Gulf of Ismid.

The vertical distribution of temperature and of salinity is extremely interesting. In general the temperature from the surface down to a depth of 6 fathoms remains almost uniform, but between 8 and 10 fathoms a rapid fall is observed equal to 0·9° to 1·1° F. per fathom; below this depth the lowering of the temperature becomes less and less pronounced down to 100 to 120 fathoms, whence down to the bottom the temperature remains uniform at 57·6° F. (14·2° C.). At the same time the salinity increases in an inverse manner: from the surface down to a depth of 6 fathoms the salinity increases slowly, about 0·02 per cent. per fathom, then it increases rapidly down to 14 fathoms, the mean increase being equal to about 0·14 per cent. per fathom; in deeper water the increase becomes less and less, so that between 25 and 100 fathoms the augmentation amounts to only 0·08 per cent. in all, and below 100 fathoms the salinity varies only from 3·83 to 3·85 per cent. There is thus, generally speaking, a perfect correspondence in the distribution of the thermic and saline layers; the zone of thermic fall is at the same time the zone of rapid augmentation in the salinity, and the layer of constant temperature coincides with the layer of nearly constant salinity. In fact, the waters of the Sea of Marmara may be looked upon as being stratified in a vertical direction, as regards temperature and salinity, into four zones:—

1. The zone from the surface to 6 fathoms with a mean salinity of 2·46 per cent., deviation ± 0·034 per cent., and a mean temperature of 67·3° F. (19·6° C.), deviation ± 0·05° F.

2. The zone of thermic fall and of rapid saline increase (from 6 to 14 fathoms), with a mean salinity of 3·12 per cent., deviation ± 0·352 per cent., and a mean temperature of 65° F. (18·3° C.), deviation ± 1·3° F.

3. The intermediate zone of slow decrease of temperature and slow increase of salinity (from 14 down to from 120 to 200 fathoms), with a mean salinity of 3·81 per cent. and a mean temperature of 59·5° F. (15·3° C.).

4. The zone of constant temperature (57·6° F.) and nearly uniform salinity (3·84 per cent.).

The thermic character of these zones, except that of constant temperature, depends generally on the annual changes in solar radiation, and may consequently vary in different seasons, but the modifications operating on the salinity of the water during the year, due to evaporation and the increase of fresh water received by the sea, are very insignificant and are only felt in the superficial layers.

Chemical Conditions.—There is a great difference between the chemical composition of the surface-waters and of those at the bottom of the Black Sea. According to Admiral Makaroff's observations the quantity of water introduced annually by the under-current from the Bosphorus is only $\frac{1}{2500}$ * of the volume of the Black Sea; so that, while the surface-waters are renewed each year, the water of the deeper layers can only be renewed once in 2500 years, or even longer. The consequence

* According to Andrussow $\frac{1}{1700}$.

is that the upper layers, down to about 125 fathoms, are normal in character, containing the usual quantity of dissolved air—a quantity sufficient to sustain organic life, but the oxygen of the deeper, denser layers can only be renewed by diffusion and the submarine current coming from the Bosphorus, therefore much too slowly for the maintenance of organic life. In general, the sum-total of atmospheric gases diminishes with the depth; at the same time sulphuretted hydrogen is formed, being observed first at a depth of 100 fathoms (33 c.c. per litre), and augmenting gradually with increase of depth (222 c.c. per litre at 200 fathoms, 555 c.c. at 950 fathoms, and 655 c.c. at 1185 fathoms). Similarly sulphides appear and augment in quantity in ratio to the depth.

According to the researches of Zelinsky and Broussilovsky, the formation of hydro-sulphuric acid in the depths of the Black Sea is due to the activity of microbes. They have found several species, but only one has been studied (*Bacterium hydrosulfuricum ponticum*), which in anaërobic conditions sets free sulphuretted hydrogen not only from albuminous matters, but also directly from the sulphates and sulphides. A small quantity of cellulose and albumen, although not indispensable to the vital activity of these bacteria, contributes to their more rapid development. In consequence the writers are of opinion that the whole of the sulphuretted hydrogen in the Black Sea arises from the sulphates, but Andrussow thinks that part of it is due to organic matter. The superficial waters swarm with organisms (plankton), whose remains fall in a constant rain towards the bottom. In depths less than 100 fathoms these remains may be absorbed by other pelagic organisms, but beyond that depth they reach a domain devoid of life (except microbes). The organic matter reaching the bottom does not serve to aliment any benthonic organisms, as is usually the case in other seas and in the ocean, but accumulates and nourishes the bacteria, which form from the sulphur compounds sulphuretted hydrogen, and, seeing the deficiency of oxygen in the water, take from the sulphates what in turn produces sulphides and sulphuretted hydrogen:—

$$RSO_4 + 2C = 2CO_2 + RS\ ;\ RS + CO_2 + H_2O = H_2S + RCO_3.$$

The sulphuretted hydrogen thus formed is partially combined with the salts of iron (hence the abundance of sulphide of iron in the depths of the Black Sea), and only a part of it penetrates into the water and is thus distributed, its conservation being due in part to the intensity of the process, and especially to the poverty in oxygen of the deeper waters. In penetrating into the upper layers, and approaching the limit of vertical circulation, the sulphuretted hydrogen commences to oxidise and is gradually decomposed. Egounow supposes that this oxidation of sulphuretted hydrogen, observed very often in nature, is due also to sulpho-bacteria: if so, we may expect to find at a depth of 100 to 125 fathoms in the Black Sea an enormous layer of sulpho-bacteria.

Beside the formation of sulphide of iron, the hydro-sulphuric fermentation in the Black Sea leads to other chemical modifications in the water and in the deposits, viz. a relative diminution of the sulphates, and an augmentation of the quantity of carbonates, in the deeper waters, which is corroborated by the fact of the deposition of a powdery precipitation of carbonate of lime in the deep deposits.

Fauna.—The marine fauna of the Black Sea properly so-called, *i.e.* the fauna of the denser waters of the inhabited regions of the sea, consists of forms derived from the Mediterranean through the Sea of Marmara and the Bosphorus. Only those eurybiotic forms capable of supporting life in water with a much lower salinity could penetrate from the Mediterranean into the Black Sea; hence the fauna of the Black Sea is not so rich as that of the Mediterranean: several classes of organisms (*e.g.* Corals, Siphonophoræ, Echinoids, Pteropods, Cephalopods) are entirely absent, while others are poorly represented (only a single Ctenophore, one little Holothurian, and two very small Ophiurids are known from the Black Sea). The thermic conditions of the Black Sea (its more rigorous temperature, the presence at a moderate depth of a layer of cold water) are also obstacles to the penetration of organisms, permitting the establishment of only eurythermic and oligothermic forms. Hence the preservation of relics of the glacial epoch, which were able to enter the Black Sea by way of the Mediterranean; with the arrival of a warmer climate they have disappeared from, or become rare in, the Mediterranean, but, finding in the Black Sea more favourable conditions of life, some of them have there developed wonderfully. Such an example is *Modiola phaseolina*, a common shell on the shores of England, found also in the Mediterranean; but, while in the Sea of Marmara isolated examples are met with, masked by the mass of other shells, in the Black Sea it attains a very rich development, giving a special *Modiola* facies to the fauna all round the sea in depths of 35 to 100 fathoms. Over all this extent the bottom is muddy, and covered, besides an immense quantity of *M. phaseolina*, by numerous shells of other species (*Cardium fasciatum, Mactra triangula, Scrobicularia alba, Cerithium pusillum, Trophon breviatum*), peopled by simple Ascidians, little Ophiurids, a small *Synapta*, Annelids with muddy tubes, *Cerianthus vestitus*, etc.

Below this zone of *Modiola*-mud, which is very constant because of the constancy in the physico-geographical conditions, comes the hydro-sulphuric region—the domain of hydro-sulphuric bacteria—separated perhaps from the *Modiola*-zone by a zone of sulpho-bacteria. In shallower water, between the shore and the 25-fathoms line, there is a greater differentiation of the facies, corresponding to the different physical conditions. Unfortunately the observations are too few in number to indicate the exact character of the subdivisions and the facies of the littoral and shallow-water fauna of the Black Sea, which is influenced by the oscillations in the salinity of the water, as well as by the depth and character of the bottom. Thus the littoral fauna is richer on the coasts of Caucasia and the Crimea, where the salinity is higher, than on the coasts near Odessa and in the Sea of Azov, where the salinity is lower. This is well shown by the following table prepared by Ostroumow, in which the number of species of Molluscs belonging to the different basins is expressed in percentages, the number of species known from the Archipelago being taken as 100 :—

The Archipelago,	100 per cent.
The Sea of Marmara, at the entrance into the Bosphorus,	58·5 „
The upper Bosphorus,	36·8 „
The Black Sea,	22·2 „
The lower part of the Sea of Azov,	6·3 „
The middle part of the Sea of Azov,	3·6 „

At the mouths of the rivers, which in Southern Russia are known by the name of "limans," the elements derived from the Mediterranean become less numerous, giving place to forms identical with those of the Caspian Sea or to forms peculiar to the "limans." These forms may be regarded as relics of the brackish-water fauna of the Black Sea of the pliocene period. As examples of forms encountered also in the Caspian Sea may be cited:—*Archæobdella*, *Clessinia variabilis* (from the "liman" of the Bug), *Neritina lithurata* (from the Sea of Azov), *Gmelina*, *Gammarus mæoticus*, *Pseudocuma pectinata*, *Paramysis baeri*, *Mesomysis Kowalevskyi* and *intermedia*, *Lymnomysis benedeni* and *brandti*, and species of *Gobius*, *Clupea*, and *Accipenser*. There are other species which, though not identical, are closely allied to Caspian Sea forms, such as *Dreissensia bugensis* (allied to *D. rostriformis* and *grimmi*); *Cardium ponticum* (allied to *C. caspium*); *Cardium coloratum* (allied to *Monodacna edentula*); *Amphicteis antiqua* (allied to *A. Kowalevskii*); *Bythotrephes azovicus* (allied to *B. socialis*). Other species again are peculiar to the Sea of Azov (like *Corniger mæoticus*, *Mæotias inaspectata*, *Thaumantias mæotica*, and *Asperina improvisa*), or to the "limans" (like *Euxinomysis mecznikovi*).

Evolution of the Black Sea.—Andrussow draws attention to the fact that, in the deep mud of the Black Sea (from 100 down to about 600 fathoms), which at the present time is quite devoid of life (except perhaps microbes), they found the subfossil remains of brackish-water Mollusca, *e.g.* *Dreissensia polymorpha*, *D. rostriformis*, var. *distincta*, *D. tchaudæ*, var. *pontica*, *D. crassa*, *Monodacna pontica*, *Didacna* sp., *Micromelania caspia*, *Clessinia* sp., *Neritina* sp.

It is impossible to suppose that these species are to-day living in these depths. The high salinity of the water (2·1 to 2·2 per cent.) precludes this idea, for the maximum salinity of the water at which some of the forms are now living in the Caspian Sea does not exceed 1·5 per cent. The surface-water of the Black Sea has a mean salinity of 1·81 per cent., and in the southern part of the Sea of Azov it falls to about half of this, but nevertheless even here neither living *Dreissensiæ* nor brackish-water Cardidæ are found. It is further impossible to suppose that these shells have been transported by currents or waves; some of the species no longer exist in the region of the Black Sea, and if transported by waves these mostly fragile shells could scarcely have been found in an uninjured condition, but only as rounded fragments, and they would have been accompanied by the shells of species living on the continental platform in depths under 100 fathoms, which have never been observed. We can therefore only conclude that these mussels are relics of an epoch, not far distant, when the Black Sea represented a colossal brackish-water basin. This state of things must have continued up to a comparatively recent date, because these shells belong to living species, and the layer of mud is not sufficiently thick to prevent the shells being brought up by the dredge. The physical relations of this brackish-water basin were similar to those of the Caspian Sea, *i.e.* its water had a low salinity, not over 1·5 per cent., probably much less; the climatic relations were, however, more severe, at least towards the end of its existence, which was contemporaneous with the glacial period. The thermic relations were in general similar to those of the Caspian, *i.e.* the water had a perfect vertical circulation as a result of the small differences in the specific gravity at the surface and in the deeper water, but on account of the severe climate the bottom temperature must have been lower than that of the Caspian; the vertical circulation provided the deeper waters with atmospheric gases, so that organic life was possible at all depths.

Andrussow believes that the Black Sea had not ceased to be a closed sea at the opening of the post-tertiary period, and that the commencement of this state of things coincided with the pontic epoch (in the restricted sense of the term). There are reasons for believing that the formation of the deep depression of the Black Sea corresponds with a more ancient epoch than has been supposed. The existence near Bourgas of oligocene deposits like those of Ekatherinoslaw, the character of the development of the Tchokrak strata and those at Spaniodon, the presence of the sarmatic near Varna and Bourgas, on the borders of the Sea of Marmara, near Sinope and in Transcaucasia, the discovery of the Tchaouda layers, with *Didacna crassa* and *Dreissensia tchaudæ*, at Cape Tchaouda in the Kertch peninsula and near Gallipoli—all these facts show that the actual basin of the Pontus Euxinus had formerly been occupied by water. That it was as deep in the miocene period as it is now is another question. Down to the end of the sarmatic period, and perhaps in the meotic, this basin communicated, though indirectly, with the ocean, but in the pontic epoch it became isolated. The consecutive changes following the pontic epoch are very difficult to follow, the basin having probably occupied an extent less than that of to-day, and having left only feeble traces of its existence. Thus, at the epoch posterior to the pontic come the strata of Kouïalnik near Odessa, then the Tchaouda layers (upper pliocene), and finally, at the beginning of the post-tertiary period, the strata with Caspian fauna of southern Bessarabia and of the Kertch peninsula. After the deposition of the last-mentioned, topographical changes took place which led to the passage of the waters of the Mediterranean into the Pontus Euxinus. The union of this brackish-water basin with the Mediterranean brought with it a perfect revolution in the physical, chemical, and biological relations.

Neumayr[1] has shown that this union was brought about by the subsidence of a large continent which occupied the position of the present Ægean Sea, joining Asia Minor to the Balkan peninsula. This Ægæa

[1] "Zur Geschichte des östlichen Mittelmeerbecken, Erdgeschichte," Bd. ii., Berlin, 1882; see also Oppenheim, "Beiträge zur Kenntniss des Neogen im Griechenland," *Zeitschr. d. deutsch. geol. Ges.*, 1891, p. 482.

gradually sank under the surface of the sea, and caused a gradual approach of the Mediterranean towards the Black Sea.[1] Andrussow believes that the formation of the present straits of the Bosphorus and Dardanelles was not a geotectonic process, but that they were old river-beds, through which the waters from the Ægæan continent flowed into a sea occupying the site of the present Sea of Marmara, and from this through the Bosphorus into the Black Sea, the surface of which has several times been below its present level.

The presence of the sea-pig (*Phocœna communis*) in the Black Sea can only be explained by supposing that it communicated with the Mediterranean while certain northern species remained in the Mediterranean, *i.e.* during the glacial period. The introduction of the dense Mediterranean water into the Black Sea gave rise to the upper and under currents of the Bosphorus and Dardanelles, as we see them to-day, due to the great difference between the densities of the two bodies of water. Had this difference in the density become equalised the currents would long ago have ceased, but since the climatic conditions in the region of the Black Sea, as compared with the region of the Mediterranean, are very unlike, the Black Sea receiving a great supply of fresh water while the evaporation is much less than in the Mediterranean, equilibrium is never reached, and the currents continue. The relative uniformity in the specific gravity of the water in the original basin was gradually destroyed, a thicker and thicker layer of salt heavy water was formed in the greater depths, until finally there is at the present time a stratum of water about 1000 fathoms in thickness at the bottom of the Black Sea having a salinity of 2·1 to 2·5 per cent., while the upper 100 fathoms has a salinity, decreasing rapidly towards the surface, of 2 to 1·7 per cent., and even less. The formation of the dense under layer has had an important result: the limitation of the vertical circulation to the thin upper layer, and the stagnation of the deeper portion. This doubtless accounts for the remarkable distribution of temperature observed in the Black Sea, viz. the presence of a cold stratum of water between two warmer strata. The limited circulation led to the defective ventilation of the depths, for the atmospheric gases could no longer reach the greater depths through descending currents but only through slow diffusion, hence the conditions for life became unfavourable. The deep-sea inhabitants of the Black Sea would thus be killed out, while some of the shallow-water forms might retire to the river mouths; at the same time only a very small proportion of Mediterranean forms would be able to penetrate into the Black Sea, and only such of these as could withstand great changes in temperature and salinity would be able to survive. The neighbourhood of the Bosphorus was the first station (and is so now) for this immigration; the salinity at the bottom is here much higher, consequently a greater development of animal life is found than in the remainder of the Black Sea. Some forms would be unable to migrate

[1] Stefani, on the contrary, believes that the Ægean Sea existed already in the pontic epoch, and that it communicated with the Pontus Euxinus; the lower salinity of the latter would be maintained owing to the climatic and topographic conditions (*Ann. Soc. geol. Belge.*, 1891).

further, while others would be distributed round about the Black Sea, actively along the coasts, and passively with the currents (larvæ and plankton). At the same time a movement towards the deep water would commence, but the muddy character of the bottom, the shallowness of the Bosphorus, and the rigorous climatic conditions, explain the comparative poverty of the mud-region between 30 and 100 fathoms, while the immigration of animals into depths exceeding 100 fathoms was impossible, for deep-sea organisms could not pass through the Bosphorus.

Deposits.—The deposits now being laid down on the floor of the Black Sea may all be called Blue Muds, but in the shallower water between 30 and 100 fathoms there is an admixture of mussel shells (principally *Modiola phaseolina*), and at one place opposite the delta of the Danube the bottom appears to be covered by large *Mytilus* shells overgrown by *Lithothamnion.* Only one sample, from 58 fathoms, opposite the Bosphorus, contains what can be called sand or gravel, and here it is mixed with a very large proportion of broken shells.

Manganese was not observed in any of the samples from deep water, and even in shallow water it occurred in abundance only in one deposit-sample from 53 fathoms, in the form of concretions of iron and manganese around the small shells of *Modiola*; these concretions take the form of the separated valves, being oblong, concave on the one side and convex on the other. Sometimes there is a large proportion of manganese in the concretions, but in other cases the characteristic black streak when treated with concentrated hydrochloric acid is not observed, and the proportion of peroxide of iron is greater. At another station, from a depth of 58 fathoms, the edges of the broken shells were covered by a cushion of oxide of iron, containing little or no manganese. At other places, in shallow water (25 to 67 fathoms), some of the shells and fragments are discoloured, apparently by manganese, but it is present only in small quantity.

Sulphide of iron is widely distributed in the deeper samples. It is observed in the deposit-samples from 220 fathoms down to the greatest depths. Usually it is in the form of minute spherules disseminated through the mud, or impregnated in the Diatoms, etc., but sometimes it is seen as larger spherules and irregular particles, and in one sample from 387 fathoms it was found in great abundance in the form of elongated irregular little nails, looking at first sight like small twigs, some of them being a centimetre in length.

Chemical analysis showed that these pyrites concretions consisted substantially of sulphate of iron ($FeSO_4$), with traces of sulphur, calcium, carbonic acid, and insoluble matter. The total iron calculated as sulphide (FeS) is equal to 44 per cent., and as sulphate ($FeSO_4$) 76 per cent. Doubtless before oxidation, *i.e.* before exposure to the air, this material consisted of ferrous sulphide (FeS) with traces of lime, magnesia, and insoluble clayey matter. It is very peculiar to find such a deposit so practically pure as this, and its formation would have been impossible unless the materials were protected from oxidation by being surrounded by water containing a large amount of sulphuretted hydrogen or carbonic acid. Its deposition cannot be explained otherwise than by supposing that the iron was present in a soluble condition in the water, and that it gave rise to a precipitate of nearly pure ferrous sulphide. In its present condition the material has a strongly acid reaction from formation of acid sulphate of iron, causing indeed slight effervescence when treated with water, owing to the decomposition of the carbonates present.

This Station in 387 fathoms, situated in the south-eastern portion of the Black Sea basin, to the east of Sinope and north of Samsoun, is one of the most peculiar and interesting of the whole series, and may be referred to in some detail. The sounding-tube here brought up only a light coloured blue-grey mud, but the dredge had evidently dipped deep into the deposit, and brought up, as well as the light blue-grey mud, a greenish mud, and a stratified mud. The upper surface of the deposit at the bottom is evidently formed of the light blue-grey mud brought up by the sounding-tube, but what the thickness of this layer may be is doubtful; this mud contains 36 per cent. of carbonate of lime, which is mostly in an amorphous condition, though one or two small Mollusc and Ostracode shells were observed; the nail-like concretions of iron pyrites above mentioned were observed only in this layer, along with smaller particles of various shapes and sizes, and a few of the usual mineral particles (quartz, felspar, mica, hornblende, glassy particles), one or two Sponge spicules, and clayey matter. Beneath this upper layer was apparently the green-grey mud, which is tenaceous and clayey, and tends to separate into layers; it contains 16 per cent. of carbonate of lime, mostly amorphous, but with a few small Mollusc shells and skeletal fragments of small fishes, along with small mineral particles, a few Sponge spicules, and clayey matter. Beneath the green mud came apparently the stratified mud, composed of layers of a blue-grey tenaceous, clayey mud, separated by thin layers or mere lines of a white, chalky, powdery substance, along which the material splits up with ease; this mud contains 18 per cent. of carbonate of lime (which in the blue layers is amorphous, while the white layers and white spots are composed of crystalline carbonate of lime in the form of minute elongated grains, about 0·01 mm. in maximum diameter), with many very small ordinary mineral particles, a few Sponge spicules, and clayey matter. A sample of dark blue-grey mud was received from Professor Andrussow, labelled as from this Station, the position of which at the bottom is doubtful, but it may possibly have formed the lowermost stratum of all, since it contains a much larger proportion of mineral particles, and less carbonate of lime (11 per cent., in an amorphous condition) than any of the others.

The percentage of carbonate of lime found by analysis in the samples from depths less than 100 fathoms varies from 11 to 37; this result depends largely upon the proportion of shell-fragments present in the small quantity of material used for the analysis. In depths over 100 fathoms the percentage of calcium carbonate also varies to a great extent, but here the carbonate of lime is mostly in an amorphous condition, though there may be a few fragments of Mollusc shells, or Ostracoda, or Foraminifera, but in one instance (already referred to) the carbonate of lime appeared to be in a crystalline condition.

The percentage of carbonate of lime was determined in nearly all the samples received by us, and we have laid down the results on the accompanying map with the view of showing the distribution, which has apparently no definite relation to the depth of water. The only general remark applicable to this distribution is that the higher percentages (over 40) occur in deep water (748 to 1184 fathoms), and yet the deposits from the deepest part of the sea (over 1200 fathoms) contain only a small percentage (13 to 18). The highest percentage (65, which is much higher than in any other sample) was observed at 1184 fathoms, about eighty miles from the Bosphorus, and other two percentages exceeding 40 occur farther to the north and east, in the course, according to some authorities, of the inflowing current from the Bosphorus, but a percentage of 48 is recorded in the deposit from 1050 fathoms in the south-eastern part of the sea, removed from the influence of the inflowing Bosphorus current. The lowest percentage (9·74) is recorded in the deposit from 220 fathoms opposite Batoum, in the extreme eastern part of the sea.

We give here a few general remarks on the deposits of the Black Sea, received from Professor Andrussow in manuscript, followed by detailed descriptions of the *Tschernomoretz* samples, and a few notes on the contents of the dredges and tow-nets:—

Sands.—Coarse sediments (sands and gravels) have a very limited distribution in the Black Sea. More or less clean sand is confined within very shallow depths; thus the deeper boundary of the area of distribution of the sand is found at Laspi in 10 fathoms, at Kikineiz in 11 fathoms, at Gutsuf in 13 fathoms, at Aluschta in 10 fathoms, at Sudak in 11 fathoms, at Koktebel in 8 fathoms, at Cape Kodor in 18 fathoms. In the north-western shallow part of the Black Sea, sand is more widely distributed, the sand-zone reaching at least a depth of 29 or 30 fathoms. The greatest depth to which sand reaches in the Black Sea is found opposite the Bosphorus in a depth of 58 fathoms. The dredge here brought up a muddy sand, which contained little rounded grains of quartz and of volcanic rocks, apparently transported by the Bosphorus under-current.

Mussel beds.—Banks of mussels (*Ostrea, Pecten, Mytilus*) are found principally in the sand-zone. The *Tschernomoretz* came across two such banks: at Station 54 the trawl brought up only shells of *Mytilus edulis,* overgrown with Monaxonid Sponges; at Station 55 the trawl came up full of *Mytilus* shells, overgrown by *Lithothamnion,* on which *Phyllophora* was observed.

Mud deposits.—The remainder of the floor of the Black Sea is covered by mud, which varies in character according to depth and position. I was able to distinguish the following kinds:—

(*a*) Black Mud of the north-west part of the sea. This mud covers the bottom of those shallow depressions lying south-east of Odessa; its greatest depth is 17 fathoms. The mud is of a black colour, but on exposure to the air becomes slowly grey. The Molluscan fauna is very different from that of the Modiola Mud, for mussels are rather rare, the principal species being *Mytilus edulis,* while the presence of *Cardium exiguum* is also characteristic. The existence of arenaceous Foraminifera is very interesting. Diatoms are numerous, the most abundant being *Melosira, Navicula, Nitzschia, Pleurosigma*; other pelagic forms are rare.

(*b*) Modiola Mud. This mud was found by the *Tschernomoretz* in depths of 30 to about 100 fathoms, forming a girdle around the whole sea. Sometimes it contains a fair quantity of thin, transparent Molluscs (*Modiola phaseolina, Cardium fasciatum, Syndesmia alba, S. nitida, Mactra subtruncata, Trophon breviatum, Cerithium pusillum*). The colour is usually blue (when fresh); often there is a thin surface-layer of a reddish colour, which is due to the oxidation of the iron protoxide compounds. Sometimes there are manganese-iron concretions. At Stations 2 and 3 these concretions are formed in the shells of *Modiola phaseolina*; at Station 15 the iron-hydroxide precipitations form incrustations on the edges of the broken *Mytilus* shells. The Modiola mud is moderately tenaceous, contains very little sand, and is very poor in the remains of microscopic organisms. There are Ostracodes, and rarely little Foraminifera (*Rosalina, Lagena,* and *Entosolenia*); Diatoms are extremely rare; Sponge spicules are moderately abundant.

(*c*) Black Mud from medium depths. A sticky, tenaceous, light grey mud, with black upper surface, is found near the shore in depths of 200 to over 700 fathoms, that is on the flanks of the deep basin of the Black Sea. The black colour of the surface is due to the large quantity of sulphide of iron, which in the air is easily oxidised, and therefore the mud becomes grey immediately on exposure to the air. When the freshly collected mud is treated with cold hydrochloric acid, one observes the abundant development of sulphuretted hydrogen, the mud at the same time turning a bluish grey. Under the microscope the black pigment (sulphide of iron) appears in the form of little black globules, or impregnated in the quartz grains. Especially interesting is the entrance of the sulphide of iron into the interior of the Diatoms. It is difficult to find an example of a Diatom without one or more little black globules, and often the Diatoms are quite full of them. The presence of sulphide of iron in *Rhizosolenia* gives it a singular appearance, resembling under low powers a string of pearls. There is always a certain quantity of fine quartz sand. Of microscopic organic remains may be mentioned Diatoms, *Dictyocha,* and embryonal shells of bivalves. The shells of growing, living Molluscs are absent, there being only sub-fossil shells of brackish water forms which are no longer found living in the Black Sea, like *Dreissensia rostriformis, Cardium ponticum,* and *Micromelania caspia.* At one station from a depth of 87 to 105 fathoms, the dredge brought up a grey mud, which contained a mixture of brackish water mussels with the usual forms of the Modiola Mud.

(*d*) Blue Mud. At Station 39, from a depth of 387 fathoms, the sounding-tube brought up, instead of the usual grey mud with black surface-layer, a blue-grey mud. The same mud came up in the dredge, but was there mixed with two other kinds of mud (green mud and stratified mud). This mud contained many little pyrites concretions

(FeS_2), in the form of long drawn-out knobby nails, with small twigs of plants, and bones of small fishes (pelagic *Singnathus*?).

(*e*) Green Mud. This mud has a greater consistency than the Blue Mud brought up by the sounding-tube, which seems to indicate that the green mud underlies the blue mud.

(*f*) Stratified Mud. The dredge brought up at the same Station a very remarkable kind of mud. In the fresh condition the pieces of this mud look like a colloidal substance, being to a certain extent plastic and elastic. Even in the wet state the mud was seen to be finely stratified, and this is more evident as the mud becomes dry, for it splits up into thin layers. Some layers are greenish; others quite white. The green substance is clayey, and effervesces very little (if at all) on treatment with hydrochloric acid, but the white substance is completely dissolved with strong effervescence. Under the microscope this powdery, white substance is seen to be composed of very small, elongated, rounded, wheat-grain-like, little crystals, which give strong interference-colours in polarised light; one observes also ×-formed twin-crystals. In the greenish, clayey substance isolated embryonal bivalve shells are imbedded.

(*g*) Dark blue Mud, and light blue Mud with white spherules, in the great depths of the Black Sea. The flat, deep bottom of the Black Sea, beyond 700 fathoms, is covered by two kinds of mud, which pass the one into the other by various transitional kinds. The light blue mud differs from the dark blue mud in that it contains a greater or less abundance of light coloured little lumps or spherules, which remain behind on washing the mud in a sieve. Crushed under the microscope, they are seen to be composed of a fine-grained mass; when dry the spherules become white and pulverulent, and dissolve with effervescence in acid. As regards organic remains, it may be remarked that Diatoms are here less numerous, and they belong mostly to true pelagic species; there are also more embryonal shells of bivalves and little fish-bones.

Descriptions of the Deposit-Samples collected by ss. "Tschernomoretz."[1]

Station 2, lat. 45° 4′ N., long. 2° 14′ E., 53 fathoms.

Light blue-grey Mud ("**Modiola Mud**"), containing many shells of *Modiola*, some of which are more or less impregnated and coated with oxide of iron and manganese; the mud is coherent and clayey.

Calcium Carbonate (33·5%), amorphous calcareous matter, with many Mollusc shells and fragments of Ostracodes, Foraminifera (*Rotalia*).

Residue (66·5%), brownish grey.

Minerals [10%], m.di. 0·1 mm., angular, spherules and irregular particles of sulphide of iron, quartz, felspar, mica, hornblende, glassy particles, glauconite (?) There is only 2 or 3% of minerals proper exceeding 0·05 mm. in diameter, but the iron sulphide is abundant.

Siliceous Organisms [1%], Sponge spicules.

[1] The longitudes are referred to St. Petersburg.

Fine Washings [55·5%], amorphous clayey matter, with many minute spherules of iron sulphide, and other small mineral particles.

The dredge brought up at this Station: small Monaxonid Sponge, *Amphiura florifera*, *Cynthia*, *Modiola phaseolina*, *Scrobicularia alba*, *Cardium fasciatum*, *Trophon breviatum*, *Rissoa*, and *Cerithiolum*.

Station 3, lat. 44° 39′ N., long 2° 59′ E., 50 fathoms.

Modiola Mud, blue-grey when fresh, with a thin red surface-layer, grey when dry; contains *Modiola phaseolina*, *Bulla truncata*, *Cerithiolum pusillum*, Annelid tubes composed of mud and slime, and concretions of iron and manganese.

Station 4, lat. 44° 11′ N., long. 2° 34′ E., 993 fathoms.

The sounding-tube brought up a very little blue-grey mud. The tow-nets at the surface gave *Cydippe*, Copepods, *Sagitta*, *Noctiluca*, *Coscinodiscus*, and unicellular Algæ.

Station 5, lat. 43° 1′ N., long. 2° 0′ E., 1144 fathoms.

The sounding-tube brought up only a small quantity of flocculent dark-grey mud with white spherules; under the microscope were seen *Dictyocha*, *Actiniscus* *Coscinodiscus*, mandibles of *Sagitta*, and vegetable matter.

Station 8, lat. 41° 41′ N., long. 0° 1′ W., 984 fathoms.

Mayer's water-bottle brought up a little blue-grey mud. The tow-net at the surface gave: *Noctiluca*, unicellular Algæ, and embryonal Gasteropods.

Station 10, lat. 41° 25′ N., long. 0° 20′ W., 445 fathoms.

Stiff grey mud with black upper surface. The black colour is due to an excess of black spherules of sulphide of iron, which occur either isolated or in the interior of the Diatoms: *Rhizosolenia*, *Navicula interrupta* (?).

Station 11, lat. 41° 25′ N., long. 0° 41′ W., 363 fathoms.

Blue-grey Mud, clayey, very coherent.

Calcium Carbonate (12·95%), mostly amorphous, but a few fragments of Bivalve and Ostracode shells were observed.

Residue (87·05%), darker grey.

Minerals [3%], m.di. 0·1 mm., angular, quartz, mica, felspar, hornblende, glauconite (?), glassy particles, spherules and irregular fragments of pyrites.

Siliceous Organisms [1%], Diatoms, Sponge spicules.

Fine Washings [83·05%], amorphous clayey matter impregnated with sulphide of iron, and with many small mineral particles.

The trawl brought up a large mass of mud, which appeared to be grey, but was in many parts quite black; on being exposed the black parts immediately became grey. In the washings were sub-fossil shells of *Dreissensia rostriformis* and *Micromelania caspia*.

STATION 12, lat. 41° 21′ N., long. 0° 53′ W., 50 fathoms.

Modiola Mud, with *Polystomella*, *Entosolenia*, *Textularia*, shells of *Codonella*, smooth Ostracodes, *Coscinodiscus*, *Navicula*, *Striatella unipunctata*.

STATION 13, lat. 41° 26′ N., long. 1° 8′ W., 60 fathoms.

Modiola Mud, with *Amphiura*, *Cynthia*, and Molluscs (*Cryptodon*, *Cyclonassa*, *Trophon*, *Bulla*, *Cardium*).

STATION 14, lat. 41° 23′ N., long. 1° 7′ W., 58 fathoms.

Grey Muddy Sand, with rolled pebbles.

The dredge brought up some interesting things, especially: Foraminifera (*Haplophragmium*, *Textularia*, *Triloculina*, *Rotalina*, *Truncatulina*, *Polystomella*), *Amphiura*, *Cucumaria* (*Ocnus*) *orientalis*, Echini spines, *Salicornaria*, many Sponges, *Virgularia*, Ascidians, Polychaeta, etc. Besides the species of Molluscs characteristic of the Modiola Mud, were several forms which are unknown or rare in the Black Sea, e.g., *Nucula nucleus*, *Turritella*, etc. There were also sub-fossil brackish water species: *Dreissensia* and fragments of large *Limnocardium*. The relative richness of the fauna at this Station may be explained by the fact that it lies in the bed of the Bosphorus under-current, which on entering the Black Sea moves along for a long time independently, and is only gradually mixed with the waters of the Black Sea. At this Station the specific gravity on the bottom was 1·0204, while at the surface the usual specific gravity of the Black Sea (1·01293) was observed. The position also explains the presence of the rolled pebbles and gravel, which have been transported by this under-current, for at this depth in other parts of the Black Sea fine mud is usually observed.

STATION 15, lat. 41° 21′ N., long. 0° 26′ W., 58 fathoms.

Modiola Mud. The edges of the broken Mollusc shells are covered by a cushion of oxide of iron. In the stomach of a *Cynthia* from the dredge were many Diatoms: *Striatella unipunctata* (?), *Cocconeis* sp. (?), *Nitzschia* (*Tryblionella*) *punctata* (?), *Achnanthes*, *Epithemia*, *Synedra delicatissima*, *Campylodiscus*, *Rhizosolenia*, *Navicula lyra*, *N. interrupta*, *N. elliptica*, *Grammatophora marina*, as well as silico-flagellata (*Dictyocha fibula*, *D. speculum*, and *Actiniscus*).

STATION 16, lat. 41° 22′ N., long. 0° 5′ E., 60 fathoms.

Modiola Mud, reddish when dry, containing a good deal of sand. Besides the usual mussels (*Modiola phaseolina*, *Scrobicularia alba*, *Cardium*), microscopic examination showed in this mud also Foraminifera (*Rosalina*, *Truncatulina*, *Textularia*, and *Entosolenia*), spicules of *Synapta*, and Diatoms (*Coscinodiscus*, *Melosira*).

STATION 17, lat. 41° 55′ N., long. 1° 20′ E., 1142 fathoms.

Fine Mud, dark blue when wet and freshly collected, becoming rapidly grey in contact with the air; grey when dry. Contains much sulphide of iron in the form of little spherules or infiltrated into the cracks of the larger mineral particles. Of microscopic remains of organisms were observed: embryonal shells of bivalves, and arenaceous Foraminifera, Diatoms: little *Coscinodiscus*, *Melosira*, *Epithemia*, and *Hyalodiscus* (?).

STATION 18, lat. 41° 55′ N., long. 2° 0′ E., 715 fathoms.

Blue-grey Mud, with white spots, very coherent, clayey.

CALCIUM CARBONATE (18·25%), mostly amorphous, but one or two small Mollusc shells and fragments were observed.

RESIDUE (81·75%), dark grey.

Minerals [2%], m.di. 0·1 mm., angular, quartz, felspar, mica, hornblende, olivine, glauconite (?), coloured particles, glassy particles, spherules of sulphide of iron.

Siliceous Organisms [1%], Diatoms, Sponge spicules.

Fine Washings [78·75%), amorphous clayey matter, impregnated with sulphide of iron, and with many small mineral particles.

The sounding-tube brought up a light blue mud, while in the water-bottle was a blackish mud mixed with water. Sulphide of iron was specially abundant in the interior of the Diatoms as well as isolated. Of organic remains were observed: embryonal shells of Bivalves, one embryonal shell of a Gasteropod, *Actiniscus* (many), Diatoms: *Coscinodiscus, Melosira, Rhizosolenia, Hemiaulus hauckii, Navicula, Pleurosigma, Synedra gracilis* (?), *Grammatophora*, spicules of Monaxonid Sponges.

STATION 19, lat. 42° 5′ N., long. 2° 8′ E., 1182 fathoms.

Of organic remains were observed: a tiny Foraminifera shell, *Dictyocha, Actiniscus*, Diatoms: *Coscinodiscus* several species, *Cocconeis scutellum* (?), *Rhizosolenia, Grammatophora macilenta* (?), *Melosira, Synedra gracilis, Navicula abrupta* (?), *Pyxilla, Striatella unipunctata, Cymbella*, and many Sponge spicules.

STATION 20, lat. 43° 10′ N., long. 3° 47′ E., 1219 fathoms.

Light blue mud, with very many spherules of sulphide of iron. Organic remains observed: *Melosira, Navicula lyra, N. elliptica, Coscinodiscus, Actinocyclus, Grammatophora marina, Thalassiothrix, Epithemia, Synedra undulata* (?), *Striatella unipunctata, Rhizosolenia, Chætoceras, Cocconeis scutellum, Actinoptychus undulatus, Campylodiscus, Grammatophora serpentina, Navicula interrupta* (?), *Diatoma* (*Odonellum*) sp. (?), *Surirella fastuosa* (?), *Pleurosigma, Stephanodiscus astrea*; Foraminifera (*Lagena, Entosolenia*); *Actiniscus, Dictyocha speculum, D. fibula*; Sponge spicules.

STATION 21, lat. 44° 41′ N., long. 4° 57′ E., near Meganon, 240 fathoms.

Light blue-grey Mud, very coherent, clayey, with black lines and spots due to sulphide of iron.

CALCIUM CARBONATE (16·75%), mostly amorphous; one or two small Bivalve shells observed.

RESIDUE (83·25%), darker grey.

Minerals [10%], m.di. 0·1 mm., angular, pyrites, quartz, felspar, mica, glauconite (?), glassy particles. The minerals proper make up probably only 2 or 3%, but of pyrites alone there is probably 5 to 10%.

Siliceous Organisms [1%], Sponge spicules, Diatoms (*Epithemia* and *Navicula*) filled with sulphide of iron.

Fine Washings [72·25%], amorphous clayey matter, impregnated with sulphide of iron, in the form of minute spherules (0·01 to 0·02 mm. in diameter), and larger irregular particles, and small particles of other minerals.

STATION 23, lat. 44 28′ N., long. 4° 3′ E., opposite Nikita, 344 fathoms.

Grey Mud, with black upper surface, containing many quartz grains. Organic remains observed : *Cocconeis scutellum*, *Grammatophora*, *Actinoptychus undulatus* (?), *Rhizosolenia*, *Campylodiscus*, *Pleurosigma*, *Biddulphia pulchella* (?), *B. tuomeyi* (?), *B. bailyi*, *Surirella fastuosa* (?), *Navicula interrupta*, *N. elliptica*, *Synedra undulata*, *S. fulgens* (?), *Coscinodiscus* several species, *Melosira*, *Striatella unipunctata*, *Surirella*, *Amphora*, *Amphipleura sigmoidea* (?), *Stauroneis pulchella* (?), *Biddulphia* (*Amphitetras*) *antediluviana* ; embryonal shells of Bivalves ; *Entosolenia*, *Rosalina* ; *Codonella ventricosa* ; little fish-bones ; *Actiniscus*, *Dictyocha speculum* ; Sponge spicules.

STATION 24, lat. 44° 26′ N., long. 3° 55′ E., 49 fathoms.

Blue Mud with *Modiola phaseolina*, fragments of *Amphiura*, *Rosalina*, Ostracoda, *Biddulphia pulchella* (?).

STATION 25, lat. 43° 37′ N., long. 4° 19′ E., 1226 fathoms.

Blue Mud, blue-grey colour, extremely clayey, dries into lumps which require a blow from a hammer to break them.

CALCIUM CARBONATE (12·5%), almost entirely amorphous.

RESIDUE (87·5%), grey.

Minerals [5%], spherules of sulphide of iron, quartz, felspar, mica, green particles.

Siliceous Organisms [1%], Diatoms, Sponge spicules.

Fine Washings [81·5%], amorphous clayey matter, with minute mineral particles.

Organic remains observed : *Coscinodiscus*, *Biddulphia* (*Cerataulus*) *smithii* (?), *Actinoptychus undulatus* (?), *Navicula interrupta*, *N. elliptica*, *Pleurosigma*, *Nitzschiella lorenziana* (?), *Grammatophora marina*, *Actinocyclus*, *Striatella unipunctata*, *Cocconeis scutellum*, *Surirella fastuosa* (?), *Amphipleura sigmoidea*, *Melosira*, *Nitzschia* (*Tryblionella*) *punctata* (?), *Biddulphia* (*Amphitetras*) *antediluviana*, *Chætoceras*, *Rhizosolenia*, *Epithemia*, *Thalassiothrix* ; little *Rosalina* or *Rotalina* ; *Dictyocha speculum*, *Actiniscus*.

STATION 29, lat. 43° 12′ N., long. 8° 32′ E., 1157 fathoms.

Blue-grey Mud : after washing a blackish sand remains, principally quartz grains and spherules of sulphide of iron. Organic remains observed : *Coscinodiscus*, *Thalassiothrix*, *Rhizosolenia*, *Synedra*, *Cocconeis scutellum*, *Striatella unipunctata*, *Chætoceras*, *Hyalodiscus*, *Asterolampra*, *Grammatophora*, *Surirella fastuosa* (?) ; embryonal shells of Bivalves ; *Actiniscus*, *Dictyocha speculum* (?) ; mandibles of *Sagitta* ; vegetable matter.

STATION 30, lat 43° 12′ N., long. 9° 6′ E., 1009 fathoms.

Blue-grey Mud with a few white globules ; after washing there remains a blackish sand (of sulphide of iron spherules). Organic remains observed : *Hemiaulus hauckii*, *Rhizosolenia*, *Cocconeis scutellum*, *Synedra ulna*, *S. undulata*, *Coscinodiscus*, several species of *Chætoceras*, *Navicula*, *Surirella*, *Grammatophora serpentina*, *G. marina*, *Epithemia*, *Pleurosigma*, *Asterolampra*, *Amphipleura sigmoidea*, *Melosira* ; embryonic Bivalve shells ; *Dictyocha speculum*, *Actiniscus distephanus* ; *Textularia* ; Sponge spicules ; vegetable matter.

STATION 33, lat. 41° 54′ N., long. 10° 53′ E., 567 fathoms.

Blue-grey Mud with a few white globules and spherules of sulphide of iron. Organic remains observed: *Coscinodiscus*, *Chœtoceras*, *Rhizosolenia*; very many embryonic Bivalve shells; *Actiniscus*; *Codonella ventricosa*; a shell of *Textularia* having a sub-fossil appearance; vegetable matter.

STATION 34, lat. 41° 49′ N., long. 11° 3′ E., 220 fathoms.

Grey Mud with white spots, clayey, extremely coherent: the pieces require a blow from a hammer to break them.

CALCIUM CARBONATE (9·74%), mostly amorphous; a few small Bivalve shells observed.

RESIDUE (90·26%), a little darker.

Minerals [20%], m.di. 0·08 mm., angular, quartz, mica, felspar, hornblende, coloured and glassy particles, glauconite (?), spherules of sulphide of iron.

Siliceous Organisms [1%], Diatoms, Sponge spicules.

Fine Washings [69·26%], amorphous clayey matter, with many small mineral particles.

A detailed analysis gave :—

Insoluble silicates and clayey matter,	64·53
$Fe_2O_3 + Al_2O_3$,	6·73
$CaCO_3$,	9·74
$MgCO_3$,	5·04
Water, organic matter,	13·00
Sulphates,	trace
	99·04

Organic remains observed: *Coscinodiscus*, *Grammatophora marina*, *Podosira*, *Amphipleura*, *Diatoma* (*Odontidium*) *hiemale* (?), *Surirella gemma* (?), *Stauroneis*, *Synedra*, *Cymbella helvetica* (?), *Amphora quadrata* (?), *Hemiaulus hauckii*, *Cocconeis scutellum*; embryonal shells of Bivalves; fragments of *Amphiura*; *Dictyocha speculum*, *Actiniscus*.

STATION 35, lat. 41° 47′ N., long. 10° 17′ E., 973 fathoms.

Blue-grey Mud, with white layers, coherent, chalky.

CALCIUM CARBONATE (23·37%), mostly amorphous, but with one or two fragments of small Molluscs, and skeletal fragments of small fishes.

RESIDUE (76·63%), dark greenish grey.

Minerals [2%], m.di. 0·08 mm., angular, quartz, felspar, mica, hornblende, glauconite (?), glassy particles, and particles of sulphide of iron.

Siliceous Organisms [1%], Sponge spicules, Diatoms (some impregnated with sulphide of iron).

Fine Washings [73·63%], amorphous clayey matter, with many minute spherules of sulphide of iron, and small mineral particles.

Organic remains observed: Small Foraminifera; *Coscinodiscus*, *Grammatophora marina*, *Chœtoceras*, *Melosira*, *Cocconeis*, *Synedra*, *Dictyocha speculum*.

STATION 38, lat. 41° 55′ N., long. 7° 12′ E., 1050 fathoms.

Blue-grey Mud with white globules and grains of sulphide of iron. Organic remains observed: *Coscinodiscus*, *Melosira*, *Rhizosolenia*, *Navicula didyma* (?), *Actiniscus*.

STATION 39, lat. 41° 59′ N., long. 6° 12′ E., 387 fathoms.

This Station is specially referred to in the preceding general remarks on the deposits, and each layer is here described in detail:—

(1) **Light blue-grey Mud**, compact, clayey, with iron pyrites in the form of irregular nails, looking like small twigs, some 1 cm. in length.

CALCIUM CARBONATE (35·75%), mostly amorphous, but one or two small Gasteropod, Bivalve, and Ostracode shells were observed.

RESIDUE (64·25%), a little darker in colour.

Minerals [3%], m.di. 0·08 mm., mostly angular, quartz, felspar, mica, green particles (hornblende), glassy particles, and particles of pyrites of various shapes and sizes.

Siliceous Organisms [1%], one or two Sponge spicules.

Fine Washings [60·25%], amorphous clayey matter, with many mineral particles less than 0·05 mm. in diameter.

(2) **Green-grey Mud**, tenaceous, clayey, does not break down in water so readily as the light blue mud, and tends to separate into layers.

CALCIUM CARBONATE (16·0%), mostly amorphous, with a few white particles (having the appearance of organic fragments, but in reality crystalline sulphate of lime formed after collection ?), small Mollusc shells, bones and scales of small fishes (*Singnathus* ?).

RESIDUE (84·0%), greenish grey.

Minerals [2%], m.di. 0·06 mm., angular, quartz, felspar, etc.

Siliceous Organisms [1%], a few Sponge spicules.

Fine Washings [81·0%], amorphous clayey matter and minute mineral particles.

(3) **Stratified Mud**, of a blue-grey colour with white lines, along which the material splits up with ease; the mud between the white layers is very tenaceous and clayey, while the white layers are chalky.

CALCIUM CARBONATE (17·75%), principally in the form of minute elongated crystalline grains (about 0·01 mm. in maximum diameter), which constitute the white layers and small white spots, while the clayey layers contain amorphous carbonate of lime.

RESIDUE (82·25%), darker grey.

Minerals [2%], m.di. 0·06 mm., angular, quartz, felspar, mica, etc. The number of mineral particles exceeding 0·05 mm. in diameter is very small, and not one was observed exceeding 0·1 mm. There were a few white particles (having the appearance of organic fragments), which proved to be crystalline sulphate of lime (secondary formation after collection ?).

Siliceous Organisms [1%], Sponge spicules.

Fine Washings [79·25%], amorphous clayey matter, with very many minute mineral particles.

(4) **Dark blue-grey Mud** ("unwashed"), coherent, clayey.

CALCIUM CARBONATE (11·0%), mostly amorphous.

RESIDUE (89·0%) dark grey.

Minerals [15%], m.di. 0·1 mm., angular, quartz, black and white mica, felspar, hornblende, glauconite (?), glassy particles.

Siliceous Organisms [1%], Sponge spicules, Diatoms.

Fine Washings [73·0%], amorphous clayey matter, with very many minute mineral particles.

STATION 40, lat. 42° 16′ N., long. 6° 12′ E., 1099 fathoms.

Light blue-grey Mud, with white patches, coherent.

CALCIUM CARBONATE (37·25%), mostly, if not entirely, amorphous; on picking out a little of the white material forming the patches it disappears entirely on treatment with dilute hydrochloric acid, leaving behind only a few small mineral particles. On washing, the white material, extremely fine-grained, forms a thin layer on the top.

RESIDUE (62·75%), green-grey.

Minerals [5%], m.di. 0·1 mm., angular, quartz, felspar, mica, hornblende, glauconite (?), coloured and glassy particles.

Siliceous Organisms [1%], Diatoms and Sponge spicules.

Fine Washings [56·75%], flocculent amorphous clayey matter, with many small mineral particles.

STATION 41, lat. 42° 48′ N., long. 4° 40′ E., 1187 fathoms.

Blue-grey Mud. Organic remains observed: *Coscinodiscus, Melosira communis, Epithemia, Rhizosolenia, Navicula elliptica* (?); small Foraminifera shells; *Actiniscus, Dictyocha speculum*; knobby Sponge spicules.

STATION 45, lat. 44° 15′ N., long. 1° 58′ E., 817 fathoms.

Light blue-grey Mud, with white lines and patches, coherent, chalky.

CALCIUM CARBONATE (46·83%), mostly amorphous, with a few bones of small fishes.

RESIDUE (53·17%) dark greenish grey.

Minerals (1%), m.di. 0·07 mm., angular, quartz, mica, felspar, spherules of sulphide of iron.

Siliceous Organisms (1%), Diatoms and Sponge spicules.

Fine Washings (51·17%), flocculent and amorphous clayey matter impregnated with sulphide of iron, and small mineral particles.

Detailed analysis gave:—

Insoluble silicates and clayey matter,	31·28
$Fe_2O_3 + Al_2O_3$,	4·43
$CaCO_3$,	46·83
$MgCO_3$	3·48
Water, organic matter,	13·96
Sulphates,	fairly large trace
	99·98

Organic remains observed: *Coscinodiscus, Navicula, Cocconeis scutellum, Grammatophora*; embryonic shells of Bivalves; Sponge spicules; *Codonella ventricosa, Actiniscus*; vegetable matter.

STATION 46, lat. 43° 53′ N., long. 0° 58′ E., 748 fathoms.

Grey-blue Mud, with white spherules. Organic remains observed: *Coscinodiscus, Codonella ventricosa*, and vegetable matter.

STATION 48, lat. 42° 32′ N., long. 0° 30′ W., 1184 fathoms.

Light blue-grey Mud, with white patches and layers, chalky, coherent.

CALCIUM CARBONATE (64·5%), amorphous.

RESIDUE (35·5%), greenish.

Minerals (1%), m. di. 0·06 mm., angular, mica, quartz, felspar, etc., many spherules of sulphide of iron.

Siliceous Organisms (1%), Diatoms, Sponge spicules.

Fine Washings (33·5%), flocculent and amorphous clayey matter, with a few small mineral particles.

STATION 50, lat. 43° 32′ N., long. 0° 45′ W., 47 fathoms.

Modiola Mud, some of the shells blackened by manganese. Other organic remains observed: Foraminifera (*Rotalina*, *Entosolenia*, *Dentalina*), spicules of Monaxonid and calcareous Sponges.

STATION 51, lat. 44° 20′ N., long. 0° 40′ E., 65 to 107 fathoms.

Modiola Mud, some of the shells have a deposition of iron and manganese around the edges. Other organic remains observed: *Bulla truncata*, Foraminifera (*Entosolenia*, *Lagena*, *Rotalia*), Sponge spicules, and, in the deeper water, subfossil shells of *Dreissensia*, etc.

STATION 52, lat. 44° 20′ N., long. 0° 17′ E., 45 fathoms.

Modiola Mud (some of the shells impregnated with manganese and iron), very fine grained, almost without sand, with few microscopic organic remains (*Rosalina*, *Entosolenia*, *Cornuspira*, an arenaceous Foraminifera, *Coscinodiscus*, *Melosira*.)

STATION 53, lat. 44° 37′ N., long. 0° 6′ W., 35 fathoms.

Modiola Mud. Organic remains observed: *Coscinodiscus*, *Cocconeis*, *Grammatophora serpentina*, *Navicula lyra*, *N. elliptica*, *Amphipleura sigmoidea*, *Biddulphia antediluviana*, *Surirella fastuosa* (?), *Hyalodiscus*, *Striatella unipunctata*, *Amphora crassa*; *Dictyocha speculum*, *Actiniscus*; Sponge spicules; little *Rosalina*.

STATION 55, lat. 15° 45′ N., long. 0° 1′ W., 25 fathoms.

The bottom is covered by *Mytilus* shells, overgrown by large knobs of *Lithothamnion*, and with many *Phyllophora*; some of the shells impregnated in places by manganese and iron. The growths of *Lithothamnion* are almost entirely confined to the external surfaces of the shells, as though the separated valves lay on the bottom internal surface downwards, some of them still retaining something of the iridescent lustre of the fresh shell, while others are much decomposed.

STATION 57, lat. 46° 5′ N., long. 1° 0′ E., 16 fathoms.

Sandy Black Mud. Organic remains observed: *Mytilus edulis*, *Cerithium*, Ostracoda, many Diatoms: *Navicula lyra*, *N. interrupta*, etc., *Coscinodiscus*, *Cocconeis scutellum* (?), *Campylodiscus parvulus* (?), *Nitzschia* (*Tryblionella*) *marginata* (?), *Grammatophora marina*, *G. macilenta*, *G. serpentina*, *Synedra undulata*, *S. ulna* (?), *Surirella fastuosa* (?), *S. gemma* (?), *Pleurosigma*, *Amphiprora*, *Epithemia*, *Actinoptychus undulatus*, *Amphipleura sigmoidea*, *Amphora crassa*, *Achnanthes longipes*, *Striatella unipunctata*; *Rosalina*, *Textularia*; *Dictyocha speculum*, *Actiniscus*.

STATION 58, lat. 46° 14′ N., long. 0° 49′ E., 14 fathoms.

Dark blue-grey Mud, with Mollusc shells and fragments, extremely coherent.

CALCIUM CARBONATE (18·0%), amorphous calcareous matter, with fragments of Mollusc shells, Ostracodes, and Foraminifera.

RESIDUE (82·0%), dark brownish grey.

Minerals (10%), m. di. 0·12 mm. (one particle 0·6 mm. in diameter observed), angular, quartz, felspar, mica, hornblende, glauconite (?), glassy particles, spherules and irregular particles of pyrites.

Siliceous Organisms (2%), many Diatoms (some impregnated with sulphide of iron), Sponge spicules, arenaceous Foraminifera.

Fine Washings (70%), amorphous clayey matter, with many minute spherules of sulphide of iron and small mineral particles.

Organic remains observed: Ostracoda; *Rotalina* and many arenaceous Foraminifera; *Dictyocha*, *Actiniscus*; Diatoms: *Melosira*, *Navicula*, *Nitzschia scalaris*, *N.* (*Tryblionella*) *marginata* (?), *Surirella*, *Cocconeis*, *Pleurosigma*, *Grammatophora macilenta*, *Coscinodiscus*, *Epithemia*, *Striatella unipunctata*.

STATION 59, lat. 46° 21′ N., long. 0° 42′ E., 15 fathoms.

Blue-grey Mud, black when collected but becoming grey in the air.

Organic remains observed: *Gromia*; *Rosalina*; Diatoms: *Navicula* several species, *Surirella fastuosa* (?), *Nitzschia punctata* (?), *Melosira*, *Amphiprora*, *Epithemia*, *Achnanthes*, *Grammatophora marina*, *Stauroneis pulchella*, *Pleurosigma*, *Amphora*, *Amphipleura sigmoidea*, *Coscinodiscus*; *Dictyocha*; Sponge spicules; Ostracoda.

In conclusion, we may remark that the most striking differences between the deposits of the Black Sea and deposits from similar depths in the open ocean are:—(1) greater proportion of clayey matter and smaller proportion of mineral particles in the Black Sea muds; (2) glauconite may be said to be absent from the Black Sea, only a few doubtful grains having been observed; (3) the carbonate of lime is almost entirely amorphous (and in one case crystalline) in the Black Sea muds, whereas in the open sea it is almost entirely composed of remains of pelagic organisms; (4) the total absence of pelagic organic remains (except Diatoms) in the Black Sea muds; (5) the great abundance of sulphide of iron in the deposits from the Black Sea.

MOUNT ST. ELIAS: A REVIEW.[1]

IN intrusting the record of his expedition to the summit of Mount St. Elias to the pen of Dr. Filippo de Filippi, the Duke of the Abruzzi has most assuredly chosen one who has accomplished the task he had before

[1] *La spedizione di sua Altessa Reale il Principe Luigi Amedeo di Savoia, Duca degli Abruzzi al Monte Sant' Elia* (*Alaska*), 1897. (Milano: U. Hoepli, 1900.)

The Ascent of Mount St. Elias (*Alaska*). *By H.R.H. Prince Luigi Amedeo di Savoia Duke of the Abruzzi.* Narrated by Filippo de Filippi; illustrated by Vittorio Sella; and translated by Signora Linda Villari, with the author's supervision. Pp. xii+241. 34 photogravure plates, 4 panoramic views, 117 illustrations in text, and 2 maps. (Westminster: Archibald Constable and Co., 1900.)

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