# Oceanography of the Gibraltar Region.

By DR. JOHS. SCHMIDT.

THE first month spent at sea by the *Dana* Expedition was occupied with investigations in the boundary area between the Atlantic and the Mediterranean—*i.e.* in the Bay of Cadiz, the Straits of Gibraltar, and the Western Mediterranean as far as Algiers. We had worked there before, in 1908–10, with the *Thor*. We were, therefore, not unacquainted with local conditions, and it was very interesting to compare the new investigations with the old. The expedition was particularly fortunate in being able, during this month, to enjoy the cooperation of Dr. J. N. Nielsen, who, from his participation in the *Thor* expeditions, is perhaps more familiar with the hydrography of these waters than anyone else. The remaining scientific staff of the expedition consisted of Messrs. P. Jespersen and A. V. Tåning, both ichthyologists and trained in the work of general marine biology; K. Stephensen, as expert in crustaceans; while the physical and chemical investigations were carried out by Messrs. J. Olsen and N. C. Andersen, the last-named being physician to the expedition.

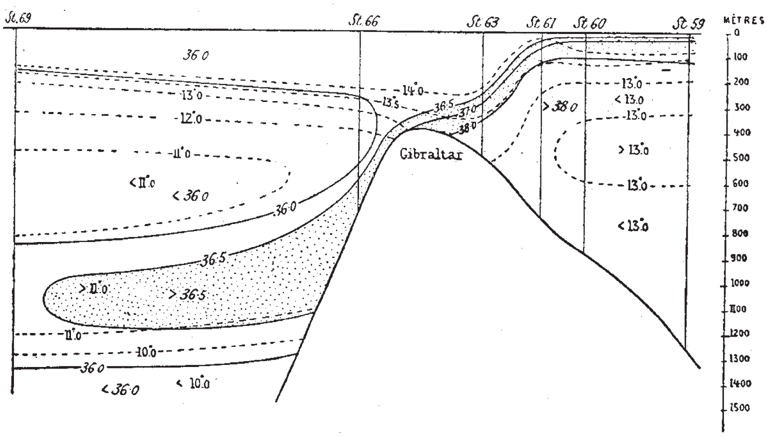


FIG. 1.—Showing isohalines (figures in italics) and isotherms. Hydrographical section through the Straits of Gibraltar from the investigations of the *Thor*, February, 1909. (Schmidt, Nielsen, and Jacobsen, 1910.)

Previous investigations—British, Danish, and Norwegian—have given us the main features (but no more) in the transfusion of water which takes place between the Mediterranean and the Atlantic. The most striking difference between Mediterranean and Atlantic water is in the salinity. Owing to the great evaporation, the water in the Mediterranean is of higher salinity than the Atlantic water—viz. more than 38 per mille (that is, 38 grams of salt in 1000 grams of sea-water) as against about 36–36·5. The less saline Atlantic water flows through the Straits of Gibraltar into the Mediterranean as a surface current. Deeper down, the Straits of Gibraltar are filled with salter water, which, coming from the Mediterranean, moves westward over the comparatively shallow threshold, in places only 400 metres down, formed here by the sea floor, which falls away steeply both to the east and west. On reaching the western edge of this ledge, the Mediterranean water pours down, like a veritable submarine waterfall, towards the depths of the Atlantic Ocean (Fig. 1). It does not, however, reach the bottom; being warmer, and therefore lighter, than the bottom water of the Atlantic, it spreads out as an intermediate layer in the Atlantic, which is recognisable in that it is of higher salinity than the water-layers above and below. J. N. Nielsen and F. Nansen have previously demonstrated the existence of this intermediate layer of Mediterranean water—or, more correctly, mixed water—right up to the west of the British Isles. At the stations of the *Dana* Expedition between Madeira and the Cape Verde Islands (Stations 1142, 1152, 1156, 1157, 1159) we found it at depths of about 1000–1500 metres, with a salinity naturally decreasing towards the south, but varying from about 35·7 per mille at Madeira, to about 35·03 near the Cape Verde Islands.

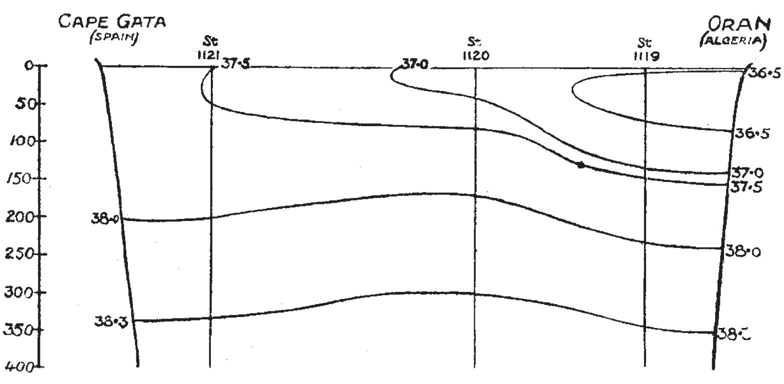


FIG. 2.—Hydrographical section through the westernmost portion of the Mediterranean as shown by the *Dana's* stations 1119, 1120, and 1121, about October 1, 1921. The isohalines for 36·5, 37·0, 37·5, 38·0, and 38·3 per mille salinity are shown. The depths are given in metres. The section shows that the inflowing Atlantic water (salinity less than 36·5 per mille) follows the coast of Africa.

Up to now we have referred only to the outflow of Mediterranean water into the Atlantic. Fig. 2 gives a picture of the inflow of Atlantic water into the Mediterranean, based on the investigations of the *Dana* Expedition in the waters between Oran, Algeria, and the south coast of Spain. The figure represents a vertical section of the upper 400 metres of sea through our three stations 1119, 1120, and

1121, showing the depths and the course of the isohalines. It will be seen that unmixed Atlantic water, of a salinity less than 36·5 per mille, flows in along the north coast of Africa. Midway (Station 1120) we find a slight, and farther north, off the coast of Spain (Station 1121), a somewhat more pronounced, admixture of Mediterranean water. From this it must be concluded that the velocity of the east-going current is at its highest close in to the African shore, and lowest off the coast of Spain, which is also in accordance with fact. The section further shows that the inflow of Atlantic water is a comparatively superficial phenomenon, almost pure Mediterranean water being found at a relatively slight depth.

For nearly a week at the beginning of October the *Dana* remained at Gibraltar in order to study the inflow of Atlantic water and the accompanying migration of pelagic organisms through the Straits. On several occasions continuous investigations were made, as, for instance, from 9 p.m. on October 8 to 6 a.m. on October 10, when series of water samples, with observations of temperature, were taken every three hours; in the intervals between hydrographical observations fishing with pelagic nets was carried out at various depths. All these investigations were made at the same spot, about the middle of the Straits, with Tarifa, in Spain, to the west-north-west. The investigations showed that both physical and biological conditions varied greatly in the course of the twenty-four hours. Temperature and salinity, for instance, did not remain constant at a given depth throughout that time. Fig. 3 shows how water of 14° C. and 37·4 per mille salinity—characteristic values for temperature and salinity of mixed Atlantic and Mediterranean water—changes its level within the twenty-four hours. It will at once be noticed that the changes are periodical, and a closer investigation of the times indicated places it beyond doubt that we have here to deal with a tidal phenomenon, albeit the magnitude of the alteration in level would appear to be also dependent upon other factors, such as the direction and force of the wind.

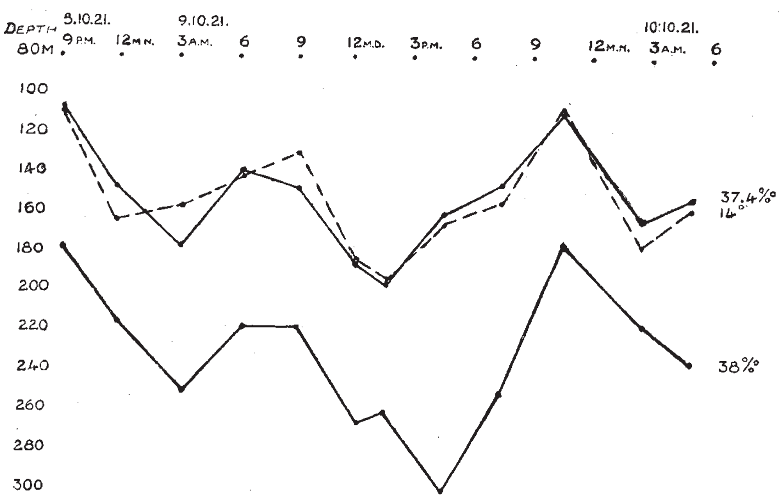


FIG. 3.—Straits of Gibraltar: St. 1138, lat. 35° 59′ N., long. 5° 30′ W. Continual observations at the same spot from 9 p.m. October 8 to 6 a.m. October 10, showing periodical shifting of the level at which salinities of 37·4 and 38·0 per mille and a temperature of 14° C. are found during the period of observation. The depths are given in metres.

A comparison of the contents of the pelagic nets throughout the night at our station off Tarifa proved highly interesting, but raised questions which I soon perceived were to be solved only by a far longer stay at this point than the *Dana* could afford. I will take one example. A net drawn horizontally at about 150 metres' depth on October 8 for two hours from 10.15 p.m. brought up about 80 litres of matter, consisting almost exclusively of a siphonophore (Diphyes). Towards morning Diphyes had disappeared, the contents of the net from 150 metres' depth then consisting chiefly of Salpæ and a schizopodous crustacean. The same phenomenon was repeated next night: first scarcely anything but Diphyes, and later on almost exclusively Salpæ. Our hauls thus showed that the depth at which Diphyes and Salpæ are found is subject to alteration, but the question then arises whether such alteration is due to active movement of the organisms in question, or to a purely passive shifting answering to the change in level of the water layers effected by the action of the tides.

A comparison of the pelagic fauna on both sides of the Straits of Gibraltar was likewise of much interest. As the main result it may be stated that several species were common to both areas, while others were found only west of Gibraltar. Among the latter may be quoted, of fishes: *Argyropelecus Olfersi*, *Vinciguerria Sanzoi*, *Myctophum laternatum*, and *M. Valdivia*, with various murænoid larvæ (*Leptocephalus Synaphobranchi pinnati*, *L. latissimus*, *L. lanceolatoides*, etc.). In contrast to these I may mention the larvæ of the common freshwater eel (*Leptocephalus brevirostris*), which pass through the Straits of Gibraltar in enormous numbers. This phenomenon was one of particular interest to the expedition, and I hope to be able to say more about this to readers of NATURE later on. Here again we are faced with new problems. Why, for instance, should certain pelagic species stop just outside the Straits of Gibraltar, and others, which out here may be taken in the same haul with the former, not be found in the Mediterranean? Are they killed immediately on entering the Mediterranean by the natural conditions prevailing there, or are they able in some way, despite their pelagic habit, to maintain their position—possibly by means of vertical migrations? Various features would seem to suggest that it is not sufficient to regard the problem solely from the point of view of direction of current as found by the use of a current meter, but that other factors also come into play. Otherwise it would be difficult, for instance, to understand how certain pelagic species of fish (*Myctophum glaciale* and *M. Dofleini*, *Stomias boa*, etc.) can at all seasons occur in far greater quantities—have a maximum of density—in the Alboran Sea (the westernmost part of the Mediterranean, between Spain and Morocco) than either west or east of there, despite the fact that the surface layers are in constant movement towards the east. This is actually the case, as was first shown by A. V. Tåning and Vilh. Ege on the basis of material from the *Thor* expeditions. The *Dana* Expedition has proved the same thing. Comparatively few specimens occur west of Gibraltar and east of Oran, but in the Alboran Sea itself great quantities of all three species were found, so that the contents of a single net might show, for instance, more than 1500 specimens, especially *Myctophum glaciale*.

In conclusion I cannot refrain from emphasising the extreme importance an intensive study of the Straits of Gibraltar and adjacent waters would have for general—physical and biological—oceanography. When, at the commencement of October, I was obliged to leave this area in order to take up the other tasks allotted to the *Dana* Expedition, it was with the conviction that the expedition would in all probability have been able to do more for the cause of oceanography in general by keeping station at Gibraltar during the ten months we have for work, than by cruising about the ocean. Being so convinced, I venture to hope that British naturalists may soon take up this important task, which Great Britain, with Gibraltar as a base, has unique opportunities for dealing with. A research vessel stationed at Gibraltar would take but half an hour to arrive on the scene of operations, the meeting-place of two deep seas. The saving in time and coal, and the unparalleled opportunities of utilising all favourable weather conditions for oceanographical work, are self-evident.

(On board the *Dana*, at San Vicente, Cape Verde Islands, November 1, 1921.)

## Photographic Studies of Heights of Aurora.

By DR. C. CHREE, F.R.S.

THE two publications referred to below,[1] by Prof. Carl Störmer, of Christiania, merit the attention of all interested in the physics of the atmosphere. As is generally known, Prof. Störmer discovered a satisfactory method of measuring the height and position of aurora by means of photographs taken simultaneously at the two ends of a long base. The photographs include two or more stars, the exact positions of which in space are ascertainable, the precise time of taking the photographs being known. The difference between the positions of the aurora relative to the stars in the two photographs enables the necessary calculations to be made.

The first memoir gives a very full account of photographs taken in the spring of 1913 at two Norwegian stations, Bossekop (B.) and Store Korsnes (K.), 27·5 km. apart, near latitude 70° N. Some of the results have been already discussed in a series of papers enumerated on p. 7, which have appeared in different publications, especially *Terrestrial Magnetism and Electricity*, the *Astrophysical Journal*, and the Paris *Comptes rendus*. But the present memoir, besides summarising these, contains much new matter. In chaps. 1 and 2, pp. 8–37, there is a description of the apparatus and equipment and of the methods of observation. This is intended to be supplementary to descriptions already given, but describes various improvements and simplifications. Chap. 3, pp. 38–156, is a complete journal in chronological order of all the 336 pairs of photographs discussed. Besides the date and hour and time of exposure, values are given of the parallax of each selected auroral point (*i.e.* the angle subtended at the point by the 27·5-km. base), its astronomical co-ordinates (altitude and azimuth), and several calculated data, including the height of the point above the ground, and the distance from Bossekop of the point itself and of the corresponding point on the earth's surface vertically under it. The vertical heights vary from 87 to 323 km., the horizontal distances from Bossekop from 5 to 780 km. Some of the more notable auroras are discussed in considerable detail. The 336 pairs of photographs appear in plates 1 to 28, each plate containing twelve B. (Bossekop) and the corresponding twelve K. (Korsnes) photographs. To each pair of photographs there answers a diagram showing the stars used in the calculations, the positions of the auroral points, usually distinguished by numerals, and dashed lines to represent the parallaxes.

We reproduce two pairs of B. and K. photographs. One (Fig. 1) represents an auroral curtain in which twenty-one points were measured. The nearest point (towards the apparent tops of the photographs) was at a horizontal distance of 99 km. from Bossekop, the most remote point (near the lower left-hand corner) at a distance of 265 km. The heights measured varied from 90 to 130 km. Fig. 2 represents a band having the right-hand edge exceedingly sharp and luminous. The twelve points measured are shown in the key diagram (Fig. 3). Their heights varied only from 102 to 108 km. The horizontal distances from Bossekop of points 1 and 12 were respectively 61 and 178 km., and their parallaxes were 13·1° and 7·7°. The stars used were $\alpha$, $\beta$, and $\theta$ Aurigæ. $C_1$ and $C_2$ represent the positions relative to the stars of the centres of the plates for Bossekop and Korsnes. The other details as to the stars refer

[1] Carl Störmer: "Rapport sur une expédition d'aurores boréales à Bossekop et Store Korsnes pendant le printemps de l'année 1913." *Geofysiske Publikationer*, vol. 1, No. 5. Pp. 269+104 plates. (Kristiania, 1921.)
"Exemples de rayons auroraux dépassant des altitudes de 500 kilomètres au-dessus de la terre." *Geofysiske Publikationer*, vol. 2, No. 2. Pp. 5+2 plates. (Kristiania, 1921.)