The Geophysical Institute at Bergen.

By Prof. D'ARCY W. THOMPSON, C.B., F.R.S.

THE little northern town of Bergen, sea-port, fishing-haven, market town, has done more for science in the last two or three generations than many—not to say most—university towns. Its Museum, famous both on its zoological and its archæological sides, is the focus of a number of institutions, libraries, museums, and laboratories, which form among them a real academic community. Prof. Kolderup, the mineralogist, is the present director of the Museum, with such men as Prof. Brinkmann and Mr. James Grieg to help him on one side, and Prof. Haakon Shetelig (a well-known authority on Runic inscriptions) on the other.

I remember the Museum forty years ago, when Danielsson was director, and Fridtjof Nansen had charge of the zoological collections—Danielsson who, with his friend Koren (a medical practitioner), had added a host of beautiful deep-sea things to the European fauna, and Nansen, who had just discovered (almost simultaneously with Cunningham) the hermaphrodite nature of the Hagfish and had written his beautiful memoir on *Myzostoma*, a curious parasite of the Feather-stars. Some few years before, the Bergen fjords had been explored by that great naturalist Michael Sars, parish priest on a neighbouring island, and by his young son George Ossian Sars, afterwards not less famous than the father; of whom the elder was the pioneer of all that deep-sea exploration which captivated Wyville Thomson and Carpenter and their friends, and culminated at length in the *Challenger* Expedition, while the younger laid one of the foundation stones of our scientific study of the fisheries by his discovery of the multitudinous eggs of the cod floating transparent and invisible at the surface of the sea.

For the last thirty years or more the work of Norwegian geophysicists and hydrographers has been no less important than that of their brother naturalists; indeed in several cases, as in Nansen's own, one and the same man has been distinguished both as naturalist and as physicist. Oslo has played its part in this work, but it is Bergen that has done the lion's share; and last month, on June 7, there was opened in Bergen a new and splendid Geophysical Institute, built wholly at the cost of Bergen men, without a penny of subsidy from the State. The chairman of the inaugural meeting was Mr. Johan Lothe, the leading apothecary in the town, president of Bergen's Museum, a generous donor to the new Institute; the Prime Minister, Mr. J. L. Mowinckel, a Bergen shipowner, was also there, whose munificent contributions to the new building had been larger still. Many and many an opulent British town might learn the A B C of civic pride and patriotism from the town of Bergen.

The new Institute is a handsome building, set in a fine avenue of old trees and built on a bluff commanding an extensive view over the fjord and the islands and out to sea. It consists of three main storeys, with ample cellarage below, and a central tower containing three more flats in which the meteorologists have their quarters. Here they not only receive their weather reports from the usual network of wireless stations, but all the while they keep watch on the sky and draw their forecasts largely therefrom, after the manner of the Norwegian school of meteorologists. Dr. Jacob Bjerknes, who represents the third generation of his distinguished family, is in charge of the meteorological part of the Institute.

The ground floor contains chemical laboratories and the main part of the physical laboratories: these being under Prof. Helland-Hansen's charge. The work to be carried on here consists of geophysical investigations of various kinds, particularly studies of wind and water-currents from the dynamical point of view, that is to say, in relation to, or in verification of, the theoretical work of V. Bjerknes, Walfrid Ekman, Sverdrup, Hesselberg, and Helland-Hansen himself. The *Armauer Hansen*, a small but very seaworthy vessel, is at hand for the purpose of these investigations; and it is characteristic of the Institute that all its staff are travellers and explorers as well as laboratory men. The *Armauer Hansen* is a little yawl of 58 tons burden, with a 40 h.p. motor to work the winches and to drive the vessel in case of need; and with this little boat the Bergen oceanographers have surveyed the whole north-eastern Atlantic as far as Rockall, the Azores and Madeira, again and again.

The fittings of the physical laboratories have been planned with great care and experience. No less than five rooms and two cellars have been arranged for magnetic work, and are completely enclosed in a Faraday cage, the network of which is hidden in the plaster of the walls. No metallic circuits of any kind enter or leave this cage; the iron window-frames form part of it, but may be supplemented if need arise by extra gratings. Many small 'gadgets' strike one every here and there. The ceilings are all fitted with rows of screw-sockets, into which hooks or rods may be screwed for the suspension of cables, pipes, or apparatus of any kind. The smaller rooms have their walls covered with jute, on which charts may be pinned. The furniture, desks, tables, drawers, etc., is all standardised and interchangeable. I was struck by the beauty of the woodwork everywhere.

The chemical laboratories will be employed largely in the titration of water samples for chlorine and for oxygen; one or two rooms are arranged for work at constant temperatures, the thermo-regulators being controlled by bi-metallic rods. A lift brings up the water-samples from store-rooms in the basement. The experimental tank is placed in the cellarage; it is built of reinforced concrete, and is 15 m. long by 1·2 m. broad, and 1 m. deep. Three pairs of large glass windows are let into its sides for the study of sub-surface waves, vortices, and the like; and an electric tramway for the propulsion of current meters, etc., runs along overhead. Another and more unusual possession of the Institute is a disused railway tunnel, which runs for some 140 m. at a depth of 15 m. below the building. It has a constant temperature of 10° C., a little above the mean temperature of Bergen; and in this long, calm and uniformly heated tube it is hoped that various important aerodynamical experiments may be carried on.

The laboratories on the next floor are for Dr. H. U. Sverdrup, the well-known physicist and explorer, and for Dr. Krogness. Dr. Sverdrup will have his hands full for some few years to come with the observations made on his recent expedition on the *Maud* to the Siberian coast and Arctic Ocean. He and his colleagues believe that the work of this expedition has been of the very first importance on the geophysical side, next after the classical results of Nansen on the *Fram*; and they think that, profiting by all recent experience and using every modern method and device, they have brought home in the *Maud* the finest oceanographical material ever collected by any expedition. The scientific results of the *Maud* expedition are to be brought out as a separate publication of the Geofysisk Institut; and meanwhile her splendid outfit of apparatus makes a considerable part of the new laboratories' equipment.

While Dr. Sverdrup concerns himself chiefly with theoretical meteorology, Dr. Krogness occupies himself with terrestrial magnetism and cosmical physics. He is about to work up the magnetic observations from all over Norway in his new laboratory, and to undertake for the first time a magnetic survey of the whole country. In this work he is associated with a special commission including Prof. Störmer of Oslo, Prof. Saeland, Rector of the University there, and Prof. Lars Vegard, all three well-known students of terrestrial magnetism, while Dr. Störmer is famous for his mathematical studies of the aurora, for his calculation of the orbits of the cathode rays coming from the sun and of the influence of the earth's magnetism on their paths. Dr. Hesselberg, director of the Meteorological Institute in Oslo, is also associated with these investigations.

Going back for a moment to what I have been saying about the theoretical aspect of Norwegian oceanographical work, a beautiful example of the relation between observed fact and dynamical calculation is not far to seek, apart from the well-known and indispensable theorems due to V. Bjerknes. Recent cruises of the *Armauer Hansen* have added much to our knowledge of the course of the great North Atlantic Current popularly known as the Gulf Stream; and in a recent number of the *Geofysiske Publikasjoner*, Helland-Hansen and Fridtjof Nansen together have not only described its course and branching, but also have brought these phenomena into line with a beautiful theorem of Prof. Walfrid Ekman's. This theorem, published in the *Arkiv für Matematik* about five years ago, is an extension of, or corollary to, the well-known theorems which show how rotation of the earth influences the direction of an ocean current—a matter which one was apt to think had been fully explained. Coming from the westward, the great current reaches mid-Atlantic far to the west of the Bay of Biscay and about half-way between Rockall and the Azores. Here it swerves somewhat abruptly to the southward and presently divides into two branches (see Fig. 1); one, turning sharply northward towards the Porcupine and Rockall Channel, passes thence onwards into the Norwegian Sea; while the other

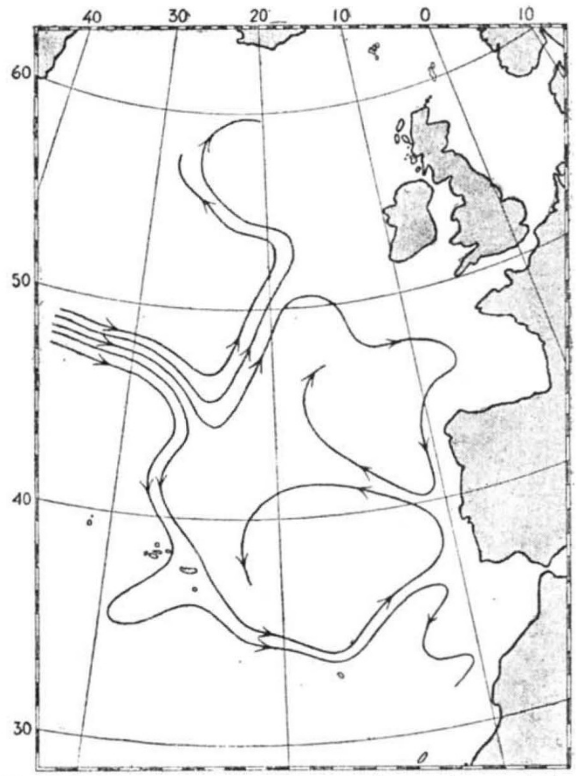

FIG. 1.—Skeleton-representation of the general sub-surface circulation of the eastern North Atlantic. From *Geofysiske Publikasjoner*, Vol. 4, No. 2.

and lesser branch continues to bend southwards towards the Azores, and then flows westward with more and more devious windings to Madeira and the Portuguese coast. Ekman's dynamical theorem tells us that a current flowing from a shallower to a deeper sea will (in the northern hemisphere) tend to be slewed to the left, and vice versa; this law holding good even though the depths be very great. Now there is a well-known 'Longitudinal Ridge' running north and south, midway through the crooked river-channel of the Atlantic; again, from the Azores to Madeira, the bottom stands somewhat higher than in the basins to the north and south, while between Madeira and Portugal soundings are variable and the topography complicated. Putting two and two together we see (or rather we are shown) how the great current bends southward (*i.e.* to the right) just when, and just because, it reaches the comparatively shallow water over the Longitudinal Ridge. Next, that part of the current which is first to cross the ridge is sharply deflected to the left when (and because) it reaches the deep water on the eastern side, and so it shapes its course northward towards the Porcupine Bank and the seas beyond; while the other and lesser portion of the great current is slewed more and more to the right as it follows the shallow waters towards the Azores. Passing Madeira and approaching the Portuguese coast, the course of the current becomes extremely complicated; and "it stands to reason" (as our authors say) that it is here closely following, in all its constant twists and turns, the ups and downs of the complicated topography of the bottom.

Heterogeneity of Steel Ingots.

WHEN a mass of molten steel, originally of uniform composition, solidifies, the analysis of the resulting ingot shows variations from point to point due to local segregations of the various constituents. The extent of this variation differs widely in different cases, and certainly increases with poor steel-making technique. Even with the best of conditions, however, segregation inevitably occurs, and the Iron and Steel Institute appointed in 1924 an important committee to investigate this point and to discover, amongst other things, to what extent segregation must be considered to be inevitable even with the very best steel-making practice.

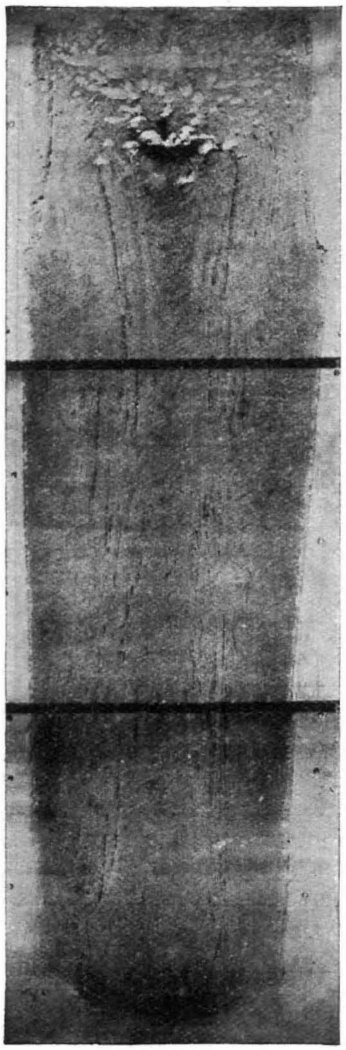

FIG. 1.—Sulphur print of an ingot of nickel-chromium steel showing Λ- and V-shaped segregations. From the Second Report to the Iron and Steel Institute of the Committee on the Heterogeneity of Steel Ingots.

The first report of this Committee was published in the *Journal of the Iron and Steel Institute*, vol. 113, in 1926, and dealt in an exceedingly able manner with segregation in plain carbon steels which were free from blow-holes. It was shown that the ingot could be divided up into zones purer than the average, and others in which definite segregation was to be detected. The lower part of the ingot, for example, is relatively very pure, and a region, shaped something like a sugar-loaf, extends upwards from the base along the central axis. Outside this are found a series of segregated zones of Λ shape separating the steel in the centre from another purer region under the skin. The most highly segregated field occurs at the top of the ingot just below the cavity in the feederhead, and from this the Λ segregates descend somewhat as do the fangs from a tooth. Finally, there is a series of V-shaped segregates extending down the axis of the ingot which may be connected with similarly shaped and situated flaws, due to contraction in the solid state. Fig. 1, which represents the sulphur print of an ingot of a nickel-chromium steel weighing 49 tons, shows these segregations clearly.

In a second report, recently published, the whole question is carried much further, and again comprises an account of some extremely careful work. It considers, first, segregation in sound alloy steels, and, secondly, segregation in ingots of carbon steel which had been deliberately produced highly charged with gas. This, on the solidification of the metal, had been liberated in part and produced blow-holes.

Dealing in the first place with the alloy steels of the nickel, nickel-chrome, and nickel-chrome-molybdenum types, ingots from 15 cwt. to nearly 120 tons have been examined and, generally speaking, the results obtained are closely similar to those given by the plain carbon steels. It is shown again that the degree of segregation normally increases as the size of the ingot increases. Nickel, although it does itself segregate, does so only to a minor degree, and in, for example, an ingot weighing roughly 3 tons, the nickel content in the highest analysis was 3·16 per cent, and in the lowest 3·05 per cent. There is also some reason to believe that the presence of this element has an influence in decreasing the extent of segregation of other elements, and taking, for example, a nickel and a plain carbon steel ingot of roughly similar size, the figures given below may be cited.

Element.	Nickel Steel Ingot.			Carbon Steel Ingot.		
	Highest (per cent).	Lowest (per cent).	Range (per cent).	Highest (per cent).	Lowest (per cent).	Range [1] (per cent).
Carbon .	0·32	0·28	13	0·43	0·32	32
Sulphur .	0·049	0·024	59	0·047	0·032	37
Phosphorus	0·032	0·022	29	0·055	0·039	37
Nickel .	3·16	3·05	3·5	nil	nil	..

[1] Calculated on mean composition of ingot.

Although there is a slightly greater segregation of sulphur, in the nickel steel ingot the segregation of both carbon and phosphorus is reduced.