Scientific Work of the Drifting North Polar Station*

By P. Shirshov and E. Fedorov

EXACTLY a year ago we were preparing for the press an article on the plans we had made for our scientific work on the drifting icefloe. This article was published after the aeroplanes had landed us at the North Pole. It is pleasant to note that everything we had planned to do before we set out on our expedition has been done. Reality brought us much of the unexpected. In particular, the drift turned out to be more rapid than we had anticipated. In consequence, we were able to carry out observations at a considerably greater number of points than was originally planned. Over a distance of 15°—from the Pole to the 75th parallel—we carried out all the work we had set out to do. From February 1, after our icefloe had split, we were compelled to cease hydrological work, because the winch, which was kept about a kilometre from our tent, was carried away.

Owing to the rapidity of the drift, we were compelled to make more frequent observations than had been planned. To cope with the work was only possible because our colleagues—Papanin and Krenkel—relieved us of all domestic duties, which they took entirely upon themselves. Naturally, work like the measurement of the depths, rotatory and other observations, was carried out by the joint efforts of the four of us. Meteorological observations were carried out by Fedorov and Krenkel.

Every observation we made during the drift had to have an exact position. Therefore we endeavoured to determine our longitude and latitude as often and as carefully as possible. For these determinations we had to measure the height of the luminaries above the horizon. During the 274 days of the drift we took 534 series of measurements, from which we calculated our positions at 143 points. These points served as the basis for the entry of our course on the map. Up to the end of September, for astronomical determinations we made observations of the sun and sometimes of the moon. Later, when the oncoming darkness permitted us to see the stars, we always used the latter for our observations. Cloudy weather sometimes left us without a position for six or seven days at a stretch, but happily this did not often occur.

The study of the movement of the ice covering the surface of the Arctic Ocean was one of the most interesting subjects of our work. During the 274 days, we went from lat. 89° 26′ N. and long. 78° W. to lat. 70° 48′ N. and long. 19° 48′ W., covering 1,134 miles (1,800 kilometres) to the south-south-west (more precisely, a course of 197°) reckoning by the shortest line. The numerous zig-zags and loops, especially in the early days, actually lengthened our course, bringing it up to approximately 2,500 kilometres. Consequently, the average speed of drift of the icefloe was 9·1 kilometres or 5·6 miles a day. Though this was the average speed of our movement, actually the movement varied greatly. There were periods when for two or three days we remained on the same spot, and others when we drifted 23 miles (37 kilometres) per day.

The rapidity of the movement increased as we drew farther to the south. It became especially rapid towards the end of the drift, in January and February. For example, from the Pole to lat. 85° N. (from May to October) the average rate of movement was 2·7 miles a day. From lat. 85° to 80° N. (from October to January) the speed of the drift increased to 4·6 miles a day. In January the average speed had already risen to 11·5 miles, and in February to 12·3 miles a day.

What causes the movement of the ice in the region of the polar basin investigated by us ? A preliminary examination of our observations shows that the ice drifts by the action of the wind blowing in a given spot ; yet at the same time it has a continuous movement (directed in general to the south) which is independent of the local wind. Thus, in calm periods the ice moves to the south. A wind blowing from the north will speed up this movement. Southern winds will retard or even overcome it, and drive the ice to the north. The speed of the ice movement independent of the local wind was about a mile a day near the Pole. Farther to the south it gradually increased, reaching 5–7 miles per day between the 75th and 70th parallels.

On this systematic movement is superimposed the drift caused by the wind blowing in the given spot. The wind is powerless to draw the ice in the direction in which it is blowing. Preventing this is the law by which a body moving on the surface of the earth in the northern hemisphere is inclined to deviate to the right of the direction of its original movement. The ice, obeying this law, deviates to the right of the direction of the wind at an angle of about 40°. The speed of movement

* Received through the Soviet Union Year Book Press Service, 623–624 Grand Buildings, Trafalgar Square, W.C.2.

of the ice naturally depends on the velocity of the wind. It is interesting to note that their interaction—the "power of the wind to drive the ice"—was not uniform during the whole of our course. Near the Pole the wind drove the ice with a speed equal approximately to one- to two-hundredths of the velocity of the blowing wind. At the end of the drift the action of the wind increased in effectiveness.

What causes the movement of the ice southwards independently of the local wind ? It seems simplest to assume the existence in the Arctic Ocean of a surface current which draws the ice. However, the rotatory observations, which will be dealt with in detail later, reveal the opposite. It is not the water which draws the ice, but the moving ice which draws after it the upper layers of the water. Evidently the general weather regime in the polar basin results in the prevalence of northerly and north-westerly winds (again we are calculating the direction in relation to the Greenwich meridian). These winds, predominating over a vast stretch, create a general flow of the ice towards the Greenland Sea.

Observations of currents arising in surface layers of the sea from the action of the drift of the ice were carried out by means of simultaneously lowering two rotators to different depths. The observations were made in series of five to six layers. Forty series of this kind were made. It appears that the ice draws only the uppermost surface layer of water. For example, with an ice-drift having a speed of 0·1–0·15 metre per second, the drift current is obvious at depths of 25–35 metres, and only on rare occasions does it affect the water down to 50 metres. The speed of the current decreases quickly with increasing depths. Whereas at a depth of 5 metres (two metres from the lower surface of the ice) the speed of the current fluctuates from 65 to 100 per cent of the speed of the drift, at a depth of 20 metres the speed of the current does not generally exceed 20–30 per cent of the speed of the ice-drift.

The drift current in the upper layers of the water sets in very quickly after the ice drift has begun, but it ceases as rapidly when the ice drift stops. A rapid and prolonged drift of the ice in any one direction draws after it a considerable quantity of water from the surface layer. An inflow of water follows from adjoining regions to replace it. A reverse current sets in to compensate for the movement of the surface waters from the given region. More often the reverse current is observable immediately underneath the surface layer of water drawn by the drift, that is, at a depth of 50–75 metres. However, during prolonged and rapid drifts, the reverse current embraces a considerably thicker layer, 35–125 metres.

In contrast to the drift current of the surface layer, the reverse current sets in after an appreciable lapse of time following the start of the drift of the ice—usually 12–36 hours. It reaches its maximum speed even later still, not infrequently only after the drift of the ice, which set the masses of water into motion, has ceased. Not infrequently, too, the reverse current continues for a long time, sometimes for several days, after the ice drift has stopped. For example, after a rapid drift to the south-east during August 10–13, the reverse current was observed at a depth of 75 metres up to August 19, that is, five days after the drift had ceased.

Measurements of depth were carried out by the help of a specially constructed deep-water hand-worked winch, equipped with a brake of the Lucas type. Altogether thirty-three observations were made, of which fourteen were at depths of more than 3,000 metres.

Starting from the Pole, up to lat. 86° 40′ our icefloe drifted over a deep hollow with an extremely sloping bottom of a depth of 4,300–4,400 metres. The greatest depth here appeared to be 4,395 metres (position lat. 88° 41′ N., long. 10° W.). Then the bottom commenced to rise—unevenly, with big jumps in depths, varying from 300 to 500 metres over a distance of 30 miles. In this region (up to the 84th parallel) the depths varied from 3,500 to 4,050 metres. At lat. 83° 56′ N., long. 0° 47′ E., we discovered a submarine elevation. The depth here was 2,380 metres. Farther on, from lat. 83° 30′ N. to 81° 50′ N., we again came to a depth of more than 3,000 metres. The greatest depth in this region exceeded 4,160 metres (lat. 81° 53′, long. 6° W.). The whole of the cable then on the drum was paid out but failed to reach the bottom. The existence of great depths in this region is of special interest in view of their proximity to Greenland. It was generally supposed that the depths here were those of the continental slope ; actually there were deep hollows situated only forty miles from the North East Foreland.

The next measurement (at lat. 81° N., long. 6° 50′ W.) was carried out on the so-called Nansen threshold. The depth here was 1,420 metres. We know that it used to be supposed that here, between Spitsbergen and the North East Foreland, the sea bed rose to within a thousand metres of the surface, thus dividing the Arctic Ocean from the Greenland Sea. However, we maintain that the depth here is no less than 1,300–1,400 metres, and that, quite probably, the depths in the central parts of the Nansen threshold reach 2,000 metres.

In the Greenland Sea the icefloe drifted over the coastal platform. Here the depths were 160–250 metres, reaching 320 metres in one spot only.

Samples of the bed were taken at eight northern soundings with the aid of a scoop. The ground in the deep hollow of the polar basin is composed of oceanic silt of a reddish-brown colour. Under this layer of silt is grey silt. We have brought samples of these deposits with us for further analysis.

The thirty-eight hydrological soundings made by us during the period of the drift represent the two hydrological sections, from the 89th parallel to Greenland, and in the Greenland Sea to the 76th parallel.

During his drift in the *Fram*, Nansen discovered under a comparatively thin layer of cold Arctic water a powerful layer of water of Atlantic origin with positive temperatures. In 1935 the same water was encountered to the north-west of Severnaya Zemlya (Northern Land) by the Ushakov High Latitude Expedition in the *Sadko*. Lastly, the expedition in the *Krasin* in the same year, 1935, also discovered water with a positive temperature to the north of Herald Island. But all these instances relate to the borders of the polar basin, and it might have been presumed that the Atlantic water penetrating to the Arctic Ocean was pressed by the deflective action of the earth's rotation to the right, towards the Eurasian mainland. However, our investigations have shown that the Atlantic water flowing into the Arctic Ocean between Greenland and Spitsbergen in a powerful current reaches the Pole, apparently spreading extensively through the greater part of the polar basin.

At all the soundings, under the comparatively thin layer of cold Arctic water with negative temperatures common to polar seas, a layer was found with positive temperatures and of considerably greater density than the water of the surface layers.

At soundings taken to the north of the 86th parallel, the upper negative isotherm is at 250 metres, the lower at 750 metres. Thus the thickness of the layer of water with positive temperatures in the region near the Pole reaches 500 metres. The maximum temperature in this region is 0·77° C. (at a depth of 400 metres). Farther on, to the south, between the 86th and 85th parallels, the negative isotherms separate—the upper rising to a depth of 200 metres and the lower dropping somewhat deeper—to 750 metres. Thus the thickness of the layer of Atlantic water here increases. There is an increase also in the temperature of the water: plus 1° C. at a depth of 400 metres, and 0·88° at a depth of 250 metres. Farther to the south the layer of Atlantic water becomes more powerful, and the maximum temperature rose to 1·72° C. (at a depth of 250–300 metres).

At the 81st parallel we came out to the edge of the current of Atlantic water. The isotherms converged sharply as we drew nearer to the North East Foreland of Greenland.

The deep layers were filled with water of temperatures and salinity common to oceanic depths. In the layer at the bottom we observed somewhat higher temperatures—common to all deep oceanic hollows. At a depth of 4,390 metres the temperature of the water reached — 0·63° C. The cause of this rise in the temperature of the water of the bottom layer lies in the warmth flowing from the earth's crust, and also in the bacterial processes of decomposition of organic remains which have sunk to great depths. The heat generated during these processes may cause the rise in the temperature of the water.

With twenty-two hydrological soundings samples of plankton were taken at different depths. As we know, Nansen advanced the theory that the ocean was very poor in organic life in high latitudes. He believed the cause of this to be that under conditions of an ocean completely covered with fields of solid ice even in summer, plant plankton cannot develop owing to the absence of light, and as plant plankton, in the last resort, is the basic nourishment of the entire animal population of the sea, then naturally the higher animals, too, particularly sea animals, could not exist here. But this hypothesis has turned out to be incorrect. During the course of an entire month (August) our observations showed that under the solid ice, in the upper layers of the sea, an intensive development took place of microscopic sea-weed, constituting that 'florescence' of plankton, observable in the 'biological' spring in seas of more southern latitudes. This 'florescence' begins at the end of the short polar summer when all the snow has melted from the surface of the ice, which has also perceptibly suffered from the thaw. Evidently, at that time, the intensity of light penetrating to the water through the melting ice is sufficient for the development of seaweed.

The quantity of plant plankton was estimated by the quantity of chlorophyll, which was determined by a spectrocolorimeter. If plant plankton was able to develop here, then naturally it was possible for animal life to exist; and certainly from all depths of the ocean—even from a depth of 3,000 metres—the plankton net brought up examples of different species of animal plankton.

If plankton exists, it is also possible for the higher animals to exist, and at the 88th parallel we saw a hare, a polar bear with two cubs, not to mention seagulls, which visited our camp on more than one occasion. The hypothesis that no life exists near the Pole must therefore be assumed to be wrong.

Measurements of the force of gravity were made by us at twenty-two points, situated between the

89th and 74th parallels. At present, we have provisionally calculated thirteen of these gravitational points. The last points it was impossible to calculate, as the increasing rapidity of the drift towards the end compelled us to carry out all observations much more frequently and to postpone their working up. The difference between our results and the values given for the same points by the international formula is as follows. At the 89th parallel the observations of the force of gravity practically coincided with the theoretical values. From the 88th to the 84th parallel stretches a field of positive anomaly. Here our measurements give a value greater by approximately 60 mgm. than was supposed. From the 84th to the 83rd parallel is observed a sharp decline in the measured value. At the 83rd parallel the anomaly already has a negative significance of approximately — 30 mgm. Evidently this jump is closely connected with the relief of the bed. Here, as it happens, a rise to the shallow waters at the coasts of Greenland commences.

The object of our magnetic measurements was to elucidate the geographical distribution of the elements of terrestrial magnetism over the course of the drift: inclination, declination and horizontal intensity. For this we made our measurements with the help of a magnetic theodolite. During our stay on the ice floe, we made fifty-five series of determinations of inclinations and horizontal intensity, and thirty-six measurements of declinations. The measurements were taken right up to lat. 84° N. Farther on, the icefloe began to rotate so rapidly that it was impossible to use the variometers. It became necessary to take more frequent measurements in order, so far as possible, to weaken the effect of the magnetic disturbances. The measurements show that over the entire stretch of our drift there were no considerable magnetic anomalies.

With the setting in of the darkness at the beginning of October, we began to make hourly visual observations of the northern lights, and continued these until February 9.

Meteorological observations were carried out by us four times a day. We measured the temperature of the air, pressure (by two aneroids), humidity (in the summer by psychrometer; from August, during the periods of frosts, by a hair hygrometer of the Kuznetsov type), direction and velocity of the wind. At first all the four daily measurements of wind velocity were carried out by an anemometer. Later, when one of our anemometers went out of action, we used the remaining one only once a day, and the other three times determined the velocity of the wind visually. Up to the middle of October we have an unbroken record of wind velocity taken by the anemograph. The barograph and thermograph kept on functioning the whole time.

The rapid drift of the ice permitted us to spend only four summer months in the region of the cold polar cap, the investigation of which is of so great an interest to meteorology. It can now be said with certitude that the weather in this region is considerably calmer than on the borders of the Arctic Ocean. For example, we never observed any very strong winds there, though we did not find the steady anticyclonic regime supposed to exist in that region. Our observations were communicated to the mainland daily.

The foregoing is a provisional account of the results of our scientific work. Immediately on our return home we shall begin to work up our material, so as to give a complete account of the investigations carried out by our expedition to the North Pole.

Oil from Coal*

THE report of the Sub-committee on Oil from Coal of the Committee of Imperial Defence serves a useful purpose, although nothing new is disclosed. Unless unexpected discoveries of petroleum should result from the exploratory work conducted by oil companies as an outcome of the recent Petroleum Act, Great Britain has only one alternative to importing practically the whole of its oil supplies: that is, the large-scale conversion of coal into oil by hydrogenation or synthesis, processes which are still very costly in both capital and operation. Oil and motor spirit are produced in small proportions as by-products from the carbonization industries, but such sources are not capable of indefinite expansion, since their industrial stability is dependent upon adequate markets for the main products—coke of various kinds or gas. They were, however, stimulated by the guaranteed preference at the rate of 4*d.* a gallon for ten years which has operated in favour of home-produced motor spirit since the Act of 1934. Although only 4*d.* per gallon is guaranteed by this Act, the actual preference which has been in operation since 1934 has been 8*d.*, but this involves a shortening of the period during which the guarantee is effective. The report recommends

* Committee of Imperial Defence. Sub-Committee on Oil from Coal: Report (Cmd. 5665). Pp. 71. (London: H.M. Stationery Office, 1938.) 1*s.* 3*d.* net.