The Danish North-East Greenland Expedition, 1906-8: Provisional Results
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of the survey in the Sudan, which, I fear, will prove most difficult to follow.

Mention has been made above of the Cadastral survey work of the department. Town surveys have also been undertaken, and those of Halfa, Berber, Atbara, El Damer, Shendi, Rufaa, Singa, and Gedaref have been completed.

The town of Omdurman comprises some 10,000 compounds, and with building land reaching the fictitious value of 10*s.* per square metre during the boom of 1907, a systematic survey became indispensable. The work is now approaching completion. The scale 1 : 500 was adopted, the town cut up by main and subsidiary traverses adjusted to trigonometrical stations, and the detail plane-tabled in, in many cases from the tops of buildings. A maze of ruins existed, and often the only entrance to a particular plot was through the property of the neighbouring owner.

The natives are now rebuilding on a very large scale, and much of the time of the Town Survey staff is occupied in fixing the alignments of the new compounds so as to fit in to a scheme for a new and sanitary town laid out with the necessary roads and lanes.

THE DANISH NORTH-EAST GREENLAND EXPEDITION, 1906-8: PROVISIONAL RESULTS.*

By Dr. J. LINDHARD.

THE moving spirit of the whole undertaking, the expedition's founder and leader, was L. Mylius-Erichsen. He succeeded after unwearied toil in obtaining so much support for his projects, both from private individuals and the state, that the vessel of the expedition, the *Danmark*, was ready to sail in June, 1906.

Mylius-Erichsen's plan was to drive the vessel during the late summer of 1906 as far north as possible, and to establish at the most northerly point a large depôt for future sledge journeys; then to seek a winter haven for the ship in the neighbourhood of Cape Bismarck, and from here to map the unknown north-east coast with dog-sledges in the early part of 1907; in the latter part of the year to sail in the vessel southwards to one of the most northern arms of the Kaiser Franz Josef's fiord, whence the voyage home might be considered assured; and in the early part of 1908 to undertake a sledge journey across the mainland to one of the most northerly Danish colonies, this detachment rejoining the main party of the expedition in Angmagsalik, whence all would return home.

This plan had, indeed, in consequence of several circumstances, to be modified in various points. The most important alteration, which however had no serious effect on the scientific work, was that the

* See *Geographical Journal*, vol. **33**, p. 40, and map, p. 116.

vessel remained at its anchorage, "Danmarkshavn," in 76° 46′ N. lat. and 18° 30′ W. long., from its arrival at the coast in August, 1906, till our departure in July, 1908.

In the following pages I shall describe the work executed by the expedition during the period mentioned, and give some account of the material brought home and the preliminary results. A general survey of the scientific material will be published, partly in English and partly in German, in the *Meddelelser om Grönland.*

The chief aim of the expedition was geographical survey, its extent and limits being determined by the work of former explorers.

In 1870 the sledge party from the *Germania* expedition reached lat. 77° 2′, but owing to unfavourable travelling conditions the mapping work became very defective even at 75° 43′, the coast about Teufel cape and in Dove bay, as well as the outer land near Cape Bismarck, remaining quite unexplored. In 1905 the *Belgica* sailed along the outermost islands from about lat. 76° to 78° N. This expedition succeeded in determining in general the coast-line up to 78°, and ascertaining the existence of land up to about 79°. From 79° to 82° the land was entirely unknown. In 1892 and 1895 Peary travelled from Cape York over the inland ice, and in lat. 81° 40′ N. and long. 35° W. came to land which he naturally assumed to be part of the east coast of Greenland. He at the same time found that a large fiord or sound stretched from the east to the south of Peary Land, so that this must be assumed to be an island. In 1900 Peary travelled northwards from Cape York, passed the northern extremity of Greenland, and proceeded down the east coast as far as 83°. The last stretch of coast was less exactly surveyed owing to unfavourable weather.

The task of the *Danmark* expedition was, therefore, to map the east coast of Greenland from 75° 43′ northwards to about 83° 30′, a distance which might be estimated beforehand at not less than 620 miles. All the work was accomplished by sledge-journeys, as the ice conditions rendered it impossible to take observations from the ship. The instruments consisted of six small Hildebrandt travelling theodolites with their compasses, six pocket chronometers, six Zeiss binocular field-glasses, pocket aneroids, sling thermometers, etc.

The annexed sketch-map * gives some idea of part of the results. Especially noticeable is the fact that Greenland extends much further eastwards than had been expected. The unknown part of the coast-line proved to be fully 180 miles longer than calculated, and to enclose an area of about 13,000 square miles. The sketch-map is compiled from a calculation of the most important observations.

The material collected comprised—

A. Astronomical determinations, including azimuth readings, executed at about 160 stations.

* See previous note.

B. Triangulation determinations of places at about 35 stations.

C. Measurements of horizontal angles and levellings executed at about 200 stations.

D. Perspective sketches and map-sketches about 150, some of especial topographical interest.

E. Artistically executed sketches in pencil, about 120 landscape paintings and sketches in oil, as well as very numerous photographs.

Besides the general geographical survey, triangulation and base measurement were included in the programme of the expedition. Such work was considered desirable, partly as a groundwork for special maps, partly to render possible a connection with the German triangulation on Shannon island and Hochstetter's foreland, and lastly in connection with the proposed investigation of terrestrial refraction. The base-measurement was carried out on a level stretch just to the north of the permanent observatory, which, in summer a swamp, was at the time of the measurement frozen and partly covered with snow. The terminals of the line were marked by two bronze standards secured in solid rock. The measurement was made with a 24-metre steel ribbon, which had been adjusted at the standard base of the General Staff, in Copenhagen. The line was measured nine times in all, and the preliminary calculation gave as result a length of 1450 metres (4757·2 feet).

In September, 1906, the work of reconnoitring and erection of marks was proceeded with at twelve stations in the environs of Danmarkshavn. A cylindrical pillar was carefully built up, and its axis formed by a bronze rod, which was driven into a hole bored in the rock. The measurement of angles was continued from September 8 to 28, 1906. Horizontal angles were measured in three sets, vertical angles (trigonometrical levelling) in two sets. To obtain a starting-point for levelling, the zero point from the expedition's water-level measurements was carried to a zero post on land, and thence in a loop on to the permanent observatory and the ends of the base. At the end of the same year the permanent observatory was connected with the triangulation network.

These preliminary observations were executed in the first winter. The following year the triangulation network was extended westwards to the Orientirung islands and Hvalros (walrus) point and southwards to the Haystack, whereby a connection, though somewhat uncertain, was effected with the survey of the *Germania* expedition, so that it was possible to take advantage of this expedition's determinations of longitude and those carefully executed by Sabine on the Pendulum islands.

In view of the importance of detailed maps, not only for the topographical description of the country, but also for other scientific

investigations of the expedition, ethnographical, botanical, and zoological, the following works were executed :—

1. Plane-table survey on the scale of 1 : 50,000 of Danmarkshavn and its surroundings, 52 × 52 centimetres (20½ inches). Area included about 260 square miles, but a large part of it water. The relief of the ground was indicated by contours at intervals of 10 metres (33 feet).

2. Plane-table survey on the scale of 1 : 100,000 of Danmarkshavn and its neighbourhood, 52 × 52 centimetres. Area about 1040 square miles, more than half being water. This map extends on all sides beyond the limits of the foregoing. The relief is similarly indicated.

3. Map on the scale of 1 : 2000 of the wintering station. This map, 26 × 21 centimetres (10¼ × 8¼ inches), shows the position of the ship, the situation of the storehouse, the observatory, the meteorological, the magnetic and electricity of the air installations, etc. The relief is shown by contours at 1 metre intervals.

4. Map of the Gnipa cavern on the scale of 1 : 4000; contours at 5 metres (16·4 feet). The map, in consequence of the nature of subject, can only show the surface of the ground and indicate the situation, extent, and breadth of the cave with the relief of its bottom. The cavern being a unique occurrence of peculiar character and of particular glaciological interest, a longitudinal section was drawn, as well as a large number of cross-sections, and photographs were taken.

As the surveys 1 and 2 represented only one of the characteristic landscape forms, namely, the *moutonné*, there was surveyed map—

5. A map on the scale 1 : 50,000 of the plateau country at Pustervig and Mörkefiord. The relief will be shown by hatchings.

Lastly, in order to give a graphical representation of the chief geographical conditions affecting the peculiar bird fauna of the swampy district west of Storm cape, in the summer of 1908 was compiled—

6. An ornithological map of the area mentioned. The map, on the scale of 1 : 25,000, embraces an area of about 15 square miles.

In connection with the cartographical work the following problems had to be solved :—

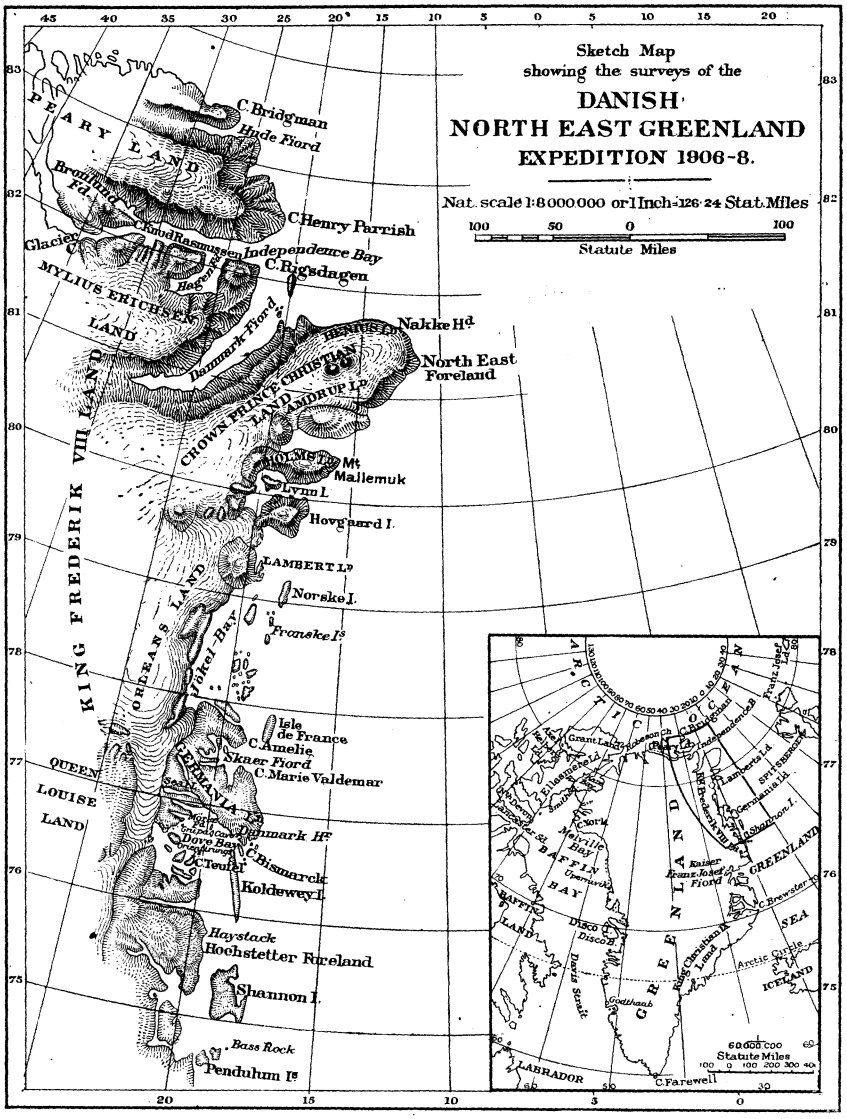
Determination of the geographical co-ordinates of the winter station.

Azimuthal readings for the orientation of the triangulation network.

Determination of the local time.

In September, 1906, the observatory was installed on a granite pile, which was firmly fixed in the ground with cement. On the pile, and securely fastened to it, was an iron plate, on to which the instrument, a Hildebrandt theodolite, with its micrometers, was screwed. Latitude observations were made in the latter part of 1906 by zenith distance measurements of two stars near the meridian on either side of the zenith. When later observations had been taken to determine the sidereal refraction there was material to ascertain the latitude with any desired degree of exactness.

It was intended on a sledge journey in November, 1906, to transfer the time from the Pendulum islands to Danmarkshavn with the aid of three pocket chronometers. The attempt failed owing to the difficult



travelling conditions and the awkwardness of using the chronometers at the very low temperature. As the determination of the longitude by trigonometrical methods in September, 1907, could not be considered reliable, the longitude was obtained from the movements of the moon.

The method of lunar azimuths was adopted, which was well suited both for Arctic conditions and for the instrument of the expedition. Altogether, lunar azimuths were measured twenty-one times, with forty-two corresponding determinations of time whence material was obtained for twenty-six pairs of independent values of longitude. Azimuth observations were made of the polar star at its greatest meridian distance. Almost all the time determinations were transit observations of a polar star, the stars α and λ *ursæ minoris* being used. In summer, of course, the time had to be fixed by zenith distances of the sun.

The astronomers of the *Germania* expedition were led by a regular difference in solar observations for time, morning and afternoon, to the conclusion that the refraction of light in East Greenland must be less than that given in the tables of Bessel and others. To settle this question a series of investigations into sidereal refraction was instituted. The observations took exclusively the form of zenith distances near the meridian for the determination of latitude.

In summer the sun had to be resorted to exclusively. In general, six readings were taken at the upper and lower culmination of each limb of the sun, grouped so that the meridional zenith distances could be conveniently calculated both for the upper and lower limb. In all twenty-eight sets of twelve zenith distances of the sun were taken. In the latter part of 1907, meridional zenith distances—single observations—were made of fifty fixed stars, so grouped that they were distributed at about equal distances on both sides of the zenith. Some of the solar observations were worked out, and as these showed no clear agreement with the tables issued by the *Germania* expedition, a series of experimental solar time determinations was taken morning and afternoon, as well as intermediate determinations at night in the vertical of Polaris. Neither did these observations seem to give results in the direction indicated by the *Germania* expedition.

As terrestrial refraction, both as regards its absolute value and its variations, is of great importance on a geographical exploration, where one cannot always choose time and opportunity for observations, a special series of investigations was instituted with regard to this phenomenon. A scientific determination of periodic refraction constants could not be effected with the means available, but results sufficient for practical purposes might be expected.

From August to October, 1907, reciprocal simultaneous zenith distances were measured five times over the land between the fixed observatory and pillar X., and once over the water between the observatory and a rock. The distances between these points were about $4\frac{1}{2}$ and 6 miles respectively. For the measurements the fixed instrument was used at the observatory, and at the pillar and reef one of the small portable alt-azimuth instruments. In view of the different conditions at the two terminal points, 2×20 readings were taken each time from

pillar X. and from the rock, while the simultaneous observations at the observatory consisted of 2 × 8 readings. The interval between the two groups was about five hours, during which levellings were executed from the observatory to the pillars V., IX., and X., as well as to the reef.

To ascertain the refraction variations a series of levellings was executed in two sets to the pillars V., IX., and X., as well as to the rock mentioned, and to the horizon at three different points. These measurements (in the summer of 1907) were frequently executed at the same time with balloon and kite ascents, or with special meteorological observations at the crow's nest of the ship.

Altogether fifty-three double sets were obtained to the pillars and rock, forty-seven single sets to the three points on the horizon, and thirty special levellings to pillar X. As expected, the levellings proved that the refraction is subject to very considerable variations.

Geologically, the country exhibits great uniformity; the archæan massive extends out to the coast along far the greater part of its extent. There are, however, in some parts high plateaus, as round Mörkefiord and Seal lake around Skærfiord, and also alpine country occurs in Queen Louise's Land, in a limited extent at about 80°, and Peary Land. Sedimentary rocks occur in a very small belt along the coast, and as a rule in fairly undisturbed beds. Late eruptive rocks are not to be found either in association with sedimentary deposits or elsewhere. Large palæological collections were brought home from various sources.

In the southernmost region, Hochstätter's foreland, the fossils were in a bad state of preservation and collection was difficult, for the land at the time of investigation was still covered with snow; but still the material brought home shows that the view hitherto held of the Tertiary age of this formation cannot be maintained. Covered by the lofty bed-rock which forms the western side of the large Koldewey island are found on the east side of the island Jurassic deposits with many well-preserved marine fossils. The beds form a plateau about 390 feet high, overlying gneiss, and are very conspicuous in some fissures out towards the sea. In contact with the Jurassic deposits but not overlying them is found a less extensive, much disturbed, deposit of late Cretaceous rocks.

In the region west of the ship's harbour is a considerable extent of raised sea-bottom, a singularly undulating country, consisting of sand-banks up to a height of 490 feet, which in section was seen to consist of quite loose sandstone, with belts of lime and a very fine seam of coal. At one place were found half-petrified bones of a large whale. The raised bottom was of large extent, and attained a height of some 1600 feet. Bivalve shells were found on this formation up to a height of 800 feet.

In the most northerly part of Germania Land, at the edge of the ice-stream which descends to the south-western point of Glacier (Jökel) bay, a bed containing fossil plants was found in a ravine. The fossils brought home from here were not so well preserved; their age is not yet determined.

By far the largest and most interesting sedimentary deposits occur to the north, between lat. 80° and 81°, where they form grand elevations on the south side of Holms Land and partly along the southern coast of Amdrup's Land. The material collected seems to show from a preliminary examination that these beds must be referred to the Carboniferous system, and in the circumstances of their bedding they bear a close resemblance to the early Carboniferous strata of Spitsbergen.

The coast land is bounded to a great extent by inland ice on the west and ice-covered sea on the east.

The glaciological investigations dealt chiefly with the winter harbour and its immediate surroundings, 76½° to 77°, but were also extended over all north-east Greenland from 75° to 83½°. While a broad coastal zone with prominent elevations occurs at Scoresby sound and Franz Josef's fiord, the ice-free land farther north becomes lower and narrower, and west of Danmarkshavn, where the heights are everywhere less than 3300 feet, the inland ice runs out to the sea in a glacier 12 to 18 miles broad. North of the winter harbour, the ice-free strip becomes still narrower, and from the neighbourhood of Lambert's Land a continuous coastal belt does not exist, but only some patches separated from one another by broad tongues of ice. Yet north of Lambert's Land, between 79½° and 80¾°, occurs a high mountainous land, intersected by numerous fjords, which blocks the course of the inland ice and at the same time has protected the sedimentary rocks lying here from glacial abrasion; but north of 80¾° the land sinks quite down; the coast-line disappears almost entirely under the inland ice. In relation to the small precipitation in north-east Greenland, the ice-mantle may be considered to be very extensive. On the other hand, the mountainous Peary Land, as far as may be judged from Peary's and the *Danmark* expedition's journeys, is almost clear of inland ice.

From the glacier, 25 miles broad, south-west of Lambert's Land, the ice streams out over Glacier bay, between 78° and 79° N. lat., which is covered and almost entirely filled up with a continuous mass of inland ice. Only the south-west corner of the bay is free of inland ice; it is instead full of calved ice from the glaciers, which here reach to the water. Only occasionally do the ice-floes escape from the bay; as a rule, they melt or evaporate away on the spot.

The ice in Glacier bay has most of the features characteristic of the marginal zone of the inland ice—fissures, undulations, reports produced by thawing, just as, also, the structure, stratification, and

surface moraines show that one is really on inland ice; but in other respects this ice exhibits striking peculiarities, due to—

(1) That the ice is for the most part afloat;

(2) That the surrounding sea is always covered with sea-ice.

The results are, firstly, that the crevasses are not very deep, scarcely anywhere more than 115 feet, and that the bottom is horizontal and covered with salt ice; but a far greater effect on the character of the ice is exercised by the great compression caused by the tide. This is due to the same cause as is active where the ice-sheet breaks off from a glacier or at the formation of an ice-foot—the rending and pressure of tidal water in an ice-bound fiord. The result, however, is different, an ice-foot, for instance, being a very rare occurrence.

When the sea outside is free of ice, the ice which breaks loose in the tidal water produces calf ice or icebergs, and is carried away, while the margin of the inland ice stands up like a wall, as is the case far north on the east coast of Greenland, between 80¾° and 81¼° N. lat., where the open sea is in direct contact with the inland ice, just as occurs in the Antarctic regions; but at Glacier bay sea-ice bars the way and the ice-sheet remains in its place or is crumpled up. In consequence of the movement of the whole ice mass out from the coast, the crushed ice is gradually worn down and at length loses its character. The area of compression thus contains parts within which the ice rests on the bottom and outside which it is floating. Here the under side is attacked by the salt sea-water, thins out, and finally is lost in the sea-ice. The peculiar circumstances thus cause the transition from inland ice to sea-ice to become quite effaced, and in the early part of the year, when the snow-mantle is thick, one may drive half-a-day's journey without being able to decide whether one is on land or sea-ice. Such conditions as in Glacier bay are met with in the broad fjord north of Lambert's Land as well as between Danmarksfiord and Nakke (occiput) head.

South of the north-easterly sweep, on the other hand, where open sea runs right up to the coast, one finds, as already mentioned, an ice-wall about 30 miles long with a height attaining to 50 feet.

In March and May, 1908, two sledge-journeys were undertaken over the inland ice. The goal of these journeys was a mountainous country, 5000 to 6500 feet high, lying about 90 miles west of the expedition's winter haven, Queen Louise Land, which is entirely surrounded by inland ice. Neither of these journeys yielded absolutely new observations on the ice, but yet they contributed in no small degree to our knowledge of the conditions in the marginal zone (the surface and gradient of the ice, distribution of precipitation, snow limit, extent and structure of ground moraines, water-line at *nunataks*, etc.), and the excellent photographs obtained on these two journeys are of more than usual interest.

In the course of the winter huge masses of snow were piled up in the hollows, which the short summer was unable to contend with. Besides large sheets of firn occurring in abundance, in the later part of the year frozen remains of snowdrifts were seen in the valleys, and, especially in the river-beds in the valley bottoms, quite small firn-patches, beneath which the river had made its way and hollowed out the drift. Though the first breach is made by water, the excavation is continued by the circulation of air, and thawing and evaporation can produce caverns of considerable dimensions. The largest of these, the Gnipa cave, was more than 2600 feet long; its height varied from 13 to 65 feet, and its maximum breadth was about 100 feet. Dirty layers alternated with layers of transparent and opaque ice. In the central part where the cave was quite dark, the form was a very regular barrel vaulting, but towards the ends the structure was more variable. The reflection of light from the vaulting, the shining points of the icicles a yard long, and the fantastic forms of the ice lent this section of the cave a romantic beauty.

Besides the map already mentioned, and a complete description of the details, as well as investigations into the circumstances of the cave's formation, the expedition brought home a very large and very good collection of illustrations of the Gnipa cave.

Investigations of the sea were principally executed during the sea-voyages from and to the winter haven between 75° and 78°, but they were continued during the sojourn on land by sledge expeditions to the ice-covered fiords and lakes in which were constantly collected material. The results consisted chiefly of (1) a cross-section of the polar current from the Atlantic ocean-depth (about 1300 fathoms) across the current over the submarine plateau to the coast. In agreement with earlier researches an intermediate layer of warm salt water was found, above it polar water of lower salinity, and a bottom layer of colder and likewise highly saline water. In the middle layer, which was first detected by Ryder and afterwards was the object of a careful investigation by the *Belgica* expedition, with results agreeing well with those of the *Danmark* expedition, was found a temperature of 34·3° and a maximum salinity of 34·97 per mille, while the bottom water showed a constant salinity of 34·88 per mille, and a temperature of about 30°. In contrast to these layers, both originating from the Atlantic, the surface water has a salinity of only 32° per mille. This water forms the southwards-flowing ice-bearing polar current which seems to follow fairly closely the submarine plateau (30 to 220 fathoms deep), over which it has its greatest velocity. The velocity diminishes very quickly out towards the Atlantic depths, and also decreases towards the coast, where deeper water (247 fathoms) often occurs. The distribution of ice in the stream was the old familiar one: an outer zone, with somewhat scattered ice in small pieces; a central zone occupying the greater part of the current, with heavy pack-

ice several years old, and densest at the margins of the belt; and an inner zone of open coast-water with scattered ice, partly detached floes from pack-ice, and partly winter ice from bays and fiords. (2) A series of determinations of the fjord water's salinity and temperature. The water of the upper layer was cold and slightly salt, whereas in the deeper fiords, where the depths were over 800 feet, warmer (32·9°) and salter water (34·85 per mille) was found.

In a lake, lying about 30 feet above the sea, there was found at a depth of about 200 feet a temperature of 35·6°, and a salinity of 28° per mille. This salt bottom-water smelt strongly of sulphuretted hydrogen. The lake had an outlet to the sea by a broad and abundant river; its lower part, about 30 miles from the river head, was full of morainic deposits, the inland ice sending out a small glacier into the lake. Almost all over it floated broken calf-ice. (3) Investigations into the fiord ice, which showed that its conditions were very different in the two winters. About Danmarkshavn the fjord ice in the winter 1906–7 attained an average thickness of about 70 inches. It was hard and compact, and increased considerably in thickness at the beginning of winter and afterwards slowly. The maximum thickness was reached in March, and there was little diminution in April and May. The breaking up of the ice in the summer of 1907 was on the whole very incomplete. In the winter 1907–8 the ice in the same places attained a thickness of only about 47 inches. Early in the season, while the ice was still thin (about 8 inches), a heavy fall of snow caused it to be covered with water, which was turned into less compact, granulated snow-ice. This ice melted completely in the summer of 1908. Besides these measurements, current measurements were taken in various fiords, and a detailed sounding of the sounds at Danmarkshavn was executed.

In continuation of Dr. Krogh's researches in West Greenland * a series of simultaneous determinations of carbonic acid tension were made in the surface water and the atmosphere at the season when the sea was free of ice. Also a large series of carbonic acid observations in the atmosphere were made in different seasons with relation to respiration experiments.

At the ship's harbour continuous series of tidal observations were repeatedly recorded but the results cannot yet be given.

The meteorological investigations consist of the following observations. At the station Danmarkshavn the following instruments were read three times daily (8 a.m., 2 p.m. and 9 p.m.) from August 16, 1906, to July 21, 1908: barometer (mercurial), thermometer, psychrometer, hair hygrometer, and Wild's anemometer; also at 8 a.m. the rain-gauge and the maximum and minimum thermometers (as at Danish meteorological stations). During the whole stay the self-recording instruments for temperature and atmospheric pressure were in operation.

* *Meddelelser om Grönland*, xxvi.

In addition daily readings were recorded in the winter of 1907-08, of the same kinds at the Pustervig station about 37 miles west of the ship's harbour. The object of this latter station was to investigate the climate in the inner fiords as contrasted with the coast climate at Danmarkshavn. Interesting observations resulted both as regards the distribution of precipitation and particularly with respect to the polar föhn. For instance, it may be mentioned that a föhn, which at Pustervig brought the temperature 72° up, made the thermometer at Danmarkshavn rise only 48°. Lastly, at the Pustervig station temperatures were recorded at various heights on the slopes of the Monument mountain (about 2600 feet). These readings have an especial interest when compared with the results of kite ascents at the main station.

At the head station an especial investigation was made into the daily movements of temperature in the lower 100 feet during calm weather. With this object readings were taken once a month every two hours during twenty-four hours, and at various heights from the sea-ice to the crow's nest. The instruments employed were Assmann's aspiration psychrometer, a hair hygrometer, anemometer, and black-bulb thermometer. As a rule there was an inversion of temperature, which in the spring attained the considerable difference of 14°.

For the first time in the history of Arctic exploration kites and captive balloons were employed by the *Danmark* expedition for the systematic investigation of atmospheric conditions in the higher strata of the atmosphere. Altogether kites were sent up ninety-nine times and balloons twenty-six times to an average height of 3163 feet. The maximum height was for kites 10,200 feet, for balloons 8140 feet. The chief results obtained are already published.*

On mirage there is a large number of observations as well as good photographs, while repeated ascents of kites and balloons exhibit the peculiar arrangement of the layers of air which produce this phenomenon. Of other observations in the domain of meteorological optics may be mentioned those of solar halos, of which photographs were likewise brought home.

Observation of cloud forms revealed cloud formations characteristic of these regions, called in the mean time "föhn-clouds." These may be considered as waves of interference in a surface of discontinuity at a height of 4000 to 4200 feet, produced by friction against the high mountain land to the west of the station. Good photographs have also been brought home of cloud forms.

Lastly, material has been collected to illustrate the very sudden and unusually large variations of temperature which the thermograms from Danmarkshavn, and especially from Pustervig, exhibit, and for

* *Meddelelser om Grönland*, xlii. vol. 2, No. 1.

elucidating the polar föhn. Furthermore, there are numerous scattered observations on meteorological phenomena—insolation, depth of snow, and the quantity of snow in the atmosphere during snowstorms, etc., as well as a number of notes during the voyage of the vessel and during sledge journeys.

The proposed investigation into the electricity of the air could only be attacked in the summer of 1907. Once a month observations were made extending over twenty-four hours and dealing with the electrical potential of the air and its conductivity (Gerdien's apparatus). In winter there was necessarily a reduction in the plan of observation, but a certain number of records were obtained. Several short registrations were made of the electric potential (Benndorf's apparatus), the longest of which extended over little more than a month.

Once a month the three magnetic elements—declination, inclination, and horizontal intensity—were determined with a theodolite; the last, however, only till the end of 1907, as the instrument's mirror became useless. The record of declination extends over a year. During the measurements at Germaniahavn an attempt was made to ascertain the secular variation since 1870. Lastly, on sledge journeys a large number of rough determinations of declination were made.

The ethnographical work of the expedition was seriously affected by the loss, during a journey in 1907, of the leader, on whom research in this domain depended. In the latter part of 1906 some preliminary journeys were undertaken with an ethnographical object, so that the field of work was partly known in main outlines, but all the summer of 1907 was lost for systematic work. At the end of the year 1907 the secretary of the expedition (C. B. Thostrup) was deputed to continue Mylius Erichsen's interrupted investigations, and to his energy is due the collection of very considerable material.

As in other branches of inquiry, exact systematic research was confined to a small region, but from sledge journeys collections and notes were also obtained for the whole of the coast-line visited by the expedition. It was found that the country was uninhabited, but numerous remains were left indicating former settlements of Eskimos.

The material brought home consists of a large collection of ethnographical objects (more than twelve hundred), including all kinds of weapons and implements or fragments of them, as well as ornaments and domestic utensils. At 80° 24′ N. lat. was found a large collection, exclusively bone articles, at other places stone implements; no iron was found. It appears that women's boats and kayaks were known, and that sledge-travelling had reached a very high development. Among implements of the chase are salmon spears and bird bolts. Whetstones were scarce; lamps and cooking vessels are made of hard stone.

The kitchen refuse brought home shows that the extinct tribe subsisted on pretty nearly all the kinds of animals living in the country

(*Lepus variabilis*, *Myodes torquatus*, *Canis familiaris*, *Ursus maritimus*, *Rangifer tarandus*, and *Ovibos moschatus*), besides several marine animals (*Balæna mysticetus*, *Trichechus rosmarus*, *Erignathus barbatus*, *Phoca fœtida*, *Monodon monocerus*) and various birds (*Lagopus mutus*, *Anser segetum*, *Larus glaucus*). Of land animals, the musk-ox (*Ovibos moschatus*) seems to have been of great importance.

A quantity of human skeletons and fragments, including eight skulls,* were obtained from some burial-places. In some of these the teeth were worn away almost to the jaw.

In addition there are a large quantity of notes, comprising descriptions of localities and settlements, drawings of settlements, arrangement and measurement of certain ruins as winter houses, tent circles, meat pits, boat stations, graves, etc. A quantity of photographs were also taken.

To judge from the winter houses, it would seem that there must have been three different settlements. Between the first and second a considerable space of time must have intervened; while between the second and third there was a comparatively short interval. In the district round the winter harbour were found thirty-two of the oldest winter houses, twenty of the second period, and only four of the latest. This may indicate that two immigrations took place at a long interval, and that possibly the few most recent houses are the work of a remnant of the last tribe, which, after trying to reach other and better districts, had to make a return journey along the coast, and finally (as various finds point out) perished here. The ice-free land being here of small breadth, the Eskimos could not make annual journeys inland as they do in other districts, though there are traces of something of the kind in the inner parts of Dove bay at the south end of Seal island and at Rype mountain, where there was opportunity to hunt musk-oxen and reindeer, and also for salmon fishing.

If we consider the circumstances of the first case, we find that the earlier settlers were not spread over the long coastal strip, but were collected in groups at the most suitable spots, separated by more or less inaccessible and extremely barren stretches of coast. On Peary Land no ruins were seen and no trace of man, but elsewhere they occurred from Shannon island to C. Glacier, where the conditions rendered human residence possible, relics of a time when Eskimo tribes inhabited the country.

The ornithological booty of the expedition was unexpectedly abundant. After preliminary investigations at the close of the summer of 1906, continuous observations and biological inquiries were made in 1907 and 1908 in a specially selected district (of which a special map

* A large work on Eskimo crania by Prof. F. C. C. Hansen, Copenhagen, and Prof. Fürst, Lund, will soon appear.

on the scale 1 : 25,000 was afterwards drawn up), in which most of the birds existing in the country were found breeding, particular attention being paid to the breeding-places of such little-known species as *Tringa canutus*, *Calidris arenaria*, *Phaleropus fulicarius*, *Larus sabinei*, *Larus eburneus*, *Anser leucopsis*, and *Somateria spectabilis*.

Of all the species here mentioned, the ornithologist brought home an extraordinarily complete set of specimens, not only of full-grown birds, but also of eggs and young in different stages of development. Thus, for example, twenty-four eggs, and at least as many downy chicks, were collected of *Calidris arenaria*; also eggs of *Larus sabinei*, *Larus eburneus*, and *Phaleropus fulicarius*. Moreover, a breeding-place was noted of about thirty pairs of *Tringa canutus*. New for East Greenland was *Fuligula marila*, of which a specimen was brought home. The better-known bird forms are also fully illustrated, both fully developed birds and young ones and eggs; also photographs of flying birds, birds on the nest, and nests with eggs were taken.

The biological notes include exact dates of the arrival and departure of birds, remarks on the life conditions of all the birds, pairing peculiarities, enemies, etc., thorough investigations into the change of plumage of *Lagopus mutus*, etc. In the unfavourable summer of 1907 there was an opportunity of studying the serious inconvenience which the untoward conditions of the ice caused to birds whose breeding is dependent on open water. Besides this systematic work, many observations of ornithological interest were made during the journeys; thus important bird cliffs were noticed at lat. 80° 12′ and 80° 30′, where *Fulmarus glacialis* was observed breeding.

Abundant information has also been obtained regarding the occurrence of land mammals. On such a well-known animal as *Ursus maritimus* scarcely anything new can be said; yet observations on the mating and bringing-forth of the bear may arouse interest. Of *Canis lupus* there is a very full account, notes on its habits and mode of life; five specimens of the animal were obtained. *Canis lagopus* was also the object of a thorough biological investigation as to the shedding of its coat, breeding, and means of subsistence in the dark season.

With regard to *Mustela erminia*, so seldom obtained in Greenland, very full biological information was obtained. The collections were enriched with eight specimens—five in the winter, two in the summer, and one in the intermediate coat. *Lepus glacialis*, owing to its relative frequency and its remarkable fearlessness at most seasons, was an especially easy object of observation. Among other things a large collection of photographs was obtained of the living animals at close quarters. *Myodes torquatus* was a very interesting subject, as with the existence of the lemming was bound up that of several other animal forms. When the unfavourable weather in the winter 1906–7 reduced considerably the number of lemmings, it also produced serious interference

in other forms of animal life. Wherever the expedition travelled numerous traces of *Ovibos moschatus* were found—skeletons, excrements, spoor. The animal itself was seen only in small numbers, chiefly in the northernmost parts, in Danmarkfjord and in Peary Land. *Rangifer tarandus* had also left numerous signs of its former existence in the country, but the living animal was never met with.

With regard to the sea mammals only scattered notes have been collected. One of the most interesting is that *Trichechus rosmarus* kills seals for food. On one occasion a combat was witnessed, and on another occasion large pieces of seal skin and blubber were found in the stomach of a slain walrus.

The insect fauna* in the district round the winter harbour has in the main the same character as that of the southern region of East Greenland, and differs only in containing a small number of species. A peculiarity is that no representation of the order Coleoptera was found, nor do Physopodæ occur in the collection. On the other hand, *Hæmatopirnus trichechii*, not known hitherto from East Greenland, was found on a dead walrus.

Two species of wasps (*Praon sp.* and *Nematus sp.*) are new for East Greenland, and the latter has hitherto never been found in Greenland at all. The nests and grubs obtained of the two Greenland humble-bees show that their mode of life here is the same as in more southern places. Flies are represented by fifteen species, besides a couple that cannot be identified, and a large collection of larvæ. One species (*Catabomba grœnlandica*) is new. Almost all the hares shot were infested with fleas, as was found to be the case by the Swedish expedition on the east coast. Hare fleas were reported by O. Fabricius from the west coast, but have not been seen since his time. Of the nine butterflies one species (*Sericoris schultziana*) is new, and also a larva was found which belongs to none of the known species of butterfly. A bug (*Nysius grœnlandica*) was also new for East Greenland.

The collections of the sea fauna proper present great interest, particularly with regard to the contrast between the conditions of animal life in the seas of North and South Greenland. The material has not yet been completely worked up. Of the more interesting discoveries hitherto revealed may be mentioned a feather star (*Antedon prolixa*) with young in many different stages of development, a very valuable addition to the exceedingly scanty material hitherto known.

Botanical collections were chiefly made on the south coast of Germania Land, and particularly in the immediate neighbourhood of the ship's harbour, and on the rocks and small islands south of the harbour. But there is also a small number of plants brought from Peary Land, and a few from the *nunataks* west of Danmarkshavn. The vegetation

* From Dr. N. C. Nielsen's examination of the collection.

was scanty. In all about ninety species of flowering plants were brought home, of which one only (*Alsine rossii*) is new for Greenland. Small collections were also made of mosses, lichens, fungi, and sea algæ, as well as a quantity of plankton, the last during sea voyages. There are, besides, plants in spirits for anatomical investigation.

During the whole sojourn of the expedition in Greenland observations were made of conditions affecting plant life, the depth of the snow, the date of its disappearance, temperature readings in the under layer of snow and the surface of the ground, radiation of heat, evaporation, sprouting time, flowering season, seed nutrition, etc., so that very important biological data have been obtained.

In conclusion, I may mention that on the *Danmark* expedition physiological investigations were instituted on a greater scale than on any preceding Arctic expeditions. In spite of various difficulties a series of respiration experiments was successfully carried out for one individual; altogether there are about 120 experiments recorded. These are partly morning observations spread over the seasons to detect a possible annual variation, partly distributed over the hours of the day with regard to the daily period.

These tests established the frequency of respiration, the total amount of air respired (ventilation), the alveolar tension of carbonic acid, and the carbonic acid given off. A clearly marked annual period was detected with turning points at the end of winter and the end of summer, and characterized by a diminution in the frequency of respiration, and of alveolar carbonic acid tension from winter to summer, while the ventilation and metabolism increased considerably in the same period. The respiration characteristic of the Arctic summer, which showed a very striking similarity to that in a mountain climate, seems to be due to the effect of light.

A series of temperature readings was also taken to investigate the conditions governing the temperature of the body, and a trial was made in the Polar night of the frequently unsuccessful experiment to test the constancy of the daily temperature curve in the peculiar circumstances, when night is turned into day and *vice versâ*. Temperature curves of the inverse type were successfully obtained. Lastly, a number of blood samples were investigated with respect to the number of *Leucocytes* and the causes of their variations.

Perhaps it is as well to mention that by all work in which instruments were employed numerous tests were made of the advantages and drawbacks of the instruments under Arctic conditions.