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TO THE

PAPERS ON THE EASTERN AND NORTHERN EXTENSION

OF

# THE GULF STREAM.

PUBLISHED BY

THE UNITED STATES HYDROGRAPHIC OFFICE,

WASHINGTON, D. C.

APRIL, 1875.

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# National Oceanic and Atmospheric Administration

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# ERRATA.

Page 1, line 2: for 51 read 55.
Page 6, line 33: for *tidal hours* read *tidal hour.*
Page 7, line 31: for *Arabic Sea* read *Arctic Circle.*
Page 8, line 17: for *arämetrical* read *aräometric.*
Page 15, line 17: after *could* insert *not.*
Page 16, line 29: omit *and* at beginning of line and insert *and* after *masses.*
Page 17, line 11: for *accumulatest* read *accumulates.*
Page 32, line 16: for *flood-wave* read *tidal-wave.*

[From the "Hydrographische Mittheilungen," published by the Hydrographic Office of the Imperial German Admiralty, 1875, p. 51 et seq.]

# METEOROLOGY AND HYDROGRAPHY OF THE EAST COAST OF GREENLAND.

Among the most important results of the second German North-polar Expedition, under command of Captain Karl Koldewey, June 15, 1869, to September 11, 1870, are the contributions to the climatology of Greenland, and to the better knowledge of the meteorological phenomena of the Arctic region in general, derived from a series of actual meteorological observations which extend over a full year, (August 1, 1869, to July 31, 1870.)

The British Arctic expeditions for the discovery of a northwest passage, with the observations in the Danish settlements in West Greenland, embracing a number of years, and the expeditions of Kane and Hayes, have furnished an insight clear at least in some measure, into the meteorology of West Greenland and of the American-Arctic archipelago. There were also some good observations obtained at Nova Zemla for some years, (1833, 1835, 1838, and 1839, see "Papers on the Eastern and Northern extensions of the Gulf Stream, p. 284,) which, with the summer observations of Scoresby and the few unconnected observations of Sabine and Clavering, are the only means for research into the distribution of heat over the Arctic regions north of Europe. There were no winter observations either for Spitzbergen or East Greenland, and the isothermal curves constructed from that meager material, by Professor Dove, could only be regarded as a first attempt toward an inquiry into the temperature at the pole.

The observations of the second North-polar Expedition, obtained under the direction of Dr. Börgen and discussed by Captain Koldewey, fill up the first essential gap, as they impart knowledge of the meteorology of a coast concerning which the most contradictory views had prevailed. While some geographers inferred, from the vicinity of the great Atlantic water-basin, a very mild winter temperature, and in consequence an easy navigability of the waters washing that coast, others thought that the immense stream of ice which pours down along it must cause there a very low temperature. Captain Koldewey's discussion (published in the fourth chapter of the second part of the scientific

results of the expedition, pp. 521 to 570) throws considerable light upon the true condition. The following is a brief abstract of the discussion:

From the temperature observations on board the *Germania* in the winter harbor at Sabine Island and on the island itself, in latitude 74° 32′.3 N., longitude 18° 49′ W., hourly, and from May two hourly, the following monthly means were derived:

| | | | | | |
|---|---|---|---|---|---|
| 1869— | August, | + 33°.3 F. | 1870— | February, | — 10°.8 F. |
| " | September, | + 24°.3 F. | " | March, | — 9°.9 F. |
| " | October, | + 7°.2 F. | " | April, | + 2°.3 F. |
| " | November, | — 0°.9 F. | " | May, | + 22°.3 F. |
| " | December, | + 1°.2 F. | " | June, | + 36°.1 F. |
| 1870— | January, | — 11°.6 F. | " | July, | + 38°.8 F. |

and the mean for the year is + 10°.9 F.

Thus the coldest month is January—but February and March have almost the same temperature; and the lowest observed (— 40°.5 F.) occurred on February 21st. July is the warmest month, the highest temperature (+ 55°.6 F.) being observed on the 1st of July, 1870. The annual range is, therefore, 96°.1 F.

In order to obtain data for ascertaining how far these means differ from the normal relations, (such as are derived from a series of observations embracing a longer period,) Captain Koldewey computed, at the suggestion of Professor Dove, the means of the observations for 10 years at the Norwegian stations and at Omenak, (latitude 70° 40′ N., longitude 51° 59′ W.,) and compared them with each other and with the temperatures observed at East Greenland. From this comparison he infers, with at least some degree of probability, the existence of similar relations between the temperatures of the west coast of Norway and that of the east coast of Greenland, as have been found to exist for the opposite coasts of Europe and America, viz: Cold winters in America corresponding with mild winters in Europe, and *vice versa.* He further infers that there were, in 1869–'70, no great deviations from the normal relations except, perhaps, for the month of December, which was decidedly warmer, as also that the entire year may have been somewhat warmer than usual. Should these inferences prove true, the coast would prove colder than would appear from the isothermal chart of Dove;* it would not, however, be

* According to which, the isothermal curve for the year, of —6° C., (+ 21°.2 F.,) passes through Sabine Island, while according to the observations the island would be crossed by that of + 11° F.

as cold in the winter as it has been generally believed to be. A comparison of the observations at Sabine Island with the winter temperatures observed by Captain Hegemann on board the *Hansa*, and during the drift on the ice-floe, as also with the observations at the West Greenland stations, affords some data for the decline of the temperature with increasing latitude; it was found almost to correspond on both coasts, and as the monthly means do not differ much for the same latitudes, it would appear that the isothermal curves for the year, as well as the greater number of the monthly, are (in Greenland) running parallel to each other and to the parallels of latitude.

Very remarkable, especially for a series of observations extending over only one year, is the daily period of the temperature at Sabine Island. The graphical representation of it for the several seasons, as well as for the year, show almost regular curves, with the exception of the winter months, in which the thermal wave is very weak. The daily maximum of temperature takes place, in the mean of the year, at 1.30 p. m., the minimum at 1.30 a. m., and the daily range amounts to only 4°.5 F. The greatest daily range occurred in April, amounting to 10° F. This great regularity is indicative of quite simple relations in East Greenland, almost free from sudden disturbances, as is also shown by the table of daily means.

The inquiry into the winds and the weather shows similar simple relations. The prevailing wind at Sabine Island is northerly, and blows, especially in the winter, almost with the regularity of the trades, although it frequently increases to violent gales. Polar air-currents appear, according to the observations of Captain Hegemann, in general to prevail on the East Greenland coast, the wind blowing throughout parallel with the latter, viz: from the North when the coast trends North and South, and from the NE. where it runs NE. and SW. The mean direction and force, according to Beaufort Scala, is, at Sabine Island for the several months, as follows:

| | | | | | |
|---|---|---|---|---|---|
| 1869— | August, | N. 88° W., 1.7 | 1870— | February, | N. 35° W., 3.1 |
| " | September, | N. 14° W., 2.6 | " | March, | N. 19° W., 3.5 |
| " | October, | N. 27° W., 2.3 | " | April, | N. 26° W., 3.0 |
| " | November, | N. 23° W., 3.6 | " | May, | S. 12° E., 1.9 |
| " | December, | N. 15° W., 4.1 | " | June, | N. 45° E., 1.9 |
| 1870— | January, | N. 22° W., 1.6 | " | July, | S. 36° E., 1.2 |

and for the year N. 19° W., 2.5, an almost direct northerly direction. From

September to April the north winds are interrupted by calms; from May to July the wind blew frequently from the South and the East.

That this almost exclusive prevalence of northerly winds was not an occurrence of only the years 1869–'70, but that they always prevail on this coast, Captain Koldewey infers from the following facts: Numerous traces of the prevalence of this wind were found on the land as well as on the firm land-ice: stones were polished and rounded on the sides exposed to the north; the smaller fragments lay everywhere in a North and South direction, which was, without exception, also that of the snow-furrows in the valleys and on the slopes; on the firm ice the snow was furrowed parallel to the meridian so decidedly that we could shape our course by it on the sleigh excursions when beset with fog. The table of winds enumerates 2,603 hours (three-tenths of the year) of wind blowing directly from the North, while there were 2,435 hours of calms, so that only four-tenths of the year remained for all other winds. The great number of calms also appears to be a peculiarity of this coast; they are especially frequent in the summer and in midwinter; in the summer months the winds are in general so light that a sailing-vessel will rarely be able to work through the ice. The only strong winds are the northerly, which, as the figures show, increase in force gradually from the summer toward the winter, in the latter to gales often of a fury which has no parallel in the temperate zones.

In connection with this prevalent polar air-current is the great dryness of the air, the little precipitation, and the comparatively very limited cloudiness. Although the psychrometrical observations were abandoned on account of the great difficulty of obtaining correct readings, Dr. Börgen is able to state: "The great dryness of the air is proved by the rarity of precipitation and the almost constant clear weather, whenever the air was quiet, as also from the fact that even with the strongest cold human breath never was visible, as it is in our moist climate at temperatures just exceeding the freezing-point." The quantity of precipitation could never be measured, for which Dr. Börgen cites the following cause: "Snow or rain never fell in quiet weather, but there was no storm without it. As there was then always a tremendous snow-drift, carrying along the old snow together with the new, it would have been impossible to obtain correct measurements or even good approximations." The precipitation is, therefore, only given by the hour; in the whole year 531 hours of snow and 104 hours of rain, only 7 per cent of the year, are recorded, and this per cent-

age even is still lessened in considering that the rain frequently did not last throughout the entire hour in which the record was put down. The fifth part of the whole year, 1,927 hours or 80.3 days, was completely cloudless. The number of clear days, but slightly cloudy, naturally was far greater, as 0 was only recorded when there was actually no cloud at all visible. The mean cloudiness amounts to 4.9, (a completely clouded sky being recorded as 10,) that is not quite one-half.

There were altogether 32 gales observed, blowing 764 hours, all from the quarter N. to NW., the only exception being a slight gale which blew for 6 hours from the South. A gale from the 16th to the 20th of December lasted 103 hours, with a mean force of 9.1 according to Beaufort, or a velocity of 57 miles per hour. A peculiar characteristic of these storms is that, almost without an exception, they set in with a completely clear sky, and are not indicated in advance by a fall of the barometer. The only indication of an approaching storm was a bank of stratus clouds forming on the *southern* horizon and advancing slowly, while toward the north the sky remained extraordinarily clear and transparent. This appears to point to the presence of a warm compensation-current in the upper atmosphere, the same as was frequently observed on the mountains of Sabine Island.

The winds prevailing in only one direction made it difficult to construct, from the observations embracing only one year, an accurate baric and thermic wind-rose. An attempt has been made for the four seasons and for the year, and this shows the highest pressure of air to lay doubtless over the ice-covered interior of Greenland, from whence the coldest winds come, while SE. winds carry along the lowest pressure and the highest temperature.

The pressure of air observed at Sabine Island and the comparatively very high barometer are also indicative of the prevalence of polar winds. The mean of the barometer readings for the year was 29,878 inches, equal to 758.88 mm.—the highest, 766.878 mm. in March, the lowest, 754.57 mm. in July; while at Reykjavik the mean for the year from observations embracing 14 years is only 750.10 mm. From all this it would appear that there exists along the east coast of Greenland a compensation region for the violent SW. gales which blow in the winter on our coast, and that these have a certain connection. Further exploration of the meteorological relations of East Greenland is therefore very important.

The hydrographical labors of the second German North-polar Expedition embraced observations of the temperature of the sea and currents, deep-sea soundings, tidal observations, and aräometer observations, with ice observations in the Polar Sea. The two first classes were discussed by Captain Koldewey, the latter by Dr. Börgen.

The deep-sea soundings show that there exists along the Greenland coast, between the parallels of latitude 70° to 75° to a distance of 60 to 80 miles from it, a submarine plateau rising from 100 to 200 fathoms below the surface; eastward of it the bottom descends quite steeply to more than 1,000 fathoms. Close under the coast are some deeper places, for instance, on the East Cape of Shannon and at the mouth of the great fiords, south of Cape Broer Ruys, places of 200 fathoms; and in the inner parts of Emperor Francis Joseph Fiord depths of more than 500 fathoms; the bottom is everywhere mud, indicating that there are no strong currents. Regarding those which were observed, Captain Koldewey remarks: "At the outer edge of the ice and in the drift-ice up to the floes farther inside the barrier, between the parallels of latitude 70° and 75°, exists a continual southerly current of from 8 to 10 miles in 24 hours, deflected, however, by the wind and the corresponding drift of the ice often considerably to the eastward or westward. Immediately on the coast, this current is decidedly weaker than on the outer edge of the ice, although in general a motion of the ice and the water southward prevails, (the average drift of the ice on which the crew of the *Hansa* found rescue was 4.6 miles in 24 hours;) it ceases frequently altogether, especially in the summer, when the northerly winds become weaker and veer around to the South, so that the ice-fields become almost stationery, or move only off and on the coast. In the winter the drift of the ice southward is more rapid on account of the stronger and more constant northerly winds. There is no regular ebb and flood tide, although spring tides rise as high as 5 feet; even in the large Emperor Francis Joseph Fiord there is no regular tidal-current, at least it was not observed during our short stay."

The tidal-observations on board of the *Germania* from October 1, 1869, to the end of April, 1870, are the first on the East Greenland coast. At Sabine Island they embrace a period of seven months, and permit a pretty accurate determination of the constants, viz: the tidal-hours, the semi-monthly fluctuation with the relations of sun and moon tide, and the retardation of the tidal-wave, as also the most essential tidal phenomena. Observations were also made at

other points of the coast reached by the *Germania*, which, as imperfect as they may be, sufficed, with the aid of the constants established at Sabine Island, for an approximate establishment of the tidal-hours and of the progress of the tidal-wave on these coasts. The constants for Sabine Island are as follows:

| | |
|---|---|
| Time of highwater at new and full moon - - - - - | $11^h$ $13.7^m$ |
| Proportion of the sun to the moon tide - - - - - | 0.4162 |
| Age of the tidal-wave - - - - - - - - - - - | 1¼ day |

The approximate tidal-hours were ascertained for—

| | |
|---|---|
| Cape Börgen, latitude 75° 26′ N. - - - - - - - - | $12^h$ $7^m$ |
| Cape Philip Broke, latitude 74° 56′ N. - - - - - - | $11^h$ $28^m$ |
| Little Pendulum, latitude 74° 37′ N. - - - - - - | $11^h$ $21^m$ |
| Jackson Island, latitude 73° 54′ N. - - - - - - | $11^h$ $3^m$ |
| Cape Broer Ruys, latitude 73° 28′ N. - - - - - - | $10^h$ $51^m$ |
| Eleonora Bay, latitude 73° 27′ N. - - - - - - - | $10^h$ $45^m$ |
| Nubarbik, latitude 63° 24′ N. - - - - - - - - - | $6^h$ $30^m$ |

These show a regular progress of the tidal-wave from South to North of about half an hour for each degree.

The concise coincidence of the values for the semi-monthly fluctuation, found from actual observation, with those computed by the formula of Bernoulli is remarkable. Captain Koldewey attributes this to the fact that the ice-cover, which prevents a high sea, neutralizes also the atmospheric disturbances, and that there is no considerable current. The comparatively young age of the tidal-wave, or the time between the syzygies and spring-flood, 1¼ day, is also remarkable, as on the European and American coasts of the Atlantic Ocean, the latter comes about 2 days after the full and change of the moon. It may be inferred from this that the Polar Sea is of an extent large enough for the formation of an independent tidal-wave, on which the constants depend.

The results of the aräometric observations by Dr. Börgen and Dr. Copeland establish a considerable difference of the specific gravity of the surface-water of the North Atlantic Ocean from the 60th parallel of latitude to the Arabic Sea, and of the Polar Sea to the outer limit of the ice, while the water of the North Sea, between the latitudes 55° and 60° N. and the meridians 1° and 7° E., is but of little less gravity than that of the North Atlantic Ocean.

The means of the observations reduced to 18°.75 C. give the following values for the specific gravity of the surface-water:

| | |
|---|---|
| North Sea - - - - - - - - - - - - | 1.02545 = 3.511% |
| North Atlantic Ocean - - - - - - - - | 1.02594 = 3.578% |
| Polar Sea, July 7 to 16, 1869, and August 24 to 29, 1870 - - - - - - - - - | 1.02493 = 3.439% |
| In the ice, July 17 to August 4, 1869 - | 1.02411 = 3.326% |

The difference in this respect between the North Atlantic Ocean and the Polar Sea (on the 6th and 7th of July) was so great and so sharply defined that it would appear as if the line between the Gulf Stream and Polar Stream might be accurately laid down in about latitude 68° N. and longitude 6° W., which agrees also with the observations of the surface temperature.

The increase of the density of the sea-water with the depth already established in other parts of the ocean is confirmed, by the observations on board the *Germania*, also in these seas; it was found to be greater in the ice than in the sea south of it, and in the latter also greater than in the Atlantic Ocean. Although the materials for ascertaining the density relations at the several depths is still too meager for definite conclusions, there is no doubt that connected arämetrical observations over a large extent of the ocean will result in valuable information for hydrography, as shown by the results of the *Challenger* expedition.

[ From Dr. Petermann's "Geographische Mittheilungen" for 1875, pp. 65 et seq.]

# THE GLACIERS OF NOVA ZEMLA, BY PROFESSOR HANS HÖFER, OF KLAGENFURT, GEOLOGIST OF COUNT WILTZEK'S ARCTIC EXPEDITION IN 1872.

The glaciers of Nova Zemla have, thus far, been very little discussed; the following brief remarks will, therefore, be of interest and will fill a gap in the knowledge of this island.

The southern portion of Nova Zemla, from Kara Strait to latitude 72° N., is, on the whole, almost completely free from glaciers; in one instance only, after a snowfall of several days, we saw off Kostin Shar, to the NE., a white peak somewhat resembling a glacier.

Farther north, up to Matotschkin Shar, glaciers are more numerous, their formation being favored there not only by the more northerly position, but also by the greater height of the mountains. They are confined, however, to the higher parts of the interior, and descend nowhere to the western coast, from which they cannot, generally, be seen.

The highest peak on this part of the west coast, Mt. Lütke, which, according to Ziwolka's measurements, rises to 1,841 feet, shows only detached snow-patches in the ravines. This part of the west coast, which is a flat foreland covered by fallow-green reindeer pasture, beyond which groups of sterile rocks rise, showing, notwithstanding their pronged contours, their slate formation, has no resemblance whatever with Spitzbergen, characterized by grand glaciers and sharp rocky mountain ridges.

But the bay next north of Matotschkin Shar, Silver Bay, shows in the background quite a bold development of glacier forms. Farther on, the steep rocky walls of the Mitjuschew Channel do not permit the snow to settle on them, and terminate in the flat, bald forelands of Suchoi Noss.

With Cross Bay the coast begins to assume an entirely different character, much resembling that of Spitzbergen. Grand and connected masses of glacier and snow ascend gradually, frequently immediately from the shore to the mountain ridges, the rocky peaks which protrude from them adding by their dark color to the effects of the contrasts. These are decided inner glaciers, presenting themselves in succession up to the Barents Islands, which consist of immense isolated fragments of the flat foreland beyond them. As far as the

prevailing snow-storm permitted us to ascertain there were no glaciers on the more southern Richthofen and Sterneck Mountains.

According to Petermann's chart of the island, glaciers of colossal dimensions again appear east of Cape Nassau, descending directly to the water and thus forming the coast-line through 4 degrees of longitude from Hohenlohe Bay to the Icy Cape.

There are no glaciers on the eastern shore of the northeast part of Nova Zemla from Cape Mauritius to Ice Harbor; immediately back of it mountains ascend so steep that they do not offer on that side a hold for the permanent snow from which glaciers develop, while the descent to the opposite western coast is gradual, and, therefore, in the region beyond the snow-line, well qualified for the development of great inland glaciers, which, in fact, push down to the northwest coast. Only small local glaciers can form on the eastern slope of this mountain range.

Following the east coast from Ice Harbor southward, we again find great inland glaciers in the vicinity of Cape Middendorff, extending with a few gaps to Cape Edward. The topography of the coast from there to Matotschkin Shar is very little known, but from the latter to the Kara Strait the coast appears, according to Russian statements, to be free from glaciers. Pachtussow states, in his description of Lütke Bay, (latitude 72° 25′ N.,) that the mountains rise there in terraces to a height of 800 feet, and that they were covered with snow, (July 21st, 1833.)

From all these observations the following may be inferred as the general character of glacier development in Nova Zemla as far as it can be drawn from the circumnavigation of the island: "The southern part, up to the vicinity of the parallel of latitude 72° N., has probably no glaciers of any extent; around Matotschkin Shar there are only isolated inland glaciers, but north of the Shar begins an extensive development of glaciers, which cover the greater part of the interior, the masses of ice from which push down to the sea and form complete ice-walls."

For describing the local glaciers, which are considerably developed in the higher mountain ranges surrounding Matotschkin Shar, an ascension of Wilczek Peak, on the northern shore of the latter, will furnish the best point of view. An hour's travel from the coast through a ravine sloping about 25 degrees leads to a snow-field, and soon after to a glacier almost free of clefts, and terminating in moraines partly covered with snow. Numerous rocks lie scattered over the glacier. Ahead is a peak covered with ice, apparently the highest

elevation in this region, and named by us Hohenlohe Peak. At about two-thirds of the distance from the summit the glacier branches to the right and left into two saddles, over the right or eastern part of which we wend our way, climbing over a partly glazed and partly stony ridge to the summit, which we reach after nearly 5 hours' travel. West of us, back of the left glazed saddle, we see the still higher Wilczek Peak, on the northern slope of which is a mighty wildly broken ice-field, pushed down almost to the shores of Silver Bay. It is connected with the grand masses of ice which stretch down from the NW. slope of the same saddle and from the Hohenlohe Peak. Beyond, east of the Mitzuschew Kameni, another apparently unbounded ice-field descends into the same valley which forms the continuation of Silver Bay inland. Farther to the north, every spot capable of carrying and holding glaciers is covered with them. An icy ridge trends from Hohenlohe Peak northward, rising to a point, and thence bending to the eastward in a gradual slope. This also is covered with glaciers, which, after connecting, push through a valley opening southward close to the Matotschkin Shar.

Before leaving Hohenlohe Peak, which surely has been ascended this day for the first time by men, we read our aneroids, from which we ascertained that we were at an elevation of 3,018 feet above the sea.

We now climbed over a serrated rocky wall to the left saddle, and thence over a ridge covered partly with ice, from which glaciers descend on either side, to Wilczek Peak, which also sends glaciers from the permanent snow-field that covers it east, north, and west, and only the steep and rocky eastern slope is bald. The aneroid showed an elevation of 3,614 feet above the sea.

Here we could plainly distinguish the mountains south of us on the other side of Matotschkin Shar. Numerous sharp peaks protruded over a table almost entirely glazed; most of them were of the same elevation as our peak, two were several hundred feet higher, and all were covered with the glittering permanent snow. Several glaciers branched toward Matotschkin Shar, reaching at Walrus Cape nearly to, and at Crane Cape wholly to, the coast.

It is certain that Hohenlohe Peak, as well as the two glazed saddles which are about 400 feet lower, reach beyond the snow-line; from all indications we place the latter at about two-thirds of the height of Hohenlohe Peak, and it will, therefore, be a very close approximation when we adopt for the snow-line in the vicinity of Matotschkin Shar a height of 1,900 feet. This is corroborated by the great and connected fields of deep snow on all extensive plains higher than 1,800 to 2,000 feet above the sea, on the gradual slopes as well as

in the high valleys, where the snow is not the drift of the previous winter but evidently permanent snow, the embryo of the glacier, (Saussure calls such formations glaciers of the second order.) Such a snow-field, for instance, extends over the trough between Bessel's Ridge and Petermann Chain.

All the peaks and ridges referred to rise to heights of from 3,000 to 4,000 feet. It would be very desirable that a future expedition should examine their southern slopes, for which purpose it should land in Mushroom Bay, although dangerous reefs are at the entrance of it, and push from there into the interior. An ascension of Mt. Lütke would reveal to a great extent the relations in that region. The first part of the summer would be the proper time, as drift-ice then prevents vessels from pushing north.

The difference in the height of the snow-line between the northern and southern slopes of a mountain range will be but inconsiderable when the sun acts in the summer uninterruptedly. Other influences, especially that of the configuration, are so great that it would be difficult to ascertain an essential difference resulting from the exposure.

The height of the snow-line, together with the mountain structure of Nova Zemla, explains clearly the formation of the glaciers on this double island. The part south of the parallel of latitude 72° rises hardly to 1,900 feet, and therefore does not reach the snow-line, which, on account of the more southern position, would lie here higher than in the vicinity of Matotschkin Shar. The ridges north of the latter rise certainly beyond the snow-line, which descends there to less than 1,900 feet, not only from the more northern position, but also on account of the extensive fields of drift-ice which there generally envelope the western coast, thus preventing the tempering influence of the extreme branch of the Gulf Stream that has been observed in the more southern parts, for instance in Moller Bay and in Geeseland. The still greater accumulation of drift-ice around Jan Mayen is doubtless the cause that we find there, notwithstanding the more southerly position, (lat. 71° N.,) the snow-line depressed as low as 1,220 feet, although this appears abnormal. That the snow-line does not descend anywhere in Nova Zemla, or in Spitzbergen either, to the level of the sea, is proved by the fact that the Barents Islands and the mainland near them, which ascends in low terraces, were free of glaciers in the middle of August.

The other details observed regarding the glaciers of Nova Zembla are such as we find in Spitzbergen and on the Alps of Europe.

(From Dr. Petermann's "Geographische Mittheilungen for 1875," pp. 65 et seq.)

# THE SECOND AUSTRIAN-HUNGARIAN NORTH-POLAR EXPEDITION UNDER WEYPRECHT AND PAYER, 1872-'74.

*Lecture of* LIEUTENANT WEYPRECHT *on the Scientific Observations under his direction, delivered at Vienna, January* 18, 1875.

The chief purpose of our expedition was not to attain the highest possible latitude, but to explore the unknown great sea north of Siberia. We fostered the idea that we might reach as far as Behring Strait, but our hopes were not oversanguine in this respect. Although we were not successful in carrying out all we intended, we have, through a series of mishaps on the one hand and good fortune on the other, reached results in another direction which fully compensate for any failure in our proposed plans.

When, in the year 1871, the preliminary reconnoissance of these regions was determined upon, the great sea between East Spitzbergen and Nova Zemla was still so little known that, during a stay of six weeks at Tromsö, I could absolutely learn nothing regarding the general nature of the ice in that sea, although I inquired most diligently among the Tromsö seal-hunters and fishermen. A very few vessels only had been able to penetrate beyond the parallel of latitude 76° N. We have explored this unknown sea between the meridians 40° and 73° E.—in the western part to the parallel of latitude 79° N., in the eastern to that of 80°. We had the good fortune to discover extensive land, over which Lieutenant Payer traveled in sleighs to a position in latitude 82° N., where he could trace it by the eye as far as the 83d degree.

The principal impulse to the expedition was given by the fact that in 1871 we had found the sea north of Nova Zemla completely free from ice to latitude 78° N. This free sea we intended to follow east, expecting that the great Siberian rivers would, by their immense volume of water in the summer, free the coasts from ice. But unhappily 1872 was one of the most unfavorable years as regards the ice; we encountered the latter as low as 74½° N., and could only by great exertion work as far as Cape Nassau, where in the preceding year no ice at all had been met within a radius of 100 miles, and none also two years later. We never came within the reach of the Siberian rivers and cannot, therefore, know whether our surmises regarding their influence

on the ice along the Siberian coast were correct. This question has not been touched at all by our expedition, and it remains as open as it was before. But our experience proves positively the ice relations between Spitzbergen and Nova Zemla to be so uncertain and so much subject to changes from year to year that expeditions there depend altogether upon chance. This would be the main objection to further attempts for explorations with Francis Joseph Land as a base. In 1874 we found the ice in almost precisely the same position as in 1871; an ice-chart for a number of years might perhaps establish, to a certain degree, a periodicity.

Whene xplaining our programme before the Academy of Science, (December 7th, 1871) I attributed the general motion of the ice in the Arctic Sea, for the greater part, to the currents; our drift in the pack-ice for 14 months proves that this was an erroneous supposition; the propelling power of the current against that of the wind, at least in this portion of the sea, is hardly perceptible. That the Gulf Stream extends into the great basin between Norway, Spitzbergen, and Nova Zemla is beyond all doubt; a glance at the isothermal chart shows it, and our deep sea temperature observations during our preliminary reconnoissance furnish proof by figures; but the current is no longer direct in its course, and its existence can only be ascertained by the unproportional high temperature of the water for these latitudes. As a consequence the Gulf Stream does not here regulate the limits of the ice, but, on the contrary, the ice propelled by the wind regulates the limit of the warmer water while absorbing gradually its higher temperature. It can only be ascertained by a comparison of the drift of the *Hansa* with the winds, whether the drift along the East Greenland coast is caused entirely by the latter; it is so in Baffin's Bay, as has been proved with figures by Sir Robert McClintock. It is hardly necessary to say that the speed of the drift depends not altogether upon the force of the wind, but also greatly on local relations, the configuration of the coast, and the more or less open water. The great power of the wind, even over large ice-fields, is through the unevenness of the ice; each hillock and any raised piece representing a sail.

Different relations exist in the vicinity of land, where there are in many places powerful currents, caused by the configuration of the land, by the tides, and sometimes also by the motion of the ice as propelled by the wind.

A general tendency of the ice to push southward in the summer is unmistakable; its source may be the confluence of the water from the melting ice,

causing a general dissolution of the ice. But, compared with that of the wind, all other influences are insignificant, and, at the most, only perceptible in the general result.

Our observations prove clearly that there is, south of Francis Joseph Land, a constant flow of the ice from the east (that is from the Siberian waters) to the west, and this with the prevailing winds would have drifted us to the northward of Spitzbergen had our floe not grounded on the land-ice off Wilczek Island.

This influence of the wind may, with great probability, be also the cause of the open water which in April prevented Lieutenant Payer from pushing with his sleigh still farther north. Off Francis Joseph Land the winter storms blow, almost without exception, from ENE., breaking up the ice continually under the western coast, and thus preventing the formation of heavy ice. Lieutenant Payer, when compelled to turn back, was under the western coast of the eastern portion of the discovered land.

The ice in this sea is also very different in quality. While in the early summer of 1873 we could trace to its end the field in which we lay frozen in, we never met on our return home with fields of so great an extent. The thickness of the ice also was greatly different in the two summers: our field of 1873 was an irregularly frozen mass, covered on all sides with ice-walls and high hillocks; in the following year we met many almost level fields, and although the thaw set in so late that we suffered greatly from thirst for one and a half months, it frequently occurred at the end of July that we broke through the ice while sleighing. I am sure that by the end of August the greater part of this ice had melted. All the ice in the sea was evidently packed very densely during our drift; the field into which we were frozen did not turn the entire year, although drifting continuously, the bow of the vessel pointed steadily in the same direction. Not earlier than September, when the field was greatly reduced, it began to sway, and not before October and the early part of November were openings of any extent seen to the southward.

An important question is, whether Francis Joseph Land can again be reached in a vessel. From the above-stated facts it will be seen that this depends entirely upon the ice and weather relations which exist when the attempt is made. It will require, under all circumstances, a very favorable summer, and will only be successful late in the year. Nova Zemla, however, should not be made the base, as the ice drifting down from the eastward will always lay more

close between Nova Zemla and the south coast of Francis Joseph Land than farther to the west. The proper point from which the vessel should push into the ice, I would select in about longitude 45° E. of Greenwich, where, in 1871, the border of the ice lay 50 miles farther north than on the 60th meridian. There were also on our return many indications of more open water to the westward of us than to the eastward.

In this preliminary reconnoissance we observed on the parallel of latitude 78¾° N., in longitude 43° E., so numerous signs of land that, in laying our programme before the Academy of Sciences, I could venture to propose this unknown land as the base for an expedition to the North Pole. The mythical Gillis Land is generally placed in longitude 30° E. of Greenwich; the southern coast of Francis Joseph Land was, by Payer, seen to extend to longitude 50° E.; and it is surely not a very bold surmise to connect these three collections of land. Francis Joseph Land would thus have a very great extent, corroborated also by the numerous great icebergs which drifted along the coast discovered by us. All these reflections intensify the interest of Arctic exploration.

We had good occasion through one and a half years for observing in close proximity the formation and the drift of the heaviest pack-ice. The process is instructive as regards all the ice relations in the Inner Arctic region.

With the exception of the fast land-ice along the coast, which nowhere extends far into the sea, all the ice, the fields as well as the icebergs, is constantly in motion under the influence of the wind, in the winter as well as in the summer. This motion, however, differs almost with every field on account of their various forms and dimensions, causing them to press against each other where they touch. By this pressure, and, to a greater extent, by the contraction of the ice resulting from sudden decrease of temperature, the fields part continually into smaller floes, which, from their incongruous motion, again cause new pressures. Considering the great extent of some of the fields and their enormous masses, the colossal power thus in action, their immense effect may readily be conceived.

First all the projecting parts and edges break off, until the fields come in close contact, when a contest begins which terminates often in a few minutes, frequently, however, only after days and weeks. The edges turn up regular ice-walls of confused blocks, forming above as well as beneath the surface; blocks 8 feet in thickness rise 30 and 40 feet, and tumbling down give way to others; at last one field pushes partly beneath the other. Often they separate

after a short contest, to again renew it, until the intense cold unites them to a solid mass; the two fields become one, which, however, parts again in another direction with the next sudden change of temperature, and there is then the same contest over again. In such a manner are formed the irregular fields traversed by hillock-ridges and valleys between them, often only a conglomerate of compactly frozen ice-blocks, which, as "packed ice," constitute the most important feature of the Arctic Sea.

In the winter the smaller indentations are completely filled by drift-snow. As soon as the sun begins to exercise its influence the ice pressure ceases, and the winterly ice-walls grow smaller, the blocks exposed to the air being the quickest reduced; immense masses of ice and snow melt, and the water accumulatest on the lower parts of the fields to large sweet-water ponds. Four feet of ice thaws off, in the average, in the three summer months, under the effect of the higher temperature. The field, with everything encased by it, (for instance, the ship,) rises as much, but in the following winter it grows from beneath again to the same thickness. Thus the ice undergoes, continually, a renewing process, and it may readily be assumed that the old pack-ice is replaced by new every two years.

The continual pressure crushes during the winter a vast mass of ice and throws the pieces over each other. The intense cold covers immediately any opening thus created with young ice, which, at a temperature of —35° to —60°, grows in 24 hours one foot in thickness. This rapid formation does not allow all the salt to separate from the sea-water; a considerable quantity freezes into the upper strata of the ice, but in less quantity the slower the ice forms, until, after the latter has attained a certain thickness, it separates completely. The moisture retained in the ice by the salt causes it as long as it is young, and even after it has attained a considerable thickness, to remain tough, almost glutinous, readily bending under the feet; but in a very short time the salt crystallizes toward the surface, which rapidly covers with a white layer of it, resembling snow, and growing by degrees to two inches in thickness. This crust retains for a long time, even in the most intense cold, so much humidity that it almost appears as if there was a thaw; it dries only slowly, through evaporation and under the drift-snow.

In such a manner all the salt frozen into the ice crystallizes by degrees, and is washed off in the following summer by the melted water, with which it returns to the sea. It impregnates thoroughly the melted water, which attains in the end of the summer a specific gravity of 1.005.

From all this it will be seen that a smooth surface of ice, like that of an inland lake, occurs in the Arctic Sea but rarely, and then only for a short time.

The most beautiful and the most interesting phenomenon in these regions, the only change in the dead-like pallor of the long Arctic winter night, is the aurora borealis; no pen, no artist's brush, can do justice to its splendor when at its greatest intensity. We saw one in February, 1874, which resembled a mighty stream of fire extending all over the sky from east to west and beyond the zenith, continually throwing, with the celerity of lightning, deep waves of light in prismatic colors from one side of the horizon to the other. At the same time quivering rays flashed from the south to the magnetic pole as if chasing each other in a wild dance.

On some other occasion I will demonstrate by figures that the intensity differs in the various parts of the Arctic region independent of the latitude; and that the region of our winter quarters has the greatest. With a clear sky there were almost always at least traces of the phenomenon visible. In the second winter most thorough observations were made of it and carefully recorded, but we could not arrive at any positive results from this record. The phenomenon defies any detailed description; it changes from moment to moment, showing new forms. I never succeeded in grasping its commencement; it appears all of a sudden; no one can say how and whence it came.

Three forms may be distinguished very generally: steady and regular arcs ascending from the southern horizon to and beyond the zenith, and gradually expiring toward the northern horizon; then again streamers of light, either rays or only bright matter, manyfold entwined in each other, which continuously vary in place and form; and lastly the corona, a circle of rays radiating from or toward the magnetic pole. The color is generally white of a greenish hue, but when the intensity and commotion are greatest prismatic colors appear, often of very deep tints, especially in quivering rays.

Our spectroscope had, unluckily, not enough lights for successful observations of the spectrum. I could never distinguish anything besides the well-known green line.

Whether the phenomenon has a connection with the weather can only be established after the discussion of the meteorological observations. The many hundred auroras seen by us lead us to believe that it is atmospheric, and, therefore, closely connected with the meteorological relations. Intensive, especially the flaming, auroras were mostly followed by storms.

In the closest connection with the aurora borealis are the magnetic disturbances. While in the Temperate Zone these are abnormal, they are normal in the Arctic Zone; the needle is hardly ever quiet; they affect variation and dip as well as intensity.

As long as the ship drifted, until October of the second year, the declinometer could not, of course, be used. Absolute determinations were frequently obtained with Lamont's magnetic theodolite, especially on some of the magnetic term-days, but we had already found at Nova Zemla that these observations were, on account of the continual disturbances, of little value without cotemporaneous readings of the declinometer.

As soon as I ascertained, in November, 1873, that we lay fast, I caused the snow-huts to be erected, in one of which I placed the declinometer with the instruments belonging to it; in the other the magnetic theodolite and the dip-circle for absolute readings, as also the astronomical instruments. The instruments for declination, intensity, and dip were those which had been constructed under the superintendence of Dr. Lamont, director of the Munich Observatory, from patterns there in use.

After the very first trials I ascertained that simply readings at stated hours were of no value in these regions; as they were altogether dependent on the momentary disturbance, they could not result in absolute means, nor show the independent motions of the needle. The term-days of the previous expeditions were too far apart for furnishing correct conclusions. Under these circumstances I adopted the following method: The three instruments were read every three days one minute each fourth hour, different hours being selected each day, and in addition, in each month, twice from 5 to 5 minutes throughout the day. The instruments, the telescopes of which were adjusted into the same axis, were always read in quick succession (on the average in 8 to 10 seconds) so as to obtain the readings as simultaneous as possible. These observations were continued from the middle of January to the end of April, 1874, altogether on 32 days; I believe that they will furnish a correct representation of the continuous disturbances in the direction and the intensity of the magnetic functions in this region.

In order to ascertain the connection of the aurora with the motions of the needle another officer observed simultaneously the motions and changes of the aurora. The adjustment of the instruments was frequently tested by absolute determinations of the three constants.

With the observations of the late Swedish expedition, which are not yet published, ours are the first regularly simultaneous for the three constants obtained in the Arctic regions; we were also the first using the lighter Lamont needles. Heavy needles, such as were used by the previous expeditions, are, under the magnetic conditions which exist in the Arctic, entirely unreliable; even the comparatively light intensity-needle of the Lamont theodolite gave on account of its great *vis inertiæ*, altogether illusory readings.

There were almost in every magnetic term-day some so great disturbances that the scala could not be brought by deflection into the field of the telescope. I had to construct an apparatus by which, in such cases, at least approximate readings were obtained.

We cannot, for various reasons, claim for our observations the same degree of correctness which is attained in observatories proper. But our experience will suggest means for a modification of Lamont's instruments which will enable future expeditions with a greater force of observers to reach accurate and desirable results.

Altogether about 30,000 readings of the various magnetic instruments were obtained, which are to be reduced and discussed. The following will be the principal results:

The magnetic disturbances in this region are uncommonly great and frequent. They are in closest connection with the aurora borealis; they are the greater, the more quivering and quicker the commotion of the rays and the more intensive the prismatic colors of the latter are. Quiet, regular arcs, without commotion of light or rays, exercise hardly any influence upon the needle.

In all disturbances the declination-needle deflected eastward, the horizontal intensity decreased, and the dip increased. The rare deflections in the opposite direction can only be considered as caused by reaction.

The nature of the magnetic disturbances is of the highest interest While we observe all other phenomena of nature through our senses, (eye, ear, or feeling,) these convey to us a colossal power of nature enshrouded in mystery, as we cannot directly discern them through the same agents.

I had expected that I should be able to trace a connection of the aurora with the galvanic earth-currents, but the earth-galvanometer gave no results whatever. As the vessel lay 2½ miles from the shore I could not connect the collecting plates with the ground, but had to place them in the ice, which, not being a conductor, isolated them and almost neutralized their action upon the needle

of the galvanometer. That excellent instrument had also been furnished, by Director Lamont, with conducting wire 400 feet in length. Subsequently I connected the collector for air-electricity with the multiplicator of the galvanometer, but also without result, probably from the same cause.

The observations for declination were made by Lieutenant Brosch, Ensign Orel, and myself, the absolute determination by the former and myself.

The astronomical observations during the drifting of the vessel were only for latitude and longitude, the latter by chronometer and by lunar distances wherever there was a chance; the sextant and the prismatic circle with an artificial horizon were employed. When the vessel became stationary a small universale was employed for the observations for latitude, longitude, and azimuth. The longitude was obtained by 210 moon distances, as many as we could measure during the winter. The azimuth of a base 2,171 meters long, measured with a Stampfer leveling-instrument, was found with the magnetic theodolite.

All these observations were made by Ensign Orel; I assisted only at the lunar distances. The observations for position were repeated as often as there was a chance, without regard to the temperature; whenever the mercury of the artificial horizon froze, turpentine colored black was substituted.

The result of the meteorological observations can be mentioned here only imperfectly, as they are not yet properly arranged and reduced. They embrace 22 months, from the day we left Tromsö to that on which we abandoned the vessel. They were made two-hourly, and at 9 a. m. and 3 p. m., together 14 times a day, by Lieutenant Brosch, Ensign Orel, Master Lusina, Master Carlsen, by Engineer Krisch from the fall, 1872, to the spring, 1873, and by Dr. Kepes in the two last months.

The winds were estimated in force and direction. I prefer for Arctic regions this method, in which errors in general balance each other, to observations with instruments, by which errors that cannot be ascertained, such as those resulting from permanent ice, drift-snow, etc., multiply instead of balancing each other. After some practice the estimation will be nearly correct.

Until the autumn of the second year the winds were quite variable. Near Nova Zemla they blew mostly from SE. and SW., veering around in the spring to NE. There was no definite prevailing direction until in the second winter, when we lay under Francis Joseph Land. There all snow-storms (50 per cent. of all the winds) came from ENE. They generally covered the sky with

clouds, which only disappeared when the wind veered to north. We did not experience the severe northerly gales which the *Germania* encountered on the Greenland coast, and which appear to prevail in the Arctic during the winter. There were, in general, no winds of such force as we encounter every winter in our own seas, for instance the Bora in the Adriatic; they are tempered by the ice, as every Arctic seaman knows. Frequently fog-balls drove rapidly past us at no considerable height, while beneath them it was almost calm.

I have stated the influence of the wind on the drift-ice, and must refer again to it in order to mention a peculiarity from which there was not a deviation. The ice never drifted in exactly the same direction as the wind blew, but always to the right of it as seen from the center of the compass; with a NE. wind we did not drift SW. but West; with a SW. wind, E. instead of NE.; with NW. winds, South; and with SE. winds, North. This peculiar deflection cannot be caused by the currents or by the vicinity of the coast, as in either case winds from opposite directions would cause corresponding deflections.

In both years the contest between the cold northerly and the warmer southerly winds is of interest; in January, shortly before the strong cold of the winter sets in, the warm southerly and southwesterly winds brought masses of snow along, and changed the temperature frequently 30° to 35°.

Of the barometer observations but little can be said before a thorough revision of the many thousand figures. There were very extreme readings, from which conclusions can be drawn only after their reduction and comparison. We had three tube and four aneroid barometers. All these were read for comparison at noon of each day, by Ensign Orel. The regular observations were made with one of the aneroids.

The air-thermometers were placed about 25 paces from the vessel, four feet above the surface of the snow. With the exception of the maximum thermometer, they were all spirit-thermometers, made by Capeller, of Vienna. They were frequently compared with a very sensitive normal thermometer of the same maker.

A minimum thermometer was read daily at noon. In the summer a black ball thermometer was exposed to the rays of the sun. In the winter, covered and free minimum thermometers were frequently read at low temperatures for ascertaining the radiation. During both winters the lowest monthly mean fell into February, while the temperature in January was remarkably higher than in December and February. In the winter the temperature was variable, and

sudden changes not uncommon; but in the three summer months it remained very constant, the highest monthly mean being in July. The lowest reading was —52°.4 F.

The effect of so extreme cold upon the human body has been greatly exaggerated. We have never experienced a difficulty in respiration, pain in the chest, etc., which are said to be a consequence of it. Although most of us were natives of a southerly climate, we bore the cold very readily, and some of the sailors did not wear fur; we smoked our cigars in the open air at the lowest temperature. The cold becomes unbearable only with a high wind, though the latter always raises the temperature. The effect of the cold differs greatly with the humidity of the air and the personal disposition. The same low temperature is at one time very unpleasant, while at another it has hardly any effect.

The humidity of the air was ascertained with an ordinary pschychrometer, (dry and wet bulb thermometer.) With low temperatures, however, the observations with this instrument are not reliable; we dropped them in the winter altogether, as the smallest error would cause great differences in the absolute humidity. In order to ascertain, at least approximately, the evaporation of the ice in the winter, I exposed carefully weighed ice-cones to the air and ascertained their loss of weight every fortnight.

In the winter the air appears always to contain atoms of ice, which could be seen distinctly when there were parhelia, (mock sun,) or paraselena, (mock moon,) on a clear sky. They cause the images of the stars to appear in the telescope more dimly than with us, although there is considerably less absolute humidity in the air. Fine ice-needles form frequently in great numbers in a completely clear sky.

It is entirely impossible to measure the quantity of precipitation, as in snow-storms the drifting snow cannot be distinguished from the falling. In the first winter, at a distance from the land, the small quantity of snow was remarkable as compared with the snow of the second winter, under Francis Joseph Land, which almost buried the vessel. There was the same contrast in the quantity of rain between the second and the third summer. In the former there was but little rain, late in the season, while during our return home it was frequently pouring in streams for days as early as July.

The character of the clouds, naturally, differs altogether from that with us; there are no nimbus or cumulus clouds at all. They are either cirrus or the

uniform dreary gray of fog. The cirrus clouds, also differing from ours, consist of low fog-balls, rarely of the sharp contours which they have in the southerly zones. In general, the clouds are replaced in the Arctic by the dreary fog clinging to the ground or moving over it slowly and low. There is hardly ever, for 24 hours, a clear sky; whenever the sun breaks through, it again disappears, after a few hours, behind the thick masses of fog. But, as uncomfortable as this eternal fog may be, it is a blessing and a necessity for the ice relations; as, retaining the sun's heat, it absorbs more of the ice than the direct rays of the sun would do.

Parhelia and paraselena were very frequent, and always precursors of snow-storms. New forms of these phenomena were seen but once, when there were two suns, in addition to the double system of mock suns, at the same height as the true sun.

We have measured the depth of the water along our entire route, and found it increasing eastward. At our easternmost point, longitude 73° E., we found it to be 217 fathoms, decreasing slowly westward to a bank, which extends between Francis Joseph Land and Nova Zemla; beyond this the depth increases a little. In general, the sea east of Spitzbergen has a very even bottom, the depth rarely exceeding 1,000 feet. Specimens of the bottom were frequently obtained with an instrument constructed by Lieutenant Hopfgarten.

Deep-sea temperature observations were made at every deep sounding with Casella's minimum and maximum thermometer; these observations were continued throughout the winter; they show a decrease of the temperature downward. The salinity of the water at the various depths was also ascertained.

The surface-temperature of the sea was observed until the water around the ship froze. Too great an importance is, in my opinion, generally placed upon these observations, as they depend upon the weather, of which no notice is taken in their reduction. It appears to me entirely erroneous to infer from them warm or cold currents.

The dredging implements were diligently employed during our drifting, not only over short distances, but generally for half a day, on the bottom, so that several miles were explored at a time. The collection thus obtained will probably represent quite fully the animal life at the bottom of the sea traversed by us. At some places the dredge came filled to the surface. The greatest variety was in the crab-family; unluckily we could not transport the larger specimens, which were left in the abandoned vessel. Dr. Kepes arranged the

collection and has now turned it over to the Academy of Sciences, which has made provision for its examination by experts.

The other parts of our collection, which were also left on board, were not extensive, as we landed only in winter, when everything was hidden by the snow.

Our collection of bird-skins was almost complete, but contained only known species, with the exception of a prey-gull, which Dr. Kepes could not find in the catalogues. Of considerable value were 67 well preserved and packed skins of the Polar bear, among which were some beautiful specimens of winter skins, which surpass the summer skins in beauty and rarely come into the trade.

There are but few animals of higher orders existing in this sea. The principal are the Polar bear and the seal, the former so numerous that we could not, during the winter, leave the ship unarmed. Frequently we were sorely surprised by it, but nevertheless the animal was always welcome, as it furnished very nourishing and healthy fresh meat. The seal was represented in two species: Phoca barbata and Phoca groenlandica; they were met wherever there was open water between the ice-fields, but not abundant enough to pay the hunter. The walrus we saw but once, near Francis Joseph Land, although we lay frequently over grounds where they might have been expected. Of the whale we met only the white whale, near the coast, in considerable numbers.

Birds were in very great numbers near the coast, but disappeared more and more the farther we receded from it, until on our return a bird was a rare sight.

Interesting as all these observations are, they have by no means the value which can be attained under other circumstances. They give, as it were, only an idea of the strange and manifold actions of the agents of nature, but as to their sources and causes we remain as much in the dark as before for the want of simultaneous observations in different localities. Only when we shall have these will we be able to draw correct conclusions regarding the sources, the development, and the nature of the abnormal phenomena in the high North. The key to the many mysteries of nature, the solution of which has vainly been attempted for centuries—such as magnetism, electricity, meteorological phenomena, etc.—lies surely in the vicinity of the Poles; as long, however, as the Polar expeditions remain nothing but an international race for the empty honor of attaining the highest latitude, these enigmas will not be solved.

The purely geographical exploration, Arctic topography, which thus far had the first place in the programme of Arctic expeditions, must be made secondary to these great scientific questions, and their solution will not be attained until the nations in the first rank of civilization relinquish all rivalry and agree to joint action. For final scientific results cotemporaneous expeditions are required to penetrate into different parts of the Arctic region, where they must observe with the same instruments, collated before and after, and under homogeneous instructions for a length of time, at least one full year. Thus only sufficient material can be obtained for the solution of the great problems of nature which lie buried in the Arctic ice, and then only will we reap the reward for the immense capital of labor, deprivation, and money which has been squandered without result in the Arctic Zone.

The Polar explorers differ as to the manner in which the highest latitude may be attained; some advocate sleighs, others prefer the ship. As long as only a high latitude is aimed at the former is probably the more promising; but whenever scientific results are desired, the ship only should be relied on. Both aims can hardly be fully combined; one must always remain secondary.

In conclusion, I cheerfully take advantage of this first occasion to express publicly my deep gratitude to all the officers of the expedition for their untiring energy, often displayed under the most trying circumstances.

# CAPTAIN DAVID GRAY'S OBSERVATIONS IN THE EAST GREENLAND SEA, 1874, AND HIS VIEWS AS TO THE BEST ROUTE FOR THE NORTH POLE.

**From a letter to Dr. Petermann, in Gotha, published in German, in Petermann's Geographische Mittheilungen, 1875, pp. 105 et seq.**

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The views regarding Arctic exploration which I expressed, in my letter of February 22, 1868, to Sir Roderick J. Murchison, (see papers on the Eastern and Northern extensions of the Gulf Stream, pp. 288 et seq.,) have not been essentially modified by my six subsequent Arctic cruises, nor by the greater knowledge of the extreme northerly regions gained through the observations and experience of the several Polar Expeditions of the same period.

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On my return from my last cruise I read the discussion of Admiral Sherard Osborn, in August, 1874, before the British Association, in which he opposes, for new polar expeditions, any route through the sea between Spitzbergen and Nova Zemla, and cites as proof of their impracticability the fate of the Austrian expedition, of which there were no tidings at that time. Although his fears for the safety of that expedition have, very fortunately, not been realized, the objection to the routes through that sea are still open for discussion, and I will briefly review Captain Osborn's conclusions as to the comparative practicability of the several routes to the north pole—the Nova Zemla route, the Spitzbergen route, and the Smith Sound route.

Of the Nova Zemla route Admiral Osborn says, in his discussion: "The theory that there exists between Spitzbergen and Nova Zemla a channel of open water up to the north pole is but an hypothesis, unsupported by established facts and in contradiction to all experience."

I have not heard that any one has asserted the existence of an open channel between Nova Zemla and Spitzbergen to the pole. But that open water is found there in favorable years has been sufficiently proved by the cruises of Mr. Leigh Smith and the preliminary Austrian reconnoissance in 1872. Mr. Leigh Smith came very close to Francis Joseph Land, and would doubtless have reached it had he not remained the greater part of the favorable season in

Hinlopen Strait An unobstructed route northward may, in my opinion, be confidently expected along the western coast of that complex of land, if the ice relations there are not altogether different from those on the west coasts of Nova Zemla, Spitzbergen, or Greenland, which is improbable.

Regarding the practicability of a north-pole expedition with Spitzbergen for a base, Admiral Osborn says: "All the attempts made in the last hundred years to push north from the coast of Spitzbergen, which terminates in latitude 80° N., have failed entirely." An investigation into this assertion results as follows:

The elder Scoresby sailed in May, 1806, through a broad open sea to latitude 79° 30′ N., longitude 8° W., without seeing any indications of ice 30 miles to the westward of his track, nor any land within a radius of 60 miles. As he did not fall in with whale there, he sailed thence in an ENE. direction, through equally open water, until he came in latitude 81° 31′ N., longitude 19° E., to an ice-border which extended in an ENE. direction; there was no ice visible to the westward of the bearings ENE. and SE., neither was there land within a radius of from 60 to 100 miles. Captain Scoresby remarks that, had discovery been the object of his cruise, he would most probably have been able to contribute to the better knowledge of our globe by the exploration of a rarely accessible region. It seems to me fully justifiable to assume that this broad open sea, described by Captain Scoresby, beginning probably west of Francis Joseph Land, is normal in this region under the influence of long-prevailing easterly winds upon the east—westerly ice drift, well known to exist there, and that it extends with the season, thus offering a broad field for navigation north of Spitzbergen, and a navigable channel along the west coast of Francis Joseph Land, and thence northward.

Sir E. Parry sailed, in 1827, up to latitude 81° 05′ N. Had this eminent Arctic explorer not been prevented by his instructions, he could have pushed farther in a northeasterly direction. where the ice was so thin that he might have reached, as he says, without difficulty, the 83d degree of latitude, where he would most probably have discovered land, along the western coast of which he would have been able to proceed still higher; thus he would have attained a far higher latitude than by his toilsome sleigh excursions.

Two British whalers, the *Eclipse* and the *Perseverance*, sailed in July, 1838, along the meridian of Greenwich to latitude 80° N., rounding there the extreme point of an ice-border. The *Eclipse* then turned homeward; but the

other vessel pushed on farther north, and found an open sea of such an extent that a northerly double-reef topsail breeze created sufficient sea to necessitate taking the boats inboard.

In May, 1855, I sailed for the whaling-grounds in latitude 80°, and there found the ice in a very unusual position, forming a strip of only 6 miles in width, which lay NE. and SW., 150 miles to the westward of Spitzbergen. No ice was visible beyond the strip except a few broken pieces floating about. The late Captain Graville, then in command of the *Sarah and Elizabeth*, pushed through the strip to its western border, but saw no ice to the north, northwest, or west. Caring at the time only for whale, I inferred from this extraordinary character of the ice that I should find them south of the parallel of latitude 75° only, and on reaching that locality there were great and small whale in abundance, although I never before had seen or heard that young whale were met in any number so far to the southward. The whale never remains at any feeding-ground, even the best, after the ice has drifted away; that region must, therefore, have been at that time the northern limit of the ice in the Greenland sea.

In my last cruise (1874) I experienced, in March, April, and a part of May, an almost uninterrupted series of strong winds from the north and northeast, which, as it seemed to me, must have caused a great extent of open water in the vicinity of the north pole, increasing with the season, until about the middle of August a great part of the ice in the polar basin had drifted south to about the 80th parallel of latitude. I shall refer to this again.

As sealing ceased at the end of March, I took to following the whale earlier than usual, and after reaching, on April 25, latitude 80° 15′, I had, from that time to the close of the season, frequent occasion for observing the drift of the ice. Reliable meridian altitudes proved that immense ice-fields were drifting south at the rate of 26 to 27 miles per day, sometimes against violent southwest winds. I am sure that with strong northerly winds the rate of the drifts sometimes exceeded 40 miles; but, as I had not been able at that time to obtain noon sights, I have omitted this exceptional rate in computing the mean rate, which I found to be 16 miles in 24 hours.

The ice which, between Greenland and Spitzbergen, drifted south from March 1 to August 15, extended about 300 miles east and west; the quantity of ice discharged from the northern part of the polar basin must therefore have been enormous.

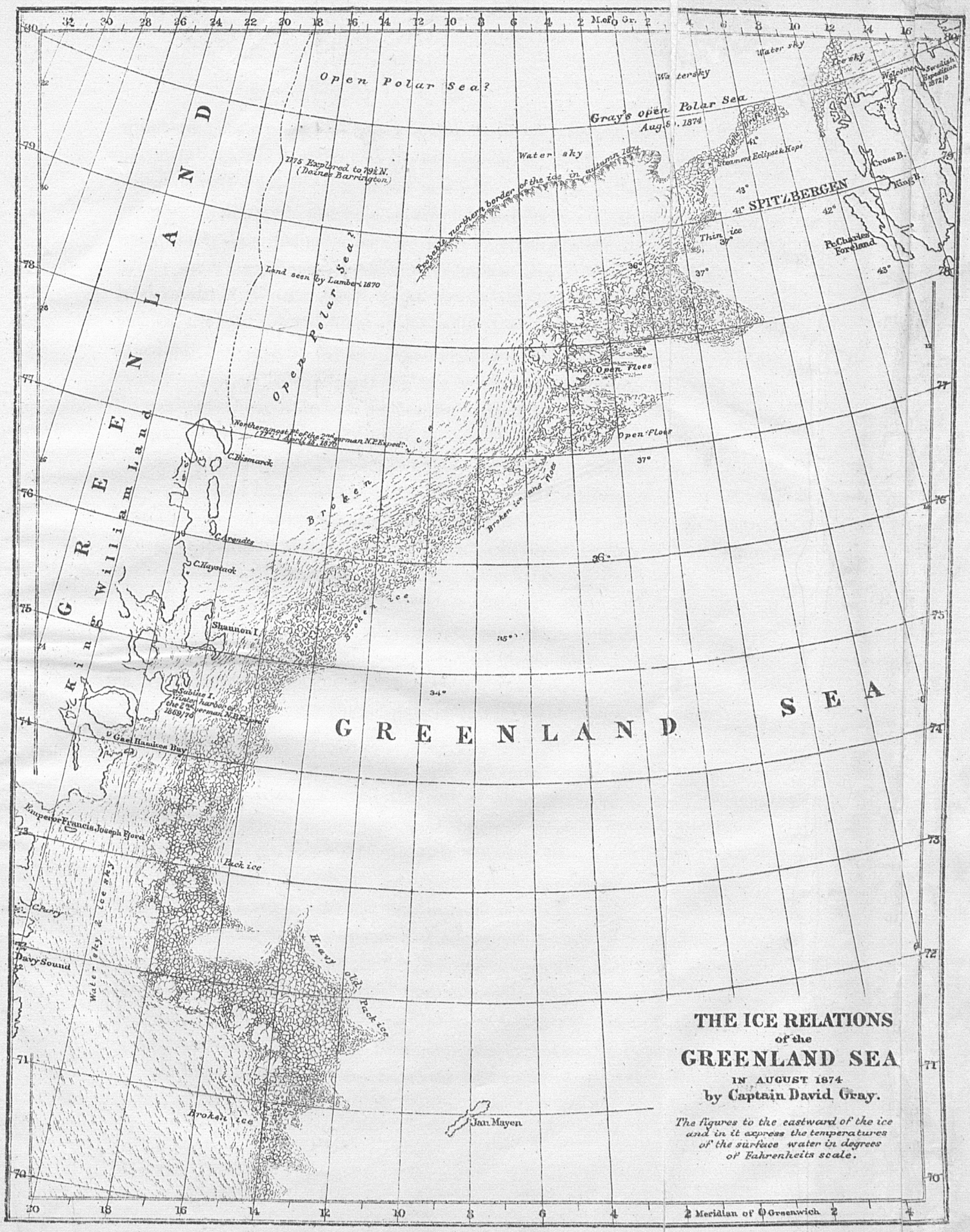
We left our whaling-grounds, in latitude 74° N., toward the end of July, and sailed thence northward as far as latitude 79° N., through ice which consisted of large floes with numerous channels between them, showing by its character that there had not been, for some time, a swell from the southward or southeastward. Farther north the ice was more broken and thinner, but packed densely, from which I inferred that we were near its northern limits, as a southern swell could not have thus broken the ice so far north without breaking also the large floes 300 miles to the southward. Only northerly winds and a pressure by open water could have broken and packed the ice in such a manner.

While under sail in a dense fog, with a brisk northwesterly breeze, close to the border of the pack-ice, I saw that it steadily drifted to the southward upon us. When the weather had cleared, all the boats were launched for taking in fresh-water ice, but the drift proved so strong that they had to be recalled for fear of their encasing. This state of the ice appeared to me a proof of a pressure against it from the northward by a swell of open water. Having reached a position in latitude 79° 45′ N., longitude 4° E., I distinctly saw, north of the strip of ice, the open water and a dark-water sky, which extended from NW. to ENE. as far as the eye could distinguish. There was evidently a broad open sea before us, extending to a far higher latitude than has ever been attained.

Chances for observing the ice relations of the high North late in the summer are rare for whalers, and these chances, when occurring, are generally neglected; otherwise the practicability of attaining high latitudes north of Spitzbergen would have been proved by them. The facts stated by me will suffice to show that an attempt for the north pole by that route may readily be successful; I would not, however, advise that an expensive expedition be fitted out for it.

The accompanying chart will illustrate my observations of the ice relations of the Greenland Sea between the parallels of latitude 80° and 70° N.

I have followed whaling along the east coast of Greenland for a long series of years, and have always devoted close attention to the action of the wind and the currents upon the ice. The result of my observations is the impression that the chances for reaching a high latitude by this route are greater than those by any other route. It has the advantage of a west coast extending far to the north on its eastern side, and on the other side that of a broad ocean,


THE ICE RELATIONS
of the
GREENLAND SEA
IN AUGUST 1874
by Captain David Gray.
The figures to the eastward of the ice and in it express the temperatures of the surface water in degrees of Fahrenheit's scale.
GREENLAND SEA
GREENLAND
King William Land
Open Polar Sea?
Gray's open Polar Sea Aug. 8. 1874
Water sky
Ice sky
Probable northern border of the ice in autumn 1874
1875 Explored to 79½ N. (Dainer Barrington)
Land seen by Lamber 1870
Open Polar Sea?
SPITZBERGEN
Steamer Eclipse & Hope
Cross B.
King B.
Pr. Charles Foreland
Swedish Expedition 1872/3
Thin ice
Open Floes
Northernmost pt. of the 2nd German N.P. Exped. (77° 1' April 15. 1870)
C. Bismarck
C. Brandes
C. Hayestack
Broken ice
Broken ice and floes
Shannon I.
Sabine I. Winter harbor of the 2nd German N.P. Exped. 1869/70
Gael Hamken Bay
Emperor Francis Joseph Fjord
Pack ice
Cherry
Davy Sound
Water sky & ice sky
Heavy Pack ice
Jan Mayen
Meridian of Greenwich

which permits the ice to diffuse and to open in every direction. It is true northwesterly winds will drive the ice against the land, but this disadvantage will gradually diminish the farther north the vessel proceeds, as the winds and currents follow, from the pole downward, at first a directly southern course, from which they gradually diverge more and more to the westward, propelled by the earth's accelerated rotation. This also causes the coasts of East Greenland south of latitude 70° N. to be less accessible than between latitude 70° and 75° N. I have no doubt that, should this coast extend still farther north than known at present, the open waters along it will gradually extend in width in proportion. The southwesterly and westerly winds coming in conflict with the southerly current deflect the ice, and, opening it quickly, create landwater of from 50 to 60 miles.

There have certainly been favorable years when a vessel by pushing along the coast might have attained a very high latitude without much molestation from the ice. I, myself, have frequently sailed in latitude 80° N., directly through ice-fields, with abundant water in each direction, as also into and out of the channels of the Greenland coast, without any difficulty even in thick fogs.

It has been asserted that all attempts to push north in this direction have utterly failed. I, however, maintain that no British-Arctic explorer has ever made an earnest attempt along the east coast of Greenland. Clavering visited, in 1823, this coast solely for the purpose of pendulum observations; after this he sailed a short distance southward along the coast without any difficulty from the ice. In 1868 a German yacht intended to make the attempt, but failed in reaching the coast. Toward the end of July of the same year, I sailed easily, in a well-fitted vessel, into Scott Inlet, in latitude 73° 30′ N. In the following year, 1869, two German vessels renewed the attempt, but could not reach higher north than to the usual channels of the whalers. In these two years, however, the ice relations were particularly unfavorable.

Captain Koldewey has stated that his experience on the Greenland route has entirely dispersed his faith in the theory on which its practicability is based. I presume the fault lies in the fact that he accidentally chose two so unfavorable years.

In regard to Smith Sound I cannot agree with Captain Koldewey, who, with Admiral Osborn, believes it to be the best route to the pole or for the exploration of the inner polar region. Their assertions are not sufficiently war-

ranted by our present experience and knowledge. I anticipate that the energy of our sailors will carry them, at least, as far as their predecessors; but it is not entirely clear to me that there must necessarily be in Smith Sound a channel with favorable ice relations and a broad navigable sea north of it, either one of which, at least, is an indispensable condition for the success of an expedition intending to explore the highest northerly latitudes.

That there was open water at the point reached by the Americans, or that it was seen beyond it, would only justify an inference of the existence of land farther north, in which case the open water was caused by the rebound of the ice which cleared the northern part of the sound. This would also result, should the sound be connected with a great basin north of it by a narrow, perhaps crooked strait. Both cases would be unfavorable for an expedition.

More information regarding the tide in Smith Sound seems to me very desirable. The rise and fall of it, as also the currents, do not appear to have been ascertained accurately enough for accepting as a fact the statement that the flood-wave moves south in the northern part of the sound, which would be a very important feature regarding the practicability of the route.

Should an expedition through Smith Sound reach land-ice, it may penetrate to a great distance by sleighs; very probably, however, they would soon find their progress stopped by broken ice, an obstacle which cannot readily be overcome even with the means suggested by late experience. But it is not my purpose to discourage the bold explorers who are preparing to penetrate into these regions. Many valuable scientific results may be gained there in one or two favorable years. * * *

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