U. S. TREASURY DEPARTMENT
COAST GUARD

THE "MARION" EXPEDITION TO DAVIS STRAIT AND BAFFIN BAY

UNDER DIRECTION OF
THE UNITED STATES COAST GUARD

1928

SCIENTIFIC RESULTS

PART 1

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Bulletin No. 19

THE "MARION" EXPEDITION
TO
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PART 1

The Bathymetry and Sediments of Davis Strait

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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1932

For sale by the Superintendent of Documents, Washington, D. C. - Price 50¢ (paper cover)

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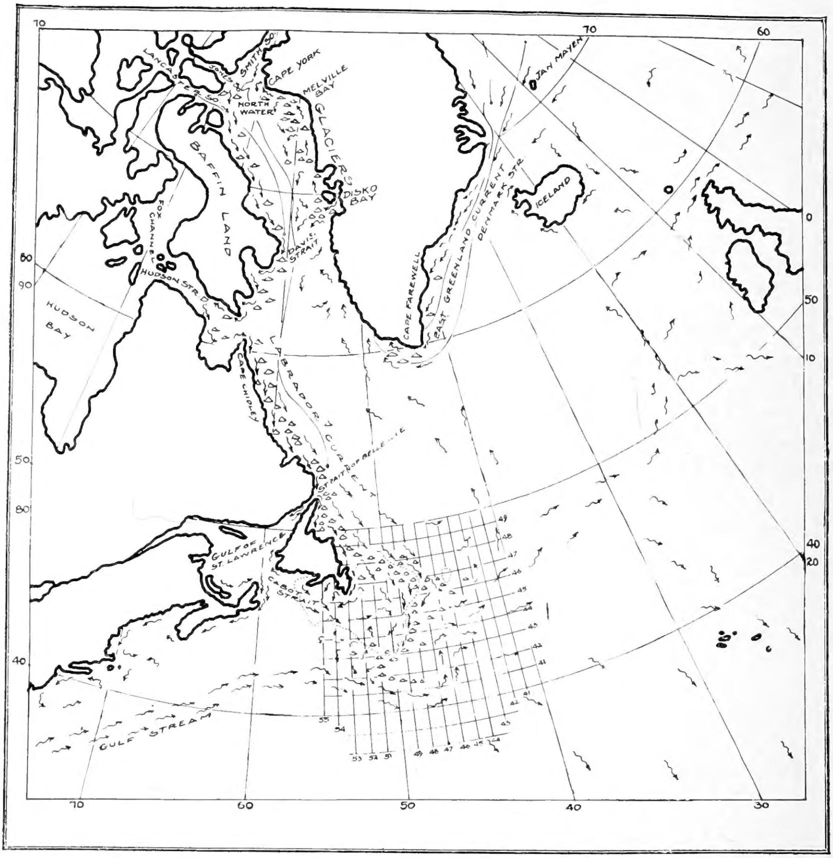


THE NORTHERN PORTION OF THE NORTH ATLANTIC OCEAN

FIGURE 1.—This map shows the general location of the region which was investigated by the *Marion* expedition during the summer of 1928. All of the *Marion's* work was done between Disko Bay, in west Greenland, and the northeast coast of Newfoundland. For a more detailed chart of the area actually surveyed, see Figure 39. The latter shows the track of the ship and gives all the important place names.

FOREWORD

Prior to the loss of the *Titanic*, on April 14, 1912, as the result of a collision with an iceberg in the North Atlantic, no patrol was maintained in the region of the Grand Banks for the purpose of safeguarding lives and property against the iceberg peril, and no systematic study had been made of physical and oceanographic conditions pertaining to icebergs and their drift in the North Atlantic. While a patrol of the ice zone was maintained during the seasons of 1912 and 1913 to meet an almost universal demand, arising from the *Titanic* catastrophe, for protection against the iceberg menace, it was not until the season of 1914 that the United States Government undertook the management of the international service of study and observation of ice conditions and of ice patrol, pursuant to the International Convention for the Safety of Life at Sea signed on January 20, 1914. This was a new and important duty, inaugurating the entry of the United States Coast Guard into an international service of iceberg scouting and patrol, and into a field of scientific study and research not previously developed nor sufficiently known.

The early history of the International Service of Ice Observation and Ice Patrol represented a pioneering service and purpose not only to maintain an efficient patrol worthy of the high standards and traditions of the United States Coast Guard, but also to accumulate scientific data to afford an intelligent understanding of the forces of nature having an effect on or a relationship to the iceberg menace. With the growing importance of a knowledge of ocean currents, and of the source, characteristics, and drifts of icebergs in the conduct of this international service, every opportunity was availed of and every effort directed, each ice season, toward assembling data and making studies of oceanographic conditions in the Grand Banks region. The data gathered during the ice seasons were supplemented by observations made during special cruises at other periods of the year in order to study seasonal changes in ocean currents and water temperatures. Each succeeding season brought to light extensive and important data in furtherance of our knowledge of the elements entering into the study of ice conditions, and strengthening and corroborating opinions held as a result of prior scientific investigations. Reports of these observations were published in the annual bulletins of the International Service of Ice Observation and Ice Patrol.

With the accumulation and studies made of scientific data since the inauguration of the Ice Observation and Ice Patrol Service, it is believed that sufficient information is now available to permit of the publication of a treatise dealing with the subject of icebergs and their distribution and drift in the North Atlantic Ocean, embodying conclusions and scientific results of many years of intense specialized study and research. To broaden the scope of this work and to obtain data necessary for a complete analysis and exposition of the iceberg situation and related subjects, the *Marion* expedition was dispatched in the summer of 1928 to carry out an oceanographic survey of the waters between Greenland and the North American Continent, with especial reference to a study of ice conditions. The observations made during this cruise, in addition to being helpful to the completeness of the treatise on icebergs, have also been made the subject of separate publications dealing with the bathymetry and sediments, and with the physical oceanography of Davis Strait, representing important contributions to the scientific knowledge of this area. The results of this research work, and of years of study and observations are being published in three parts under the title of "The *Marion* Expedition to Davis Strait and Baffin Bay."

These contributions to our knowledge of the iceberg problem mark an epoch in the international Service of Ice Observation and Ice Patrol, and great credit and praise are due the authors. Their work presents a most comprehensive and valuable reference on the subjects treated, and undoubtedly will form a foundation and a guide for any future studies or research work which may be undertaken along similar lines.

F. C. Billard,
Rear Admiral, United States Coast Guard,
Commandant, United States Coast Guard,
Chairman Interdepartmental Board on International Service of Ice Observation and Ice Patrol.

THE LEADER OF THE EXPEDITION

FIGURE 2.—Lieut. Commander Edward H. Smith, United States Coast Guard, leader of the *Marion* expedition. At the termination of the World War, Lieutenant Commander Smith was assigned by the Coast Guard to its ice-patrol service. There he spent 10 years, and it was because of this work that he was chosen to command the *Marion* during her Arctic cruise. The instrument is a Greene-Bigelow water bottle—a device used to obtain a sample of the water and the temperature from any level to which it is lowered.

THE "MARION" EXPEDITION TO DAVIS STRAIT AND BAFFIN BAY

Noble G. Ricketts

Chapter I

INTRODUCTION

In 1928 the United States Coast Guard sent the *Marion* expedition north into Davis Strait and Baffin Bay to carry out scientific investigations connected with the international ice patrol. The object of the expedition was to obtain all the information possible regarding ocean currents, depths, and ice conditions in the region to the north of that usually covered by the ice-patrol vessels each spring and summer. The leader of the *Marion* expedition, Lieut. Commander Edward H. Smith, United States Coast Guard, has fully worked up the scientific data that was obtained about oceanography and ice. The reader is referred to United States Coast Guard Bulletin 19, part 3, for the report relating to Arctic ice and its drift into the North Atlantic Ocean, and to United States Coast Guard Bulletin 19, part 2, for the report relating to the oceanography of Baffin Bay and Davis Strait. The former publication was printed in 1931 and the latter will be distributed at an early date. The present paper, constituting part 1 of the Bulletin 19 series dealing with the *Marion* expedition, contains a narrative of the *Marion's* cruise; a report and discussion of the sounding work accomplished; and a description and discussion of the bottom samples obtained at some of the places where wire soundings were made.

DESCRIPTION OF VESSEL AND APPARATUS

The *Marion* is one of a number of similar vessels which the Coast Guard had built in 1925 for offshore patrol duty. She is 125 feet long, with a 23½-foot beam and an 8½-foot draft. Her normal displacement is about 220 tons. Her twin screws, each driven by a 6-cylinder air-injection Diesel engine of 150 horsepower, could give her a maximum speed of about 10½ knots. When she departed for the north she carried a total of 9,000 gallons of fuel oil, of which 7,000 were in her tanks and 2,000 in drums on deck. With this amount of oil, her cruising radius was upward of 6,000 miles at a speed of 7½ knots. Figure 4 shows the *Marion* as she looked just prior to her departure for the north.

The *Marion's* highest compartment was the bridge, the afterpart of which was partitioned off shortly before the start of the expedition to form a radio room. The large deckhouse on the next deck below the bridge contained the wash rooms and water-closets, the upper engine room, entries to berthing and messing spaces, and several lockers used for ordnance equipment, boatswain's stores, carpenter stores, and cleaning gear.

The steel deck over the upper engine room had an extension built out to starboard and the whole served as the platform for the oceanographic work. The main oceanographic platform can best be seen in Figures 10 and 11. The latter figure shows the water-bottle rack and considerable detail about the large winch. In addition to the large winch working some 10,000 feet of $\frac{5}{32}$-inch wire rope from the

PERSONNEL ON MARION EXPEDITION, 1928

FIGURE 3.—The officers and crew of the Coast Guard patrol boat *Marion* just prior to their departure for the Arctic in July, 1928. The *Marion* had a complement of two commissioned officers, two warrant officers, and 23 enlisted men. Sitting left to right: Boatswain J. B. Krestensen, Lieut. Commander Edward H. Smith, Lieut N. G. Ricketts, and Boatswain (T) A. L. Cunningham.

overhanging platform, there was a smaller winch farther aft using 12,000 feet of $\frac{3}{32}$-inch wire rope. The latter was employed for bottom sampling and for taking the lower levels at the oceanographic stations, usually at the same time that the big winch was being operated.

Below the spar deck there was but one continuous deck level. It contained from forward aft, the following compartments: Forehold, crew's berthing space, three staterooms for officers, engine room, galley, pantry, furnace room, officer's mess room and ship's office, coal bunker, water tank, crew's mess room, and the afterhold. Below this level, under the living and messing spaces, were shallow holds that were used as magazines and storerooms.

A number of extra items of equipment were installed on the *Marion* prior to her departure from the United States. The principal ones were a radiocompass, a short-wave radio set, two oceanographic winches, an electric salinometer, a fathometer, several extra banks of storage batteries, a special generator driven by an internal-combustion engine for running the oceanographic winches, and another for charging the numerous banks of batteries needed for the radio and the fathometer work. All the ice patrol's deep-sea thermometers, thermographs, Greene-Bigelow water bottles, water sample bottles, and other articles of scientific apparatus were taken on board for use. One of the items of special equipment was the bottom sampler. There was amply sufficient apparatus on board for comprehensive oceanographic research, including the occupation of a large number of stations at which serial temperatures and salinities were determined for the purpose of working out the dynamic currents of the area traversed.

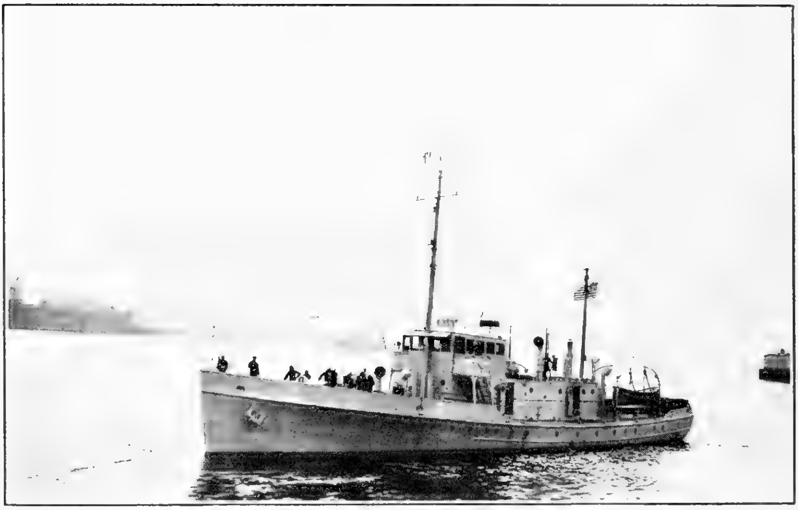
It was intended to make the vessel self-sufficient throughout the expedition, so a tremendous load of stores and many spare parts were carried. Below deck, almost all available spaces were filled with coal for cooking and heating and with food. On deck, around the rails from stem to stern and completely filling the extreme after deck space, were lashed no less than 78 drums of petroleum products. The principal item here was diesel fuel oil for the main engines, but there were also many barrels of lubricating oil, kerosene, and gasoline. A spare electric winch for use at oceanographic stations and two extra dories were also carried on deck.

At the time of departure from Sydney, Nova Scotia, the *Marion* carried sufficient fuel to cruise a total of almost 7,000 miles, and this figure represented the limits northward to which the ship could range. Later on in Godhavn, Greenland, we were surprised to find a plentiful supply of Diesel oil, which permitted the oceanographic program to be greatly extended. In order to conserve fuel the *Marion* at the start was operated with only one engine at a time, alternating motors at the end of each 4-hour watch. In this manner we cruised along at the slow rate of 6 miles per hour. After arrival at the northern terminus, Godhavn, and learning of the available oil supply there, the ship was cruised with both motors and maintained a higher rate of speed, averaging almost 9 knots.

PERSONNEL

The complement of the *Marion* during her regular Coast Guard duty was 3 warrant officers and 18 enlisted men. On account of the large amount of work of a special nature to be done in the north, just prior to the start of the *Marion* expedition, the personnel was increased to the following: 2 commissioned officers, 2 warrant officers, and 23 enlisted men. All of the latter were easily accommodated on board in the large crew spaces, those men for whom no bunks were available being swung in hammocks in the crew's mess room. The enlisted men were distributed among the following ratings:

Chief boatswain's mate	1
Chief motor machinist's mates	2
Boatswain's mate, first class	1
Quartermaster, first class	1
Radiomen, first class	2
Motor machinist's mates, first class	2
Yeoman, second class	1
Motor machinist's mates, second class	2
Pharmacist's mate, second class	1
Seamen, first class	4
Seamen, second class	6



UNITED STATES COAST GUARD PATROL BOAT MARION

FIGURE 4.—The *Marion* departed from Boston, Mass., for Davis Strait and Baffin Bay on July 11, 1928. When she left Sydney, Nova Scotia, the last port where regular supplies could be obtained, she carried 78 drums of fuel oil and gasoline on deck in addition to her full capacity of tanks below. She was equipped with spare parts for practically every piece of machinery on board.

NARRATIVE OF THE EXPEDITION

After leaving New London, Conn., on July 7, 1928, the *Marion* called at Vineyard Haven, Mass., and Boston, Mass. Final preparations for the cruise were made at the Boston Navy Yard during a spell of extremely hot weather. At 6.30 p. m. July 11, 1928, the *Marion* departed from the United States, heading toward Halifax, Nova Scotia. Immediate relief from the heat was had upon leaving Boston Harbor. On the foggy run eastward across the Gulf of Maine all oceanographic equipment was tested and the personnel was given practice and instruction in the special duties connected with the expedition's work.

Halifax was reached at 8.30 p. m. on July 13, 1928. Several British Admiralty charts and a few last items of equipment were purchased on the following day. A number of persons experienced in the waters of the Canadian Arctic gave, on request, valuable advice regarding conditions that would probably be met by the *Marion* in the waters of the north.

Halifax was left on the evening of July 14, and some 24 hours later we arrived at Sydney, Nova Scotia. Foggy weather with little intermission prevailed during our run northeastward along the Nova Scotian coast. On the 16th the ship was fueled and loaded up with fresh commissary stores. All hands sent letters home and made last purchases of needed articles, for it was realized that no other truly civilized seaport would be visited for at least some weeks.

Just before leaving Sydney Harbor, Captain Falk, of the *Beothic*, was interviewed on board his ship. He was preparing to depart with her on a far northern cruise which for several years has been annually carried out by the Canadian Government. Captain Falk's advice was extremely valuable, and so were several special charts of northern harbors that he generously presented to the *Marion*. His cheerful description of the Arctic summer removed many doubts and misgivings, and heightened the pleasant anticipation which animated the ship's complement when Sydney Harbor was left behind on the evening of July 16.

Fog enveloped the ship almost as soon as it got outside, and it remained thick throughout the crossing of Cabot Strait. On the afternoon of July 17, after the run north across the Gulf of St. Lawrence was finished, the *Marion* began skirting the western shore of Newfoundland, the first land to be sighted being the high rocky bluff of Cape St. George. The fog which had surrounded us since leaving Sydney, quickly departed and the weather became warm and fine. The setting sun lit up brilliantly the colorful slopes of Red Island, as the *Marion* passed close by it on a smooth and bright blue sea. The next day was clear and pleasant at first, but a thickening haze gradually cut off our view of the Newfoundland mountains and valleys. By midafternoon fog had again shut in thick.

Looking back upon the cruise, one of the most uncomfortable situations was the night of July 18, as we chugged heavily into the narrow Strait of Belle Isle. Running before a fresh southerly wind in the dense fog, we had left the warm water of the gulf to enter abruptly into almost Arctic conditions. The thermograph, which registered only a few degrees above the freezing point, brought home only too vividly the prospects of colliding with an iceberg. There was little solace to be had in attempting to seek shelter along the precipitous rocky shore of Newfoundland, so we kept on, sounding frequently with the fathometer and hoping for better weather conditions at daylight.

Throughout the night the *Marion* cruised northeastward in the Strait of Belle Isle, sighting nothing the next morning because of the fog's continuance. Some 15 icebergs were known from reports received by radio to be in the strait, but fortunately none were encountered. Thanks to occasional radio bearings, the *Marion* was able to proceed right up under the diaphone of the southwest lighthouse, and then halfway around Belle Isle itself, despite the dense fog. Not until the afternoon of the 19th did the visibility clear up sufficiently to permit the rocky heights of the island to be sighted.

Our arrival at the Atlantic end of the Strait of Belle Isle marked the inauguration of a rigorous program of oceanography upon which all of us were now to be busily employed for the ensuing eight weeks with little cessation. All hands except the two commissioned officers were green to the station work, and therefore plenty of time was devoted to patiently instructing the crew in their various duties. Since the station work was to be pushed from now on, day and night, as the main task of the expedition, the men were divided into three watches with a team on each watch consisting, as a rule, of three members—winchman, recorder, and platform man. Good station work requires practice, experience, and cooperation from all, as the slightest blunder or mistake on the part of any member of the team may mean the loss of a valuable instrument, or errors creeping into the observations, or, most common of all, undue delay. A false move made near the end of an oceanographic station often necessitates the retaking of the entire set of observations.

BATTLE HARBOR, LABRADOR

FIGURE 5.—We entered Battle Harbor, Labrador, on the evening of July 19, 1928. This is a small fishing settlement on the north side of the Strait of Belle Isle. Here we saw Eskimo dogs and Arctic mosses and flowers for the first time.

Regular half-hourly fathometer soundings began to be taken for record as soon as the vessel had passed to the eastward through the Strait of Belle Isle. Many sounding values had been taken previously for navigational purposes and for practice, but south of Belle Isle the charts already contained many plotted soundings and did not need to be improved by additional carefully located values like the blanker, less detailed, charts of the north.

The first real oceanographic station of the cruise was close to the northeast end of Belle Isle (ice patrol station No. 936; see Coast Guard Bulletin 19, pt. 2), and thence, a line of three stations was taken to a point just south of Battle Harbor, Labrador. These afforded the crew good practice in the correct procedure to follow in handling the sounding weights, wires, bottles, and messengers.

The *Marion* moored for three hours at Battle Harbor, Labrador, on the evening of July 19. Our water tank was topped off with fresh water by placing the *Marion's* forefoot lightly against the harbor's bank and drawing water with buckets from a near-by stream. Fresh water for scrubbing clothes was also put into four open barrels on deck. One member of the engineer force had to be left in the International Grenfell Association Hospital at Battle Harbor, as he was suffering from chronic rheumatism that had been greatly aggravated by the raw and damp climate into which the *Marion* had suddenly come. Through the aid of the American consulate at St. Johns, Newfoundland, he was later furnished with transportation by commercial vessel back to the United States.

There was little time to observe shore conditions at Battle Harbor, but the quickest of inspections sufficed to show that here was an entirely different world from that left behind in New England a few days previously. In the strait where the stations had just been taken three small bergs had been sighted, and stranded near Battle Harbor were two more. The dark rainy weather marred their whiteness, but brought out strongly their tints of blue and green. This day's bergs constituted the first specimens of glacial ice ever beheld by the majority of the crew. The water in the harbor was surprisingly transparent. Despite the dullness of the day, details of the rocky bottom and sides of the little cleft of a harbor could be observed in many places as the *Marion* nosed about slowly between the two rows of small wharves.

Ashore, the rounded rocky hills were covered wherever there was any soil with a rank, soggy growth of grass, moss, and flowers. Many of the latter were strange to our southern eyes. All our remaining doubts about being on the edge of the Arctic were quickly dispelled by the sight of the port's tiny houses and the fish-drying stages, about which were walking the fishermen and the Eskimo dogs of the little town. At 8.50 p. m. the *Marion's* business had been completed and we stood out to sea to head northward into the fog and the rain.

The morning of July 20 brought good visibility. A few bergs were sighted off the coast in the Labrador current and over 20 were seen grounded along the rocky shore. A northwest gale piped up just before noon, so the deeply loaded *Marion* was run into sheltered waters and anchored off Domino Harbor, Labrador. Only two persons were found at this place—a father and son from Newfoundland who were spending the summer there catching cod. The surroundings were uninviting and bleak, for the ground was rockier and the vegetation less vigorous than at Battle Harbor, only 70 miles farther south.

In the afternoon the *Marion* was swung in Domino Run to determine the deviations of the radiocompass, the local commercial radio station transmitting whenever test bearings were required. At 4.50 p. m., as it was still overcast and very windy, the *Marion* was anchored at Spotted Island Harbor. This town was considerably more populous than Domino Harbor, lying across the run from it. There was a hospital of the International Grenfell Association at the new village. The hospital people and the natives were most cordial throughout the ship's 45-hour stay. It was here that we had our first taste of seal meat, the consensus of opinion being that it was very good if properly cooked.

In the intervals between boating off fresh water and dumping oil into the bunkers from the drums on deck, much information was obtained about the hard life of the people who live in Labrador throughout the year. Some of the natives had distinct Eskimo features, others showed traces of Indian blood, while still others were apparently pure white. All talked in an old-fashioned English dialect.

The people lived in tiny houses and shacks set back a short distance from a few small wharves that were built mostly of poles. In sheds on the wharves the summer's catch of fish was salted and piled like cordwood. There were numerous Eskimo dogs about, groups of which from time to time engaged in howling choruses. The weird howling could be heard out at the ship's anchorage above the noises of the wind. Some of the better houses had near them garden patches from 20 to 30 feet square. These gardens were always fenced off with poles brought out from the forests of the interior to protect them from being torn up by the dogs. In them we saw nothing but a miserable growth of cabbagelike greens.

By 2 p. m. on Sunday, July 22, the gale had blown itself out, permitting the *Marion* to get under way. A stop was made just seaward of the mottled black and white rocks of Spotted Island where an oceanographic station was occupied. Until the 25th the ship was engaged off Labrador taking two lines of oceanographic stations located more or less at right angles to the general trend of the coast. The first line extended seaward 120 miles from Spotted Island, while the second was taken from a point 120 miles off Bulldog Island to a point 2 miles off the same. In general, fine weather prevailed throughout this time. In making the coast about Bulldog Island we were thrown upon our own resources, as very few aids to navigation, like buoys, lighthouses, and beacons are maintained north of the Strait of Belle Isle. The best aids available consisted of prominent landmarks such as mountain peaks, small islands, and reefs awash.

We were somewhat apprehensive as to the behavior of the *Marion* in "laying to" while the deep-sea observations were being made. It is quite important not only for the accuracy of the observations but also for the reliable operation of the water bottles that the wire to which the instruments are clamped remain as nearly vertical as possible. When it is blowing with any great strength, most ships, especially if high sided, with a deckhouse, experience considerable drift to leeward and also forge ahead. On the United States Coast Guard cutters used on the international ice patrol service this drifting off causes such a bad slant to the sounding wire that the station work often has to be abandoned until the wind moderates. Naturally it was very pleasing to find that on the *Marion* we were able to keep the wire and instruments perpendicular throughout the station work under all sorts of weather conditions. A kick ahead, first on one motor and then on the other, as she fell off on either side of the eye of the wind did the trick, even in a strong breeze and high sea. The fact that the *Marion* possessed twin screws made such maneuvering possible, and this handiness, by the way, was only one of the fine qualities to be displayed by the little craft throughout the entire expedition.

From Bulldog Island the course led northward along the shore toward a point near 56° north latitude, whence a 575-mile line of stations was to be run to the northeastward to the west coast of Greenland in latitude 63° N. About 200 bergs, most of them grounded along the Labrador coast, were seen while on the run toward the fifty-sixth parallel. In the Labrador current offshore a few large bergs were drifting southward.

The surface water ranged from 48° to 50° F. throughout the middle part of the run between Labrador and Greenland. There was no ice and no cold surface water in Davis Strait from 80 miles off Labrador to 85 miles off Litchtenfels, Greenland. The *Marion* was engaged on the above-mentioned long line of stations from the evening of July 25 until daylight on July 31, 1928.

Due to the comparatively warm water, the air temperatures were rather high over Davis Strait, ranging from 42° to 51° F. Cloudy and overcast weather prevailed most of the time, but it was frequently possible to get observations of the sun through the thinner parts of the cloud blanket. The winds were in general very light, and there were no storms or general rains, but the ocean swell out in the middle of Davis Strait was always present.

All hands became thoroughly familiar with their special duties in connection with the scientific program; nevertheless, the first really long line of stations was not taken without mishaps. At 11.30 p. m. on July 27, while over the deepest part of the basin between Labrador and Greenland, we lowered out three Greene-Bigelow water bottles with the small winch to a depth of 3,000 meters, while the large winch with the heavier wire was being used to take observations down to 1,200 meters at the same time. When we started to heave in on the small high-speed winch about 10 meters of the wire was reeled and then without warning the shaft coupling connecting the drum to the motor snapped. The 3,000 meters of wire were "stopped off" at the rail and a cut was made back on the drum. The new inboard end of the $\frac{3}{32}$-inch wire was carried to the large winch, which had meanwhile finished taking the portion of the station down to 1,200 meters. It reeled in about 600 meters when the side flange on the big drum burst outwards, jamming the drum and the wire against the housing of the apparatus.

Here was a fine mess! Dark; rainy; rough; all of the hoists broken down one way or another, and about two miles of wire with three valuable instruments dangling over the side. It looked as if the expedition was about over, nevertheless, all hands were turned out and set to work. The first thing we did was to "stop off" the small $\frac{3}{32}$-inch wire a second time. After much backing and filling with the engines, we got it to the ship's windlass, when for nearly three hours we heaved in wire, finally getting it all on board and reeled down on a portable wooden drum. The three Greene-Bigelow water bottles were recovered with their deep-sea thermometers intact.

In the meantime another group of the crew had been working on the main deck dismantling the spare ice patrol winch in order to take the drum from it to replace the broken one. The broken drum was removed after much trouble, not only because it was tightly jammed by the spreading of the wire, but also because the drum, being full, was most heavy and cumbersome with the vessel rolling as it was on the swell. Neither was it a small task to hoist the spare drum with its heavy shafting from the main deck up to the top of the deck house, considering the gear with which we had to work. It was done, however, and by 9 a. m. the next day, after working the whole night, the new drum was in place and the wire being reeled on it. At noon we took our next station.

In the cold current close to the Greenland coast a few bergs were located. A number of birds were on the bergs and a few with strangely shaped tails were noted soaring about under the gray clouds overhead. The mountains of Greenland were sighted at 2.20 a. m. on July 31. Throughout the day, glimpses of the high rugged coast were had as the vessel cruised northward toward

GREENLAND CODFISH

FIGURE 6.—While waiting for the fog to lift off the entrance to Godthaab Fiord, Greenland, on July 31, 1928, we threw over our lines and immediately began to pull in large codfish as fast as we could bait.

Godthaab from 8 to 18 miles offshore. It was overcast over the sea, but clear over the land and in places the sun lit up brilliantly the streams and the trickling waters proceeding from snow patches.

Our first landfall on the Greenland west coast was truly a grand and inspiring sight. The piloting along the sunken mountainous shore was very difficult because of the jutting headlands, the hundreds of bare rock islands, and the outlying reefs which lay peppered about. Aids to navigation, such as we mean by the term, did not exist, of course, and, added to these conditions, the best chart with which we could be supplied before we left was only a general one of the entire west coast. Fog shut in about us just before the entrance to Godthaab was reached, so we anchored off Raven Island. While waiting for the fog to lift the crew caught several dozen large codfish like those shown in Figure 6.

At 4.30 p. m. the ship got under way and began to move in slowly among the numerous islets that block the southern entrance to Godthaab Fiord. On our general chart these offlying rocks and skerries were clustered like so many flyspecks. Over the land the air was very clear and somewhat warmer than over the cold water just off the coast. The only snow that could be seen lay in sheltered niches and clefts on the higher mountains. No sign was visible of the great Greenland ice cap, because its western edge lies separated from Godthaab by over 50 miles of rough and mountainous country.

We were surprised to see so many evidences of plant life upon the near-by rocky shore. Brownish-green vegetation extended in most places very close to the water's edge, showing that the islets can not be exposed to as much heavy surf as might be expected from their location near the open sea. Many soundings were taken with the

GODTHAAB, GREENLAND

FIGURE 7.—As we approached the village of Godthaab, the *Marion* fired a national salute of 21 guns. This was the first honor of the kind from an American man-of-war, in many years, and the first ever rendered by a United States Coast Guard vessel in Greenland.

fathometer in the approach to Godthaab, while the ship was being carefully conned in with a good lookout for submerged rock ledges kept from aloft.

At 6.30 p. m. the *Marion* stopped off the town of Godthaab, Greenland, and fired a national salute of 21 guns. The town was amazingly different from the summer fishing villages seen a few days before in Labrador. Even from the harbor it was seen to be much neater and more prosperous looking. Here the majority of the buildings were freshly painted in red and white.

Several hundred natives in brightly trimmed costumes watched the *Marion* from points of vantage on the low hills about the town. Minor Danish officials were brought alongside in a pulling boat from which they came on board after they had been satisfied that health conditions on board were good. One of them offered to conduct the ship to a secure berth. He explained, while piloting the ship around to the landlocked anchorage behind the town, that the higher local officials, knowing through radiograms sent them of the probable time of arrival of the *Marion*, had gone out in a motor boat to meet the expedition off the north entrance to the fiord. They had missed sighting our ship due to her coming in among the rocky islets scattered along the little used southern approach to the town. The official welcoming boat returned to Godthaab a short time after the *Marion* was secured, and the commanding officer duly exchanged official visits with the local Danish authorities.

At 8 p. m. the welcome word was received on board that liberty could be granted. Those members of the crew not having watches or other duties aboard went ashore immediately and were very hospitably treated by the Greenlanders, a dance being staged for them as was the case at almost every Arctic village visited.

The evening in the anchorage was calm and beautiful. Due to the high latitude, it did not get quite dark all night. Bands of the vapor which rose from the arms of the fiord and from damp spots ashore, lay in places across the landscape. A crescent moon and a brilliant planet moved along near the tops of the neighboring mountains. The anchor watch idled away the time in the strange long twilight by catching the small-sized codfish that abounded in the fiord. Birds that seemed to be species of wild ducks could be heard quacking and splashing along the shore.

The warm sunshine of August 1, 1928, quickly dissipated the mists, causing the air temperature to rise from 45° F. to 57° F. between 4 a. m. and 2 p. m. In the morning all those who had been unable to get ashore the previous evening were given an opportunity to visit the town. From the inner anchorage to the village was about 15 minutes' walk across low rocky hills and grassy meadows which were marshy in places. The warm sun brought out sweet aromatic scents from the vegetation, and the only thing that detracted from the perfection of the walk and day were the bothersome gnats that frequently had to be brushed aside. As Godthaab was approached it was noted in several places that men were busy painting already quite well-painted houses and buildings. Numbers of women and children were going to and fro in the paths and streets in light fur clothing. The most striking and gorgeous pieces of apparel were the high skin boots which the women wore. As a large proportion of the men were off fishing, the women and children greatly predominated in the town. One of the many photographs taken during the morning is reproduced here as Figure 8.

The Government officials at Godthaab advised us in good though slightly halting English that their town was not only the capital of the Godthaab district but also of the whole of South Greenland. From them we learned much concerning the nature of local life and about the history of the place. There is not room to go into details here. It is sufficient to say that fishing is the principal industry and that the town boasts a church, a hospital, several Government houses for officials, storehouses, schools—including a normal school for training native teachers from all parts of Greenland—a radio station, a fox farm, and a large statue of the famous eighteenth century missionary to the Greenlanders, Hans Egede.

The grass was rank and tall, especially in the vicinity of the houses, but we saw no gardens. There must have been at least one, however, for the colonial agent of the district presented the officers of the *Marion* with a paper bag full of fine large radishes that he had raised. There were no dogs about the town because the fiords do not freeze up solidly in winter, and the rocky hills bordering the fiords are not good for sledge travel. Due to the absence of the fierce Eskimo dogs, it is possible to keep goats and ducks at Godthaab, and a number of these creatures were seen wandering about the town.

Besides some local commerce with near-by villages by means of coasting craft, a number of fine Danish Government steamers make calls at Godthaab each year. The latter vessels carry official passengers and freight to and from Copenhagen, serving, we were told, all of the principal Greenland ports.

Our first stop in Greenland brought home to us the fact that the land is a closed country, open only to certain Danish officials and to

THE WATER FRONT OF GODTHAAB

FIGURE 8.—The principal industry of this Danish colonial village is fishing. The building in front of which six people are standing is the home and office of the local colonial agent. Godthaab, being the capital of South Greenland, has also a number of other Government houses, but they are located farther back from the sea.

scientists who are vouched for by their own governments and approved of by the Danes. The natives live like wards of the Government on an enormous naturally isolated reservation. Our pleasant experiences at Godthaab, as well as at other places in Greenland, made us regret that the country is not open to at least the more adventurous and hardier class of tourists. Each year a certain number of such people could undoubtedly be induced to visit and examine the more accessible villages, ice fiords, mountains, and other wonders of the historic land that was first colonized from the north of Europe five centuries before Columbus discovered the New World.

All liberty was up at noon. Right after dinner the *Marion* shifted anchorage to where a small stream from near-by mountains rushed down into the fiord. The afternoon was spent watering ship and dumping into the fuel tanks the last of the deck load of barreled

Diesel oil. While this work was going on the photograph shown in Figure 9 was obtained.

In going over the warm, rocky hills to get the above-mentioned view, two varieties of berries and many low bushes and plants were seen. This surprised the writer greatly, for having read very little about the true nature of the summer in Greenland he had imagined it a place of almost continual ice and snow. Those persons unable to go there but who nevertheless would like to get detailed and authentic information about any aspect of Greenland should read The Discovery of Greenland and the Exploration and Nature of the Country, Copenhagen and London, 1928, published by the Commission for the Direction of the Geological and Geographical Investigations in Greenland. This book and its companion volumes are profusely illustrated bulletins published in English by the Danish Government. They contain an enormous mass of information about Greenland that has been compiled by scientific authorities who are prominent in their several lines.

SOUTH GREENLAND TERRAIN

FIGURE 9.—The rocky land devoid of trees supports in favored places during summer a brief but rich vegetation. The coastal waters are characterized by irregular sounds and bays. It was from such brooks as the ones shown here that we replenished our supply of drinking water from time to time.

At 5 p. m., watering ship was finished and the *Marion* got under way again. She stopped off the town to pick up a member of the engineer force who, thanks to the courtesy of the local officials, had been working in the Government machine shop at Godthaab repairing our broken winch drum with the assistance of a native mechanic. These two men could converse only by means of signs, but they had succeeded in effecting the repairs necessary to put the hoist in first-class condition again.

Meanwhile, on board the *Marion*, by dint of lifting with tackles and crowbars, we had succeeded in getting the 2-ton spare winch from the main deck up to the top of the deck house. There it was bolted down in the place from which the small high-speed winch with the broken shaft had been removed. The new hoist, although not so fast as the one that had been designed for the job, worked well for the remainder of the cruise. It took with the smaller wire all the deeper observations and collected over 50 samples of the ooze from the bottom of the Labrador-Greenland Basin.

At 5.45 p. m. Godthaab was left behind. The *Marion* stood out the north entrance under the pilotage of Nis Lynge, a native Greenlander who had been sent to school in Denmark to study navigation and piloting. We learned that many of the brighter natives are sent to Denmark when young to learn trades and arts which will be useful to them and their countrymen upon their return home.

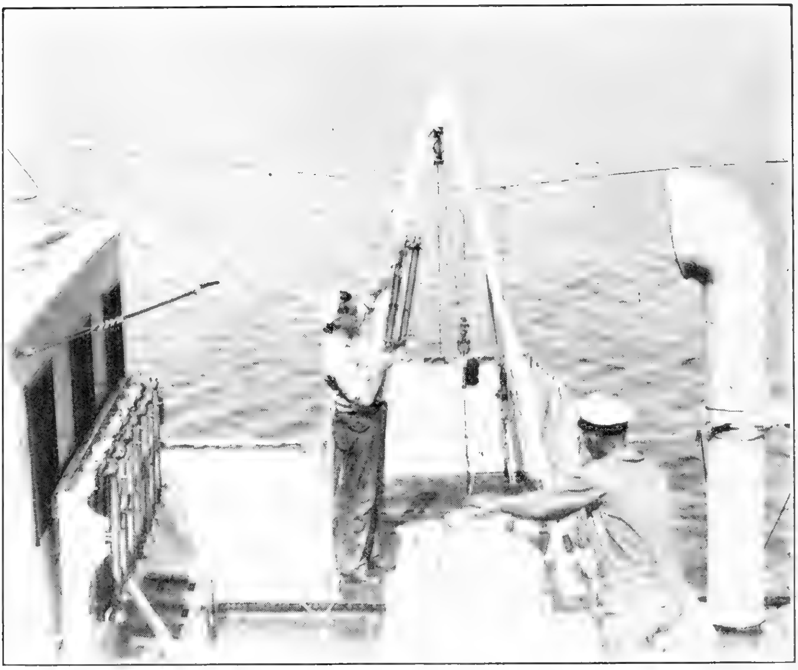
THE "MARION" STOPPED FOR OBSERVATIONS

FIGURE 10.—From the starboard side of the main deck house a platform was constructed which overhung the side. The wire on which the instruments were lowered into the sea ran from an electric winch on the deck house and through a sheave at the head of a small pair of sheer legs. A Greene-Bigelow water bottle is here being hoisted up to the working platform.

At 6.50 p. m. on August 1, 1928, the pilot was dropped into his small motor boat, and the *Marion* stood out past the Kok Island beacon to begin a line of oceanographic stations extending offshore for 170 miles. Early on August 3 the offshore row of stations was completed and a northerly course was set up the center of Davis Strait. After running north for 150 miles, a new row of stations was started in toward the Greenland coast in latitude 65° 20′ N. On the morning of August 5, this other row of stations were finished.

The weather since leaving Godthaab had been fine and the sea almost smooth, except for a confused ground swell. We sighted only one or two icebergs and no pack ice. When near the Greenland coast, however, the weather became foggy and misty. Just before the last station was taken, breakers about a small rocky islet were sighted less than 1 mile away. From this last station, some 10 miles southwest of Cape Burnil, the *Marion* headed northwest and then north across Great Hellefiske Bank, bound for the region about Disko Bay.

The weather grew worse as the 5th progressed. The ship was noted to be making very little progress into the wind, and so she was anchored at 4.40 p. m. in 24 fathoms of water, just a few miles north of the Arctic Circle in 66° 39′ N., 54° 20′ W. Fishing with handlines was tried here but without success. A moderate gale from the north blew throughout the night.



OCEANOGRAPHIC OBSERVATIONS

FIGURE 11.—This gives a general idea of a part of the upper deck arrangement on the *Marion*. The man in the right foreground is operating the winch which contains about a mile of stranded steel wire. The water bottles, on the rack to the left, are clamped at successive intervals to the wire as it is lowered away. The bottles contain the deep-sea thermometers that record the temperature and also a chamber which holds about a quart of sea water taken from the depth to which the bottle is lowered.

At 11 a. m. on August 6 the *Marion* got under way and proceeded northward. The wind moderated rapidly during the afternoon, which fact permitted the ship to make good progress along her course. Thousands of gulls and ducks were seen from time to time. An eider duck that was shot from the bridge on this day was prepared and eaten for supper by the officers with much relish.

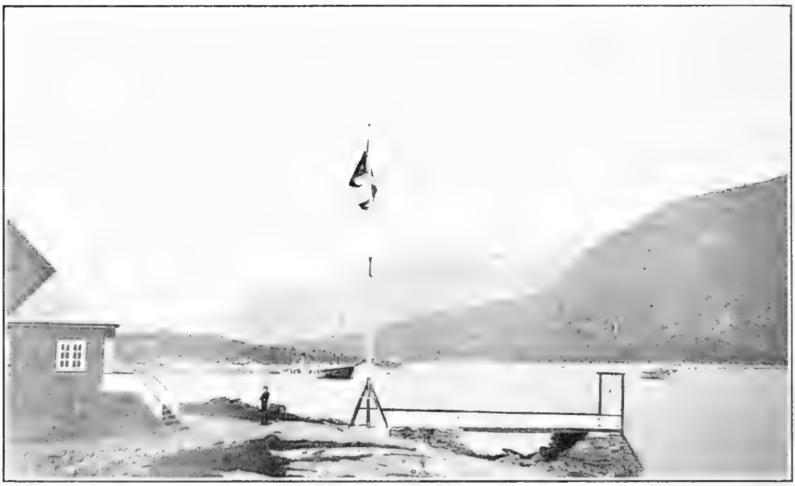
By 4 a. m. on the 7th the *Marion* had run off the northern end of Great Hellefiske Bank and was over deep water. Several large bergs were sighted at this time, but no more were seen along a 40-mile line of stations that was taken to the eastward to a position 10 miles south of the Western Islands in the southern entrance to Disko Bay. The weather was foggy most of the 7th from 9 a. m. on, and once more the first warning that the ship was near the Greenland coast was had through sighting islands and breakers in the fog and mist close aboard.

READY TO LOWER AWAY

FIGURE 12.—The water bottle has been clamped to the wire and has a messenger attached to its lower end. This messenger will be free to run down the wire as soon as a similar messenger from the bottle to be placed higher on the wire runs down to strike the top of the bottle shown here. In this manner the bottles are successively tripped after an entire string of them is lowered to the desired depth for observations.

The afternoon was spent running northward from the inshore station of the above-mentioned line. As the ship passed the Western Islands and the Whalefish Islands occasional breaks in the fog permitted the position to be fixed by means of bearings of the islets that were taken from time to time. At 7.48 p. m. the ship ran out into a clear space and we could see the towering heights of Disko Island boldly standing up in the sunlight some 8 miles ahead. So deceptive was its appearance over the glassy waters of the berg-studded bay that the lookout forward thought it was very close when he first sighted it through the thinning fog bank and excitedly yelled out to stop the ship as land was right ahead.

Two stations were taken while approaching Godhavn, on Disko Island, from the southward, the last one being located about 4 miles off the port. The town, which is the capital of its local district and also of North Greenland, is perched on a rock bench at the edge of the sea. Immediately behind it rise great red mountains that are much cut up by ravines. There were ice domes on the highest parts



GODHAVN, GREENLAND

FIGURE 13.—The *Marion*, on arriving at Godhavn, fired a national salute. This settlement is the capital of North Greenland and it is, like Godthaab, the residing place of a number of Danish officials. A Danish whale catcher can be discerned to the left of the flagstaff, moored alongside a 4-masted sailing vessel.

of these mountains, but nearer sea level there was everywhere a faint tinge of green, caused by the vegetation which reached apparently almost up to the areas of perpetual snow.

About 100 bergs, some very large and some with much dirt from the land on them, were drifting off Godhavn in the mouth of Disko Bay. Though it was 9 p. m., the sun was still over 5° high and would be up nearly two hours longer. The sun's declination was much less than it had been a month and a half earlier, but, due to the comparatively high latitude of Disko Island, there was still daylight 24 hours per day. In response to a request by radio for permission to enter port, the Danish officials replied that the *Marion* was welcome to Godhavn, and gave helpful advice concerning how the harbor entrance should be approached from the south.

Soon a motor boat was seen standing out from the town. It came alongside the ship and a welcoming delegation consisting of a pilot, the scientist at the head of the Danish Arctic station at Godhavn, and the local colonial agents, climbed on board. By 11 p. m., on August 7, the *Marion* had run in through the narrow entrance of lichen-covered rocks and anchored in the fine harbor, near two Government whaling vessels.

Because of the persistence of daylight, liberty was granted at once to look over the town. As at Godthaab, the natives were for the most part dressed in neat sealskin garments decorated with brightly dyed strips of sealskin from which the hair had been removed. They were most interesting to watch, and apparently they found the sailors from the *Marion* equally interesting, for a crowd of them surrounded each little group of bluejackets that landed and followed the latter about wherever they went while ashore.

We were told that some 300 natives and 27 Danes now live at Godhavn the year round. At the time of the *Marion's* visit the

GODHAVN, GREENLAND

FIGURE 14.—Danish flags fly near the well-kept and red-painted Government houses. A stone and sod hut of a native Greenlander lends local color to this view across the inner portion of the harbor.

European population was augmented by the officers and crews of the two whaling vessels, but these people were to leave for Denmark late in the fall as soon as the weather should become too severe for further whale catching. There were many Eskimo dogs at Godhavn, for here the winters are cold enough for solid sea ice to form in the bay. This makes sledging with dog teams much more practicable than in South Greenland, where the winters are milder and good ice for traveling can not be depended upon. Shortly before midnight the natives gave a dance for the crew in the cooper shop, while the officers were entertained by the colonial agents and other Government officials in their homes.

The morning of August 8 was very pleasant, with the air temperature around 50° F. The commanding officer exchanged official calls with the Danish officials, and the latter kindly agreed to furnish the ship with fresh water and with 1,400 gallons of good Diesel oil. The latter item was an unexpected and most welcome accommodation, which made it certain that the *Marion* could visit the iceberg producing glaciers at the eastern side of the bay and also complete her projected oceanographic program at sea at a good speed and without danger of fuel shortage.

At 1 p. m. the *Marion* got underway for Jacobshavn, firing a 21-gun salute before leaving the harbor. The scientist, Mr. M. P. Porsild, director of the Danish Arctic Station at Godhavn, accompanied the ship during her cruise around Disko Bay. He was a mine of local information and his patient replies to innumerable questions, as well as his tales about the life of Government agents,

SOUTH SHORE OF DISKO ISLAND

FIGURE 15.—Along this coast, from left to right in the picture, there is a continual procession of icebergs being carried westward into Davis Strait. Many of the bergs which pass this wireless station eventually find their way to the North Atlantic steamship tracks.

visiting scientists, and natives, were listened to with great attention. Through his kindness our almost complete ignorance of the country was gradually dispelled and we began to appreciate the true character of the land we were so privileged to visit.

By 11 p. m. the *Marion* had finished taking a row of stations eastward for 50 miles to the berg-choked entrance of the Jacobshavn ice fiord. Over 500 large bergs from this fiord were sighted during the run across Disko Bay. The tallest one that was passed close to was found by means of sextant angles to be 265 feet high.

The mountainous land behind Jacobshavn could be seen from the moment Godhavn was left. Over these mountains of the main-land we could see the brilliant white glare of ice blink caused by reflection from the great dome of the inland ice. The ice itself was not visible because of its distance and of the intervening mountains, but the evidence of its presence was plainly visible in the sky.

At 11.20 p. m. on August 8, the *Marion* was anchored in the little bottle-necked harbor at Jacobshavn, a town situated less than 2 miles north of the great ice fiord of the same name. Despite the hour, the entire populace of about 500 natives seemed to be up and about. This place now boasts the distinction of being the most important town, commercially, in North Greenland. It exports much fish and seal hunting is also an important local occupation. After presenting the ship's health certificate to the local colonial agent, we turned in to rest in preparation for a tramp over the hills which had been planned for the next morning.

JACOBSHAVN, GREENLAND

FIGURE 16.—This village is located near the great iceberg fiord of the same name. Its small harbor, even in summer, is seldom free from glacial ice.

At 8.30 a. m. almost the entire ship's company, followed by a crowd of native women and children, started out over rocks and meadows for a point southeast of the town, an Eskimo guide leading the way. Mr. Porsild, of the Danish Arctic station, accompanied the commanding officer, talking steadily about Greenland, and as usual answering all questions in his thorough and cheerful way. The day was dull and overcast, like the preceding one, but fortunately visibility was again good.

After an hour's walk we reached a high point from which there was a fine view of the Jacobshavn ice fiord. The whole length and breadth of it, comprising over 50 square miles, was one jam of icebergs that had calved from the producing glaciers to the eastward. From the western end of the ice fiord these massed icebergs protruded into Disko Bay. For details regarding the berg production of this and other Greenland glaciers and ice fiords the reader is referred to Smith, Edward H. (1931).[1]

Upon returning to the town the officers visited the homes of the Danish officials, where they were very cordially received. These homes at Jacobshavn were very well furnished and comfortable. After we had admired the potted roses and asters in a sort of conservatory by one of the southern bay windows of the local doctor's house, we were led outdoors to see the garden. Here an astonishing profusion of growth was shown us, considering that we were well above the Arctic Circle and near where one of Greenland's mightiest ice streams debouches into the sea. Close to the house all sorts of flowering plants were growing, and just south of them was a lawn no bigger than a large rug, yet with seats and a tea table on it.

OFF THE MOUTH OF JACOBSHAVN FIORD

FIGURE 17.—An excellent illustration of the manner in which icebergs are discharged from the mouth of the fiord into Disko Bay. Every year approximately 1,500 large icebergs enter the open waters of the bay at this point.

There was a tiny clover patch near by, and beyond it was a vegetable garden which was said to be cultivated for amusement only and not as a source of food. All the plants outdoors were entirely unprotected except for being in sheltered spots inside a yard where the village dogs could not destroy them.

Cabbages, cauliflowers, tomatoes, potatoes, lettuce, radishes, turnips, and many other things were growing in little beds in the garden. Due to the very long cool days, these plants in some instances grew strangely. Some were long and trailing, whereas, if in their home surroundings, they would have been stocky and sturdy. The tomatoes and potatoes were not expected to mature, but almost all the other vegetables were certainly large enough to be useful on the table at any time.

[1]Arctic Ice with Especial Reference to its Distribution to the North Atlantic Ocean. The Marion Expedition to Davis Strait and Baffin Bay, under the Direction of the United States Coast Guard, 1928, Scientific Results. Bulletin No. 19, Part 3, pp. 1–221, with 122 figs. Washington.

At noon, after an opportunity had been given the Danes and the natives to visit the *Marion*, we got under way and stood out of the tiny harbor, so picturesque with its kyaks and other native boats and its numerous small ice masses brought in by wind and tide from the bay. Upon leaving the harbor the massed bergs just off the mouth of the Jacobshavn ice fiord were visited. A few minutes were spent examining the great ice wall formed by the congestion of icebergs and in obtaining from a dory photographs of it like the one shown in Figure 18.

At 1.45 p. m. the *Marion* was headed for Ata, a small village 32 miles to the northward on Prince Island, where a native guide to conduct a party up into the inland ice was to be received. From 4.48 to 5.25 p. m. the ship drifted off Ata while the pilot and guide, a Greenlander named Peter Peterson, made ready, came out in his

AN ICEBERG JAM

FIGURE 18.—The *Marion* cruising off the mouth of Jacobshavn Fiord on August 9, 1928, found the bergs so tightly packed together that not even a ship's boat could penetrate beyond the outer line. On the average of twice monthly in summer, usually about the time of the spring tides, large numbers of these bergs float free.

kyak, and was taken aboard. At 8.10 p. m. the ship anchored in Port Quervain Harbor, near the south end of Ekip-Sermia Glacier, which produces large numbers of very small bergs. This glacier runs down steeply from the inland ice and is broken up by innumerable crevasses where it passes over a rock spur. Apparently only this breaking up process prevents it from forming large bergs like those that push seaward from the Jacobshavn ice fiord.

The sea wall of this glacier was about vertical, and near its center was a great ice cavern, probably the end of a tube serving farther inland as the conduit pipe for a subglacial stream. A strong milky current setting out from under the ice was carrying away rapidly all the bergs and small ice pieces as fast as they were calved. Shots fired into the glacier from the *Marion's* 3-inch gun brought down a few tons of ice from weakened and overhanging cornices, but the firing was really without appreciable effect. Spontaneous calving, on the other hand, was occurring frequently because of the comparatively high temperature of the day and the steady advance of the glacier into deep water along a broad front. When the larger ice blocks calved off there were thunderous noises and the swells set up often made the ship roll suddenly and the rocky shores of the sheltered anchorage resound with breaking waves. Thousands of sea gulls were resting on the water near the ice front, particularly about the entrance to the ice cavern. These birds would fly about with excited screaming whenever ice masses crashed down in their vicinity. Figures 19, 20, and 21 illustrate conditions about the end of the glacier at Port Quervain.

A GLACIAL SCENE

FIGURE 19.—The Coast Guard patrol boat *Marion* anchored at Port Quervain on the west coast of Greenland in latitude 69° 45′ N. This glacier, Ekip Sermia, calves a considerable amount of ice yearly but never in pieces the size of a large iceberg.

At 8.30 a. m. on August 10 the ship was left with a few ship keepers only, while most of the officers and crew were boated ashore for a hike to the inland ice. The latter is easily accessible at this point, and it was from here that Dequervain, the Swiss glaciologist, scaled it and crossed in 1912 to Greenland's east coast. We found the walking inland from the end of the glacier good, but it entailed much going up and down hill, tiring for sailors, though probably easy enough for experienced mountaineers.

There were many blueberries near the sea level, but as the altitude increased the cold became greater, the soil poorer, and the vegetation scantier and scantier. About noon the party, most of them now very tired from the rapid pace set by the native guide, began toiling up the steep slope of the inland ice's terminal moraine. Parts of this slope were covered with snow and ice surfaces inclined at an angle like that of the roof of a house. These patches of névé were probably caused by the downslope wind in winter blowing snow off the ice cap and over the top of the terminal moraine.

As soon as the moraine had been surmounted, the expanse of the inland ice could be seen rising in a gentle slope toward the interior. It looked much like a frozen sea, and a strong raw wind, like a cold sea breeze, was blowing down slope toward the ice margin upon which we stood. There were some stones and sand on the ice near the margin and the surface was cut up slightly by small running streams, most of which disappeared between the ice and the terminal

A GLACIER'S DISCHARGE

FIGURE 20.—Close view of the projecting southern edge of the Ekip Sermia glacier at Port Quervain on August 10, 1928. This gives some idea of the amount of dirt carried from the land and of the glacial flotsam in the vicinity of active discharge.

moraine. In some places these streams had cut through the latter, however, and could be seen rushing down it in little casades.

A half mile in from the ice margin the sand and gravel on the ice had decreased to a negligible amount. All that could be seen toward the interior was the slightly undulating surface of the ice cap, still cut up in places by the small brooks of ice water that were flowing in shallow beds of clean glacial ice.

After a few minutes spent in gazing, the *Marion's* party turned their backs to the searching down-slope wind, walked to the ice edge, and climbed down the terminal moraine. Some distance farther seaward in a bleak but fairly sheltered spot a stop was made to eat lunch. From this stopping point a slow march was started for the shore at Port Quervain. In the lower levels several stops were made in blueberry patches, where many handfuls of delicious berries were gathered and eaten by the tired sailors as they lay sprawled about to rest.

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Upon returning to the ship, several members of the crew who had taken special pride in the work of the expedition went to the commanding officer and requested permission to erect some sort of a monument ashore at Port Quervain to mark the northernmost point ever attained by a United States Coast Guard vessel on the eastern side of North America. Accordingly a written record was wrapped in a weatherproof covering and placed in a cairn built on top of a promiment near-by hill. The men amassed an impressive pile of stones for their purpose and topped it all with a 3-inch brass cartridge case inscribed "Marion Expedition, 1928."

At 7.05 p. m. on August 10, 1928, the *Marion* began proceeding toward Ata, where the guide, Peterson, was returned to his home at 9.10 p. m. This little outpost village consisted of a few tiny houses built on a rocky lowland at the base of towering mountains. The

A FLANK VIEW OF A GREENLAND GLACIER

FIGURE 21.—Looking back towards the glacier that discharges at Port Quervain, Greenland. The steep slope passed over by the ice just before reaching the sea breaks the glacier up into small pieces. Therefore, this ice stream never produces large bergs.

house of the native outpost manager was visited by some of the officers, who were given strong black coffee there in a room which contained a hard wooden sleeping bench, a few chairs, and a potted plant on a stand by the window. There were some inexpensive framed prints on the walls. The outpost manager then visited the *Marion*, accompanied by his wife and grown daughter. The latter, a tall, splendid-looking Eskimo girl, was dressed in fine sealskin clothing and wore the bright and elaborately decorated high boots that are possessed by all native women of any means.

Several bergs were grounded off Ata near the *Marion's* anchorage. A little fleet of seal hunters in kyaks were soon seen among them, approaching from Ata Sound. Each tiny boat had a white cloth like a little square sail at its bow. We were told that these were not used for propulsion, but were for the kyakers to hide behind while stealing up close to unsuspecting seals. Some of the natives were induced to maneuver and throw their spears at objects in the water near the ship and the grounded bergs. The Greenlanders could dart about very skillfully in their tiny craft and could throw their spears very accurately into pieces of meat and blubber from distances of about 20 yards.

At 6.15 a. m. on August 11 the *Marion* departed from the smooth anchorage off Ata. She rounded the southern tip of Prince Island and then proceeded northward into the Vaigat. The day, like the preceding one, was almost calm, with partly cloudy skies and temperatures from 40° to 51° F. The northern end of Disko Bay and the Viagat—the same as the water between Godhavn and Jacobshavn—was studded with hundreds of bergs of every size.

BOUND FOR THE INLAND ICE

FIGURE 22.—During our stop at Port Quervain we took the opportunity to journey eastward to the edge of the vast sheet of inland ice that covers about half a million square miles of the surface of Greenland. Only the coastal regions of the great island are free from glacial ice. This view shows some of the crew surmounting the terminal moraine of the ice cap.

The run up the Vaigat between the heights of Disko Island and Nugsuak Peninsula was most impressive, for on either side of the narrow strait towered mountains over 5,000 feet high. Their tops were capped with ice domes, but lower down there was little but bare rock. Low vegetation flourished where there was soil near sea level and could be seen in ever-diminishing quantities as altitude was gained.

The higher parts of the mountains were formed of alternate layers of red lava and ash. Farther down they consisted of yellowish limestone and sandstone, streaked with almost horizontal seams of coal. Near sea level, as at Godhavn, the usual rock was ancient ice-worn gneiss.

From 2.23 to 4.45 p. m. the *Marion* was engaged taking a series of oceanographic stations to the southwestward across the Vaigat from 70° 08′ N., 52° 37′ W. After the last station the Disko Island shore was skirted southeastward for a couple of miles to where the Danes were developing a coal mine in latitude 70° 04′ N. Near the mine a muddy torrent roared down from the ice cap on the lofty plateau of Disko Island. In the yellow water off this stream the *Marion* came to anchor at 5.30 p. m., Doctor Porsild having advised

COAST GUARDSMEN AND NATIVES DANCE

FIGURE 23.—Almost every hamlet at which the *Marion* stopped honored us with a dance. The settlement about the coal mine at East Disko on the shores of the Vaigat (latitude 70° 04′ N.) was no exception. Note the picturesque sealskin boots of the Greenland women.

a short stop to afford the European mining engineers and their families a break in the monotony of an isolated life.

The coal seams about the mine were visited, and the ship was inspected by the Europeans and a few of the natives of the place. The Danes hope to produce enough coal at the mine to take care of Greenland's requirements, making further importation of European fuel for heating unnecessary, and furnishing work for a number of natives at the same time.

True to form, the latter got up a dance at short notice for their sailor visitors. It was held here on a small board platform in the open. Although the sun was still several hours high, the mining settlement already lay in the shadow of the rocky heights of Disko

Island to the southward. The sunny berg-dotted waters of the Vaigat, just north of the village, made a strange and picturesque background for the dance on the darkening shore. (See fig. 23.)

At 9.15 p. m. the ship was got underway and headed southeastward. During the night the shoals off Mudder Bay were passed, and at 7.20 on August 12 the *Marion* came to anchor at Godhavn for the last time. A busy day ensued, which included taking aboard 1,400 gallons of fuel oil, 650 gallons of water, and saying good-by to new-made friends. The officers went to a dinner at the Danish Arctic station, where they were royally entertained by the Porsild family. After an hour spent in examining the museum and library at the station, the officers and their hosts went through pouring rain to a soggy field where a soccer game was held. The *Marion's* crew played against the combined forces of the Danes and natives, proving no match for them. The local forces won easily over their less experienced competitors by the tremendous score of 26 goals to none.

The evening was rainy and foggy, but the mountains behind the harbor broke the force of the wind at the anchorage, so a quiet night was spent on the ship while waiting for the storm raging offshore to moderate. Finally, at 12.45 p. m. on August 13, 1928, the last farewells were said, the anchor was hove up, and the *Marion* and her complement departed from Godhavn, carrying away many fine gifts from the hospitable inhabitants of North Greenland. Still more valuable and more imperishable than the material gifts which we took with us were the vivid recollections of the kindness and helpfulness of the people of the Arctic wonderland surrounding Disko Bay.

We were much interested in a Danish oceanographic expedition under Commander Riis-Cartensen, of the Royal Danish Navy, which was cruising during the summer of 1928 in the waters of Baffin Bay. His ship was north at Etah, Greenland, while we were around Disko Bay, so we failed to meet him personally. Greetings were exchanged by radio, however, and a package containing sketches of our track and a description of our work was left for Commander Riis-Cartensen at the Danish Arctic station just before we departed.

The *Marion* ran westward and northwestward until about 15 miles from Godhavn. Then an oceanographic station was taken close to the land, the first of a row of stations that we hoped to take to the southwestward for 220 miles to Cape Dier, Baffin Island. A fresh southeast breeze was still blowing and it was cloudy. The next day the weather was worse—fog, then rain, and then more fog. The southeast breeze increased to gale force, but the *Marion* kept on taking her stations and other observations as best she could. Between 4 p. m. and 8 p. m. the gale moderated suddenly to a flat calm, but the dense fog still persisted. Several bergs and growlers were sighted during the day, becoming more and more numerous along the course as the evening advanced.

At 12.20 a. m. on August 15 the *Marion* was stopped on the eastern edge of pack ice. The night was much darker than the nights had been some 100 miles farther north at Godhavn, and it was very foggy, but the pans of ice close aboard were plainly visible, though they were at first thought to be icebergs and growlers instead of pack ice. At 5 a. m. the fog began to dissipate, permitting a fair view to be had of the ice pack to the westward. At 7.30 a. m. it was clearing rapidly, and 16 bergs, some in and some east of the flat ice, were counted within the circle of visibility. At 7.45 a. m. the *Marion* was headed on her course to the southwestward, proceeding into the open pack.

By 8 a. m. visibility was excellent. The sky remained overcast throughout, but there was no wind all day long. The *Marion* ran among the ice cakes, making good a general course of south-southwest. The pack ice averaged perhaps 10 to 12 feet in thickness and was of the late summer variety, consisting of small pans from a very few yards to about 50 yards across. There were almost no open leads in the slack ice, but in some directions the scattered ice pieces were less numerous than in others, and these paths of least resistance

AN ICE-CHOKED WAVELESS SEA

FIGURE 24.—This late summer pack ice was encountered in Davis Strait off Cape Dier, Baffin Island, on August 15, 1928. The further westward the *Marion* worked the closer packed this ice became. It effectively stopped all progress when the ship was still 36 miles from the Baffin Island coast. This sort of ice was never on the land, like the icebergs, but represents the melting remnants of ice fields frozen during winter on the surface of the sea.

were taken whenever they led in the general direction of our objective, Cape Dier, Baffin Island.

The farther the *Marion* penetrated to the westward the closer packed the shattered ice became. The land about Cape Dier could not be reached because of 36 miles of close-packed ice without leads at which the *Marion* was soon vainly pushing, trying to force a way. Oceanographic stations, soundings, and bottom samples were taken at regular intervals just as though the *Marion* were on an ordinary sea instead of a silent, motionless one, choked with broken pack ice above which in all directions rose scattered bergs. Sun sights taken through the light cloud blanket showed that the ship and the ice were both steadily drifting southward with the cold current.

Early in the day several walrus were seen resting on ice cakes. One of them was shot with a rifle, but it plunged into the sea, where it died and sank before it could be captured. Therefore no walrus meat was had for the mess, but much seal and whale meat brought out from the Disko Bay region was eaten.

At 5.07 p. m. a large polar bear and two young ones were seen eating a seal on a near-by ice cake. The ship worked toward them. They tried to escape by swimming and running, but two of them were killed with rifles before they could get away. The third, a cub, weighing about 200 pounds, remained roaring about in the vicinity of the dead bears. A dory was quickly lowered and the small bear was noosed and towed alongside. The two dead bears were hoisted aboard and then the live one, growling and snarling, was lifted to the deck by numerous lines slipped about the neck, body, and legs. On the ship it was overpowered and muzzled by many hands, then dragged forward and thrown into the forehold. After the hatch was

CLOSE TO A TOWERING ICEBERG

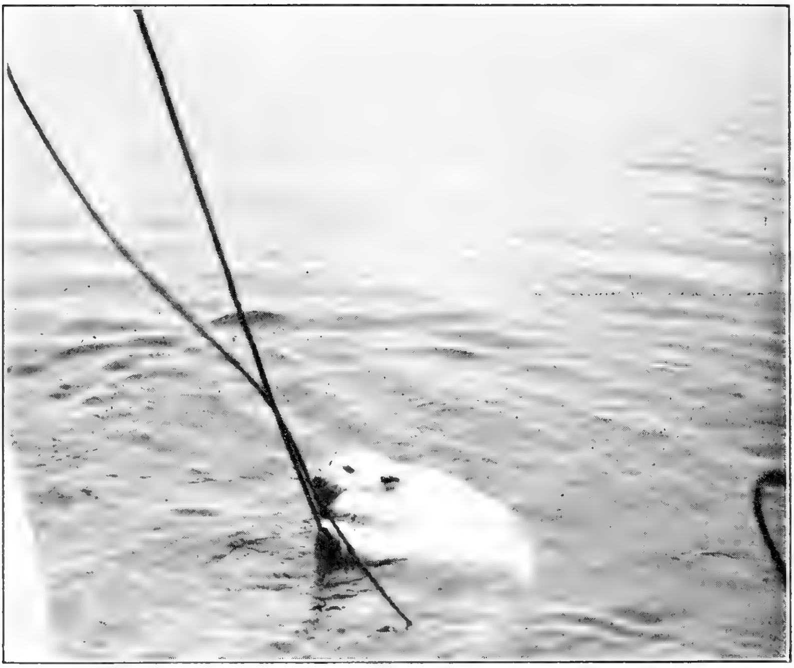
FIGURE 25.—The *Marion* has just landed photographers on the iceberg, and is about to back away. The manned dory by the ice cake is for rescue work in case the berg should break up or turn over. There were numerous icebergs like this one drifting south with the pack ice in the western portion of Davis Strait. Note the one near the horizon between the two masts of the patrol boat.

dogged down, the bear was a secure captive, though free to rage about among the lines, bags of coal, and paint cans of its large prison.

At 7 p. m. the weather grew foggy again, but it remained calm. Every effort made to push to the southwestward was thwarted by the ice. The ship lurched and shook when it encountered heavy floes, and the corners of the ice cakes cracked and thundered as they scraped aft along the sides. At 8 p. m. the attempt to go southwestward was abandoned and the ship was headed southeast in hope of finding more open water. After bucking the ice for some 5 miles we became wedged between floes, from which position no amount of backing and filling could dislodge us. At 10.30 p. m. the engines were stopped and the ship remained drifting quietly southward in the grip of the ice until the next morning.

Dawn presented a beautiful Arctic scene. We could as well have been at the Pole itself, except for the distant mountains of Baffin

Island, which in the early morning light were transformed to purest white and gold. Ice stretched as far as we could see, and the impressiveness of our surroundings was further emphasized by the great stillness prevailing everywhere. It was plain that attempts to secure observations near Cape Dier would have to be abandoned, for the time being at least. Most of the floes that now surrounded the ship consisted of heavy pack ice that extended downwards in the water 10 to 15 feet. We were timid about using our propellers, which, of course, were quite light and very easily bent. Even at their depth of 7 feet just one lick would be enough to place one permanently out



A CAPTIVE IS ABOUT TO BE HAULED ABOARD

FIGURE 26.—This polar bear cub was noosed from a dory sent out among ice cakes after her mother and brother were shot. She was towed alongside, secured with additional lines, and placed in the forepeak after a stiff fight. She remained aboard from August 15, 1928, until shipped from New London, Conn., to the National Zoo at Washington, D. C., over a month later.

of commission, and two such blows against cakes of ice might suddenly leave us helpless in a very precarious position. So we worked things gently for a while and finally got the ship turned offshore by placing the stem against an especially heavy floe.

By 4.07 a. m. on August 16 the ice had slackened somewhat and the ship cautiously began working due southward. The fog cleared up early and another fine calm day was experienced, with much bright sunshine, especially in the afternoon. Due to the ice and cold water about, the air temperatures remained between 36° and 42° all day, about 10° colder than average temperatures experienced around Disko Island.

At 8 a. m., as soon as we were out of the worst of the pack, we headed northwestward in a final effort to approach close to the shores of Baffin Island in the present latitude. The air was so remarkably clear that the high land to the southward of Cape Dier and due west behind Cape Walsingham could be seen in detail plainly, though our observations showed it should be over 40 miles away. Close packed ice was soon encountered, and it was impossible to make much progress toward the beckoning peaks, glaciers, and snow fields. After bucking the ice for two hours, the last attempt to reach Cape Dier was abandoned and the vessel was headed south-southeast toward the open water in the center of Davis Strait.

One large polar bear and several seals were seen on the ice, and in the water between the floes thousands of murres and dovekies were swimming about in pairs. The bear showed up cream-colored against the dazzling whiteness of the pack ice, just as the three bears of the previous day had done. No animals were shot because of the addition of several hundred pounds of bear meat to the larder on the previous day.

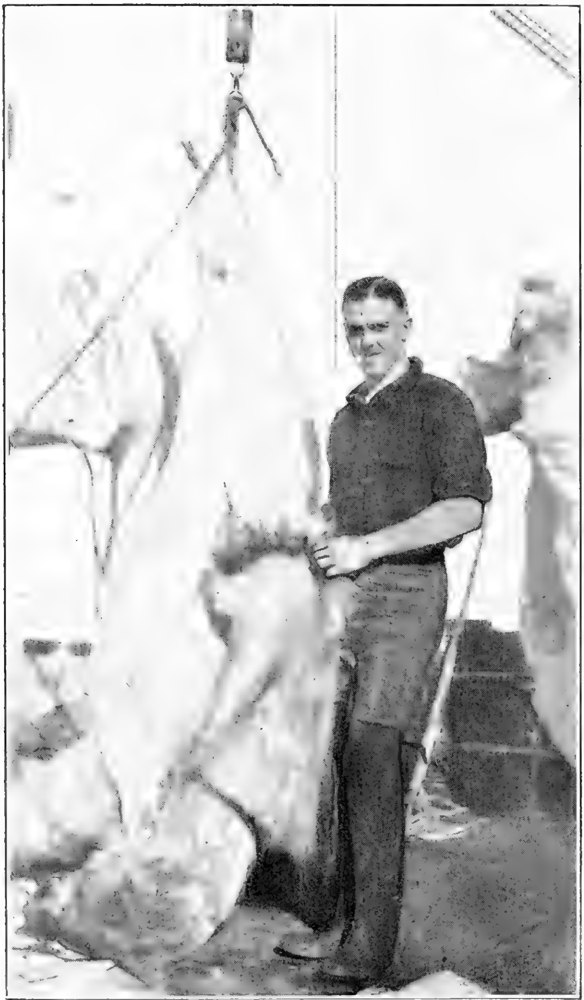
During the early afternoon the ship cruised south-southeastward through the ice, the floes becoming more and more separated by open water. When a few miles from the edge of the pack, the ship was stopped near one of the numerous bergs long enough to permit photographs of the *Marion* and the pack ice to be taken. (See fig. 25.)

For some time before making the above stop a slight swell from the southeast had been noticed. It grew stronger as the edge of the pack was approached, making loud, gurgling noises about the edges of the rolling ice cakes. By 5 p. m. the last of the small pans were left behind. A few bergs were sighted outside the limits of the pack ice, however, and until evening iceblink and damp vapor rising from the ice and cold water to the westward could be seen.

Very foolishly, just before the pack ice was left, the hatch to the forehold was slightly opened to enable the captive bear to get light and ventilation. It was believed that the weight of the steel hatch cover, high over the bear's head, would prove sufficient restraint to keep it a prisoner. In a short time, however, the officer of the deck saw from the bridge that the bear's head and paws were prying the hatch cover farther open. An instant later the bear squirmed its way free and began running about the forward deck. The alarm was given and officers and men rushed madly forward to keep their prize from getting away. Four times the bear tried to leap over the rail into the sea, but each time it was pulled back by the hair on its hind legs. On one of these occasions it turned and severly bit the hand of its restrainer before he could let go. An attempt was made to throw a blanket over the bear's head, but the big cub was too fierce and quick. It tore the blanket aside, knocking down the man who was holding it and ripping the back out of his coat. A lively fight ensued until many men closed in on the bear and by force of numbers held it helpless until it could be dragged to the hatch and thrown into the forehold once more.

A little later the bear was securely noosed by several lines and lifted from the hold. It was dragged to a strong cage that had been constructed of lumber and wire and wedged in among the oil drums on the deck aft. Here the bear, which was soon named Marion, was kept until shipped from New London, Conn., over one month later, to the National Zoo at Washington, D. C.

She ate very little during this period, practically refusing to touch any food except slices of her dead mother and brother, of which she would eat sparingly from time to time. She was always trying to scratch and gnaw her way out, so the cage frequently had to be repaired with new boards and reinforced with more wire. Marion was extremely sly and vicious and would make sudden rushes to surprise and bite those working about her cage. The only time she seemed to like her captivity was when the wash-deck hose was turned on her to give her a daily bath. Her bad temper at all other times was well understood by everyone, and many anxious hours were spent by light sleepers who had visions of her escaping at night and seeking vengeance upon her abductors by means of tooth and claw.



THERE WILL BE BEAR STEAKS TO-NIGHT

FIGURE 27. One of the seamen is here skinning the mother of the captive cub "Marion." The skin of this bear was salted down and brought in excellent condition to the United States. Lean meat as sweet and tender as veal was found under the insulating layer of fat.

Through the calm clear night of August 16 the *Marion* ran to the southward in open water, taking stations, soundings, and bottom samples, according to plan. At 4.30 a. m. on the 17th the southeastern corner of the pack ice was sighted in 64° 40′ N., 59° 08′ W. The thick pans here were small and deeply waterworn. Some of them resembled giant mush rooms raised on short stems a little above the sea surface. The sea and swell made a noise like the roaring of breakers as it lapped at the melting floes. The edge of this last pack ice sighted during the expedition was skirted for 5 miles to the southeastward, after which the southerly course could be resumed again without hindrance.

From 64° 07′ N., 59° 05′ W., a line of stations was taken to the westsouthwest toward Cape St. David, Baffin Island, for nearly 120 miles. The weather was mostly clear, with fine visibility, while light westerly airs prevailed. About 46 icebergs were sighted during the day, but the ship was south of all the pack ice that had prevented a close approach to Baffin Island, 120 miles farther north. Many astronomical observations were taken, and at about 11 p. m., after the evening star sights had been computed, it was thought that the ship's position was quite well known. Throughout the late afternoon the heights of Baffin Island had been visible to the westward, and many bearings were taken of points thought to be Cape St. David and Cape Murchison. The station program was continued on through the night, however, it being planned to take the last station a safe distance east of Brevoort Island at 4 a. m.

At 1 a. m. the fathometer showed the officer of the deck that the water was shoaling considerably. He looked around in the darkness and saw the dim outlines of an island to the northeastward and the high land ahead seemed to be close aboard. He took the inshore station at once, not daring to go on any farther. Then a course to the southeastward was run.

No land was visible at daylight on the morning of the 18th, but a. m. star and sun sights verified the positions carried forward by dead reckoning from the evening before. The chronometer's error was well known, because radio time ticks were being heard almost daily. Apparently the land about Cape Murchison and Cape St. David was charted on our copy of British Admiralty Chart 235 about 20 miles to the southwest of its true position. This can not be stated as an absolute fact, due to the slight possibility of unusual refraction, to the darkness, and to the hurried manner in which the *Marion* had to approach and leave the coast. The fact that an apparent error in the chart was noted should certainly be mentioned here, however, in order that the land's position may be checked up in the future by the next expedition passing through the region concerned.

August 18 was a fine clear day with moderate northwesterly breezes. All day long and until 4 a. m. August 19 the ship continued cruising to the southeastward, stopping to take stations every 25 miles. Numerous bergs were sighted until the ship ran out of the cold current with surface temperatures of 37° F. and got into the 47° F. water situated farther out in Davis Strait. The last berg sighted from this line of stations was passed in 62° 53′ N., 61° 35′ W.

The greater part of Sunday, August 19, was spent running to the westward on a line of stations laid in toward Resolution Island. There was a moderate northwest gale almost all day. Late in the afternoon, while it was blowing the hardest, an end flange on the drum of the forward winch began to bulge out with a crack that grew wider and wider, and finally prevented turning at all. The manufacturer that supplied the hoists for use on the ice patrol in 1927 had not designed the drum flanges with sufficient strength to withstand the side thrust which occurs when several thousands of meters of wire are tightly wound on the drum. The same failure happened to the other large winch drum on the first long leg of the expedition, and it also occurred once during the ice patrol of 1927. In the latter instance repairs were not attempted until the season was over, but in this case no such delay could be thought of, for we badly needed the winch for use at the next station, which would be reached in three hours' time. All hands were turned to reeling off the 2,800 meters of $\frac{5}{32}$-inch wire to the large wooden spool upon which it had come. As soon as the winch drum was empty the most resourceful of the motor machinist's mates set to work repairing the damage by bolting on pieces of $\frac{1}{4}$-inch scrap iron bent in the form of arms to strengthen the drum and to hold on the wire. By 10 o'clock that night the wire was back on the drum and the winch was in operation taking the next set of observations.

By 5 a. m. on August 20, the wind had died down to a gentle northwest air, and the weather remained fine and sunny until 6 p. m. Several bergs were sighted during the day. Around noon, Resolution Island, the northern portal of Hudson Strait, was sighted ahead. At 2.30 p. m. the last station of the line was taken 20 miles due east of Cape Resolution. Many observations of the sun were made both prior to and after the time this station was occupied and all of them showed that the coast about Cape Resolution was apparently laid down on our copy of B. A. Chart 235 about 12 miles east of its true position. This seemed unbelievable, as we were now in fairly well-known waters. Unfortunately, bad weather on the 22d, when we were again near Cape Resolution, made it impossible to verify this possible discrepancy. Abnormal refraction may have thrown off all our observations of the 20th by 12 minutes of arc, but if refraction was normal on August 20, the land about Cape Resolution was certainly drawn in on the chart too far to the east.

From the inshore station near Cape Resolution, the ship ran south for 20 miles and then west about 25 miles to a point $1\frac{1}{2}$ miles south of Hatton Headland, Resolution Island. At 8.45 p. m. a station was taken off the latter point, the beginning of a line of stations run southward across the eastern entrance of Hudson Strait. Through the mist and drizzle at the station off Hatton Headland the land appeared to be mountainous and rocky, but the low clouds and the bad visibility prevented our seeing very far back from the water's edge. There were some small patches of snow in sheltered places, even within one or two hundred feet of sea level. The dim twilight and the mist prevented us from telling whether or not there was much vegetation on the shore.

Out in Hudson Strait, a few bergs were drifting about strangely, not quietly and imperceptibly as they do normally, but with noticeable turnings and rapid relative motions with respect to each other and to the drifting *Marion*. The agitation of the waters by strong tidal currents was further evidenced by the peculiar waves that had little relation to the force and direction of the wind. These strange waves or overfalls twice struck the *Marion* resounding blows that made spray dash up to the bridge windows, something which would have never occurred in a gentle breeze while drifting in any sort of normal swell at sea.

By 9 p. m. the station off Hatton Headland was completed, and a course was set through the rain and darkness toward the Button

Islands, 30 miles to the southward off Cape Chidley, Labrador. It was an anxious night for those who knew of the strong currents and the poor charts, but fortunately the line of stations was taken without disaster and by 1.15 a. m. on August 21 the *Marion* was heading eastward once more, bound for the open sea.

A break in the routine of the cruise now occurred. In obedience to a radiogram from Coast Guard headquarters, a search was commenced in the waters east of Resolution Island for the fliers Hassel and Cramer. They were on a flight from Canada to Mount Evans, Greenland, and had not been heard from since early on August 19, when they had reported themselves as about 40 miles eastward of Hatton Headland. Two full days were devoted to a vain search for these aviators. Later on we learned that they had succeeded in reaching Greenland before losing their plane.

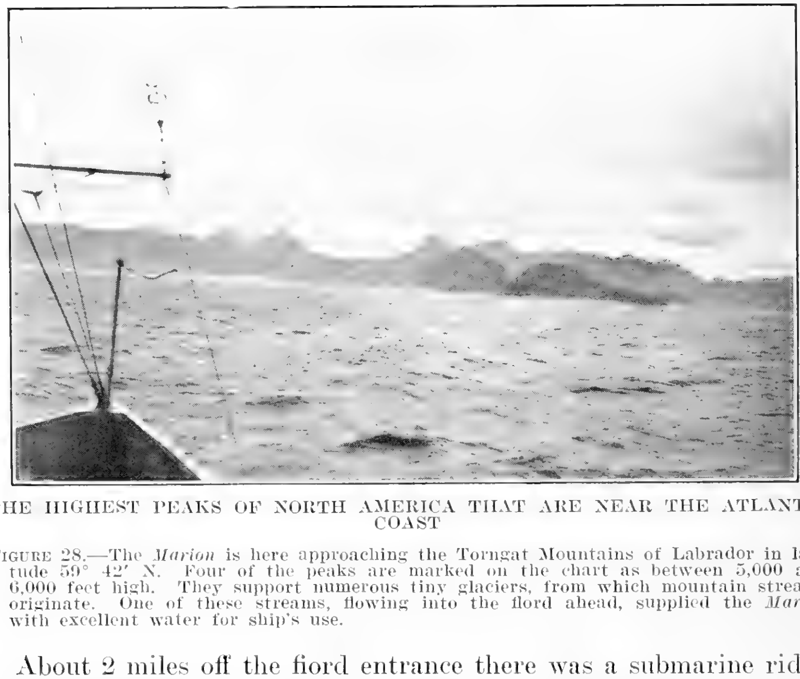
The 21st was a fine day with full visibility, but the 22d was marred by moderate to fresh gales and rather rough to very rough seas. At 4.40 a. m. on the 22d, before it had started to blow, the eastern side of Resolution Island was seen again, this time close aboard. There were many stranded bergs along the rocky coast, but exactly what part of the island was sighted will never be known, for the storm which came up suddenly at this time ended the period of good visibility and forced the *Marion* to head offshore. Late in the afternoon the sky cleared and the wind moderated suddenly, but only to pipe up again to a fresh gale from the south, and to cloud over after three hours of moderate to strong breezes from the same direction. On the morning of August 23, after a night of great pitching and rolling the gale moderated enabling speed to be increased on our southerly course.

Visibility was so good after the storm that frequent bearings could be taken of the rocky heights of the Button Islands and Cape Chidley, 25 miles to the westward. Inshore an unidentified steamer which was heading northward looked very lonely and small on the wild empty waters between us and mountainous land.

Half a dozen bergs and a few growlers were sighted during the day. According to our observations the Button Islands and Cape Chidley seemed to be charted on B. A. chart 1422, about 12 miles to the eastward of their true position, but there must have been something like unusual refraction affecting our sights, for it is almost unbelievable that these well-known places can be so improperly located on the charts in use to-day. The charts on board were evidently still far from perfect, however, for they differed among themselves. For instance, the eastern point of the Button Islands was 176° true from Hatton Headland on H. O. chart No. 5380, while this bearing was 159° true on B. A. chart No. 1422.

We had been eating much whale meat and salt horse even before leaving Disko, and now, in Labrador, we hoped to catch or buy some cod. We had bought a saddleback seal carcass at Ata, Greenland, but nobody took much of a fancy to this food despite the fact that it is keenly relished by the Greenlanders. Whale meat if hung in the rigging for about a week is not at all bad, but best of all were the steaks from the polar bears shot on the pack ice of Davis Strait. Meat, it was observed, keeps an exceedingly long time if hung out in the polar air. Both the whale meat and the bear were eaten three weeks after they had been killed. The whale meat dried up somewhat toward the last, but the bear meat seemed as fresh as ever.

Around noon on August 23 an attempt was made to enter Eclipse Harbor, Labrador, mainly for the purpose of getting fresh water, but the innumerable rocks and breakers sighted off the north end of Aulalsivik Island kept the *Marion* from entering this anchorage. From off it the ship stood to the east-southeastward 16 miles and then ran southwestward the same distance into the entrance of the fiord at the southern end of Aulalsivik Island. Several rocks were sighted near the coast. A few of them were uncharted and two were not noticed until they were ahead close aboard. South of the sixtieth parallel our sights showed the coast to be charted close to its observed position.



THE HIGHEST PEAKS OF NORTH AMERICA THAT ARE NEAR THE ATLANTIC COAST

FIGURE 28.—The *Marion* is here approaching the Torngat Mountains of Labrador in latitude 59° 42′ N. Four of the peaks are marked on the chart as between 5,000 and 6,000 feet high. They support numerous tiny glaciers, from which mountain streams originate. One of these streams, flowing into the fiord ahead, supplied the *Marion* with excellent water for ship's use.

About 2 miles off the fiord entrance there was a submarine ridge with its higher points just reaching sea level. A few rocks marking the crest of this ridge could be seen along a line following the trend of the coast to the NNW. and SSE. Inshore the soundings deepened again, and remained fairly deep in the fiord. (See fig. 44.)

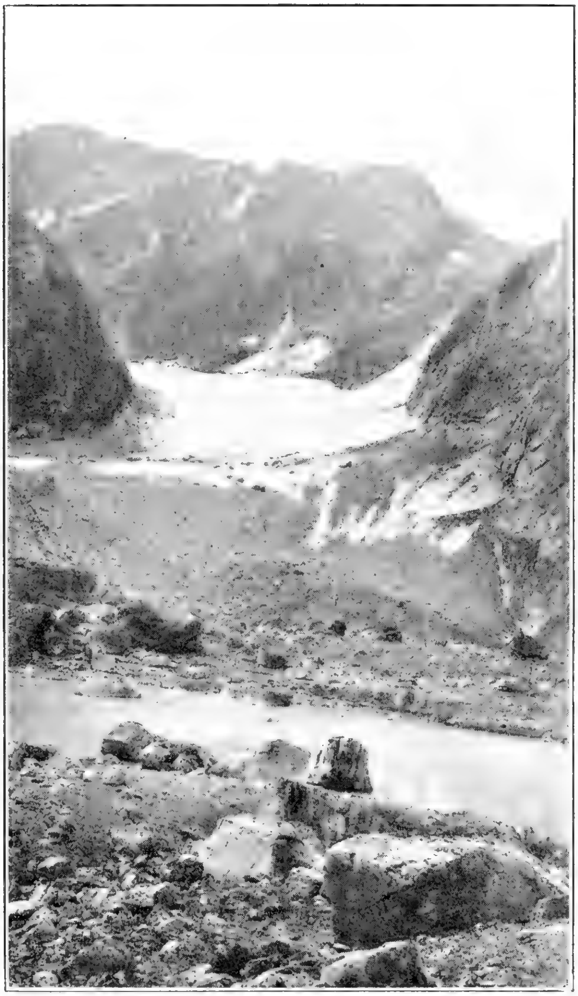
The land was high and mountainous to the north and south of the fiord entrance. Just to the south of it were the four peaks of the Torngat Mountains, marked on the chart as 5,000 to 6,000 feet high. (See fig. 28.) These Labrador mountains did not seem so impressive as those of North Greenland, possibly because of the absence of ice-blink behind them and possibly because we were now accustomed to seeing great mountains close to the sea.

It was difficult to distinguish the fiord entrance from off the coast, but by running at slow speed and closely observing the shore it was at last found and entered. Then a tortuous course inland between the mountain walls was begun. The fiord was very crooked and not at all open and crescent shaped as shown on the small-scale chart which we used. (B. A. Chart No. 1422.) At times it appeared as though the head of navigation had been reached, but always there would be a way out around the spurs and ridges that projected into the fiord from either side. For a long time no streams were seen, but finally a few tiny ones began to appear. At 5 p. m., when about 7 miles in from the entrance, a large brook was noted rushing into the fiord on the port hand. It was fed by several small glaciers located halfway up the mountains on the south shore.

A HANGING GLACIER IN THE HEART OF THE TORNGATS

FIGURE 29.—While the *Marion* was taking on water from a mountain brook, some of the officers made a trip to the glacier which formed its source. From the point near the fiord where this view was taken, a 2-hour climb was necessary to reach the nearest ice. The summer day was warm and pleasant, but in the winter this uninhabited country is terribly cold and bleak.

The *Marion* was anchored off the stream in approximately 59° 40′ N., 64° 02′ W., and preparations were started for boating water aboard. While the boats were being lowered the gentle southerly breeze increased suddenly to gale force, whitening the water, heeling the ship over, and making it swing and tug at the anchor chain. As suddenly as it began, the wind squall stopped, but every little while throughout the night these foehns or williwaws rushed down the mountain slopes and tore about the fiord. They buffeted the ship but did not harm her or her boats which were engaged in bringing out fresh water. The fiord was too constricted to allow much of a sea to be built up, and the duration of the blasts was too short to cause the ship to drag or to blow off the small boats very far. The only damage done was the salting up of a few open boatloads of water, which necessitated their being emptied and filled up again at the stream. The dry warmth caused by the compression of the down-flowing air pervaded the whole locality, causing the dry bulb to read 72° F. at 8 p. m., while at the same time the wet bulb read only 55° F.



THE REMNANTS OF A ONCE LARGER STREAM OF ICE

FIGURE 30. We climbed over several former end moraines and finally got to a last steep slope of rock fragments which led directly to the ice. The heights behind this small glacier are among the highest of the Torngat Mountains of northern Labrador.

The greatly disturbed local atmospheric conditions can be realized from the following observation. Despite the dry heat of the place, several times we saw large snowflakes falling. At first, we did not believe that snow could fall with the thermometer round the 70° mark, and we supposed the great white flakes were some sort of down torn by the wind from a species of plant ashore. When we caught a few of the flakes in our hand and saw and felt them melt, however, we soon changed our opinion. At dusk the work of watering ship was suspended and all hands enjoyed a good night's rest after the strenuous 10-day run from Godhavn, Greenland, the last place where the anchor had been down.

The morning of August 24 was devoted to watering ship, to striking the last barreled oil into the fuel tanks, and to preparing for the next long run. Some of the officers started out after break-fast to walk up to one of the hanging glaciers that fed the near-by stream. The day was mostly cloudy, but calm and pleasant, with very good visibility. There were many plants and flowers and quite a few blueberries along the shore.

It appeared but a short distance up to the glaciers, but it took about two hours of steady climbing to reach the ice. The ground became rockier and rockier after the fiord was left, while the vegetation became scantier and scantier. Finally the way was over a surface made up of nothing but angular rock fragments of all sizes. Their source was undoubtedly the enormous cliffs that rose above the small glaciers ahead.

Just before reaching the ice, several old end moraines had to be scaled. In some places glacial lakes not much larger than puddles were imprisoned between these moraines. Finally a last steep slope

THE "MARION" IS DWARFED BY HER SURROUNDINGS

FIGURE 31.—The mouth of the stream from which water was being boated is directly over the officer standing in the right foreground. The *Marion* is anchored a little to the left of the stream's mouth. Across the fiord are the heights of the southern end of Aulalsivik Island, Labrador. Note how the stream, which is backed up into a tiny lake in the left foreground, disappears into the crevices among the loose rocks.

of rock fragments was ascended, and the melting ice of the nearest glacier was reached. Views taken during this excursion into the Torngats are shown in Figures 29–33.

The walk back to the ship was accomplished without incident and at 1.35 p. m. the *Marion* got under way and stood eastward toward the sea. The country about the fiord just south of Aulalsivik Island is a real wilderness. No trace of human habitation or visit could be found. This was in contrast to all the other northern places visited, for everywhere else at least a few people were seen.

Before leaving the fiord an oceanographic station was taken. Numerous fathometer soundings were recorded in the fiord and off its entrance. (See fig. 44.) Attempts to catch fish were made with hand lines, but none of them met success, possibly because we did not have the right kind of bait.

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A small berg with peaks about 25 feet high was sighted at the fiord entrance just inshore of the submarine ridge that runs along the coast. It was approached by the *Marion* for the purpose of obtaining ice. The sea was smooth, except for a very slight swell, so it was decided to run alongside the berg with the ship, instead of sending out a boat to get the ice.

The *Marion* got alongside a sheer wall of the berg about 15 feet high, and one of the men on the spar deck began cutting at the ice opposite his head with a fire ax. Whether the blows of the ax or the jarring of the berg by the gentle rolling ship was the cause can not be told, but in a very few seconds a loud crackling was heard, and the berg calved off several growlers weighing a number of tons each. There was a great scampering among the ice gatherers as the heavy masses fell down and disappeared with a roar between

THE PRESENT LOWER LIMIT OF THE ICE

FIGURE 32.—Another view of the fiord between Aulalsivik Island and the highest peaks of the Torngat Mountains just to the south. Three tiny lakelets filled with melt-water from the glacier are visible in the middle distance. Taken on August 24, 1928.

the ship and the berg. The *Marion* was pushed from the berg bodily by the ice as it fell, and was pushed away farther as the new growlers rose to the sea surface after their sudden plunge.

Two stations were taken to the eastward of the fiord just south of Aulalsivik Island on the afternoon of August 24. Then a course southward was run to a point off Ramah, Labrador. Here, less than 7 miles northeast of Mount Blow-me-down, was started the western end of a series of stations extending 450 miles to the Greenland coast off Ivigtut.

Nine bergs were sighted in the cold current between Aulalsivik Island and 60 miles east of Ramah, Labrador. Undoubtedly several more would have been seen if the greater part of this run had not been made at night.

In general, good weather was experienced on the run east-northeastward across Davis Strait. The second day out was overcast with some rain. Seven hours of strong breezes and gales from the north blew during the evening of this day, a fine display of aurora borealis following the gale and rain.

The next day was mostly clear and warm, considering the latitude, for the dry-bulb thermometer varied from 46° to 53° F. The next day out, August 27, was smooth with partly cloudy to overcast weather. Air temperatures from 48° to 52° F., were enjoyed due to the continued presence of surface water of 47° to 49° F.

August 28 was overcast with some fog and rain. Light east-southeasterly breezes were the prevailing winds. The *Marion* entered 42° surface water near the Greenland coast early in the morning and had, therefore, lower air temperatures than on the preceding days. At 7.30 a. m. the fog ended, enabling a view to be had of the mountains of the Greenland west coast between 61° and 62° N.

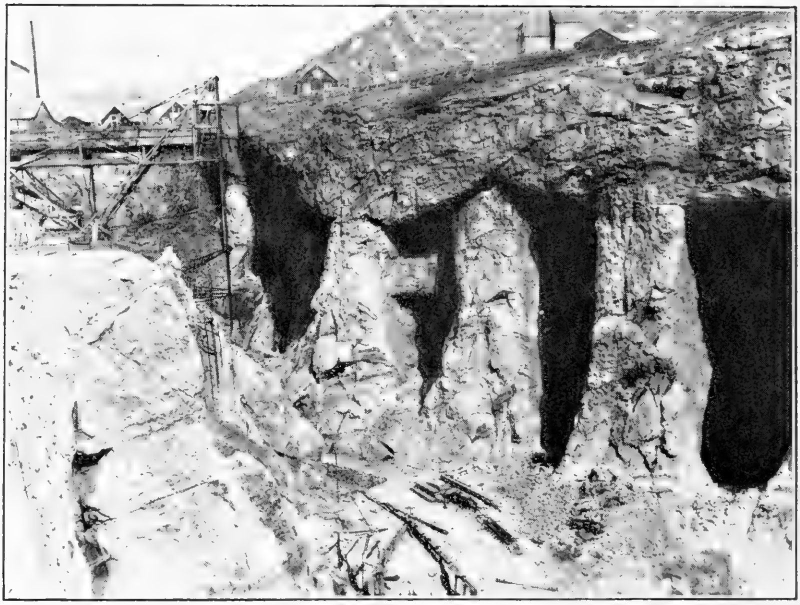
ROCKS FROM THE HEIGHTS ABOVE

FIGURE 33.—When we got upon the ice surface of the small glacier among the Torngats, the source of the enormous piles of rock fragments of all sizes over which we had been climbing became very plain. They had fallen down from the cliffs surrounding the ice on three sides. Once on the glacier they were slowly carried downward to be deposited during the course of time at its lower end.

At 11.20 a. m. the last station of the line was occupied and the *Marion* stood to the eastward toward Arsuk Fiord, having obtained many soundings at and between stations in the deep water of Davis Strait. The only trouble experienced with the oceanographic apparatus on the run from Labrador was the loss of the bottom sampler at a very deep station on August 26.

Considerable difficulty was experienced in identifying the different peaks and islands along the Greenland coast due to the impossibility of getting sights through the cloud blanket to locate the correct position of the ship. At noon it was possible to get sun sights, however, and it was found that the *Marion* was about 2 miles off the southeast corner of Sermersut Island. By 1.30 p. m. the ship was between the sharp peak of Umanak Island and Kajartalik. From the latter island the ship stood to the eastward into the narrow waters between Arsuk Island and Mount Kungnat.

At 2.40 p. m. the extremely narrow passage north of the eastern end of Arsuk Island was negotiated. This passage is less than 40 yards wide at its most constricted point, and so shallow that many details of the rocky bottom and sides could be seen from the ship. From 2.45 to 3.15 p. m. the *Marion* proceeded up the main branch of Arsuk Fiord toward Ivigtut. Depths greater than 270 fathoms were obtained with the fathometer on this run, although the fiord is only 1½ miles wide. (See fig. 45.) At 3.25 p. m. the *Marion* moored alongside the Norwegian steamship *Wagland*, which was close to the sea wall at Ivigtut loading cryolite for Philadelphia, Pa.



THE LARGEST AND RICHEST MINE IN ALL GREENLAND

FIGURE 34.—At Ivigtut, Greenland, we saw this great open-pit cryolite mine. It has been in operation for many decades, yet it is still the only mine in the world from which the mineral cryolite is obtained in quantity. The workings are but a stone's throw from the fiord, and the floor of the mine is now far below sea level. Winter and summer, the mineral is mined. The taxes which the Danish Government obtains from the mining company go far toward paying the administrative costs of the Colony of Greenland.

After the local government agent had passed upon the health of the crew and the usual formalities had been complied with, liberty was granted to visit the cryolite mine and the settlement surrounding it. We were astonished to see the great open mine pit and comfortable dwellings of the 200 Danes who get out the cryolite with the most up-to-date methods. Due to the very good wages paid the workers, the type of men working in the mine is unusually high. The miners come over from Denmark for limited periods, and there is always a large waiting list of applicants, from which only the best and most deserving men are selected. No Greenlanders were about at Ivigtut, because none are allowed to live near by. There were only two women on the reservation, the wife of the chief engineer and the housekeeper of the director of the mining company. We were royally received by the latter gentleman, whose house up there in that wild country rivals in its sumptuousness a millionaire's in the United States. The mining company, we were told, is a very rich one that pays its few stockholders a handsome profit. The taxes paid by it to the Danish Government assist in defraying the administrative costs of running Greenland and permit the maintenance of many services for the education and improvement of the Greenlanders.

The *Marion* was inspected with much interest by the Danes, the live bear, Marian, proving the center of attraction. In the evening the ship's officers were entertained at a banquet in the clubrooms of the recreation center ashore. A pleasant time was had conversing with the mine officials, and much was learned about ice and other conditions in the southwest corner of Greenland. Figure 34 shows

A SOUTH GREENLAND ICE STREAM

FIGURE 35.—On August 29, 1928, the *Marion* took on board a party of officials from the Ivigtut cryolite mine and cruised up to the head of Arsuk Fiord. Many fathometer soundings were taken on this run. After a distance of about 10 miles had been traversed, further progress was blocked by this glacier which discharges into the fiord from the inland ice.

a picture of the cryolite mine that was presented to an officer of the *Marion* by one of Ivigtut's amateur photographers.

At 9.15 the next morning the *Marion* left Ivigtut for a trip up Arsuk Fiord with a group of mine officials on board. The fiord is deep and apparently free from hidden dangers to navigation all the way up to the glacier which runs into it from the inland ice. The sea front of this glacier was about 10 sea miles above Ivigtut at the time of the *Marion's* visit. (See fig. 45.)

There was a small gravel flat along the south bank of the fiord off the glacier end. Close to this morainal deposit the *Marion* anchored in 14 fathoms of water at 10.30 a. m., August 29.

A party from the ship ascended the glacier some distance, walking over the smoothly undulating dead ice behind the gravel flat. The views contained in Figures 35–38 were obtained at this time. The glacier had an ice cavern extending in from a vertical terminal wall.

This cave was similar to the one seen 500 miles farther northward in the end of the glacier at Port Quervain. It was here in a very active part of the glacier close to the north side of the fiord. On that side the glacier produced numerous small icebergs and growlers. During the *Marion's* stay near Ivigtut a few of the former were seen drifting down the fiord toward the open sea. The bergs from Arsuk Fiord, however, are so small that such as succeed in reaching Davis Strait usually melt in the coastal waters off southwest Greenland before getting very far.

The active north side of the glacier was extremely rough and crevassed, in marked contrast to the unbroken ice surface without a vertical terminal wall which lay just behind the gravel flat. Figures 36 and 37 show the characteristics of the two sides of the glacier. These views also show evidence of recent scouring action on the rocks

THE SOUTH SIDE OF THE GLACIER NEAR IVIGTUT IS DEAD

FIGURE 36.—We found a muddy stream from under the ice flowing across the gravel flat at the south side of the head of Arsuk Fiord. The ice above the gravel flat does not move appreciably. It is easy to walk over, though it has a few dangerous circular holes in it which extend down vertically to the roaring waters of the subglacial stream.

just above the present ice level, which would indicate that the latter may have been considerably higher quite recently. At that time the glacier probably extended farther down the fiord toward Ivigtut than it does to-day.

At 12.45 p. m. the ship got under way and stood seaward past waterfalls, bird rookeries, and mountains, anchoring off Ivigtut at 2 p. m. The weather, which had been overcast but calm and pleasant all morning, became rainy and blustery during the run down the fiord. Great gusts of wind began to shake the *Marion* at her anchorage near Ivigtut's seawall. In spite of the bad weather, a line was run ashore and the *Marion's* bow was hauled in close enough to permit Diesel oil from the tank of the mining company to be pumped aboard through a hose. In addition to the oil, large quantities of provisions to supplement the *Marion's* diminishing supplies were also furnished the ship by the mining company.

At 6.20 p. m., after the mine's doctor had dressed a minor injury to the hand of one of the officers, the *Marion* got under way. Various courses were stood through the now shrieking gale toward the narrows north of Arsuk Island. Rain squalls made visibility so low that at times neither shore was discernible from the center of the 1½ mile wide fiord. Nevertheless, the entrance to the narrows was located and their passage was again successfully made.

Continuing on 3 miles farther seaward, a sheltered spot was found in Ekaluit anchorage, where the *Marion* anchored at 7.23 p. m. At this uninhabited spot, under the 4,450-foot height of Mount Kungnat, the *Marion* remained waiting almost three days for the barometer to rise. It was deemed inadvisable to run for Cape Farewell and thence across Davis Strait in the face of the unsettled weather con-

A CAVERN IN A GLACIER'S TERMINAL WALL

FIGURE 37.—We ascended some distance over the smooth stagnant ice behind the south edge of the glacier above Ivigtut. This view looks toward the rough ice of the center and north portions, which is rapidly moving seaward and calving into Arsuk Fiord. As at Port Quervain, the glacier here had an ice cavern in its vertical terminal wall. This is doubtless the seaward end of the tube of a subglacial stream.

ditions that prevailed. The time was spent watering ship and preparing everything for the long line of stations that were to be taken to the Strait of Belle Isle. While at Ekaluit anchorage "working" parties from the crew picked several bushels of the delicious blueberries that grew in the thick mat of low vegetation which covered the ground in all favorable locations. These berries were served to all hands for many days. Besides being eaten raw with sugar and tinned milk, they were made into pies and puddings that proved a splendid addition to the fare.

Other members of the crew jigged for codfish in the near-by waters. In the latter occupation they were joined by several natives in kyaks from the village of Arsuk, situated about 3 miles seaward from our anchorage. Considerable rain fell on the ship, but the mountains, down to a few hundred feet above sea level, were seen when the clouds lifted to be covered by a fall of wet snow.

At noon on September 1 the barometer registered the low value of 29.16 inches, after which it commenced to rise slowly. At 1.20 p. m. the ship got under way and stood to sea and then southeastward toward Cape Farewell. Mostly cloudy but moderate weather was enjoyed throughout the 175-mile run to the southern point of Greenland. There was some fog over the cold 39° water encountered south of the sixtieth parallel. A few large bergs were seen but there was no pack ice in the cold current coming around Cape Farewell from East Greenland.

From 6 p. m. to 6.24 p. m. on September 2, 1928, the *Marion* lay stopped 6 miles off the outer islets and 12 miles west of Cape Farewell, taking the first station of the 620-mile line of them that was to end off the Strait of Belle Isle. Just after leaving this station, the

WHERE GLACIAL ICE MEETS THE SEA IN SOUTH GREENLAND

FIGURE 38.—The *Marion* is at anchor off the gravel flat at the south side of the head of Arsuk Fiord. Many small pieces of ice have been stranded by the receding tide. In the deep water near the center of the fiord, several large pieces of ice which have just been calved from the active north side of the glacier are drifting westward toward the open waters of Davis Strait.

clouds broke away to the westward, causing the low sun to light up brilliantly the mighty peaks of the southern tip of Greenland, the Cape Horn of the north. The air was so clear that these peaks were outlined with unearthly sharpness against the dark-gray eastern sky. There were dozens of them visible, rising one above the other with extreme wildness. Never before had we seen such sharp alpine horns and pinnacles. The bright colors of the bare rock contrasted sharply with the radiant whiteness of the snow fields and snow patches, as it did with the gray shadows of the chasms and the still darker background of the steely sky. Off the coast in front of the mountains was a line of black wave-washed rocks and islets, while between the shore and us lay the uneasy surface of the cold, blue sea.

Five and a half days were required to make the run to Cape Bauld, the northern tip of Newfoundland. Twenty-eight stations were occupied, and many deep soundings were taken with the fathometer, some of the latter in the center of the basin exceeding 2,000 fathoms in depth. On three days the wind attained gale force, showing that the end of the summer was at hand. As on our other southern crossings, however, air and surface water temperatures observed in the center of Davis Strait were still around 50° F.

The first icebergs sighted after leaving the cold water about Cape Farewell were encountered on September 7, about 70 miles east of Belle Isle. Almost all of the 7th was spent searching for an "ice island" several miles long, recently reported by different passing steamers as being in that vicinity. No trace of such an unprecedently large iceberg for North Atlantic waters was found. The largest piece of ice that could be located was a tabular berg about 50 feet high and, roughly, 800 feet square.

Upon reaching Belle Isle on the evening of September 7 we decided that it would be best, on account of the stormy weather, to return via the east coast of Newfoundland, stopping at St. John's for supplies and recreation. En route it was further decided to run two additional lines of stations off the eastern shelf of Newfoundland. Although these stations were not called for in the original plans of the expedition they were deemed useful for connecting the investigations, of the *Marion* expedition with the previous oceanographic work of the international ice patrol to the southward. The entire work was completed on September 11 when we took the last station 5 miles off St. John's.

The afternoon of September 8 was spent running southward along the northeast coast of Newfoundland past the Gray Islands. When about 23 miles east of Horse Island a station was taken. This was the first of the 225-mile line of them that was run to the eastward over the 1,000-fathom curve. Excellent weather was experienced on this run.

The last line of stations, which ran in a southeasterly direction toward St. John's, was started on September 10. A short and sharp September gale held up the work somewhat, but St. John's was reached safely at 3.15 p. m. on September 11, 1928.

St. John's is a foreign port and nearly 1,000 miles from the *Marion's* base at New London, Conn., but the sight of it caused much rejoicing. It marked the end of our present arduous labors for the cause of science and a return to real civilization once more.

There had been only four days in the past nine weeks that the *Marion* had not been underway at sea. The nature of the expedition had demanded, of course, that we keep driving rather intensively most of the time in order to complete the work laid out in the few weeks before bad weather and danger from ice would make it impossible. The work of proceeding from station to station and there repeating the same operations over and over again had begun to tell on the spirit of the crew. The station work, coming as it does night and day, gale and calm, rain and shine, is no child's play either for those on deck or those at the motors. It requires alertness and knowledge of a ship to hold her up at a station on a dark night with the wind howling and 3,000 meters of wire out. Under such handicapping conditions as these, we had seen whole series of observations down to 3,100 meters repeated three times, just because waves, or other patience-trying accidents had caused the premature tripping of the instruments. There was little opportunity for amusement or diversion on a small vessel like the *Marion*, so it is small wonder that during the last month we had sometimes detected long faces on many of the men who were most eager, early in July, to seek Arctic romance and adventure.

The American consul at St. John's did his utmost to help us after our arrival. Everyone we met, in fact, was extremely kind and cordial. The commanding officer made official calls on the governor and the mayor. Fresh water and stores were taken aboard. Hundreds of people came down to the wharf where the *Marion* was secured, and once more the caged polar bear, Marion, proved a center of attraction.

At 4 p. m. on September 12, after a one-day stay, the *Marion* departed from St. John's and headed southward. Full speed was rung up on both motors, enabling us to round Cape Race by 10.30 p. m. Once past this headland, the *Marion* was steered toward the west and home. Fine weather continued on the morning of the 13th, but during the afternoon there was fog and rain. Throughout most of the 14th and 15th the ship ran before a northeast gale. Speed was never slackened, and with all four sails set and straining the now lightly loaded ship rolled and twisted, steadily covering the tedious miles.

About noon on September 16 Nantucket Sound was entered. It was very good to feel the warm land breezes and to see the green shores of the United States again. At 4 p. m. the *Marion* tied up to the steamboat wharf at Vineyard Haven, Mass., the home of the commanding officer. While he was ashore in the evening crowds of summer visitors and island residents came down to look at the ship.

On September 17 many visitors were shown about on board. The public-school children were marched down by classes. After looking at the bear and the various scientific instruments, each class was told of the trip through the northland and shown an imposing array of souvenirs that had been obtained in the land of the Eskimo.

The night of September 17 was spent running to the westward. At 6.25 a. m. on September 18, 1928, the *Marion* moored to the State pier in New London, Conn., her home station. The intensive 73-day cruise to the Arctic was finally ended.

The bear in the well-strengthened bear cage aft was shipped by express to the National Zoo at Washington, D. C., and the scientific instruments were dismantled and put in storage ashore. In a few days all the extra personnel had been transferred and the ship was ready for her regular service again.

The *Marion* proved ideal for the work and could not have been better if especially constructed for the expedition. She is a fine sea boat, capable of operating almost anywhere in the world. The fact that not once in all her cruising in the Arctic, thousands of miles from machine shops and supplies, had there been a breakdown of her motors, speaks eloquently for the reliability of the machinery installation. The Hill-Diesel, although heavily taxed with furnishing power for the winches at every station, never faltered. The Delco generator also functioned well, but when we got started on the lines of stations we found the extra output from the Hill was sufficient to keep the

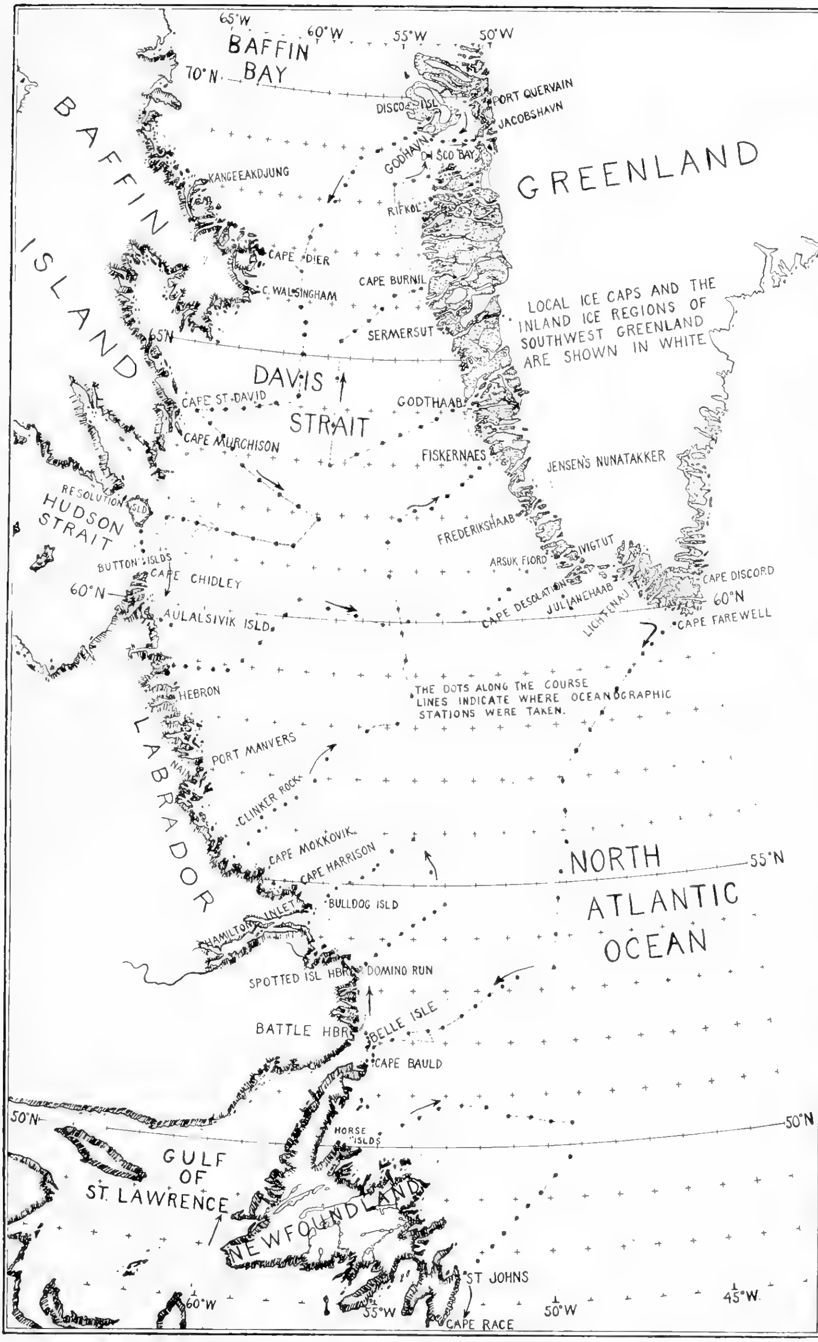


FIGURE 39.—Track chart of the Marion Expedition cruise

banks of batteries charged. The Delco was run, therefore, only intermittently. The most frequent mechanical troubles were with the oceanographic apparatus and the most serious of these difficulties have already been described.

The *Marion* cruised a total distance of 8,100 sea miles, or farther than from New York to Sydney, Australia. The motors expended 14,000 gallons of oil, the rate of consumption being 1.5 gallons per mile on one motor at an average speed of 6 knots and 2.3 gallons per mile with two motors at 8.7 knots. The survey covered that 450,000 square sea-mile area of ocean lying between Greenland and North America which is situated between St. John's and the seventieth parallel of north latitude. A total of 191 stations were taken, at which about 2,000 observations of temperature and salinity were made. All of the tests of salinity were made immediately on board by means of electric salinometers. The fathometer registered 1,700 depths for chart record and several times that number in actual practice.

The data the *Marion* had obtained during the course of her special duties were now ready for scientific analysis. Although her northern adventures were all over, the tale of them recorded in part in the foregoing pages will live long in the memories of her complement, whatever may be their future duties and wherever they may go.

Chapter II

THE BATHYMETRY

INTRODUCTION

Detailed knowledge concerning the depth of ocean basins and other large bodies of water is valuable to two classes of people: Those concerned with the navigation of ships and those who, like the geologist and geographer, desire to learn more facts about the earth. There is little sea-borne commerce in the Davis Strait area, so the bathymetrical information contained in this bulletin will prove of but slight practical value to most mariners of to-day, though new discoveries and new northern developments in the future may cause it to be of more value to them at some later date. On the other hand the detailed depth values discussed here should prove of considerable interest to geological and geographical workers, especially to those connected with the field of oceanography.

Dozens of expeditions of discovery and rescue have traversed the Davis Strait area, and a varying number of commercial vessels have frequented it annually for centuries. It is astonishing, in view of this, how few in number are the sounding values which appear on the charts, and what great areas exist between Labrador and Greenland in which, apparently, prior to the year 1928, no sounding was ever taken. Before the development of sonic depth-finding methods a great expenditure of time and trouble was necessary to obtain good soundings in deep water. This fact probably explains the lack of detailed bathymetrical knowledge of the Davis Strait area which existed prior to the time of the Marion Expedition.

DESCRIPTION OF APPARATUS AND METHODS

The *Marion* was equipped with a commercial echo sounding device of the same type as those used on the international ice-patrol vessels since the beginning of 1928. It was manufactured by the Submarine Signal Corporation, of Boston, Mass., and was called a " fathometer." (See figs. 40 and 41.) This instrument was capable of instantly showing the depth of water up to nearly 100 fathoms by the flashing of a red light opposite the proper depth value on a circular scale marked in fathoms. It was possible to make an easy adjustment which would slow down the apparatus to one-sixth speed. This adjustment automatically cut out the red light and threw in a steady white light on the disk moving past the depth scale. After this was accomplished with the aid of ear phones to detect the echoes returning from the sea bottom, the apparatus could be used to measure the depth of water up to a maximum, under favorable conditions, of over 2,000 fathoms.

By the above two methods the *Marion* recorded some 1,700 echo soundings in the Baffin Bay-Davis Strait region between July 19 and September 11, 1928. These soundings were all made along the track indicated on Figure 39. Such a small number of soundings, of course,

HOW A FATHOMETER MEASURES THE DEPTH

FIGURE 40.—This illustrates diagrammatically the sound waves going out from an oscillator installed in the hull plating of a liner. They can be seen proceeding to the bottom, whence they are reflected back toward the sea surface. The hydrophone near the keel picks up the echoes and transmits them electrically to the bridge, where they are amplified. (Courtesy of Submarine Signal Co.).

can not give a perfect picture of the bathymetry of a large region like that concerned, even if very well distributed along carefully planned lines. In view of the few soundings previously recorded in the deep water of the area, however, they suffice as taken to give much more detailed and positive information about the shelves, slopes, and basins of the region than was hitherto available.

Two things are necessary to make a sounding of value for use on a chart: First, the geographical position where it was taken must be known quite accurately; second, the sounding must be nearly correct. The *Marion* soundings can be divided into two groups, a less important one comprising those taken in harbors and sheltered waters, and a more important one comprising those taken in the open sea. In neither of these groups is the determination position all that could be desired. The unfamiliarity of the personnel with the unlighted and practically unmarked coasts and harbors made accurate determination of the position of soundings taken inshore most difficult, especially in view of the fact that the places were but once visited in every case, and then always for a very short time.

THE CONTROL PANEL OF THE FATHOMETER

FIGURE 41.—This box, usually installed on the bridge, is used to start and stop the fathometer and to control the frequency and intensity of the signals. There are two scales on its face, one graduated from 0 to 100 fathoms and the other from 0 to 600 fathoms. The latter is for use in deep water. The amplified echoes permit the depth of water to be instantly obtained from one or the other of the abovementioned scales. (Courtesy of the Submarine Signal Co.).

The soundings taken while cruising in bays and fiords were recorded against times in a book by an officer stationed at the fathometer. Another officer cut in the ship's position at frequent intervals on the chart being used. This was accomplished by means of laying down observed magnetic compass bearings of identified points and islands from time to time. The bearing observer, by means of the plotted bearing lines on the chart, could determine the approximate track of the ship, and, guided the times of the recorded depth values in the soundings book, could later place the soundings on the chart at the proper points along the track line. Both the bearings and the depths were recorded against times read from the same clock on the bridge, which simplified matters by making no corrections necessary for time observed on different timepieces.

The inshore soundings obtained are doubtless much more accurately located in some instances than in others; for instance, the soundings in the Arsuk Fiord region are undoubtedly much better with regard to position than those taken in the fiord just south of Aulalsivik Island, Labrador. For the latter place there was no large-scale harbor chart, and it was noticeable that the fiord was actually very different from the shape shown on the small-scale chart of Labrador which had to be used.

In view of the scarcity of recorded soundings on the charts of the inland waters visited it is believed that the approximately located soundings, such as those shown on Figures 44 and 45 of this pamphlet, will be useful until such times as the regions are carefully surveyed and exactly located sounding values obtained and plotted.

At sea whenever the echoes from the bottom could be heard fathometer soundings were made at stations and also at least every half hour while between stations. The location of these offshore soundings was another matter from the location of the fiord and bay soundings. The principles upon which the accuracy of the determinations rest, however, are largely the same. The time as shown by the bridge clock and the sounding values observed were recorded in a specially ruled notebook by the different watch officers, each one taking and recording the soundings made during his watch. The ship's positions offshore were determined by means of bearings of prominent landmarks, when available, supplemented by numerous lines of positions obtained from sextant observations of heavenly bodies. The latter position lines were the only available means of locating the position when the ship was out of sight of land.

The terrestrial bearings and the lines of position permitted the ship's track to be drawn on the chart, and the *Marion's* successive positions on this track, at intervals of 15 minutes, were carefully indicated by short cross lines. The cross lines marking the hourly positions were longer than those marking the half hour, while the quarter-hour cross marks were the shortest of all. The date and the ship's times from 0 to 24 hours were written at the proper places along the track, making reference at any time easy and certain.

The soundings taken at sea were entered from the soundings book, and recorded along the track on the plotting charts every two or three days. The latitude and longitude of the soundings were also entered to the nearest minute every two or three days in the soundings book from the plotting sheets. Thus a double record of the offshore soundings was maintained, which remains available for ready reference to this day.

The writer was in charge of the navigational work, so the accuracy of the offshore soundings positions depends chiefly upon how many properly worked-out sights he plotted daily. The longitude should, in general, have been accurate, for there was a good chronometer on board the *Marion* which was checked up several times each week by radio time signals from Arlington, Va. All the other officers worked out sights occasionally, and these checked up consistently with the plotted positions along the track line.

Had there been no cloudy weather nor unusual refraction, the positions at sea would have been very good, as such positions go. Unfortunately, there were frequent periods when bad weather made the heavenly bodies invisible and a few other periods when abnormal refraction was suspected. The accuracy of the track positions in some places at sea is, therefore, doubtful, though, in view of the paucity of previous soundings, almost never to a seriously damaging degree. Throughout all periods when sights were possible, many of them would be taken, permitting good estimates and interpolations to be made for the dead-reckoning positions which had to be relied on between the fixes—that is, during the bad weather periods.

The ship's track was always determined graphically by laying down and running forward the various bearing and Sumner lines on large-scale plotting charts that were on the Mercator projection. The regular plotting sheets published by the Hydrographic Office of the United States Navy were used south of latitude 61° N. Special charts constructed on board on a scale of 2.75 inches to the degree of longitude were used for tracking farther north, as no regular plotting sheets could be purchased prior to the departure of the expedition for latitudes above the sixty-first parallel.

The observations were worked out principally by means of Hydrographic Office Publications 203 and 204 when south of the latitude 60° 30′ N., and by means of the haversine-cosine formula given in the American Practical Navigator when farther north. Meridian and ex-meridian sights were worked out during the entire cruise by means of the methods given in the latter publication.

At least 10 sun sights were worked out on each clear to partly cloudy day. On days that were mostly overcast almost as many sun sights would usually be worked out, for, due to the desire to keep track of the position accurately, the intervals between observations were regularly shortened whenever the sun appeared to be in danger of being obscured for a long period by clouds.

The positions were carefully determined and checked and are believed to be free from any gross errors. Considering the number of sights and bearings taken and the methods of navigation used, they are probably the best results that could have been obtained.

In general, the positions of the soundings taken off the coast can be considered as reliable to fairly reliable, possible exceptions being off Baffin and Resolution Islands, where unusual refraction may have prevailed. On the *Marion* we seldom had positive evidence of unusual refraction, such as great distortion of objects near the horizon and failure of sights taken at close intervals to agree well with one another. It is thought that the references in the sailing directions about the unusual refraction to be expected in the Davis Strait region can be attributed in many cases to the land's being incorrectly plotted on the existing charts.

CORRECTIONS APPLIED TO THE ECHO SOUNDINGS

It is well known that echo soundings are not accurate as taken. They have to be corrected for instrumental and personal errors; also for errors arising from the varying speed of sound in the water column under the ship. The fathometer on the *Marion* was con-

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structed on the assumption that the speed of sound in the water column is always 820 fathoms a second. This, as a matter of fact, never was the truth throughout the entire expedition, it being less than this value in every case. Therefore, every fathometer sounding recorded was, theoretically at least, somewhat too great.

The speed of sound in sea water varies principally according to the salinity, temperature, and pressure. The soundings themselves, by giving at least the approximate depth, furnished a clue regarding the latter factor, and the first two could be determined with considerable precision from the salinity and temperature values observed at the 191 oceanographic stations which the *Marion* occupied. For complete information regarding this station data, the reader is referred to United States Coast Guard Bulletin 19, part 2, The Oceanography of Baffin Bay and Davis Strait. This pamphlet is not yet published, but it will probably be distributed in 1932.

The first step in correcting the fathometer soundings was to determine the speed of sound at each station. This speed was obtained, after averaging the salinities and temperatures for each 200-fathom water layer at each station, from the tables on pages 160 and 161 of Hydrographic Manual, J. H. Hawley, Special Publication No. 143 of the United States Coast and Geodetic Survey, 1928. The stations were occupied to various meter levels, but it was possible to plot the salinities and temperatures to a meter scale, graphically convert to fathoms, and average conditions by 200-fathom layers in every case by inspection without any important error.

The United States Hydrographic Office, the Carnegie Institution of Washington, and the United States Coast and Geodetic Survey, all assisted the writer with information and with advice on how to attack the problem or determining the speed of sound in the water columns of Davis Strait. The United States Coast and Geodetic Survey went over the preliminary soundings correction work in several of its stages, independently checking a large number of the speed of sound values shown on Figure 46. Because of this checking, the writer feels much more confident regarding the accuracy and value of this chart than otherwise would be the case.

After the first speed of sound chart was constructed, all the *Marion's* offshore soundings and all the speed of sound values were plotted on the Mercator projection on two large rolls of tracing paper, ruled up on a scale of 4 inches to the degree of longitude. The various soundings were grouped on the new chart with different speeds of sound varying by 2 fathoms per second. Corrections were then made in accordance with the table given below:

Speed of sound in water column at sounding spot in fathoms per second and percentage correction to be applied to fathometer readings

Fathoms per second:	Per cent	Fathoms per second:	Per cent
790	−3.64	808	−1.46
792	−3.40	810	−1.22
794	−3.16	812	−.98
796	−2.92	814	−.74
798	−2.68	816	−.48
800	−2.48	818	−.24
802	−2.20	820	(1)
804	−1.96	822	+.24
806	−1.72		

[1] No correction.

The correction for each fathometer sounding as calculated was applied right on the large chart rolls to the observed depth values. In addition, 2 fathoms were taken from each fathometer value to allow for the fathometer constant, a number which was obtained by comparing corrected red-light fathometer and simultaneously taken wire soundings with each other. The fathometer constant is a sort of index error of the apparatus. It does not vary with the depth or character of water column, but with the location of the particular fathometer oscillator and hydrophone being used below the water line of the sounding ship. After the above two corrections were applied, the shallow water or red-light soundings were corrected so far as possible.

All the soundings in fact were now better than they were when first taken, but there still remained personal errors in the white-light soundings which it was possible, in large part, to eliminate. Fifty-three wire soundings, over 100 fathoms deep, had been taken at stations during the course of the expedition, and these were now analyzed in comparison with the partly corrected white light echo soundings which had been taken simultaneously in the same places. Some 35 of these wire soundings had been fair to good up-and-down casts taken during moderate weather. It was seen that these reliable checks had rather consistent differences from the partly corrected echo soundings when the latter were grouped according to the watches of the different officers who had had the deck and taken and recorded the fathometer readings. It was found that one officer, on the average, had recorded all of his white-light soundings 32 fathoms too great, while the three others had recorded them, on the average, only 11 fathoms too great; 32 or 11 fathoms, therefore, were taken from all the partly corrected white-light soundings plotted on the chart, depending upon who had had the watch during which they were taken. This completed the corrections to all of the offshore soundings, and brought them, on the average, as close as possible to the good wire soundings and the true depth.

When all offshore soundings had been corrected, the values obtained in the harbors and inland waters were corrected in the same general manner. These were plotted on special large scale charts of the areas concerned, the soundings being much too close together in these regions to permit their being plotted and corrected on the chart rolls containing the offshore soundings on the scale of 4 inches to the degree of longitude. Some of the corrected soundings obtained in inland waters are shown on Figures 44 and 45.

It is hard to say how much the fully corrected fathometer values may vary from the true depth, just as it is to say how far wrong the different wire soundings may be. It is thought that the completely adjusted fathometer values are correct in at least half of the cases to within plus or minus 25 fathoms for all depths. There are probably a few over plus or minus 50 fathoms in error, but this number is undoubtedly very small.

FINAL RESULTS

One of the last steps in working up the soundings data was to construct a general chart of the Davis Strait region on the polyconic projection on the scale of 30,000 meters to the inch. To this chart all the fully corrected offshore echo and wire soundings were carefully transferred. Next, the various land areas and the depth values that had been obtained by others about Davis Strait were entered on this chart. The charts from which already plotted depth values were taken include:

B. A. Chart 235, marked "Small corrections, 1922–3.15."
B. A. Chart 1422, marked "Large corrections, March 16, 1928."
B. A. Chart 2060B, marked "Small corrections, April, 1927."
B. A. Chart 112, marked "Small corrections, September, 1923."
B. A. Chart 263, marked "Small corrections, October, 1925."
Canadian Chart 405, published in May, 1928.
H. O. Chart 980, marked "Small corrections, January, 1928."
H. O. Chart 2440a, marked "Edition of September, 1927."
H. O. Chart 2440b, marked "Small corrections, February, 1927."
H. O. Chart 1412, marked "Small corrections, July, 1928."
H. O. Chart 955, marked "Small corrections, December, 1930."

Besides depth values obtained from the above charts, a number of corrected echo soundings obtained by the international ice-patrol vessels just north of the Grand Banks in 1930 were used. Also 18 depth values observed by the German oceanographic ship *Meteor* off Cape Farewell, between 1928 and 1930, were furnished for use by the Institut für Meereskunde an der Universität, Berlin. Finally, 19 soundings obtained by the nonmagnetic research vessel *Carnegie* while south of Greenland, during her last cruise, were plotted. These last depth values were furnished by the Carnegie Institution of Washington, D. C. After all available depth values had been entered on the large polyconic chart, the various contour lines were drawn. Next, the land areas and the contour lines were transferred to a smaller polyconic chart of the same region. The resulting bathymetrical chart is shown here as Figure 51.

Future expeditions equipped with sonic depth finders will undoubtedly modify the details of the above chart, especially in the areas where there are still few or no soundings. It is believed, however, that the major details of the depths of the Davis Strait region have been brought out on it accurately, and it is presented here as the most important bathymetrical result of the *Marion* expedition of 1928.

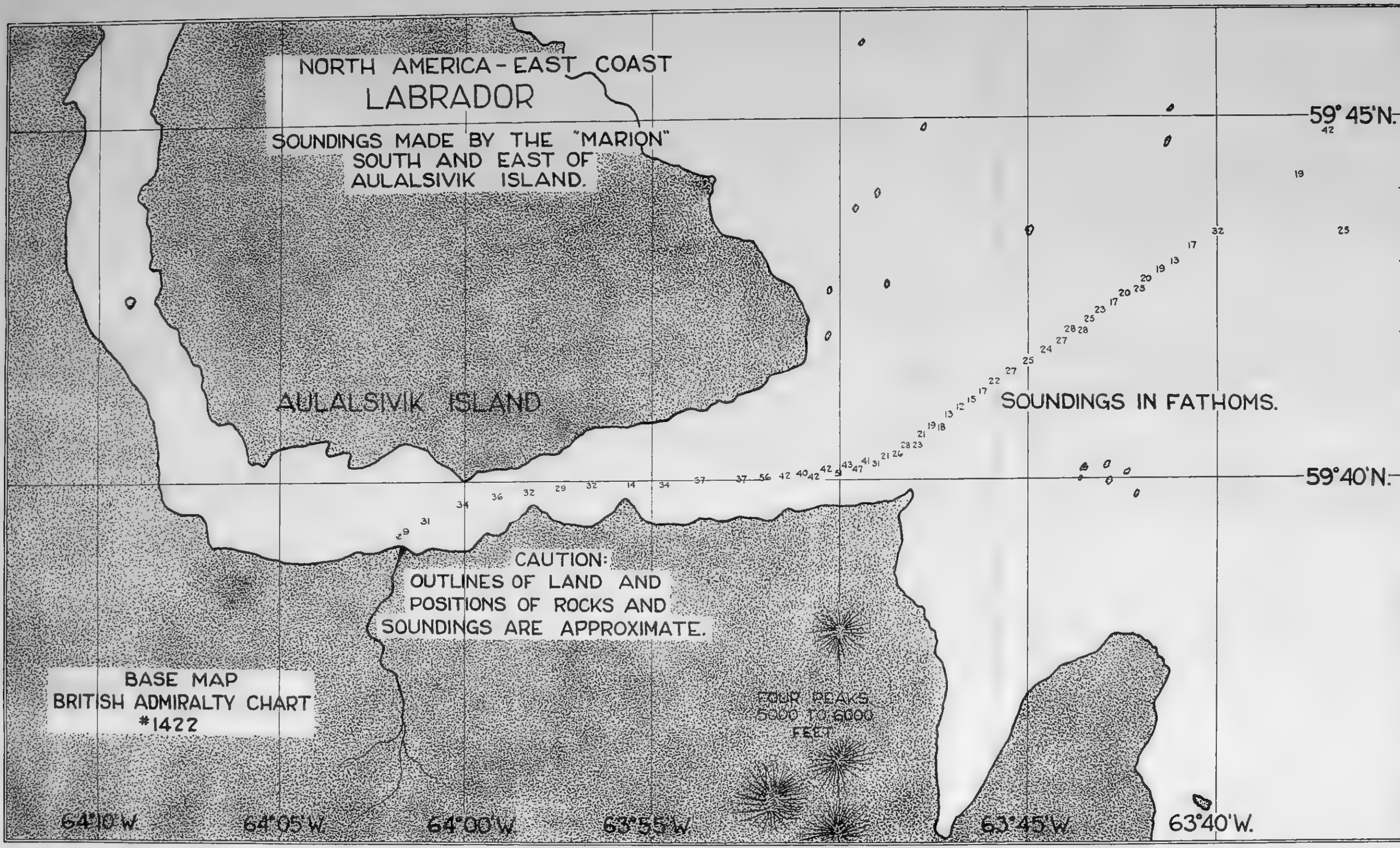

FIGURE 44.—Soundings made by the *Marion* expedition in and near the fiord just south of Aulalsivik Island, Labrador

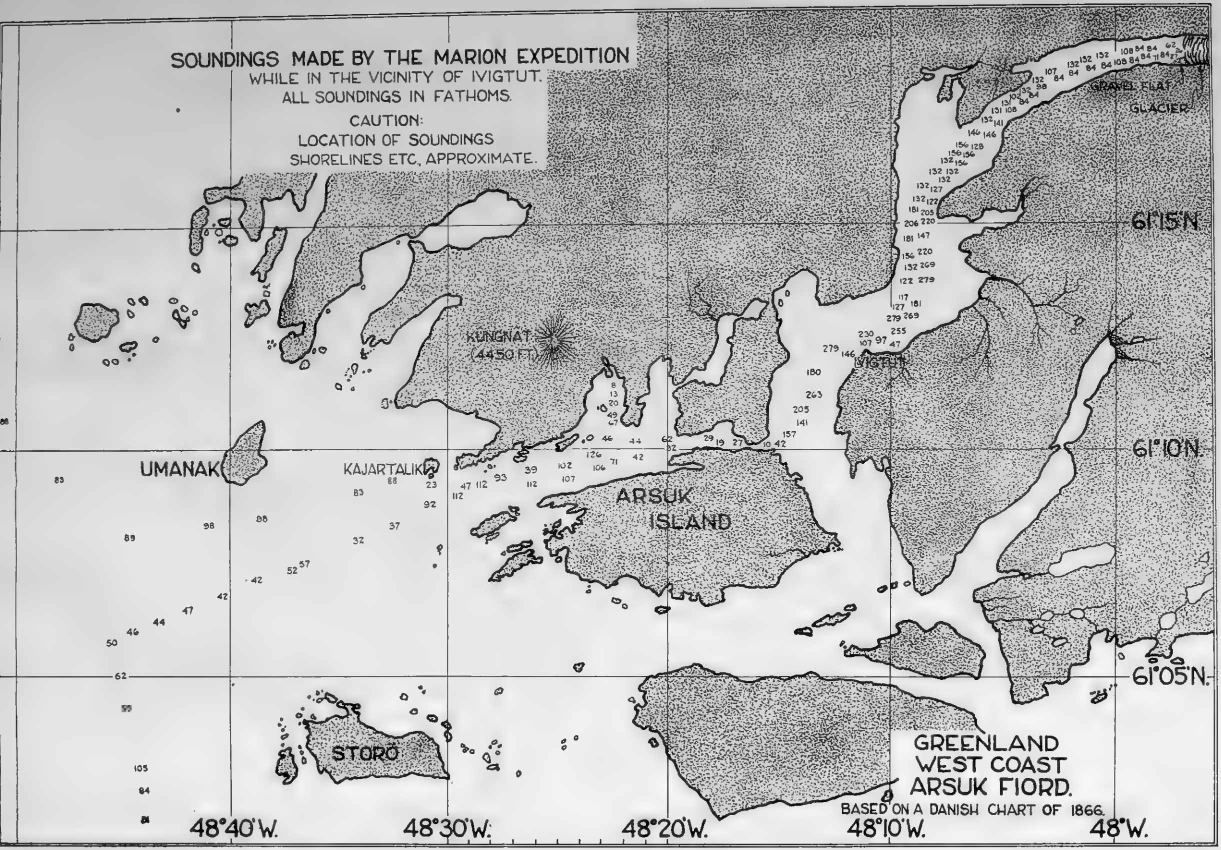

FIGURE 45.—Soundings made by the *Marion* expedition in and near Arsuk Fiord, Greenland

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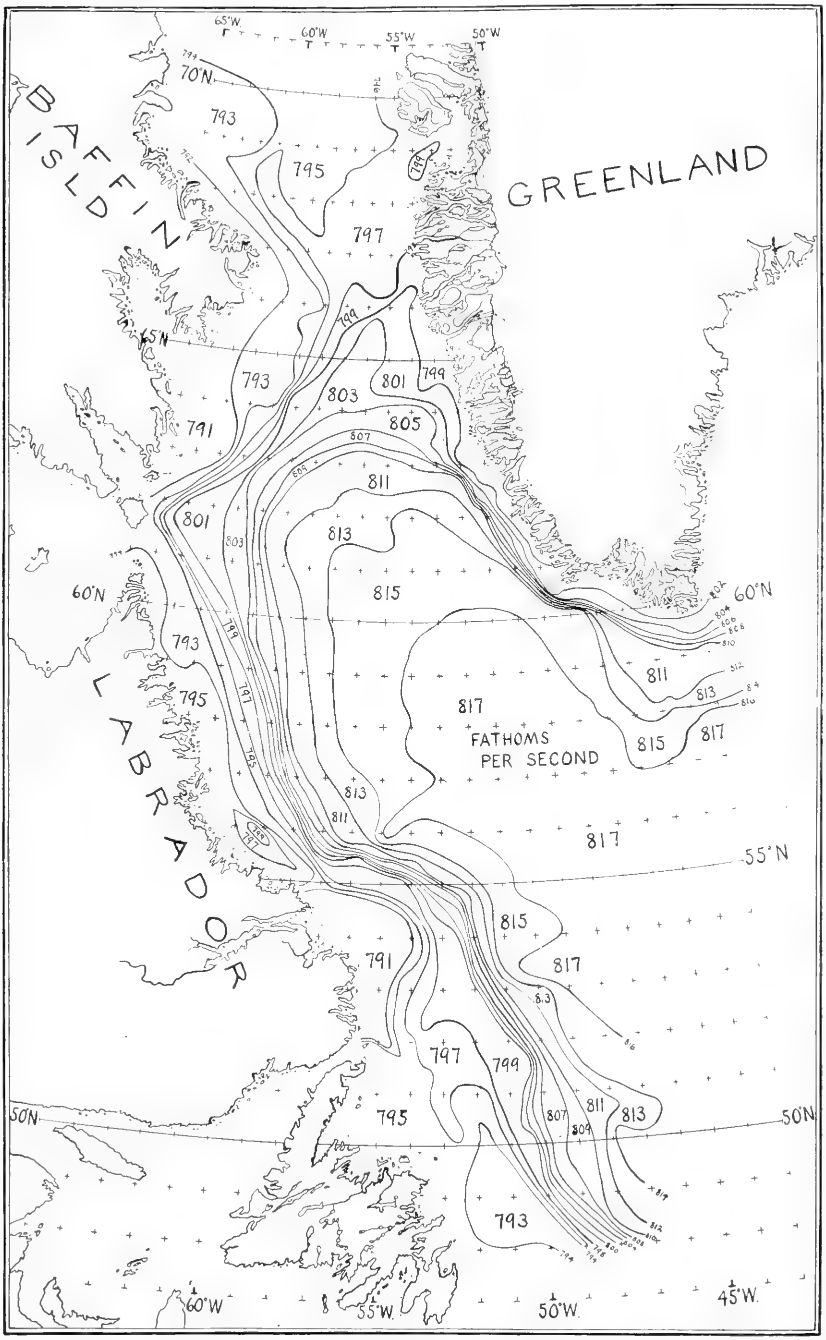

FIGURE 46.—Chart showing the speed of sound through the water for sonic sounding purposes in the Davis Strait region. The figures show the speed of sound in the water columns of different areas in fathoms per second

Chapter III

THE SEDIMENTS

Parker D. Trask

INTRODUCTION

This paper [1] presents detailed mechanical analyses and brief petrologic descriptions of 27 deposits collected by the *Marion* expedition to Davis Strait. The practicability of the fundamental constants of the size distribution of sediments, namely, the median diameter, and the coefficients of skewness and sorting is discussed. The deposits contain much ice-borne detritus. Faceted, subrounded pebbles are fairly uniformly distributed in the sediments over the entire region. They constitute 14 per cent of the deposits. Gneiss, quartzite, and aphanitic limestone are the predominant rock types. The nearest source of the limestone seems to be in northern Greenland or the Arctic northwest 500 to 1,000 miles away, but the areal geology of northern Baffin Land is imperfectly known, and the limestone may come from nearer regions not yet explored. The texture of the sediments varies with the configuration of the sea bottom and with the surface currents and tides. The deposits are relatively coarse on steep slopes and also in Hudson Strait, off Cumberland Bay, and on the transverse ridge that separates Davis Strait from Baffin Bay. The presence of 1 to 4 per cent of frosted, well-rounded sand grains suggests an eolian origin for some of the constituents. The fine sediments contain from 20 to 40 per cent calcium carbonate, which is in a finely comminuted state. Its association with the limestone rock fragments in the deposit suggests that it is derived from detritus carried by ice.

GENERAL REMARKS

This paper does not purport to be a comprehensive study of the sediments of Davis Strait. Its object is to present and interpret certain data that are available. The writer has been aided by Harald E. Hammar and M. A. Clark in determining the organic and carbonate content of the sediments and by John Lucke and F. B. Walcott in making the mechanical analyses. The description of the mineral and rock constituents of the sediments are based on hand-lens determinations and, therefore, are not as satisfactory as if they were the result of microscopical examination.

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[1] This paper, written by Trask, represents results arising from an investigation on "The Origin and Environment of Source Beds of Petroleum," listed as project 4 of the American Petroleum Institute Research program. Financial assistance in this work has been received from a research fund of the American Petroleum Institute donated by Mr. John D. Rockefeller. This fund is being administered by the institute with the cooperation of the National Research Council.

Twenty-seven samples were studied. There were taken along traverse lines of the *Marion* expedition and afford data for one longitudinal section, 200 miles in length, in the central part of Davis Strait off Cumberland Peninsula, five traverse sections on the west side of the strait between 57° and 64° N., and single localities from the middle of Hudson Strait, off Cape Farewell and east of southern Labrador. The sediments vary in texture, but they are characterized by a significant content of faceted, subrounded rock fragments, resulting from ice transportation. The sampling instrument has an internal diameter of 4 centimeters and could not procure pebbles larger than that size. Consequently the total quantity of fragments in the deposits was not ascertainable, but from the depth of penetration and the small proportion of big pebbles collected, it is probable that large rock fragments constitute a very minor part of the sediments.

INTERPRETATION OF MECHANICAL ANALYSES

Method of analysis.—The results of the mechanical analyses of the sediments are shown in Tables 2, 3, and 5 and on Figures 47, 48, and 49. The method of analysis was a centrifuge procedure which gives the complete size distribution.[2]

The customary separation of the samples into gravel, sand, silt, clay, and colloid is shown in Table 3 and the subdivision of the gravel and sand groups in Table 4. Table 2 shows the fundamental constants of the size distribution. It is impracticable to present the mechanical analyses of so many sediments in histograms, but the important characteristics of the size distribution are indicated conveniently by three constants, the median diameter, the coefficient of sorting, and the coefficient of skewness or its logarithm. These are given in columns 3, 5, 6, and 7 of Table 2 and on Figures 47 and 48.

Median.—The median diameter indicates the mid-point of the size distribution. One-half the weight of the sediment is composed of particles larger in diameter than the median, and one-half smaller. The median is the most important single constant for describing the character of a sediment, as it gives a mathematical means of measuring variations in texture. Thus, medians from 50 to 1,000 microns indicate sands; from 5 to 50 microns, silts; 1 to 5 microns, clays; and less than 1 micron, colloids.

Coefficient of sorting.—The coefficient of sorting affords a mathematical measure of the degree of sorting of a sediment. It is based on the first and third quartiles, which refer respectively to the one-fourth and three-fourths marks in the size distribution. These are given in columns 2 and 4 in Table 2. Twenty-five per cent of the weight of the sample is composed of particles larger than the first quartile and 75 per cent larger than the third quartile. Thus, by means of the quartiles, the size distribution is divided into four equal parts called quartile intervals. The coefficient of sorting, So, is derived from the formula $So=\sqrt{Q_1/Q_3}$, where Q_1 and Q_3 are the first and third quartiles, respectively. If So is less than 2.5, the sample is well sorted; if it is greater than 4.5 the sediment is poorly sorted; and if it is about 3 the deposit is normally sorted.

[2] P. D. Trask, Mechanical Analysis of Sediments by Centrifuge, Econ. Geol., vol. 25, pp. 581–599, 1930.

Consequently the coefficient of sorting indicates whether or not particles of about the size of the median are plentiful. For example, in sample 2, *So* is 1.87, which means that 50 per cent of the weight of the sample is composed of particles that differ in diameter less than 1.87 units from a certain reference diameter; that is, 25 per cent of the sample is composed of particles larger than 1.87 times

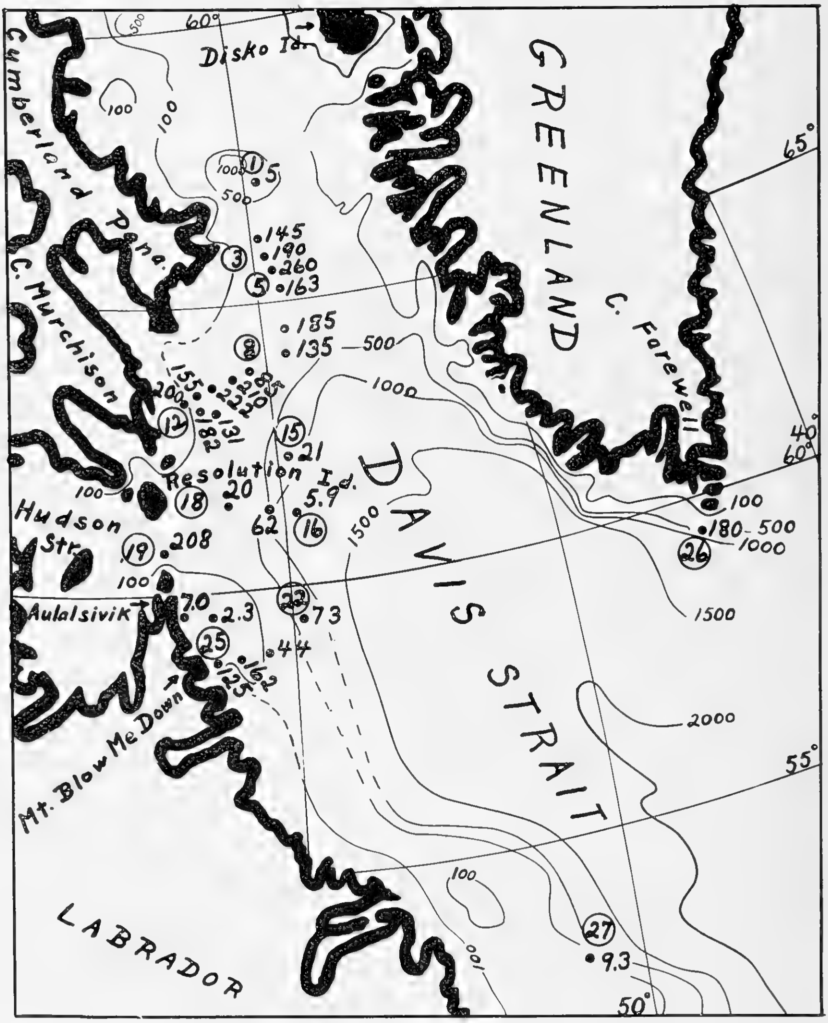

FIGURE 47

the size of this reference diameter, 25 per cent of particles smaller than 1/1.87 times the reference diameter; and 50 per cent within the diameter range of 1.87 units on either side of the reference diameter.

If the histogram of the size distribution were symmetrical, the reference diameter would be the same as the median, but since the size distribution of most sediments is unsymmetrical, the reference diameter differs somewhat from the median. Since the median of this sample is 145 microns, the sediment must be a very well-sorted, fine-grained sand. On the other hand, sample 22, is a poorly sorted, fine-grained sand, as *So* is 7.25 and *M* is 73 microns. In specimen 2 a range of only 1.87 times the reference diameter accounts for 25 per cent of the sediment, but in sample 22 it requires

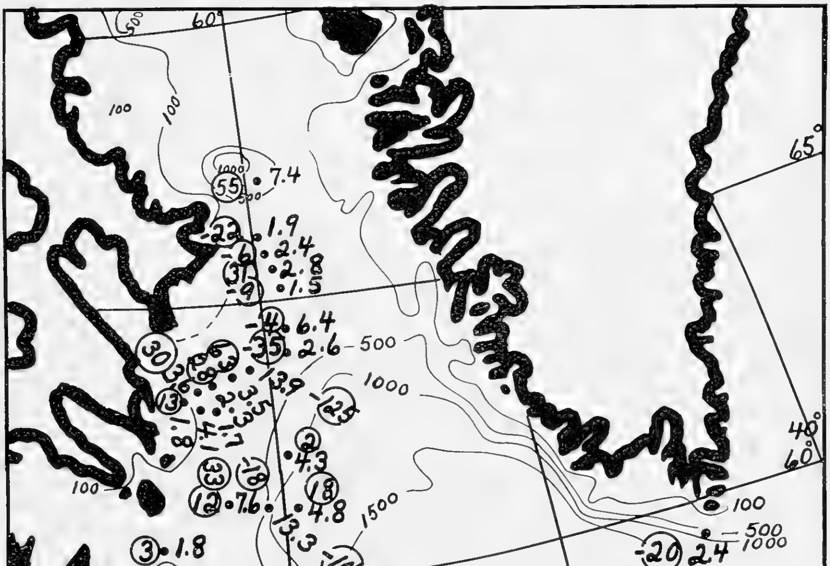

FIGURE 48

7.25 times the reference diameter to comprise 25 per cent of the deposit. The latter sediment, therefore, is very poorly sorted; that is, it contains much clay and much coarse sand or gravel.

Skewness.—If only *So* and *M* are given, the relationship of the reference diameter to the median is unknown. The coefficient of skewness, which is a measure of the dissymmetry of the size distribution fills this need. Various coefficients of skewness are used, but the formula $Sk=Q_1Q_3/M^2$ is very satisfactory for size distributions in which the quartiles are known. If R is the reference diameter, then $R=M\sqrt{Sk}=Q_1/So=So\times Q_3$. Thus, if the three fundamental constants, M, So, and Sk or *log Sk*, are given, the significant features of the mechanical composition of the sediment are at once apparent, for by multiplying the median by the square root of the coefficient of skewness one obtains the reference diameter, and by dividing or multiplying this by the coefficient of sorting he gets the first and third quartile, respectively. However the main object of the skewness is to determine the approximate position of the mode of the size distribution; that is, the diameter corresponding to the apex or crest of the histogram.

The coefficient of skewness is a ratio of the increase in diameter in the second quartile interval to that in the third quartile interval. For example, in sample 1, Sk is 3.65. This means that the ratio of increase of diameter between the median and the first quartile is 3.65 times that between the third quartile and median; because, from M to Q_1 the diameter rises from 5 to 70, which is a fourteenfold increase, and from Q_3 to M it goes from 1.3 to 5, which is a fourfold augmentation. The second and third quartile intervals, each represent 25 per cent of the weight of the sediments, but the ratio of increase in diameter for the two intervals is 14 to 3.9, or 3.65. From this it is evident that in this sample the maximum sorting occurs on the fine side of the median; that is, the mode lies in the third quartile interval.

The coefficient of skewness is a ratio varying about unity. Consequently, when one compares the dissymmetry of two samples, one of which has the mode in the second quartile interval and the other in the third, he obtains an erroneous impression unless the logarithm of the skewness is given. For example, values of Sk of 0.67 and 1.5 refer to the same degree of dissymmetry; but unless one is very familiar with reciprocals, the similarity of the two ratios is not evident. However, if they are given in their logarithmic form, namely -0.18 and $+0.18$, respectively, their equivalence is at once apparent. For this reason the skewness is given as *log Sk* on Figure 48.

The interpretation of the coefficient of skewness may be briefly summarized as follows: If Sk is greater than 1.0 or *log Sk* positive, the maximum sorting of the constituents lies on the fine side of the median; if Sk is less than 1, or *log Sk* negative, the maximum sorting is on the coarse side of the median; if Sk is about 1.0 or *log Sk* near 0, the maximum sorting corresponds approximately with the median; and the greater the divergence of Sk from 1.0, or *log Sk* from 0; the farther the maximum sorting lies from the median.

Practicability of fundamental constants.—In order to illustrate the practicability of these three fundamental constants let us take sample 1, in which M is 5, So is 7.35, and Sk is 3.65. From these three constants it follows that the sediment is a coarse-grained clay; that it is very poorly sorted; that the greatest concentration of particles occurs in the clay group relatively far from the median on the fine side; that 25 per cent of the sample is larger than 70 microns in diameter, and 25 per cent is smaller than 1.3 microns.

Furthermore, these three constants afford a mathematical basis for comparing sediments with each other. They demonstrate clearly differences in general texture, degree of sorting of entire sample, and position of maximum sorting within the deposit. They, of course, are not substitutes for a complete analysis, but they do give most of the important features of the mechanical composition.

DESCRIPTION OF SEDIMENTS

Texture.—The sediments are characterized by the plentifulness of rock fragments. Table 3, column 2, and Figure 49 show the distribution of gravel in Davis Strait. Sample 27, located more than 500 miles south of the other sediments, is the only deposit in which no rock fragments occur. The average gravel content of the sediments is 14 per cent and the maximum is 29 per cent. The distribution of rock fragments is random in nature, which indicates that gravel is fairly uniformly scattered over the sea floor in this region. Samples 15 and 16, lying in deep water far from shore, contain only 4 per cent gravel, but until this relatively low content is supported by additional evidence one hesitates to infer a decreased gravel content in the central part of Davis Strait.

The variation in texture of the sediments, as indicated by the median diameter and coefficients of sorting and skewness, are shown in Figures 47 and 48. The presence of large quantities of gravel in some samples makes the coefficient of sorting large, and masks the sorting of the sands. The longitudinal series of samples lying in 400 to 700 meters of water off Cumberland Peninsula, with the exception of sample 1, which lies in a deep depression, are well-sorted, fine-grained sands, having median diameters ranging between 135 and 260 microns. Similarly, sample 19 in 575 meters of water in the middle of Hudson Strait and sample 26 in 462 meters off Cape Farewell, Greenland, are well-sorted, fine-grained sands. Likewise, the deposits on the two sections eastward from Cape Murchison lying in 200 to 250 meters of water are well-sorted fine-grained sands. Sample 8, however, in 290 meters, although containing a fairly large amount of very fine-grained sand (21 per cent) has 12 per cent of clay and 22 per cent of colloid; consequently it is an extremely poorly sorted, fine-grained sand.

Sample 15 in 1,500 meters of water, at the seaward end of the section southeastward from Cape Murchison, is a somewhat poorly sorted, medium-grained silt. Similarly, the three samples forming the section eastward from Resolution Island, lying in water 700 to 2,300 meters deep, are silts. They contain 30 to 45 per cent clay and colloid and are fairly poorly sorted.

The texture of sediments eastward from Aulalsivik, at the northern tip of Labrador, varies considerably. Sample 20 in 65 meters of water relatively near shore is a fine-grained silt, having a median of 7 microns; specimen 21 in water 152 meters deep, about 10 miles seaward, is a medium-grained clay having a median of 2.3 microns; and sample 22 in 1,650 meters of water, 125 miles farther off shore, is a poorly sorted fine-grained sand having a median of 73 microns. The maximum amount of sorting in the last sample is in the fine-grained sand group.

The section eastward from Mount Blow Me Down, 50 miles south of Aulalsivik, is restricted to the continental platform. The sediments consist of fine-grained poorly sorted sands and, except for sample 24, contain about 25 per cent of clay and colloid. Sample 27 in 855 meters of water, 150 miles off the southern coast of Labrador, is a normally sorted fairly fine-grained silt. Similarly sample 1

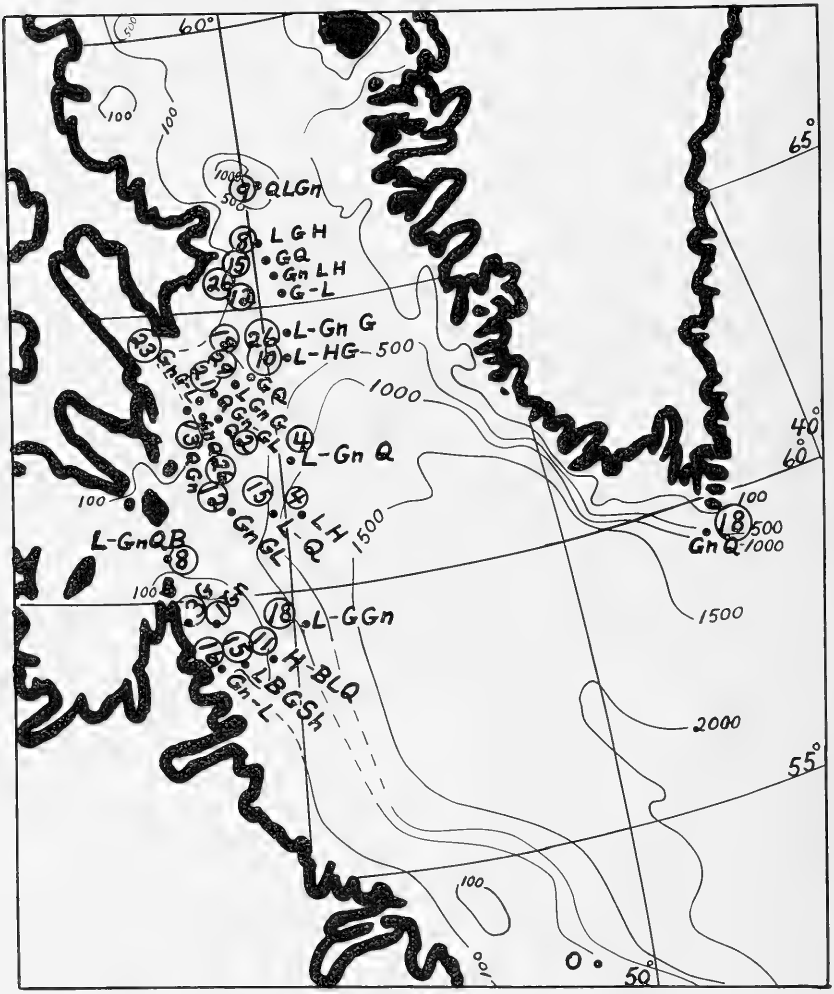

FIGURE 49

on the slope into a depression 2,000 meters in depth off Cumberland Peninsula is a fine-grained silt.

Frosting of sand grains.—All the samples contain frosted sand grains. The greatest amount of polishing occurs in the medium-grained sand group (250 to 500 microns), but some of the coarse and fine sands are frosted. The relative amount of polished grains in the medium sand subdivision is shown in Table 5, column 6. A scale of 1 to 3 is used: 1 indicates less than 5 per cent of the constituents are frosted; 2, between 5 and 10 per cent; and 3, between 10 and 15 per cent. Except for samples 8 and 9, which are used as standards and which contain about 15 per cent of polished grains, the quantity of frosted components was estimated by inspection. As this polishing occurs chiefly in the medium sands, the percentage of frosted grains in the whole sediment may be estimated roughly from column 5, Table 4, and column 6, Table 5. The maximum amount of polishing occurs in sample 19 from the middle of Hudson Strait, in which about 4 per cent of the sample consists of frosted sand grains. Most of the sediments contain 1 per cent.

If one plots on a map the relative frosting of the medium-grained sands as shown in column 6, Table 5, he will see that the amount of polishing tends to decrease toward the middle of Davis Strait; samples 7, 15, 16, 22, and 27, all situated far from shore, contain relatively few frosted grains. Sample 26 off Cape Farewell, on the other side of the strait, similarly, is deficient in polished constituents.

Description of rock fragments.—The rock fragments range in size from less than a millimeter to about 3 centimeters. Larger pebbles probably occur, but presumably not to any great extent, from the point of view of percentage composition of the sediments; because large fragments are not common and most of the pebbles are less than one-fourth inch (7 millimeters) in diameter. None of the fragments are well rounded. Nearly all of them are faceted and most of the edges of the facets are polished. The degree of rounding varies considerably, but the limestone pebbles are better rounded than the others.

The dominant rock types are gneiss, quartzite, and gray and buff aphanitic noncrystalline limestone; hornblendite and various types of granitic rocks are common; basalt occurs sporadically; and an eroded pelecypod shell was found in one sample. Some of the fragments classified as limestone probably are dolomite, as they effervesce but slightly in cold hydrochloric acid. The distribution of the rock types in the various sediments is summarized briefly in column 5, Table 5, and on Figure 49. Gneiss or quartzite occurs in practically every sample; except for the sediments off Cape Murchison, limestone is almost universally present; hornblendite and granitic rocks are less common, but their distribution is general; basalt is restricted to deposits south of Hudson Strait; and the pelecypod shell was found in sample 24 off the north coast of Labrador.

Calcium carbonate content.—The distribution of calcium carbonate in the sediments is shown in Table 5 and on Figure 50. The fine-grained deposits are fairly rich in $CaCO_3$, most of them containing from 20 to 40 per cent. The well-sorted sands off Cape Murchion have less than 5 per cent and the distribution of $CaCO_3$ along the longitudinal section off Cumberland Peninsula is variable. Samples 2 and 4 contain less than 5 per cent but adjacent samples have about 15 per cent. The Spearman coefficient of correlation, ρ,[3] between the

[3] See R. E. Chaddock, Principles and Methods of Statistics, Houghton Mifflin Co., New York, pp. 300–305, 1925.

calcium carbonate content and the third quartile diameter for all 27 sediments is 0.61±0.09, but if the anomalous sample 8 is omitted, it is 0.71±0.07. This indicates a fairly good relationship and shows that in general the calcium carbonate content increases as the sediments become finer.

Organic content.—The organic content of recent sediments is conviently estimated by multiplying the nitrogen content by 14. This is not an exact procedure, but it is a rapid means of procuring a rough approximation.[4] Table 5 and Figure 50 show the distribution of nitrogen in the sediments of Davis Strait. Except for sample 20 adjacent to the north coast of Labrador, the nitrogen content ranges between 0.05 and 0.09 per cent. This indicates that the deposits contain about 1 per cent organic matter, which compared with the content of other marine sediments is very low.

As a rule the ignition loss aids the estimation of the organic content of sediments, but the samples from Davis Strait contain so much calcium carbonate that it is not of much assistance for these deposits. However, it is included in Table 5.

THE ORIGIN OF THE SEDIMENTS

Texture.—The sediments of Davis Strait are complex in origin. They contain a considerable quantity of ice-borne débris; the presence of frosted sand grains suggests wind transport; the large amount of very fine calcium carbonate particles may possibly (but not probably) be due to chemical precipitation; and the uneven sea floor and differential current action cause great variations in the texture of the deposits.

The submarine topography is the dominant factor governing the texture of the sediments of Davis Strait. Even though considerable quantities of ice-borne rock fragments are distributed throughout the deposits, the mechanical composition of the sediments is influenced greatly by the bottom configuration. Along the longitudinal series of samples adjacent to the Cumberland Peninsula, the sediments are coarsest on the highest point on the section and they become progressively finer as the water deepens on either side. The median decreases from 260 microns in a sample in 448 meters of water to 5 microns in 1,270 meters on the north, and 135 microns in 625 meters on the south. Sample 5, having a median of 163 microns lies in 420 meters, but it contains only 12 per cent gravel compared with 26 per cent in adjoining samples, and if the gravel is discounted, the two sediments have aproximately the same texture.

The samples along the lines eastward from Cape Murchison, similarly, vary in texture with the topography. Deposits that lie in 200 meters have medians of about 200 microns; sample 11, in 250 meters has 155 microns; sample 14, in 263 meters, 131 microns; sample 8 in 290 meters, 85 microns; and sample 15 in 1,500 meters, 21 microns.

Sample 19, in Hudson Strait in 575 meters, has a median of 208 microns. This shows clearly that it is not depth of water that is

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[4] P. D. Trask, Sedimentation of the Channel Islands Region, California. Econ. Geol., vol. 26, pp. 36–42, 1931.

the controlling factor, for this sediment lies in water nearly three times as deep as do the samples off Cape Murchison, yet the deposits have the same texture. Similarly the sediments east of Resolution Island show that the bottom configuration influences the deposits more than depth of water. The normal progression of decrease in

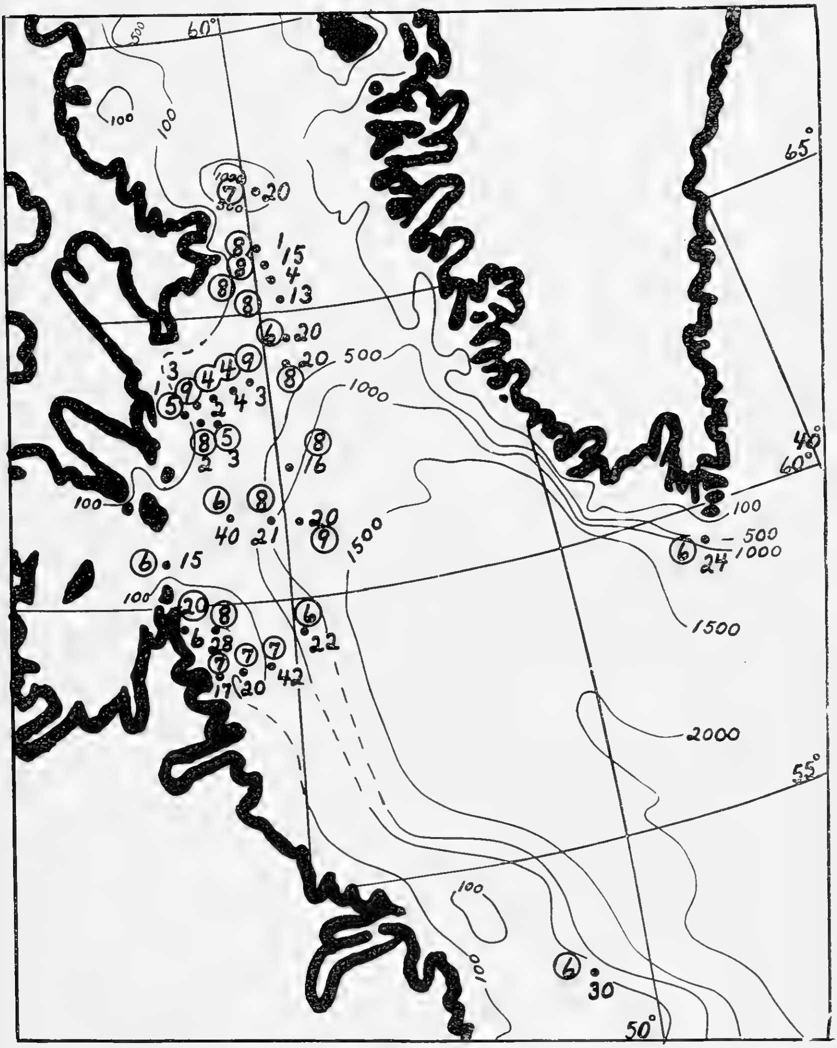

FIGURE 50

texture with increasing depth of water is interrupted by sample 17 on a relatively steep slope in 950 meters of water. The median of sample 17 is 62 microns, but sample 18 situated nearer shore in 250 meters less water, has a median of 20 microns. The section eastward from Aulalsivik, likewise, demonstrates the relative lack of influence of depth of water on the texture. Samples 20 and 21 lying in less than 150 meters of water have medians of 7 and 2.3 microns, respectively, but sample 22 on a fairly steep slope in 1,650 meters has a median of 73 microns. Samples 23, 24, and 25 lying in about 200 meters of water in a region of uneven sea floor have medians of 44 to 162 microns.

The phenomena mentioned above demonstrate that the texture of the sediments is strongly influenced by the submarine topography. However, in reality it is the motion of the sea water above the deposits that governs the size of the particles that accumulate in the sediments. The movement of the deep water is deflected and obstructed by submarine slopes and ridges. In this manner relatively strong currents are produced over many exposed slopes and ridges.[5] In fact, the relative coarseness of the deposits is a measure of the intensity of the movement of the lower part of the sea water.

Currents.—Smith and Mosby's[6] detailed investigation of the circulation of the water in Davis Strait, shows that a strong westerly current swings around Cape Farewell and up the west coast of Greenland. At various intervals as far north as latitude 75°, parts of it bend westward and slowly cross Davis Strait, where they join a strong southerly current, coming from Lancaster Sound. This southerly current continues down the east coast of Baffin Land across Hudson Strait and southward along the coast of Labrador. The dynamic topographic map of this region shows that in general the movement of water is parallel to the trend of the submarine slopes and scarps and that it is relatively rapid over steep slopes. The greatest intensity of circulation is in the upper layers of the water; but the coincidence of the relatively rapid movement of the upper part of the sea water with the coarseness of the deposits off Cape Farewell, off Cumberland Peninsula, and on the continental slope off Resolution Island and northern Labrador, demonstrates that in these regions the lower part of the sea water, especially that bathing the sea bottom, move with significant velocity. However, the movement of the deep water may be due to tides and not gradient currents.

The extremely fine sediments in the relatively shallow water off Aulalsivik lie in regions in which the dynamic gradient of the sea water is slight. This indicates that the circulation of the surface water is slow. The deposition of sediments having medians of 7 and 2.3 microns, in water less than 150 meters deep, demonstrates that the lower part of the water also is quiescent. The low gravel content likewise argues against strong current action. A similar explanation accounts for the large quantity of fine particles in sample 8, about 100 miles northeast of Cape Murchison.

The coarseness of the sediments of Hudson Strait indicates that they are washed by strong currents. Even though they lie in 575 meters of water they are very well sorted and have a median of 208 microns, which indicates that they are a medium to fine grained sand. Smith and Mosby's dynamic topographic map indicates only a slight circulation of water in this region, but it refers to move-

[5] See P. D. Trask, Op. cit., pp. 28–33.

[6] Edward H. Smith and Olav Mosby, The Physical Oceanography of Davis Strait, pt. 2 of Bulletin 19.

ments due to gradient forces and not to tides. The hydrographic charts issued by the United States Navy show currents of 5 knots in both directions through Hudson Strait. The coarseness of the sediments demonstrates that these currents extend with significant velocity to the bottom of the Strait.

Similarly the dynamic topographic map indicates a relatively slow movement of water over the well-sorted fine-grained sands northeast of Cape Murchison. Weeks [7] reports a tide of 25 to 35 feet in Cumberland Bay which lies northwest of this area. A tide of such dimensions necessitates a considerable forward and backward movement of water. As the sediments east of Cape Murchison are in the path of such oscillations, in water only 200 meters deep, it is evident they should be coarse.

Rock fragments.—The occurrence of gneiss, quartzite, and granitic rocks in the sediments is easily explainable, as the geologic maps and reports of Greenland, Baffin Land, and northern Labrador [8] demonstrate the prevalence of pre-Cambrian metamorphic and granitic rocks throughout this area. Basalt occurs on Disko Island, which if not the source of the occasional basalt fragments, at least indicates the presence of basic eruptives in the general region. Kindle [9] mentions the occurrence of Pleistocene shells in the lower part of the ice cap in west Greenland in latitude 74°. The eroded Pelecypod shell in sample 24 may have such an origin.

However, the widespread distribution of noncrystalline limestone is not so readily explainable. The land on both sides of Davis Strait, in the region from which the sediments come, is mapped as consisting almost entirely of pre-Cambrian formations. Crystalline limestones are plentiful in certain parts of the pre-Cambrian, but the noncrystalline aphanitic character of the limestone fragments in the deposits indicates they originated elsewhere. Excluding the sediments east of Cape Murchison, limestone occurs in almost every sample, and is the dominant rock type in most of the deposits.

Source of limestone.—The ubiquitousness of the limestone and its plentifulness in the deposits indicates that a very significant proportion of the rock fragments carried by the ice consists of limestone. The question is from where did the limestone come.

Drift ice on the west side of Davis Strait is estimated by Smith [10] as consisting of less than 2 per cent berg ice and more than 98 per cent pack ice. Shelf ice, extending from the shore seaward; the ice foot, that part of the shelf ice attached to the sea bottom; and anchor ice, originating on the sea bottom near shore, have opportunity both

[7] L. J. Weeks, Cumberland Sound Area, Baffin Land, Can. Geol. Surv. Sum. Rep., 1927 C, p. 86, 1928.

[8] Robert Bell, Report of Exploration of Hudson Strait Region, Can. Geol. Sur. Sum. Rep 1897 (Ann. Rep. 10) A, pp. 75–83, 1898.

Geologic Map of North America, U. S. Geol. Surv. 1911.

O. B. Böggild, The Geology of Greenland, Greenland, Publ. Com. Dir. Geol. and Geog. Investigations in Greenland, C. A. Reitzel, Copenhagen, pp. 185–231, 1928.

L. J. Weeks, op. cit., pp. 84–95.

Lauge Koch, Stratigraphy of Greenland, Dissertation for Doctorate, published by Levin and Munksgaard, Copenhagen, 1929 (contains good bibliography).

Geological Map of World, Preus. Landesanstalt, Berlin, 1930.

[9] E. M. Kindle, Ice Borne Sediments in Canadian and Other Arctic Waters. Am. J. S. v. 7. p. 277, 1924.

[10] Edward H. Smith, Arctic Ice, etc., pt. 3 of Bulletin 19, p. 190.

of transporting rock fragments and of forming part of the pack ice. However, the proportion of the pack ice of such origin is probably very small. Bergs on the other hand, are derived from glaciers, most of which contain considerable débris. Thus even though the pack ice occupies a much larger volume than the bergs, the bergs probably contribute many more rock fragments to the sediments.

Smith [11] estimates that 70 per cent of the bergs that flow down the west side of Davis Strait are derived from glaciers in the vicinity of Disko Island near latitude 70°; 20 per cent, from glaciers flowing into Melville Bay, about latitude 75°; and the remaining 10 per cent mostly from northern Greenland and the northern archipelago. A large number of bergs originate on the east side of Greenland, and flow around Cape Farewell and up the west coast of Greenland, but only a few cross Davis Strait and flow southward in the Labrador current.[12] The Labrador current, although somewhat interrupted, extends across the mouth of Hudson Strait; consequently bergs or pack ice coming through Hudson Strait, in all probability do not flow northward in Davis Strait. Therefore, limestone from the Paleozoic formations in the vicinity of Hudson Strait presumably is not deposited in the sediments of Davis Strait north of latitude 62°.

Böggild [13] found no limestone fragments in his detailed investigation of the bottom deposits off the east coast of Greenland between latitude 70° and 74°. This leads one to believe that the bergs arising north of this region carry practically no limestone. Very little non-crystalline limestone is reported from the east coast of Greenland south of this area.[14] Sample 26, lying off Cape Farewell in the path of the bergs arising in east Greenland, contains no limestone. Consequently one infers that almost none of the limestone in the sediments of Davis Strait comes from east Greenland.

Koch's [15] authoritative treatise of the stratigraphy of Greenland does not mention the occurrence of limestone in the vicinity of Disko Bay. However, he does state that the Agpat formation of early Algonkian age consists of quartzite, amphibolite, marble, dolomite, and clay shales which are more or less metamorphosed. This formation outcrops at intervals from Nugsuak, slightly north of Disko Bay, to Inglefield Gulf in North Greenland. From Koch's description of the formation one gathers the impression that the amount of non-crystalline aphanitic limestone this formation would supply the glaciers flowing into Disko Bay, would not constitute a large proportion of the rock fragments carried by these glaciers.

Koch [16] in 1918 mentioned the prevalence of granitic rocks in the vicinity of Melville Bay; but later [17] he reports the probable existence of the Agpat formation in this region, because he mentions its

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[11] Op. cit.
[12] E. H. Smith, op. cit., pp. 74–78.
[13] O. B. Böggild, Samples of the Sea Floor Along the Coast of East Greenland, 74½ to 70 N. L., Med. om Grönl. v. 28, pp. 17–85, 1909.
[14] See footnote 8.
[15] Op. cit., pp. 14–15 and 54–58.
[16] Lauge Koch, Den II Thule-Ekpedition til Melville-Bugten og Grönlands Nordkyst, 1916–1918, Geografisk Tidskrift Bind 24, Heft vi, 1918, p. 221.
[17] Lauge Koch, Stratigraphy of Greenland, 1929, p. 14.

occurrence between Umanak Fiord and Inglefield Gulf. He thinks[18] the southern border of the Paleozoic geosyncline of north Greenland coincides with the present border of the inland ice. If this is true, it means that the glaciers flowing into Melville Bay probably do not carry Paleozoic limestone fragments. The Agpat formation, as was mentioned previously, does not seem to be a likely source of unmetamorphosed limestone. Consequently one infers that the bergs from Melville Bay probably do not carry many limestone fragments.

Paleozoic limestone is plentiful along the north coast of Greenland, and limestone also occurs in numerous places in the northern archipelago. According to Smith,[19] bergs from these two regions form 10 per cent of the bergs of Davis Strait. One can not assume that the rock débris they carry consists entirely of limestone fragments, but since the glaciers that produce limestone-bearing bergs, flow over a limestone terrain it is probable that the concentration of rock fragments in the ice overlying such areas would be greater than that in ice overlying a gneiss or granite region. Therefore the limestone transported by the bergs from north Greenland and the northern archipelago may constitute more than 10 per cent of the rock fragments in the sediments of Davis Strait. Pack ice from limestone regions, and bergs from Disko and Melville Bays presumably contribute some limestone to the deposits, but if they do not add enough to account for the large quantity of limestone in the sediments, one must consider the hypothesis that more than 10 per cent of the bergs of Davis Strait have sources other than Disko and Melville Bays. Further study of the problem is needed to solve it satisfactorily. It would be especially advantageous to know the types of rock fragments carried by the berg-forming glaciers.

Comments of Lauge Koch.—The question of the origin of the limestone fragments in the sediments was referred to Dr. Lauge Koch, who has spent many years in Greenland. He kindly replied as follows:[20]

Along the west coast of Greenland from Cape Farewell to at least 70° North latitude noncrystalline limestone is entirely absent. The whole of west Greenland as far as Disko Bay is made up of gneisses, granites, etc., with the exception of a small area, near Cape Farewell, of red sandstone (age probably pre-Cambrian) which may here be left out of consideration. I think we know the land from Cape Farewell to Disko Bay so well that we are safe in concluding that noncrystalline limestone does not occur along this whole stretch, nor do the moraines of the inland ice in any place seem to indicate the presence of limestone-bearing formations below the ice cap.

From 70° North latitude northward to Cape Alexander (the westernmost point of Greenland) there is not the slightest indication of noncrystalline limestone. The moraines of the inland ice are here less well known, but everywhere where they have been examined—I may here speak of my own investigations along practically the whole coast—the moraines contain no sediments. (An old statement about the finding of a block of red sandstone in the vicinity of the inland ice east of Umanak has not been confirmed.) In the interior of the Umanak district crystalline limestone and marble of undoubted pre-Cambrian age occurs in association with granites and gneisses.

As you no doubt know, Disko Island, parts of the Nugsuak Peninsula and the regions north thereof, including parts of the Svartenhuk Peninsula, are

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[18] Op. cit., pp. 66–67.
[19] Loc. cit.
[20] Letter of Mar. 4, 1931.

partially made up of sediments up to 1,000 meters thick, consisting largely of sandstones and shales. If limestones are present here, they form at any rate, only quite subordinate beds and are highly arenaceous. As far as I remember, limestone is not mentioned in the literature concerning this region. The age of the sediments is late Cretaceous to lower Tertiary (mostly Senonian, Paleocene, and Eocene, with plant beds).

Along the stretch between Cape York and the Humboldt Glacier we find sediments more than 1,000 meters thick, consisting of conglomerates and sandstone, greywacke, and dolomite (Thule formation, age late pre-Cambrian), but it is characteristic of this formation that it contains no limestone whatever, only dolomite. On Inglefield Land south of Humbolt Glacier we find in two places within the sandstone series of the Thule formation, thin beds with traces of lime, but here the Thule formation is overlain by 200 to 300 meters of limestone (age lower Middle Cambrian and Ozarkian).

North of Humboldt Glacier, the greater part of Washington Land and the southern part of Hall Land consist of limestone (age Cambrian up to and including Silurian); the thickness is at least 800 meters.

On crossing to Baffin Land, which I do not know personally, we find around the southern lakes west of Frobisher Bay extensive, but probably very thin beds of limestone, presumably of Ordovician age. The Danish "Godthaab" expedition in 1928 went ashore for a few hours on the east coast of Baffin Land, as far as I remember in about 67° North latitude, and from this place brought back some few sediments, which, as far as I recollect, consisted mostly of shales, but also, I think, contained some limestone. In the northern part of Baffin Land sediments likewise occur, chiefly sandstone (Tertiary), and farther toward the interior of Lancaster Sound we find the old localities with Ordovician and Silurian limestone. North Devon is very little known, but on the west side sediments probably occur. As is well known, Schey found limestone, representing several of the Paleozoic formations, in Jones Sound.

As you will see, it seems quite impossible that the limestone on the bottom of Davis Strait has come from west Greenland. A transport of limestone from Kane Basin during the maximum of the glacial epoch is not quite improbable. There is no doubt that the entire eastern part of Kane Basin has been built up of Cambrian and Ozarkian intraformational limestone, and that these formations, because of their softness, have been removed by erosion. On Carey Islands in Smith Sound, which are exclusively made up of gneiss, I have found loose blocks of dolomite, but they must have been transported by glaciers or icebergs.

As to conditions along the west side of Baffin Bay and Davis Strait I must speak with the greatest caution. It is possible that the older Paleozoic beds formerly may have had a far wider distribution on Baffin Land, from which they have been removed and during Pleistocene time transported by glaciers into Davis Strait. Recently, however, it has been pointed out, no doubt rightly, by an Indian geologist, that as a rule glaciers do not carry morainic material very far. In this connection we may consider the formation of the Newfoundland Banks. It seems not easy to explain that the material of which the Newfoundland Banks consist was transported by icebergs all the way from Disko Bay. Experience seems to show that icebergs rather soon discharge the morainic material they may contain. Usually morainic débris occurs either on top of the bergs or in the form of very marked stripes in the bergs. These bands naturally form weak points, and when warmed by the sun appear as furrows and cause the bergs to split along these stripes.

It is doubtless quite right that morainic material is not transported very far by icebergs. But there may be other explanations. I do not know how it sounds in American ears that Baffin Bay might represent a subsided area, in other words that the area of Baffin Bay has once been a land area. In Stratigraphy of Greenland I have pointed out that in my opinion there are slight indications of a geosyncline in the present area of Davis Strait. In this connection I may mention the rather deeply subsided late Algonkian sediments both near Cape Farewell and in the Cape York district, as well as possibly in the vicinity of Disko Bay. But the development of the geosyncline in Davis Strait seems not to have continued.

I am afraid it will be very difficult to explain the presence of these large quantities of pure limestone on the bottom of Davis Strait. That they should originate from Disko Bay or Umanak Fjord, I would consider quite impossible. Nor does it seem probable that they originate from Kane Basin. In such case an exceedingly strong erosion in connection with an improbably long transport toward the south by the aid of icebergs must have taken place here during glacial times. A transport from Baffin Land seems on the basis of our extremely slight knowledge of the geology of this region to be the most natural explanation, provided we will not explain the process by the aid of considerable subsidences round Davis Strait, Wegener's theory, etc.

Frosted sand grains.—The frosted well-rounded grains of sand that constitute a very minor part of the sediments, may be of Eolian origin, but they also may be produced in water by attrition. The apparent decrease in plentifulness of polished constituents away from shore accords with the Eolian hypothesis. However, even if these frosted grains are of wind origin, the following questions arise: Were they blown to the neighborhood of their final resting place, either through air or along the surface of the ice; were they blown onto ice and then transported to their place of burial; or were they carried relatively long distances through the water by currents? Unfortunately, insufficient data are available to answer these questions.

Finely divided calcium carbonate.—Calcium carbonate forms a large part of the fine constituents in most of the sediments; but it has not been practicable to investigate this finely divided $CaCO_3$. It may be a chemical precipitate, it may result from wind-blown calcium carbonate dust; it may be a deposit-like clay resulting from particles suspended in the water, or it may be ice borne.

In view of the apparent absence of a local limestone source it seems that the ice-borne origin is more probable. This is also supported by the observation that the sediments off Cape Murchison are deficient in limestone fragments and that sample 8 from the same region contains a large amount of fine constituents, but almost no $CaCO_3$. It would appear from this that the source of débris in the Cape Murchison sediments is to a large extent the adjacent coast of Baffin Land and only to a small degree, floating ice from distant areas. Sample 20, off Aulalsivik, contains no limestone rock fragments, and although it is a fine-grained deposit, it contains little $CaCO_3$. In other parts of Davis Strait, limestone is a plentiful constituent of the gravel and also calcium carbonate particles form a significant part of the fine fraction of the deposits. Furthermore, because of its softness, limestone is readily abraded by ice action; therefore, one would expect that a considerable quantity of finely divided $CaCO_3$ would be trapped in adjacent ice. If this were carried out to sea it would form a deposit relatively rich in detrital $CaCO_3$. Thus, the ice-borne origin of the calcium carbonate is in accord with all the known facts. Whether or not it is the true explanation will depend on future work.

CHARACTERISTICS OF SEDIMENTS OF ICE-BORNE ORIGIN

Two factors dominate the formation of sediments of ice-borne origin; one the heterogeneous nature of the detritus brought by the ice, and the other the action of the currents. The débris brought by the ice is very poorly sorted, and if it falls in a region in which currents are weak, the coefficient of sorting of the deposits will be very large and the coefficient of skewness may differ greatly from unity. If, however, the detritus falls in a region of strong current action the deposits will be well sorted, that is, the coefficient of sorting will be small; but the skewness will be much larger than unity because of the plentifulness of rock fragments, which cause the first quartile to be large. These qualities of the coefficient of sorting and skewness may not be unique for deposits of ice-borne origin, but they should aid in the determination of the manner of formation of sediments of unknown derivation. However, as has long been recognized, the presence of faceted subrounded rock fragments is an important diagnostic criterion of an ice-borne origin.

TABLE 1.—*General description*

Sample No. [1]—	Station No. [2]—	Serial No. [3]—	Latitude		Longitude		Depth (meters)	Description
Davis Strait, longitudinal section:			°	′	°	′		
1	1016	601	67	13	59	20	1,270	Gray clay and pebbles.
2	1019	599	66	12	59	47	700±	Gray silt, sand, and pebbles.
3	1020	609	65	54	59	26	570	Gray fine-grained sand and pebbles.
4	1021	604	65	37	59	5	418	Do.
5	1022	607	65	23	59	4	420	Gray sand, silt and pebbles.
6	1024	612	64	35	59	3	510	Do.
7	1025	605	61	7	59	6	625	Do.
Cape Murchison:								
Northeast—								
8	1027	610	63	56	60	46	290	Do.
9	1028	1577	63	52	61	25	210	Gray fine-grained sand and pebbles.
10	1029	1579	63	48	62	11	210	Buff fine-grained sand and pebbles.
11	1030	614	63	44	62	44	250	Gray fine-grained sand and pebbles.
12	1031	1580	63	41	63	21	200	Buff sand, silt, and pebbles.
Southeast—								
13	1032	615	63	29	62	43	201	Do.
14	1033	1578	63	17	62	5	263	Do.
15	1037	1576	62	19	59	30	1,500	Gray clay, silt, and pebbles.
Resolution Island, east:								
16	1041	600	61	26	59	32	2,300	Gray clay and pebbles.
17	1042	608	61	32	60	26	950	Buff sand, silt, and pebbles.
18	1044	611	61	32	62	5	700±	Buff fine-grained sand and pebbles.
Hudson Strait:								
19	1050	1575	60	53	64	43	575	Do.
Aulalsivik, east:								
20	1051	602	59	40	63	52	65	Gray clay, silt, and pebbles.
21	1053	613	59	48	63	38	152	Gray clay.
22	1060	603	59	27	59	48	1,650	Gray silt and pebbles.
Mount Blow Me Down, east:								
23	1058	1571	58	55	60	54	190	Gray fine-grained sand and pebbles.
24	1056	1572	58	33	61	54	149	Do.
25	1054	1573	58	52	62	52	102	Gray clay.
Cape Farwell, south:								
26	1081	1574	59	32	44	50	462	Do.
Southern Labrador, east:								
27	1098	1570	52	55	51	36	855	Do.

[1] Writer's sample number.
[2] Station number from Marion expedition. See oceanographic station table in Smith and Mosby, op. cit.
[3] Serial number in writer's general collection.

TABLE 2.—*Mechanical analyses*

Sample No.	Statistical constants					
	Q_1	M	Q_3	So	Sk	Log Sk
1	2	3	4	5	6	7
Davis Strait, longitudinal section:						
1	70.0	5.0	1.3	7.35	3.65	+0.55
2	210.0	145.0	60.0	1.87	.60	−.22
3	430.0	190.0	73.0	2.42	.87	−.06
4	1050.0	260.0	133.0	2.81	2.06	+.31
5	228.0	163.0	95.0	1.55	.82	−.09
6	1100.0	185.0	28.0	6.37	.91	−.04
7	230.0	135.0	35.0	2.56	.44	−.35
Cape Murchison:						
Northeast—						
8	250.0	85.0	1.3	13.90	.05	−1.25
9	1500.0	210.0	125.0	3.46	4.24	+.63
10	715.0	222.0	131.0	2.33	1.90	+.28
11	800.0	155.0	60.0	3.64	2.00	+.30
12	430.0	200.0	127.0	1.84	1.36	+.13
Southeast—						
13	1100.0	182.0	65.0	4.12	2.16	+.33
14	184.0	131.0	62.0	1.74	.67	−.18
15	92.0	21.0	5.0	4.30	1.04	+.02
Resolution Island, east:						
16	35.0	5.9	1.5	4.83	1.51	+.18
17	248.0	62.0	1.4	13.35	.09	−1.04
18	175.0	20.0	3.0	7.62	1.31	+.12
Hudson Strait:						
19	390.0	208.0	120.0	1.80	1.08	+.03
Aulalsivik, east:						
20	16.0	7.0	2.9	2.35	.95	−.02
21	12.5	2.3	.62	4.50	1.47	+.17
22	300.0	73.0	5.7	7.25	.32	−.49
Mount Blow Me Down, east:						
23	190.0	44.0	4.5	6.50	.44	−.35
24	340.0	162.0	47.0	2.69	.61	−.22
25	345.0	125.0	5.1	8.24	1.13	+.05
Cape Farewell, south:						
26	340.0	180.0	60.0	2.38	.63	−.20
Southern Labrador, east:						
27	22.0	9.3	2.4	3.03	.61	−.22

Explanation: Q_1, first quartile; M, median, Q_3, third quartile; So, coefficient of sorting; Sk, coefficient of skewness; Log Sk, logarithm of coefficient of Sk.

TABLE 3.—*Mechanical analyses*

Sample No.	Size fractions				
	Gravel, 1-30 millimeters	Sand, 0.05-1 millimeter	Silt, 0.005-0.05 millimeter	Clay, 0.001-0.005 millimeter	Colloid, 0-0.001 millimeter
1	2	3	4	5	6
Davis Strait, longitudinal section:					
1	9	20	21	34	16
2	8	71	9	7	6
3	15	64	6	8	7
4	26	62	5	4	2
5	12	72	8	4	4
6	26	46	14	7	7
7	10	63	12	8	7
Cape Murchison:					
Northeast—					
8	18	39	9	12	22
9	29	62	4	3	2
10	21	69	7	2	1
11	23	59	10	4	4
12	13	75	8	3	1
Southeast—					
13	26	55	14	3	2
14	2	79	14	3	2
15	4	30	41	12	13

TABLE 3.—*Mechanical analyses*—Continued

Sample No.	Size fractions				
	Gravel, 1-30 millimeters	Sand, 0.05-1 millimeter	Silt, 0.005-0.05 millimeter	Clay, 0.001-0.005 millimeter	Colloid, 0-0.001 millimeter
1	2	3	4	5	6
Resolution Island, east:					
16	4	17	34	28	17
17	15	38	17	10	20
18	12	30	28	16	14
Hudson Strait:					
19	8	74	8	4	6
Aulalsivik, east:					
20	3	10	48	27	12
21	1	4	36	23	36
22	18	39	20	11	12
Mount Blow Me Down, east:					
23	11	36	26	12	16
24	16	58	18	5	3
25	15	49	12	7	17
Cape Farewell, south:					
26	18	60	10	5	7
Southern Labrador, east:					
27	0	10	50	20	20

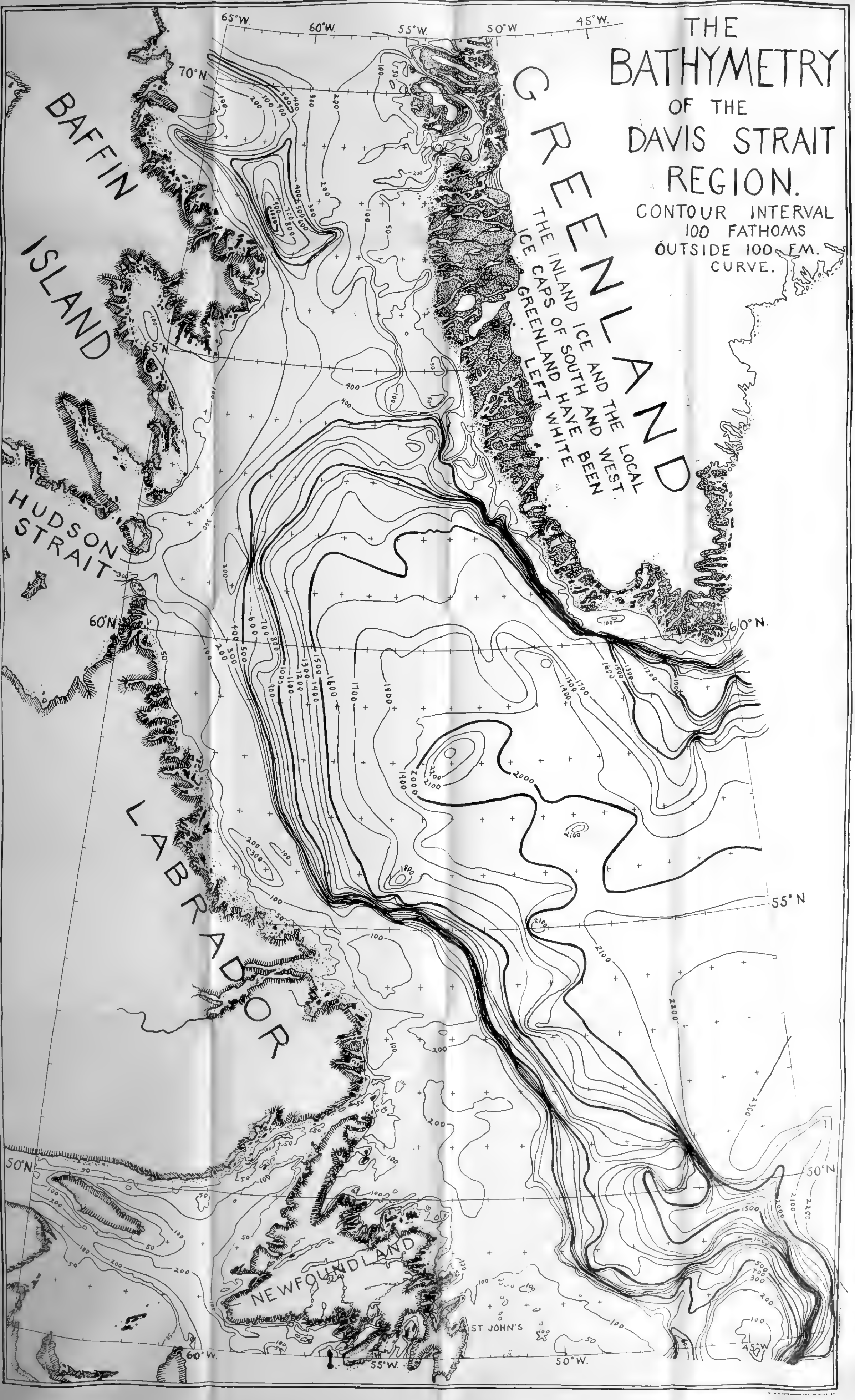
TABLE 4.—*Details of sand and gravel*

Sample No.	Coarse gravel, 3-30 millimeters	Fine gravel, 1-3 millimeters	Coarse sand, 0.5-1 millimeter	Medium sand, 0.25-0.05 millimeter	Fine sand, 0.125-0.25 millimeters	Very fine sand, 0.05-0.125 millimeters
Davis Strait, longitudinal section:						
1	4.3	5.1	1.2	1.6	5.4	11.6
2	5.5	2.2	1.0	2.6	49.1	18.2
3	4.1	10.9	7.3	14.8	33.8	8.3
4	9.5	16.5	12.3	13.1	27.3	8.9
5	8.1	3.3	2.0	4.4	53.4	12.6
6	17.2	9.1	5.1	6.4	22.6	11.6
7	6.0	4.0	4.4	6.6	34.0	17.7
Cape Murchison:						
Northeast—						
8	9.5	8.6	2.6	3.6	21.0	11.6
9	20.0	9.0	4.5	8.5	33.4	16.0
10	4.7	16.3	9.8	12.0	35.6	11.8
11	18.4	4.6	6.3	8.5	19.4	24.8
12	2.8	9.8	8.7	17.1	37.4	11.6
Southeast—						
13	19.4	6.5	6.5	8.9	18.7	21.0
14	0.0	1.8	0.7	0.9	51.7	26.4
15	2.1	2.0	2.2	3.5	11.2	12.9
Resolution Island, east:						
16	2.3	1.9	1.4	1.6	4.8	9.1
17	9.1	6.2	4.2	5.2	14.0	14.7
18	2.7	8.9	3.0	4.2	12.0	11.3
Hudson Strait:						
19	3.2	4.7	8.3	25.4	32.3	8.3
Aulalsivik, east:						
20	2.9	0.0	0.7	0.7	5.4	3.1
21	0.6	0.9	0.7	0.7	1.3	1.2
22	9.1	8.9	3.6	5.4	19.6	10.5
Mount Blow Me Down, east:						
23	2.3	8.7	3.0	4.4	17.2	11.8
24	6.5	9.9	5.2	7.1	37.2	8.5
25	2.6	12.2	5.8	7.7	22.1	13.5
Cape Farewell, south:						
26	9.4	8.6	5.2	12.0	32.3	11.4
Southern Labrador, east:						
27	0.0	0.0	0.0	0.2	3.0	6.8

TABLE 5.—*General data*

Sample No.	Per cent ignition loss	Per cent nitrogen	Per cent $CaCO_3$	Rock type	Relative frosting of grains
1	2	3	4	5	6
Davis Strait, longitudinal section:					
1	14.0	0.07	20	Quartzite, limestone, gneiss	1
2	5.8	.08	1	Limestone, granite, hornblendite	2
3	7.9	.08	15	Granite—quartzite	3
4	3.9	.08	4	Gneiss, limsetone, hornblendite	2
5	8.0	.08	13	Granite—limestone	3
6	11.3	.06	20	Limestone—Gneiss, granite	3
7	9.5	.08	20	Limestone—hornblendite, granite	1
Cape Murchison:					
Northeast—					
8	4.6	.09	3	Granite—quartzite	3
9	2.0	.04	4	Limestone, gneiss, granite	3
10	2.2	.04	2	Quartzite, gneiss—granite, limestone	3
11	4.5	.09	3	Gneiss, granite—limestone	2
12	2.4	.05	1	Quartzite, gneiss	3
Southeast—					
13	3.2	.08	2	Gneiss—quartzite	2
14	3.3	.05	3	Quartzite	2
15	10.1	.08	16	Limestone—gneiss, quartzite	2
Resolution Island, East:					
16	11.4	.09	20	Limestone, hornblendite	2
17	15.5	.08	21	Limestone—quartzite	2
18	18.2	.06	40	Gneiss, granite, limestone	2
Hudson Strait:					
19	5.7	.06	15	Limestone—gneiss, quartzite, basalt	3
Aulalsivik, East:					
20	8.7	.20	6	Granite	
21	20.5	.08	28	Gneiss	2
22	12.8	.06	22	Limestone—granite, gneiss	1
Mount Blow Me Down, East:					
23	15.0	.07	42	Hornblendite — basalt, limestone, quartzite.	2
24	8.1	.07	20	Limestone—basalt, shell, granite	2
25	9.1	.07	17	Gneiss—limestone	2
Cape Farewell, south:					
26	10.6	.06	24	Gneiss, quartzite	1
Southern Labrador, east:					
27	16.7	.06	30		2

Rock types given in order of decreasing plentifulness. Types preceded by a dash are present in only small quantities.


THE
BATHYMETRY
OF THE
DAVIS STRAIT
REGION.
CONTOUR INTERVAL
100 FATHOMS
OUTSIDE 100 FM.
CURVE.
GREENLAND
THE INLAND ICE AND THE LOCAL
ICE CAPS OF SOUTH AND WEST
GREENLAND HAVE BEEN
LEFT WHITE
BAFFIN
ISLAND
HUDSON
STRAIT
LABRADOR
NEWFOUNDLAND
ST JOHN'S
65°W.
60°W.
55°W.
50°W.
45°W.
70°N.
65°N.
60°N.
55°N.
50°N.