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SUBMARINE TOPOGRAPHY AND BOTTOM SEDIMENTS
OFF THE SOUTHEAST COAST OF ICELAND

A dissertation submitted to the
Graduate School of Arts and Sciences
of the University of Cincinnati

in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE

1955

by

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INTRODUCTION

General Statement and Acknowledgments

During the winters of 1947-1950 the writer made for the Woods Hole Oceanographical Institution, Woods Hole, Massachusetts, a study of the ocean bottom sediments and submarine topography surrounding Iceland. The study was based primarily on data from British Admiralty hydrographic charts, supplemented by information from the U. S. Navy Department SAILING DIRECTIONS FOR EAST GREENLAND AND ICELAND (29) and numerous papers on the geology and oceanography of Iceland and the northern Atlantic Ocean. Emphasis was placed on the distribution of the larger areas of bottom sediments as represented on the hydrographic charts.

For the present study a smaller area off the southeastern coast of Iceland has been investigated in greater detail. An attempt has been made to contour the submarine topography on the basis of available soundings, using a contour interval of 10 fathoms, and to show by coloring the distribution of the bottom sediments in relation to the features of submarine topography.

The writer wishes to express his gratitude to members of the Alaskan Permafrost Section of the U. S. Geological Survey and to faculty members of the Department of Geology and Geography, University of Cincinnati, for their suggestions and comments in the preparation and revision of the manuscript. To his wife, Lydia, the writer is indebted for her valuable assistance in translating a number of readings in German and Danish.

Procedure of Investigation

In making the present study the writer used the hydrographic chart B. A. (British Admiralty) 2980, approximate scale 1:270,000, which shows the ocean bottom off the southeastern coast of Iceland, from the shore out to depths of over 900 fathoms. To this chart supplementary soundings were added west of 18 degrees 30 minutes West Longitude from B. A. 2968, approximate scale 1:111,350, and across the entire chart south of the 100-fathom line from B. A. 565, approximate scale 1:750,000. The hydrographic chart was then contoured, using a five fathom interval from the coast out to about the 100-fathom line and a 20-fathom interval beyond that depth.

For reproduction of the final map (Plate 2) the scale was reduced to approximately 1:375,000 and only the 10-fathom and 100-fathom contours used, instead of the smaller intervals employed on the work sheet. In places where the 10-fathom interval was considered too large to show the desired detail, segments of the 5-fathom lines were included as fragmentary contours. In addition to the contour lines, key soundings were added from the hydrographic chart to depict the highest and lowest points of various topographic features and depression hachures drawn to indicate the enclosed basins.

Certain weaknesses are inherent in contouring a published hydrographic chart. On B. A. 2980 the distance between soundings, including the supplementary soundings added, is from 1/2 mile to 2 miles within 12 miles of the coast; beyond 12 miles from shore the distance ranges from 2 to 10 miles, and in the southern part of the chart, where great depths of water are encountered, it is even greater.

With such widely spaced soundings several interpretations of a topographic feature are possible, and a choice among these would advantageously be guided by knowledge of the general geomorphic history of the surroundings. Accordingly, after completing the preliminary contouring, the writer revised the delineation where it seemed desirable in the light of the geomorphology of the surrounding sea bottom and adjacent land. Where the soundings were more than 5 miles apart he used dashed contour lines; in the more profound oceanic depths, where no soundings appeared, he approximated contours from the Carte Générale Bathymétrique des Océans (2) and inserted question marks into the dashed lines.

After completion of the contouring, the bottom sediment and rock notations on the hydrographic chart were analyzed, and five bottom types were chosen and mapped. Where bottom notations were scarce or missing entirely, the type of bottom was inferred from the nature of the topography. In such cases a banded color was used rather than a solid.

Bottom Types Used in Mapping

Five bottom types are mapped on Plate 3. These are: sand, gravel, mud, mud and sand, and rock.

The sand is mostly fine grained, according to the bottom notations on the hydrographic chart. Mineralogically it is composed for the most part of volcanic materials, being derived from the glacial, stream, and wind erosion of Iceland's volcanic rocks or else directly from volcanic eruptions (26).

The gravel ranges from pebble through cobble size and is believed to be derived largely from the glacial erosion of volcanic rocks.

Several notations of "rock" have been construed as boulders rather than bedrock and have been included in gravel zones. This is based on their location on ridges interpreted as lateral moraines extending out into the sea.

The mud ranges from clay to silt in particle size and is largely of volcanic origin, although it may contain a certain amount of organic matter. The "mud and sand" bottom type includes sediments ranging from clay through sand in particle size.

Rock bottom is mapped only where the hydrographic chart shows rocky islets and rocks awash, or where an unusually pronounced topographic prominence suggests bedrock may be outcropping through the sediments.

Since bottom notations are the chief source of information in this study, the authenticity of the bottom types mapped depends upon the accuracy of the notations. Shepard, in his report on the continental shelf sediments written for the symposium "Recent Marine Sediments" (27), states that although lacking in geological training the hydrographer usually describes the samples as reliably as a geologist could without microscopic examination. Sand and gravel are almost always determined accurately. The finer sediments, labelled "mud", may be interpreted geologically as predominantly silt and clay. In another paper (21) he states that the term "ooze", when used on continental shelves, is probably applied to "soft liquid mud which resembles deep-sea ooze in appearance but is not of organic origin."

In the passage from "Recent Marine Sediments," Shepard writes, regarding rock bottom:

"The term 'rocky' is generally based either on the finding of dents or scars on the sounding lead or on the presence of angular rock fragments in the sample. Such observations do not prove that ledge rock has been encountered, as both the scratches and the angular fragments could come from the presence of sporadic boulders carried out by ice or by vegetation rafts. On the other hand, where the report of rocky bottom is indicated by several observations from one area it appears unlikely that sporadic fragments could be the cause, and, therefore, one can be fairly confident that ledge rock crops out on the bottom."

II. REGIONAL SETTING

Physical Geography of Iceland

Iceland, an island with an area of about 40,000 square miles, lies in the North Atlantic Ocean between the parallels of $63^{\circ} 23'$ and $66^{\circ} 33'$ North Latitude and the meridians of $13^{\circ} 28'$ and $24^{\circ} 32'$ West Longitude. Its northern promontories just touch the Arctic Circle (Figure 1). It is about 180 miles southeast of the southeastern coast of Greenland, about 600 miles west of Norway, and about 400 miles northwest of Scotland.

Topographically Iceland is a plateau, bordered in places by coastal lowlands. These lowlands are broadest and most extensive along the south coast. Where they are completely lacking, as along the east and northwest coasts, the sea beats directly against the eroded cliffs of the plateau edge.

The lowland behind the western part of the south coast near Stokkseyri, known as the Southwestern Lowland (Plate I), is about 1500 square miles in area. It is essentially an alluvial plain, increasing gradually in altitude from sea level along the coast to about 300 feet at the inner edge, 30 miles in the interior. Rivers and streams flow across it from the interior plateau, while small lakes and bogs are to be found in all parts (16). The coast is marked by a line of barrier beaches resulting from the heavy surf that continually rolls in from the Atlantic Ocean. The interior boundary is marked by the hills and low mountains forming the ragged edge of the plateau. Erosional remnants of these hills, separate from the main plateau, occur in places out in the lowland.

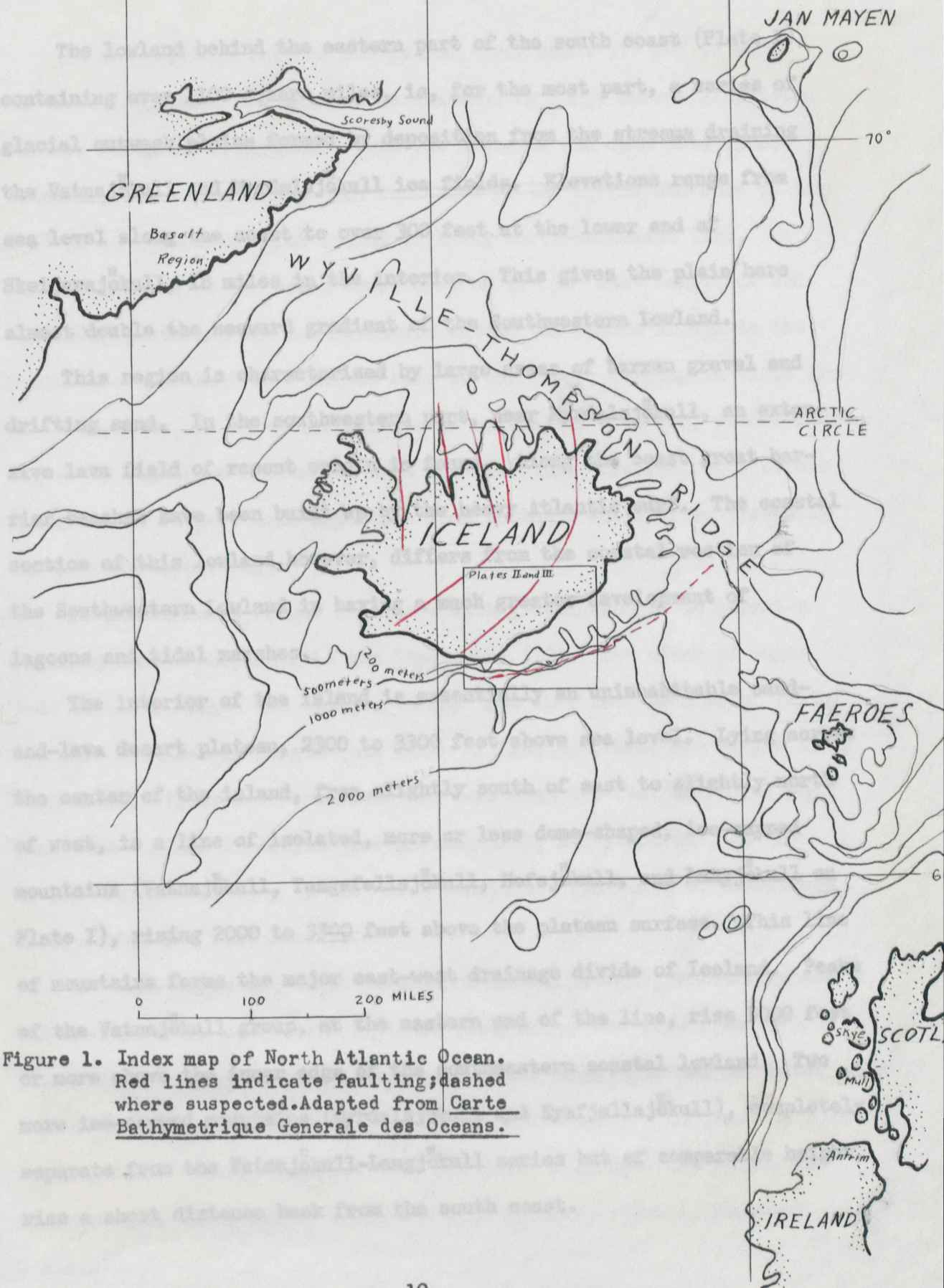


Figure 1. Index map of North Atlantic Ocean. Red lines indicate faulting; dashed where suspected. Adapted from Carte Bathymetrique Generale des Oceans.

The lowland behind the eastern part of the south coast (Plate I), containing over 1100 square miles, is, for the most part, a series of glacial outwash plains formed by deposition from the streams draining the Vatnajökull and Myrdalsjökull ice fields. Elevations range from sea level along the coast to over 300 feet at the lower end of Skeidarajökull, 18 miles in the interior. This gives the plain here almost double the seaward gradient of the Southwestern Lowland.

This region is characterized by large areas of barren gravel and drifting sand. In the southwestern part, near Myrdalsjökull, an extensive lava field of recent origin is found. Along the coast great barrier beaches have been built up by the heavy Atlantic surf. The coastal section of this lowland, however, differs from the coastal section of the Southwestern Lowland in having a much greater development of lagoons and tidal marshes.

The interior of the island is essentially an uninhabitable sand- and-lava desert plateau, 2300 to 3300 feet above sea level. Lying across the center of the island, from slightly south of east to slightly north of west, is a line of isolated, more or less dome-shaped, ice-capped mountains (Vatnajökull, Tungafellsjökull, Hofsjökull, and Langjökull on Plate I), rising 2000 to 3300 feet above the plateau surface. This line of mountains forms the major east-west drainage divide of Iceland. Peaks of the Vatnajökull group, at the eastern end of the line, rise 3000 feet or more above the inner edge of the southeastern coastal lowland. Two more ice-capped mountains (Myrdalsjökull and Eyafjallajökull), completely separate from the Vatnajökull-Langjökull series but of comparable height, rise a short distance back from the south coast.

In the northern part of the island, from about 17° 30' to about 21° West Longitude, the plateau is trenched by long, narrow alluviated valleys which trend northward from the interior and open into fjords indenting the north coast. The formation of the fjords and some of the valleys is associated with faults striking north-northwest (18).

Commencing at the north coast east of 17° 30' West Longitude and extending southward and southwestward across the entire island to the Southwestern Lowland is a curved belt of territory, varying in width from 60 to 90 miles, in which the terrain is controlled either by recent faulting or by vulcanism associated with the faulting. Erosion, both stream and glacial, is here less important than tectonic activity in producing the present topography.

In places horst ridges alternate with graben troughs to impart a striking linear character to the topography (10). The order of magnitude of these ridges and troughs varies from 1000 feet or more of relief and over 15 miles in length (see basin of Langisjor Lake and ridges along both sides, Figure 2 - West Sheet) to less than 200 feet of relief and less than 2 miles in length (see unnamed hill, elevation 643, at 64° 11-1/2' North Latitude, 18° 48' West Longitude, southeast of Thorisvatn Lake, Figure 2 - West Sheet).

In addition to the horst ridges and graben troughs, volcanic cones and craters occur frequently in lines paralleling the same trend (i. e. Vatnaöldur, row of volcanic cones, and Veidivötn, row of crater lakes, in west-central part of Figure 2 - West Sheet). In places floods of lava from fissure eruptions have partially submerged the ridges and troughs (i.e. lava fields south and west of Skaftorjökull, Figures 2 and 3).

EAST S

GEOÐÆTISK



(76 Grimevötu

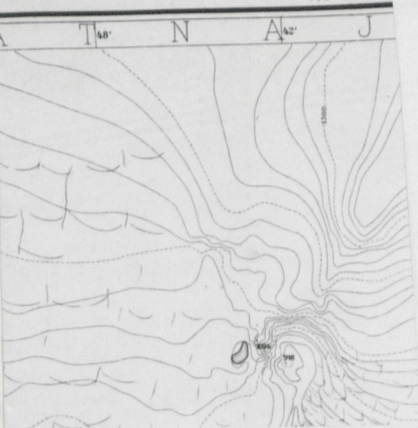
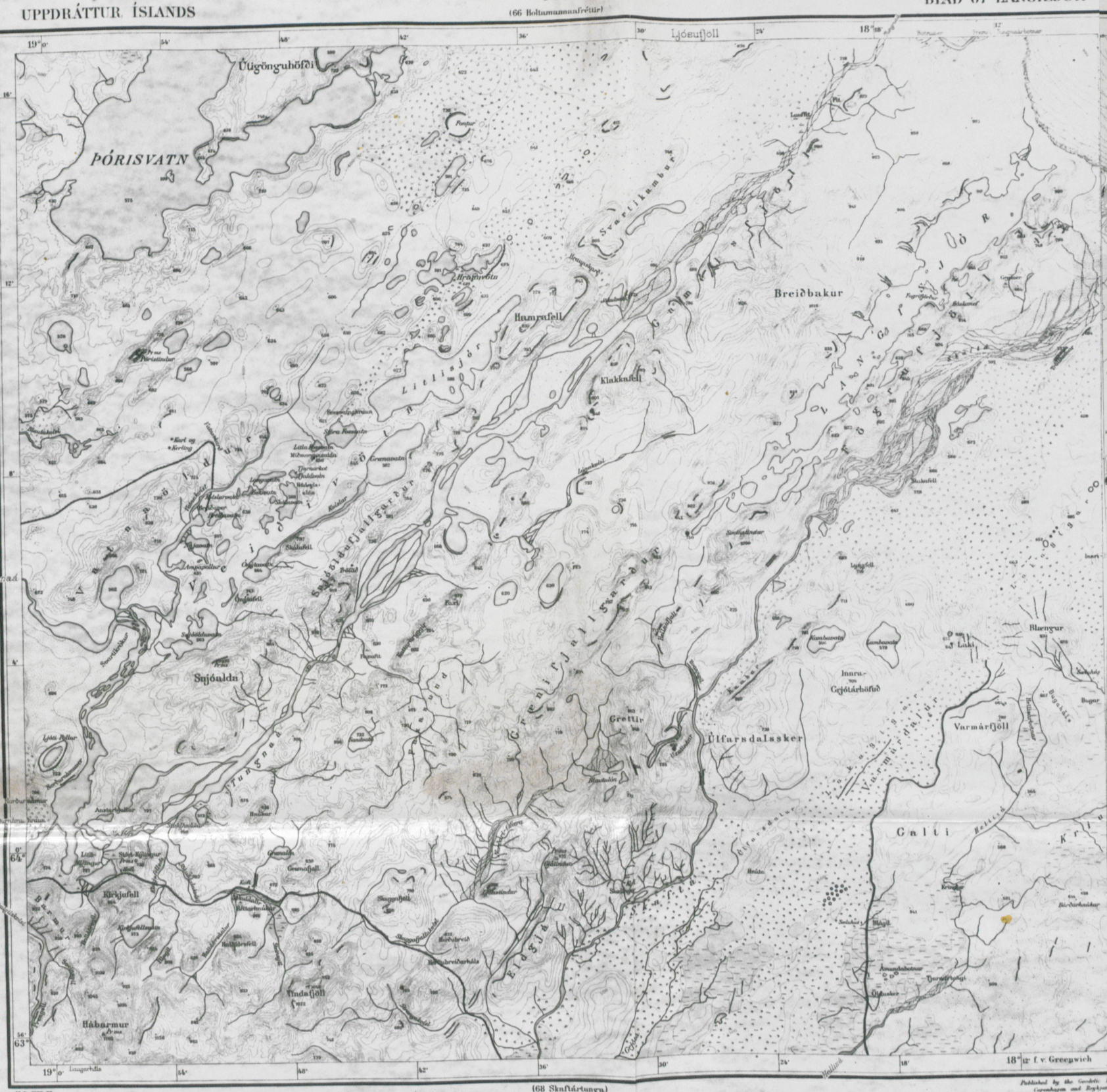


Figure 2. Topographic map of region southeast of Skaftarjökull.



1:100 000 (68 Skafárstunga) Published by the Geodetic Institute, Copenhagen 1944.

1:100 000 (78 Kirkjubæjarklaustur) Published by the Geodetic Institute, Copenhagen 1944.

Legend for the West Sheet map, detailing symbols for terrain, water, and infrastructure.

Legend for the East Sheet map, detailing symbols for terrain, water, and infrastructure.



Figure 3. View looking northwest across Skaftarjökull. Lava fields in left middleground. Langisjör Lake in left background, behind first range of mountains. Photo by Steinthor Sigurgeirsson.

North of 65° North Latitude the dominant trend of the ridges and troughs is north-south, the same as the trend of the belt; south of this latitude it curves around to the southwest, still parallel to the trend of the belt. Part of the belt disappears beneath the ice cap on the northern side of Vatnajökull and reappears on the southwestern side. Much of Vatnajökull owes its elevation to vulcanism associated with the faulting in the belt. (volcanic activity).

The ice field of Vatnajökull covers an area of approximately 3400 square miles, its greatest length from east to west being about 90 miles, and its greatest breadth from north to south, about 65 miles (19).

On the northern side the ice extends in large, curving arcs out onto the plateau surface, which lies at very nearly the same elevation as Vatnajökull. On the southern side, however, where Vatnajökull overlooks the coastal lowland, the ice forms outlet glaciers down certain valleys leading to the lowland. These outlet glaciers all descend to within 200 feet of sea level. Because of the differences in elevation of the land to the north and to the south, Vatnajökull thus has a distinctly asymmetric profile, as shown in Figure 4. As a result of the steeper

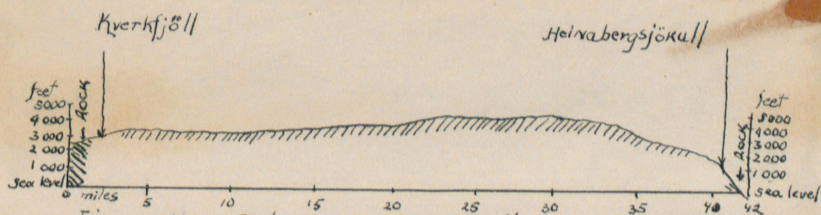


Figure 4. Section across Vatnajökull, from NW to SE
vertical exaggeration 5 times

(Adapted from Roberts)

gradient on the southern side, movement of the ice here is many times faster than on the northern side.

Numerous munataks occur in the peripheral portions of the ice field, especially along the southern edge; one of them, in the vicinity of Oraefajökull, is an active volcano. Several munataks are also found in the interior of the ice field. (Grimsvötn, in the west-central part, likewise marks a center of volcanic activity).

No definite figures are available for the thickness of ice in Vatnajökull. It is probable, however, that the ice has no great thickness, at least in the western half; here its contours obviously reflect the underlying bedrock topography (Plate I), and several munataks, including Grimsvötn, actually emerge from the ice. Flint estimates that the ice may not exceed 750 feet at any point (3).

The ice field of Myrdalsjökull, less than one-tenth the size of Vatnajökull, is also marked by irregular contours, reflecting the underlying bedrock topography. In the southeastern part bedrock is exposed around the active volcanic crater, Katla.

Surrounding all of Iceland is a submarine platform, the surface of which extends from the coast out to depths of 80 to 150 fathoms. This platform, outlined roughly by the 200-meter depth contour on Figure 1, is the equivalent of the continental shelves bordering the various continents. In this report it is called "the insular shelf", or simply "the shelf", while the submarine slope extending from the outer edge of the shelf down into the deep ocean basins is called "the insular slope". As shown on Figure 1, a number of sea valleys cross the shelf, trenching its surface for almost the full width from coastline to outer edge.

Those off the north coast are directly in line with the fjords indenting that coast. It may be inferred from this that any north-south faulting associated with the origin of the fjords and the valleys inland from them is also associated with the origin of the sea valleys.

The sea valleys are generally oriented north-south, and are often found in the same line as the fjords. This suggests a common origin for both features.

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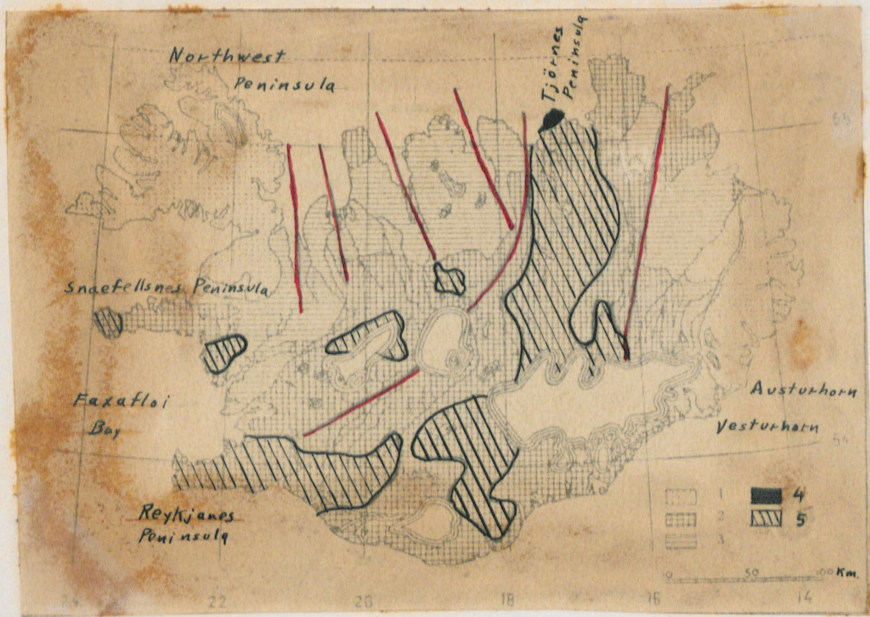
Geology of Iceland

Lithology and Stratigraphy. The rocks occurring in Iceland are predominantly volcanic, with lesser amounts of sedimentary deposits interbedded with the volcanic rocks. According to Pjeturss. (18), the relative proportion of volcanic rock to sedimentary deposits may be on the order of 5 to 1. Very minor quantities of intrusive igneous rocks also occur in widespread sections of the island.

The oldest rocks exposed in Iceland belong to the so-called "Tertiary basalt formation." While no direct proof is available, it is believed that they are no older than Eocene, if they are indeed that old. Their upper age limit may be Miocene, although this, likewise, cannot be proved definitely.

The "Tertiary basalt formation" probably underlies most of Iceland, comprising perhaps 75 percent of the mass of the island (18). However, its outcrops are confined to the northwestern and the eastern sections only and occupy less than 40 percent of the area of the island (Figure 5). Estimates of the total thickness vary from 10,000 to over 11,500 feet (12, 26).

The formation consists, for the most part, of interfingering basalt layers with occasional layers of volcanic tuff or breccia. Near the middle of the formation is an interval, several hundred feet thick, of sedimentary deposits. The interval contains diversely colored beds of clay and tuff with intercalated layers of lignite. In at least one locality a well-developed sequence of sandstone and conglomerate occurs. Plant fossils in the lignite, although numerous and well-preserved, do not yield a closer age determination than probable mid-Tertiary (18, 26).



1. Tertiary
 2. Pleistocene
 3. Tertiary and Pleistocene both
outcropping
 4. Pliocene (Tjörnes)
 5. Post - Pleistocene
- Fault system.

Figure 5. Geologic map of Iceland (After Pjeturss)

Uppermost Tertiary strata are found only on the peninsula of Tjörnes, on the north coast. Here over 1000 feet of predominantly shallow-water sediments outcrop in a region otherwise covered with Quaternary volcanic deposits. The strata consist mainly of cross-bedded arkosic and tuffaceous sandstone, conglomerate, and some claystone. The sandstone contains numerous marine fossils indicating a Pliocene age.

The greater part of the surface of Iceland is covered with Quaternary rocks and deposits, although, as previously mentioned, Tertiary rocks probably underlie them throughout the island. This is shown diagrammatically on Figure 6. Latest estimates place the Quaternary section at well over 3000 feet thick (12).

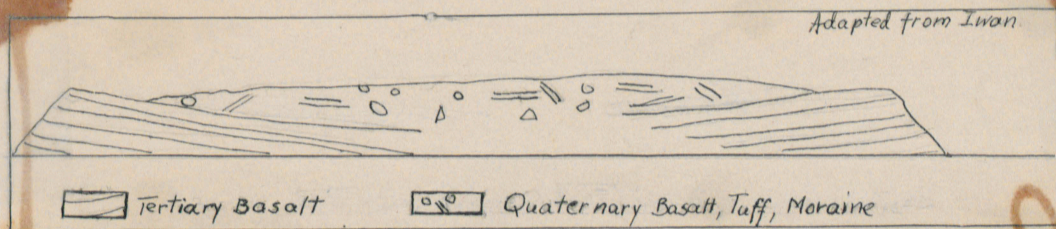


Figure 6 Generalized Geologic Cross Section of Iceland from east to west

The Quaternary rocks and deposits fall into two groups, Pleistocene and post-Pleistocene. Those in the Pleistocene group consist of interbedded tuffs and breccias; basalts; and glacio-fluvial, lacustrine, and marine sediments. Figure 5 shows the aerial extent of this group.

The tuffs consist of lava dust and lava fragments with an abundance of basaltic glass shards and feldspar crystals. The breccias differ from the tuffs in being coarser grained and containing fragments and

blocks of basaltic lava. The prevalence of palagonite, formed by the hydration of basaltic glass, gives the tuffs and breccias a characteristic yellowish brown color, because of which early geologists named the entire group "the Palagonite formation."

The basalts of the Pleistocene group are usually somewhat thicker bedded, coarser textured, and lighter colored than the Tertiary basalts. Many of the flows demonstrate a globular, pillow-like structure which, according to Noe-Nygaard (11), results from being extruded beneath glacial ice.

Interbedded with the basalt flows and pyroclastics are several intervals of glacio-fluvial deposits ranging up to 150 feet or more in thickness. The moraine layers usually consist of a heterogeneous mixture of lava blocks of different types and sizes in a sand-sized to clay-sized matrix. Frequently they have been hardened into tillite. Fluvial sands and gravels, in places consolidated into sandstone and conglomerate, are often associated with the tillite.

Intervals of marine sediments are found interbedded with Pleistocene volcanics and moraines in western Iceland, near Reykjanes and on the Snaefellsnes Peninsula. Pjeturss and Thorkelsson (17, 24) both describe localities near Reykjavik where several tens of feet of claystone, with minor amounts of sandstone and gravel, occur underlying and overlain by moraine and ice-scoured Pleistocene basalt. The claystones contain marine fossils with some warmer water forms, indicating somewhat less severe climatic conditions than during the periods of maximum glaciation. At one of the localities lacustrine clay, containing plant and insect fossils, is also found. It is the opinion of both men that correlation

from one locality to the other places the sediments stratigraphically at two slightly different levels, indicating two recessions of the ice.

At several localities along the north side of the Snaefellsnes Peninsula over 100 feet of claystone, sandstone, and conglomerate occur, lying on ice-scoured Tertiary basalt and overlain by Pleistocene basalt, tuff, and breccia (1). At one locality over 30 feet of hardened moraine lies directly on the Tertiary basalt, at the base of the sediments. The claystones contain marine fossils indicating an amelioration of the climate similar to those at Reykjavik. In one place near the top of the section a 20-foot unit of lacustrine clay occurs bearing flora that suggest a climate very similar to the present one in Iceland.

Post-Pleistocene rocks occur mostly in an irregular belt extending across Iceland from the north coast to the south and west coasts (Figure 5). The greater part of the Reykjanes Peninsula is covered by them, as well as smaller areas on the Snaefellsnes Peninsula and the east shore of Faxaflói Bay. They consist of basalt flows, tuffs, and breccias. The flows, usually darker and finer textured than the Pleistocene flows, occur either in great lava fields covering most of the previously existing topography or as individual, valley-filling flows. The largest Icelandic field, Odadahraun, located on the plateau north of Vatnajökull (Plate I), covers an area of over 1400 square miles (26). The tuffs and breccias are associated usually with individual volcanic vents, such as Katla on Myrdalsjökull, or rows of vents, such as Vatnaöldur (Figure 2), and ordinarily are less extensive than the basalt flows.

Dikes and, less frequently, sills of basalt are found throughout Iceland, intruded into rocks of all ages from Tertiary to post-Pleistocene.

Masses of gabbro of undetermined age occur in the rocky promontories of Vesturhorn and Austurhorn, east of Hornafjörðr in southeastern Iceland. This rock also occurs in intrusions on Snaefellsnes Peninsula and, apparently, under Vatnajökull, since gabbro pebbles are abundant in the outwash gravels of the outlet glaciers south of it.

Although the volcanic rocks of Iceland are predominantly basic in composition, small quantities of acidic rocks do occur in various parts of the island. Small dikes, sills, and intrusive domes of liparite (approximate equivalent of rhyolite in European terminology) are found in widely separated parts of the island, associated with rocks of all ages. They frequently are accompanied by allied glassy rocks, such as pitchstone, obsidian, and pumice. The areal extent amounts to only one percent of the total area of the island (15, 26). In addition to the liparite occurrences small intrusive masses of granite and granophyre are found associated with the gabbro near Hornafjörðr and Snaefellsnes (26), and erratic granite pebbles are described (14) from outwash gravels in the valley just east of Skeidararjökull.

Structure. The over-all structure of Iceland is essentially that of a syncline with the axis oriented northeast-southwest and running through the central part of the island. The Tertiary basalts dip inward from the east and northwest coasts at dips of less than 10 degrees, and presumably are continuous beneath the overlying Quaternary formations (Figure 6).

The belt of linear fault-block topography curving southward and southwestward across Iceland is the surface expression of a system of faults which is still extremely active. Many of the faults have registered movement visibly during historic times and earthquakes are

frequent, particularly near the north coast. Volcanic craters and hot springs follow fault lines "like beads on a string" (26). The approximate boundaries of this tectonic belt are shown on Figures 1 and 5. It is apparent on Figure 5 that most of the post-Pleistocene volcanic rocks lie within this belt.

The linear valleys and fjords of the north coast indicate another system of faults that have probably been inactive since the end of the Pleistocene epoch. The orientation of this system (Figures 1 and 5) is roughly north-northwest to south-southeast.

Several systems of curving faults on the Northwest Peninsula and around Faxaflói Bay have been proposed by Thoroddsen (25). Evidence for these is not certain, however, and they are not accepted by all geologists (18).

Iceland's Relation to the Submarine Topography of the North Atlantic Ocean. On Figure 1 a submarine ridge outlined by the 1000-meter (550-fathom) contour line is shown extending from Greenland southeastward across the North Atlantic Ocean to Scotland. This ridge, known as the Wyville-Thompson ridge, is over 100 miles wide at its base and rises in places to within 200 meters (110 fathoms) of the surface. Iceland lies on the ridge near its midpoint, while the Faeroe Islands lie near the Scotland end.

Basalt and andesite pebbles have been dredged from this ridge between Iceland and the Faeroes, and gravity surveys indicate it is probably capped by basalt flows (13). According to Boeggild (31), it is mantled by gray clay of volcanic origin.

Geologic History of Iceland. Iceland is considered a remnant of the so-called Thulean Plateau, a volcanic plateau believed to have extended across the northern part of the North Atlantic Ocean during early Tertiary times and to have been broken up by block faulting and subsidence during the Miocene epoch (10, 26). Other remnants of this plateau are believed to be the Faeroe Islands, the islands of Mull and Skye off the west coast of Scotland, the Antrim Plateau in northeastern Ireland, and the basalt region of eastern Greenland. All of these places are characterized by the extensive occurrence of basaltic rocks. The Wyville-Thompson submarine ridge is presumably the submerged portion of the Thulean Plateau.

Faulting and subsidence are believed to have continued through the remainder of the Tertiary period until the strand line, at least in northern Iceland, lay well above the present shore. The Pliocene marine strata of Tjörnes Peninsula, now found at elevations of over 300 feet above sea level, were deposited during this period of transgression. However, the comparatively great thickness (1000 feet) and limited areal extent of these strata suggests that the subsidence here may have been due to local faulting rather than to subsidence of the entire island.

According to Thoroddsen and Iwan the insular shelf of Iceland is the result of marine abrasion during this time of slow subsidence. To the writer's knowledge no geophysical studies have been made which definitely ascertain if the body of the shelf is composed of the same type of rock as the adjacent land or if it is a depositional feature, made up of sediments derived from the adjacent land and underlain by a well-defined

basement. Seismic profiles in the southwestern part of the island indicate that basalt is present very near the surface along the coast there.

At the end of the Pliocene epoch the island was re-elevated until the sea had retreated beyond the present 150-fathom line. Those submarine valleys whose origins cannot be traced directly to faulting probably were eroded at this time, when the shelf was exposed to subaerial erosion (26).

The number of glaciations of Iceland during the Pleistocene epoch is still not definitely known. It is certain that the island was glaciated at least twice. Nielsen (10) describes the occurrence of two mutually unconformable moraine series in the highlands 15 miles south of Hofsjökull. The older series is an integral part of a fault-block ridge at that place, having been covered by volcanic flows and pyroclastics, hardened into tillite, and then uplifted by tectonic movement of the block. The younger series is plastered on the lower slopes of the ridge and contains boulders of the older series.

Von Knebel (7, 8) describes similar occurrences of unconformable moraine series in the ridges and valleys of the highland above the inner edge of the Southwestern Lowland and again in the area between Langjökull and Hofsjökull. The older series occurs in the ridges interbedded with volcanic flows and pyroclastics, while the younger series occurs along the valley sides. According to Von Knebel, a considerable period of time must have elapsed between deposition of the older and younger moraine series, during which period the valleys were eroded. It is the writer's belief that faulting, rather than erosion, was responsible, in part at least, for the formation of the ridges and valleys. The early date of

Von Knebel's papers may indicate that the structural control of topography in this part of Iceland, which lies within the belt of active faulting, was not yet fully understood at the time of their writing. Regardless of whether erosion or faulting was responsible for the ridges and valleys, Von Knebel's reasoning with respect to the time interval between deposition of the two moraine series is certainly valid. He also makes a vague reference (page 552) to evidence for a third glaciation in parts of the interior highlands where he himself has not worked, but unfortunately he does not describe the evidence.

The occurrence of Pleistocene marine sediments near Reykjavik presents the possibility of two withdrawals of the ice from that part of Iceland. Whether these withdrawals were both protracted enough, however, to be considered true interglacial stages is not certain. Pjeturss (17, page 284) is of the opinion that the older of the two sedimentary intervals may possibly be an interstadial substage rather than a true interglacial stage.

The marine and lacustrine sediments on Snaefellsnes Peninsula indicate at least one withdrawal of the ice from that region.

The full extent and thickness of the ice during the earlier stage, or stages, is not known. If it had the same extent as it did during the last stage, and comparison with Pleistocene glacial stages in other parts of the world indicates it probably would have unless local factors interfered, then most of Iceland was covered. The occurrence of moraine deposits, interbedded with volcanics in all parts of the outcrop area of the Pleistocene series, supports this supposition.

Ground moraines, large and small erratic blocks, and ice striations of the last glacial stage occur in all parts of Iceland. According to Flint (3), probably 90 percent of the present land area was glaciated during this, or earlier, stages. Striations indicate that a composite ice sheet flowed radially out from central Iceland past the coastline, terminating in a floating shelf around much of the island. The Northwest Peninsula was a separate center of accumulation in which a smaller ice sheet developed and coalesced with the sheet from the main part of the island. The thickness of the ice varied greatly, ranging from about 1200 feet to as much as 3000 feet, with an average of somewhat over 2000 feet. Numerous nunataks remained above the ice, especially in the northern part of Iceland. Terminal moraine ridges, marking temporary still-stands in the retreatal phase of this glacier, are common in the Southwestern Lowland and in the valleys of the north coast (18).

Although the island was emergent at the end of the Pliocene epoch, it apparently was subjected to isostatic depression beneath the weight of an early Pleistocene ice sheet. Subsidence of sufficient magnitude to bring the strandline from its lowered position at the end of the Pliocene epoch to a position close to 600 feet above the present shore took place during this glacial stage. The top beds of the Snaefellsnes interglacial sediments occur at elevations ranging from 430 to 560 feet above sea level.

Some re-emergence of the island must have taken place as it readjusted isostatically to the decreased weight of ice during this interglacial stage. The time lag involved in the readjustment could conceivably be sufficient to permit deposition of the Snaefellsnes sediments before re-emergence commenced.

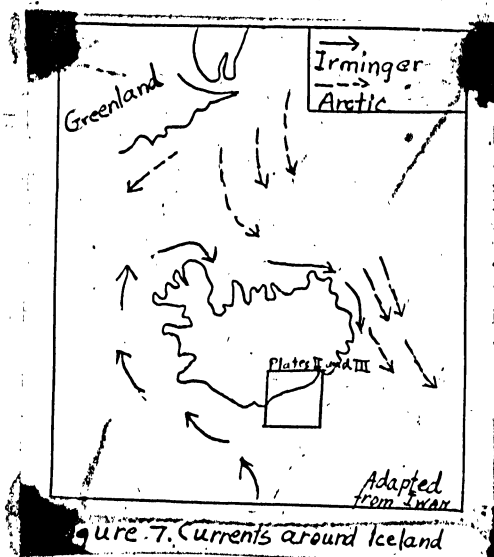
Another transgression occurred at the end of the last glacial stage, when the rising post-glacial sea invaded the still-depressed land as fast as the ice melted back. Moraines deposited at the edge of this sea are found at elevations of around 250 feet in the heads of the north-coast fjords and at several localities on the west coast (23). In the South-western Lowland one terminal moraine ridge is found, at an elevation close to 300 feet, in which the finer-grained constituents have apparently been removed from the upper portion by wave action (6).

As a result of this transgression a thin layer of marine clays was laid down in the coastal lowlands and valleys. These are found today up to elevations of over 400 feet in southern Iceland and 250 feet in northern and western Iceland. Elevated sea cliffs and rock benches at the base of the mountains behind the south coast of Iceland also mark the maximum advance.

Since the time of post-Pleistocene submergence the land has again been emerging, with several intermediate halts marked by raised beaches and marine terraces (5).

Ocean Currents Around Iceland

The Irminger Current, a terminal branch of the Gulf Stream drift, approaches Iceland from the south and turns westward along the south coast. It then curves northward and flows along the west coast past the Northwest Peninsula, whence it turns eastward and flows along the north coast, as shown in Figure 7. Off Cape Langanes, the northeasternmost point of Iceland, the Irminger Current turns southward and, in combination with the East Iceland Arctic Current, flows south along the east coast (29).



A semidiurnal tidal wave approaches Iceland from the ocean basin to the south (22). When this wave reaches the comparatively shallow depths of the insular shelf it changes from a wave of oscillation to a wave of translation and becomes a mass of water flowing slowly across the shelf.

Upon reaching the coast this translatory wave sets up tidal currents which flow parallel to the shore, entering all bays and inlets. These currents achieve considerable velocities, sometimes as much as

8 or 10 knots (29, p. 480) where the inlet entrances are narrow, but are usually inconsequential along the stretches of open coast. The general track of the tidal currents around Iceland is thus seen to be circular. The direction of flow reverses with the change of tide, the currents preceding the flood stage (high tide) running in a clockwise direction around the island and the currents preceding the ebb stage (low tide) running in a counter-clockwise direction (29).

According to Lewis (9), the dominant direction of storm wave approach along the south and southeast coasts of Iceland is from the south-southwest. It is probable that littoral currents setting to the east and northeast are generated by these waves (Figure 8), especially along the great curved bights of the southeast coast where few obstacles lie in their path.

The probability of turbidity currents flowing outward across the shelf from the coast should also be mentioned, although no studies have been made to verify their presence. The turbulence created by the ocean surf, which is particularly heavy along the entire south coast during the time of winter storms, may well put enough fine clastic material into suspension to generate vigorous turbidity currents. Once in existence these would flow across the shelf, using every available outward gradient. The sea valleys would be especially operative in channelizing the currents and directing them to the edge of the shelf.

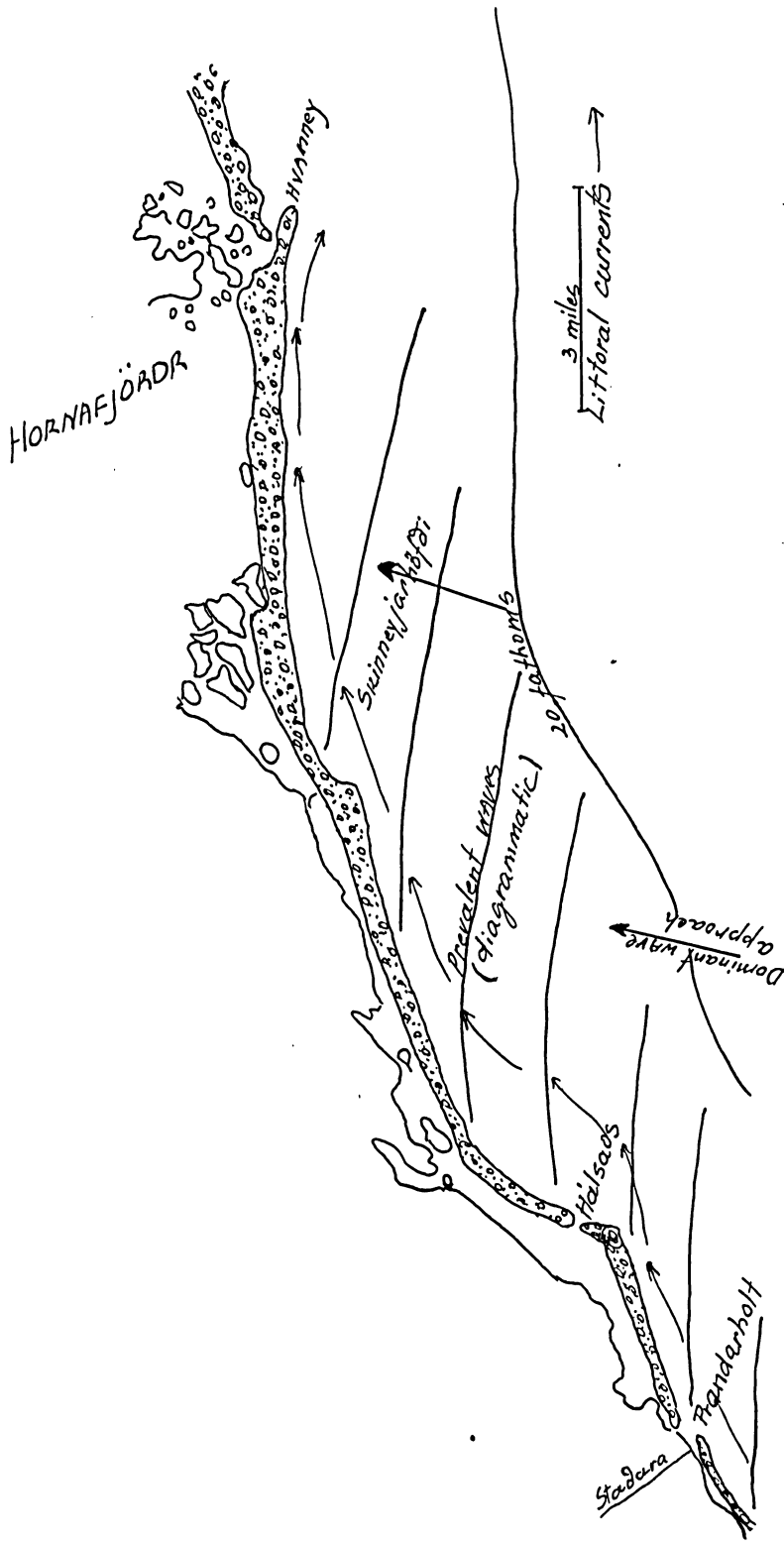


Figure 8 Shoreline at Hornafjörður (From Lewis)

III. SUBMARINE TOPOGRAPHY AND BOTTOM SEDIMENTS OFF THE SOUTHEAST COAST OF ICELAND

Submarine Topography

The Insular Shelf. The insular shelf off the southeast coast of Iceland is bounded along the outer edge by the 100-fathom contour. As shown on Plate II, it is over 40 miles wide south of Stokksnes, on the eastern side of the map. From here it narrows westward to less than 10 miles wide south of Portland, on the western side of the map.

Five sea valleys, or "dybs", indent the shelf at intervals of from 25 to 30 miles apart, extending from within a few miles of the coast out to the outer edge of the shelf. From east to west these are: Hornafjardur Dyb, Jökulsa Dyb, Skeidara Dyb, Skapta Dyb, and Reynis Dyb.

The first three named have widths ranging from 10 to 15 miles, except from Skeidara Dyb, which widens to more than 20 miles at its northern end. Skapta Dyb is only 5 miles wide at its outer end, widens to 12 miles in its middle section, and narrows again to 5 miles at its inner end. Reynis Dyb maintains a width of about 6 miles throughout most of its length.

The lengths of the sea valleys vary with the width of the shelf. Hornafjardur and Jökulsa Dyb, located where the shelf is widest, each have lengths of approximately 35 miles. Skeidara Dyb is about 27 miles long; Skapta Dyb is about 18 miles long; and Reynis Dyb, located where the shelf is narrowest, is only 7 miles long.

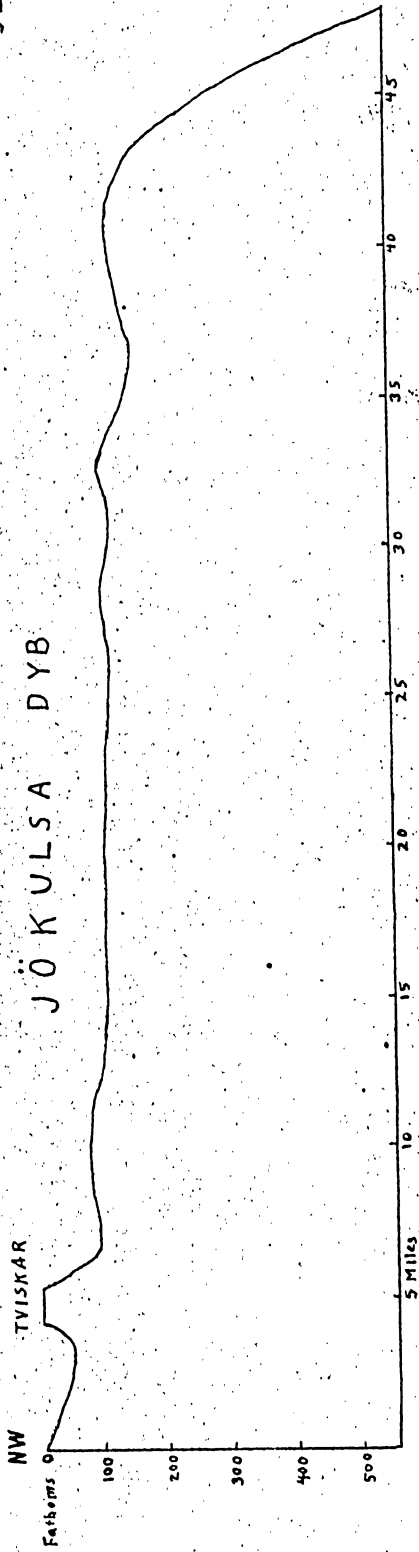
In ground plan these sea valleys are comparatively straight, from north to south, with little turning or meandering. They all, except Reynis Dyb, show a tendency to split up into tributary valleys near their inner ends, however.

Near their outer ends the bottoms of the sea valleys lie from 50 to 80 fathoms lower than the remainder of the shelf, while for over half

their lengths shoreward they exhibit little decrease in depth. Their longitudinal profiles (Figure 9) are characterized by a series of shallow basins separated by gentle ridges or swells 5 to 10 fathoms higher than the basins. In Skeidara Dyb a ridge 2 to 4 miles wide extends discontinuously down the middle of the sea valley from a point about 3 miles from the coast to a point 17 miles from the coast. Near the mid-point of this ridge, about 9 miles from the coast, a hill rises to within 51 fathoms of the surface, more than 20 fathoms higher than the rest of the ridge. Near its outer end the ridge bears another hill rising to within 67 fathoms of the surface, 20 fathoms higher than the rest of the ridge and 60 fathoms higher than the floor of the adjacent basin, one mile to the southeast. The intervening segment of ridge rises no more than 15 fathoms above the bottom of the sea valley on either side. Two miles south of the end of this ridge another hill, perched on the outer end of a spur projecting part way across the sea valley, rises to within 79 fathoms of the surface, over 10 fathoms above the rest of the spur and over 70 fathoms above the adjacent basin, one and one-half miles to the south. The eastern wall of Skeidara Dyb is remarkable in its straightness for a distance of more than 12 miles, and for its uniform degree of declivity, 70 fathoms in 1-1/2 miles, or about a 3 degree angle, throughout much of this distance. All of the soundings on which the contours in Skeidara Dyb are based are shown in Figure 10.

Another noteworthy feature is the series of offset offshore bars extending from about 15° 45' West Longitude eastward to about 15° West Longitude across the mouth of Hornafjörðr. Lewis (9) describes these in detail and attributes them to the dominant direction of wave approach,

SE



SE

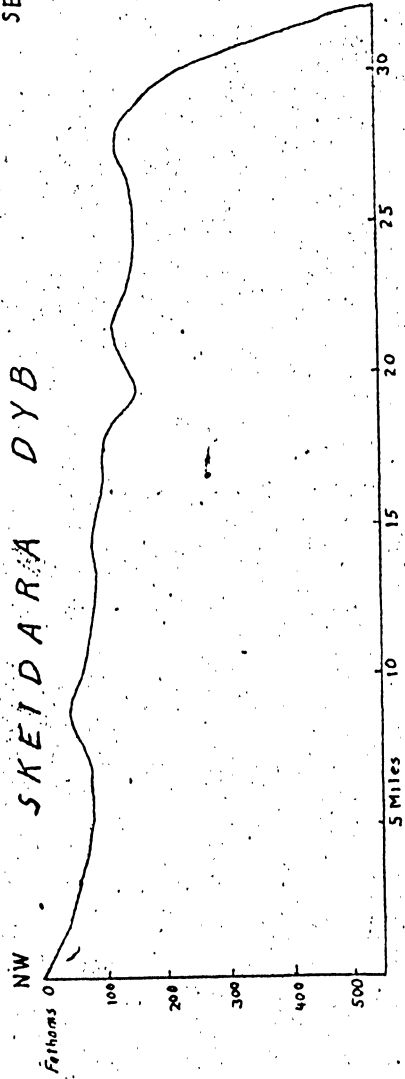


Figure 9. Longitudinal Profiles of floors of Jökulsá Dyb and Skeidara Dyb
Vertical Exaggeration 20 to 1.

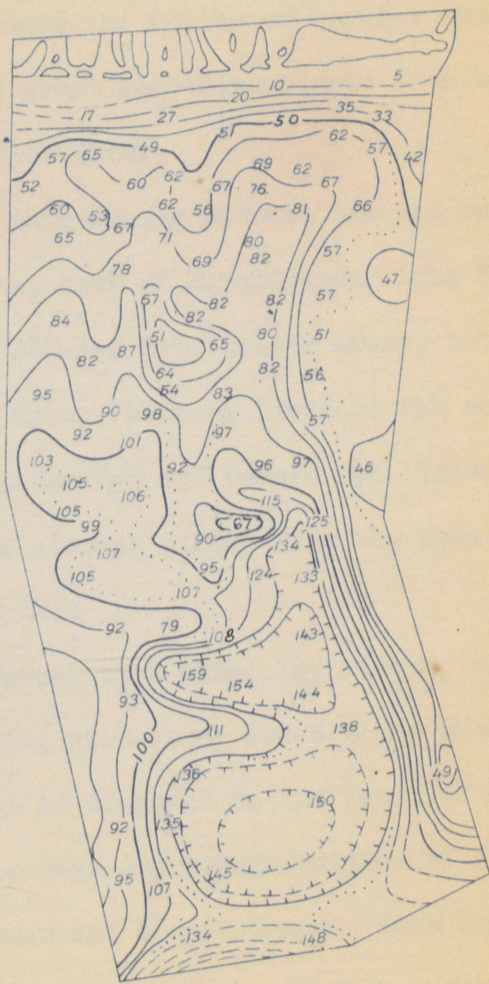


Figure 10. Hydrographic Details Of
Skeidara Dyb. Soundings in Fathoms.

which here is from the south-southwest (Figure 8). He mentions the possibility that longshore eddy currents forming in the lee of the rocky headlands just west of each offset may have a part in producing the offsets. However, he has not recognized direct evidence of this and apparently prefers to ascribe the offsets entirely to the direction of impingement of the waves. It is this writer's opinion that even if longshore, or littoral, currents do not produce the offset bars of this locality, they probably play a part in forming the string of barrier beaches and offshore bars that make up the great shoreline bights from here southwestward past the mouth of the Kudaflótt River.

The segments of shelf intervening between the sea valleys are named as follows: Stokksnes Grunn, east of Hornafjardar Dyb; Myra Grunn, between Hornafjardar Dyb and Jökulsa Dyb; Oraefa Grunn, between Jökulsa Dyb and Skeidara Dyb; Sidu Grunn, between Skeidara Dyb and Skapta Dyb; and Kötlu Grunn, between Skapta Dyb and Reynis Dyb. Essentially, these are undulating submarine plains sloping gently from the coast out to the outer edge of the shelf. (Figure 11).

It is noteworthy, however, that wide, low ridges, rising 10 to 15 fathoms above the surrounding seabottom, cross these shelf segments in directions roughly parallel or diagonal to the trend of the coastline. These are most pronounced across the middle section of Kötlu Grunn and near the outer edges of Sidu Grunn and Oraefa Grunn. They occur in less distinct form, however, in other places. The 55-fathom contour outlines a low ridge on the inner portion of Sidu Grunn ($63^{\circ} 30'$ North Latitude, $17^{\circ} 22'$ West Longitude), which trends west-northwest, roughly 45° to the trend of the ridge along the outer edge. A similar ridge, outlined by

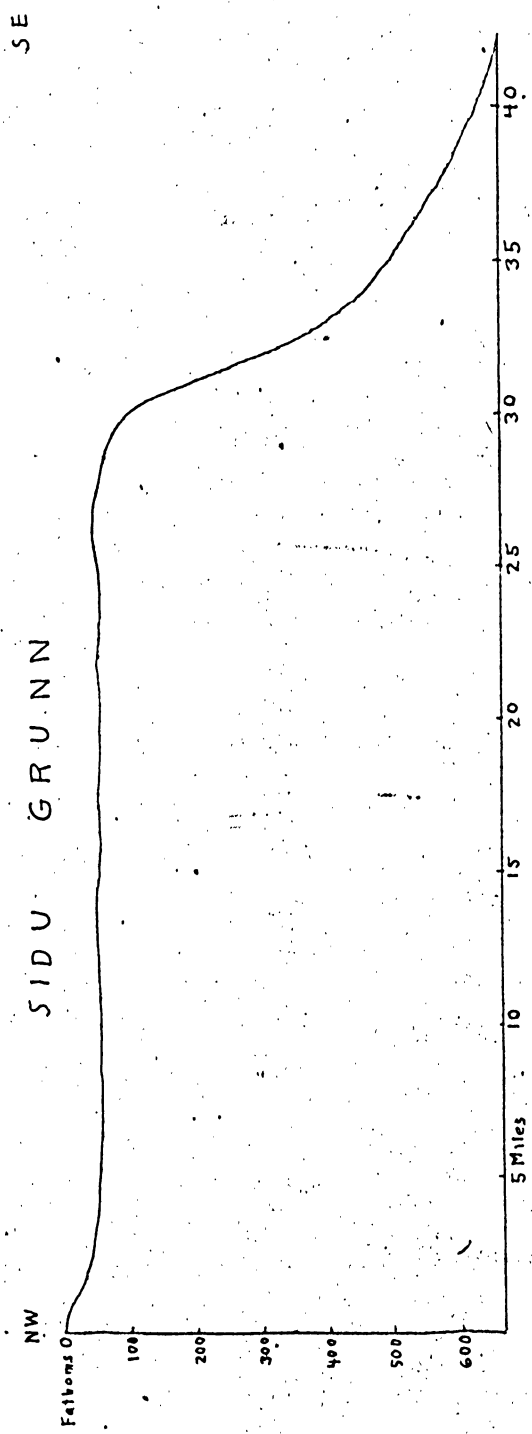


Figure 11. Profile Across Insular Shelf at Sidu Grunn,
From Northwest to Southeast. Vertical Exaggeration 20 to 1.

the 60-fathom curve, occurs on the west side of the inner portion of Oraefa Grunn (65° 35' North Latitude, 16° 40' West Longitude). This ridge is oriented roughly northeast-southwest, a little over 45° to the ridge across the outer part of the bank. Another ridge of the same type lies on the east side of Oraefa Grunn (63° 37' North Latitude, 16° 10' West Longitude), trending roughly west-northwestward. On Myra Grunn a ridge outlined by the 65 fathom contour crosses the middle section from northeast to southwest, roughly parallel to the coast and to the outer edge of the shelf.

The Insular Slope. The insular slope forms a continuous, smoothly-curving zone bounding the entire southeastern and southern edge of the insular shelf. On Figure 1 it is seen to extend about 12 miles west of the edge of the area shown on Plate II and about 60 miles east of Hornafjardar Dyb, near the eastern edge of Plate II. In this section east of Plate II the insular slope forms the northwestern wall of a very large sea valley indenting the southwestern flank of the Wyville-Thompson ridge.

The insular slope drops off fairly rapidly toward the southeast and south to oceanic depths: 100 fathoms per mile (about 7 degrees) off Myra Grunn; 110 fathoms per mile off Oraefa Grunn; 110 fathoms per mile off Sidu Grunn; and 265 fathoms per mile (about 17 degrees) just west of Reynis Dyb. These figures show a steepening of over two and one-half times on the slope west of Reynis Dyb.

The writer has shown two seamounts on the slope, one east of Skeidara Dyb and the other east of Reynis Dyb. The contours outlining these are based on a few shoal soundings which in other localities might have been considered as possibly incorrect when encountered in such deep water. The

writer, however, feels that bottom anomalies such as these are not improbable in this part of the Atlantic Ocean, where vulcanism and block faulting both are found in great abundance on the adjacent land. These seamounts are also shown on the Carte Générale Bathymétrique des Océans, from which Figure 1 of this report was compiled.

The Skeidara Dyb seamount is based on a line of four shoal soundings projecting into obviously deeper water. These are the 65-fathom, 104-fathom, 77-fathom, and 65-fathom soundings spaced about 4 miles apart along a line commencing on the east side of the mouth of Skeidara Dyb and running a little south of east at a slight angle away from the trend of the insular slope.

The exact depth of the trough intervening between the Skeidara Dyb seamount and the slope is not known. In the absence of sufficient soundings for accurate contouring, the writer has shown the bottom of the trough as lying from 100 to 135 fathoms below the top of the seamount.

Off the eastern end of the seamount the bottom drops from 65 fathoms to 185 fathoms in a distance of 4-1/2 miles, giving an average gradient of 167 fathoms per mile, or about 11 degrees. To the south, where soundings are scarce, the writer has tentatively shown the gradient as being about one-half that off the eastern end. To the west, likewise, sounding data is scarce, but it is believed the seamount merges with the slope there.

The top is characterized by two high points, the 65-fathom soundings on either end, separated by an intervening col 35 to 40 fathoms deeper. These two high points rise from 15 to 20 fathoms higher than the adjacent edge of the shelf.

The seamount off Reynis Dyb is smaller than the one off Skeidara Dyb,

and probably more circular in outline. Located just to the east of the mouth of Reynis Dyb, it projects into deeper water in all sides except the north. It rises to a high point marked by a single 29-fathom sounding. From this high point it drops off to about 600 fathoms in 2 miles southward, giving an average gradient of 300 fathoms per mile, or about 19 degrees. The slopes are probably less steep to the east and to the west, while to the north the seamount is apparently connected with the shelf by a narrow ridge whose top lies about 100 fathoms deeper than the high point on the seamount. The corner of Kötlu Grunn adjacent to the seamount lies between depths of 70 and 90 fathoms -- from 40 to 60 fathoms deeper than the top of the seamount.

Bottom Sediments

Source of Sediments. At least once during the Pleistocene epoch Iceland's insular shelf was partly or entirely covered by an ice sheet, either floating or resting on the bottom. This ice sheet must have deposited a mantle of coarse and fine clastics on the shelf, which would serve as the major source of the sediments now found there.

Another, probably much less important, source is the load of clastics carried by the streams draining from the various outlet lobes of Vatnajökull and Myrdalsjökull, particularly during the summer months when melting is at its greatest. Most of the gravel fractions are normally deposited within a few miles after leaving the glacier front. The finer sand, silt, and clay fractions, however, are carried down to the coastal lagoons where a large part of them are undoubtedly trapped when the stream current dies. It is probable, however, that a small part of them, especially from the silt and clay fractions, is carried through the outlets into the ocean by vigorous ebb tidal currents. Where the streams empty directly into the ocean, as do the Nupvatn (17° 27' West Longitude) and the Sandvatn (18° 42' West Longitude), practically their entire load is discharged into the ocean.

In addition to normal deposition from glacial streams, catastrophic deposition from "glacier bursts" periodically adds to the shoreline and offshore sediments. Active volcanic centers are located beneath the ice in Vatnajökull and Myrdalsjökull. When one of these erupts great floods of water, bearing volcanic debris and ice, sweep down over the coastal lowland into the sea. Skeidararsandr and Myrdalssandr are particularly

subject to these floods, although they occur elsewhere along this section of the coast.

Thoroddsen (26) describes these floods as follows:

"Peculiar to Iceland are the so-called 'glacier-torrents' (Jökull-hlaup). When the glaciers by the eruption of volcanoes hidden under the ice, are broken to pieces and melt, the large stretches of land beneath them are inundated by a roaring sea of dirty water with swirling icebergs. Such catastrophes may cause great changes in the surface features of the surrounding country, as the waterfloods often carry along with them an incredible quantity of gravel and rocky blocks. In this way the volcano of Katla especially has caused considerable changes — the course of rivers are constantly changed, the smaller fjords have been filled up even within historic times, and several large parishes and districts have been destroyed... Minor glacier-bursts are also occasionally due to lakes and rivers, which have been damaged by glaciers, suddenly breaking through their barriers and inundating the district."

In 1818, according to the Sailing Directions, a glacier burst from Myrdalsjökull resulted in a four-mile stretch along the coast of Myrdals-sandr being advanced seaward a distance of one mile.

The shelf off the southeast and south coasts of Iceland is subject to another type of deposition from the adjacent land. Windblown dust and fine sand from the clayey, sandy outwash plains of the coastal lowland, from weathered tuff formations in the mountains, and from volcanic eruptions undoubtedly have contributed to the seabottom here. Volcanic ash from eruptions of Icelandic volcanoes sometimes is carried by winds completely across the Atlantic Ocean to Europe, while dust whipped up by the windstorms of the land has been known to fall on vessels in mid-Atlantic (25). Therefore, if noticeable amounts of this dust and ash are carried such great distances, much larger amounts may be expected to be distributed over the nearby shelf and slope.

Considerable amounts of pumice are delivered to the sea by streams flowing through areas of volcanic activity, by glacier bursts, and directly by submarine eruptions. This occurs off other Icelandic coasts as well as the southern and southeastern. According to Thoroddsen (25), eruptions of Hekla in the Southwestern Lowland have produced pumice in amounts great enough to be transported by currents to the Faroe Islands, while in the year 1783, pumice from a submarine eruption off Reykjanes covered the sea for distances of over 100 miles. It is to be expected that agitation by ocean waves would shatter the glassy cells of most of this pumice, causing it to sink to the bottom as sand or water-logged fragments and blocks. It is likely, also, that volcanic bombs and other large fragments of ejects are occasionally contributed to the sediments on the shelf. Such fragments have been known to be blown far from the point of eruption. It is reported, for example, that in the year 1510, a bomb ejected from Mount Hekla, in southwestern Iceland, killed a man 45 kilometers away. Quantitatively, of course, this source of sediments is unimportant.

Occurrence of Bottom Types. Examination of Plate III reveals that the most important bottom type on the insular shelf is sand. This sediment covers over half the area of the shelf, extending from the coast out past the 100-fathom line. Bottom notations on the hydrographic chart show that it covers the floors of the sea valleys, even in the deepest basins. Likewise it occurs on all the segments of shelf between the sea valleys, although its relative importance there is not so great.

The gravel occurs in irregular zones and patches confined mostly to the segments of shelf between the sea valleys. On the segment west of

Reynis Dyb gravel predominates over sand in areal extent. On the other segments, from Kötlu Grunn eastward to Stokksnes Grunn, however, it occupies less than half the area of each segment.

The low, wide ridges crossing the segments of shelf are shown covered with gravel. In some cases, such as the ridge on Kötlu Grunn, the ridge near the outer edge of Sidu Grunn, or the ridge across the middle section of Myra Grunn, bottom notations are frequent enough so that the sediment determination is certain for most of the ridge. In other cases, however, such as the diagonal ridge across the inner portion of Sidu Grunn or the ridge across the western half of Oraefa Grunn near its outer edge, the gravel is shown largely on the basis of topography.

In the zone of gravel at the inner edge of Oraefa Grunn, the banded portion of the zone 5 miles southeast of Ingolfshöfði is based on the presence of a rock notation which the writer interprets as a boulder rather than bedrock. The same is true for the small, isolated banded patch of gravel 1-1/2 miles to the east: the rock notation here is also interpreted by the writer as a boulder. His reason for this interpretation is given later under CONCLUSIONS.

Mud occurs on the shelf in two large zones and several small patches. One of the zones lies across the northwestern end of Jökulsa Dyb, while the other lies about 5 miles southeast of the coastal promontory Stokksnes, in the extreme eastern part of the sheet. This second zone is also located across the head of a sea valley, which, however, does not appear on the chart.

On the shelf rock appears only as small patches lying, for the most part, near the inner edge. The writer has mapped the hill near the

southern end of the central ridge in Skeidara Dyb as probable rock because of its pronounced topographic eminence. For the same reason he has mapped the transverse spur 2 miles south of the end of the ridge, and another topographic prominence near the upper end of the northwesternmost branch of the sea valley, as probable rock.

Practically all of the insular slope is shown as covered with mud or mud and sand. The floor of the deep ocean basin, also, is believed to be mantled with these sediments, although few bottom notations are present upon which to base this except in the area south of Kötlu Grunn and Sidu Grunn. All of the ocean basin in the eastern half of the chart has been left blank, as bottom notations are completely lacking here.

The two seamounts have been shown with probable rock in their highest portions. This is based on their topographic eminence above the adjacent shelf and slope.

IV. CONCLUSIONS

From the data presented in the preceding pages a number of conclusions are drawn about the submarine topography and bottom sediments off the southeast coast of Iceland.

1. Appreciable portions of the insular shelf are underlain by bedrock beneath the mantle of the bottom sediments.

The occurrence of rock patches near the inner edge of the shelf and of probable rock hills halfway across the shelf in Skeidara Dyb are considered as evidence supporting the conclusion.

2. The insular slope probably marks a zone of faulting in which the southeastern side has been down-dropped. The bottom drops off at an angle of about 7 degrees throughout most of the stretch of slope shown on Plate III except west of Reynis Dyb, where the angle increases to about 17 degrees. Comparison with the continental slope, off the east coast of the United States, which is not considered to be produced by faulting, is enlightening. According to Veatch and Smith (30) the continental slope drops from 600 feet to 8000 feet or more in 50 miles. This calculates to a slope angle of less than 2 degrees. Veatch and Smith state that in a few sections the slope (probably meaning the slope as a whole, rather than local occurrences of oversteepened topography in the submarine canyons) is as steep as 7-1/2 degrees. However, examination of the charts accompanying their paper shows that these sections of steeper slope angles are confined to the top 500 fathoms of the continental slope, below which the angles decrease markedly. In other words, the continental slope off the east coast of the United States does not have the uniform rate of

dropoff from top to bottom like the insular slope off the southeast coast of Iceland; furthermore, its over-all gradient is less than one-third the gradient of the Icelandic slope.

Iddings and Olsson (4) attribute the continental slope off the northwest coast of Peru to faulting and describe it as having a fairly uniform slope angle of 6 degrees, extending from a depth of 600 feet to a depth of about 13,000 feet. This is slightly less than the Icelandic slope angle east of Reynis Dyb.

Also supporting the fault hypothesis of formation is the fact that the Icelandic insular slope forms the northwestern wall of a huge sea valley indenting the southwestern flank of the Wyville-Thompson Ridge (Figure 1). If the faulting does continue eastward from the area of Plate II and cuts into the Wyville-Thompson Ridge it could be expected to produce a graben valley such as is outlined by the 500-meter and 1000-meter contours on Figure 1.

3. The seamounts contoured east of the mouth of Skeidara Dyb and Reynis Dyb if authentic are probably either volcanoes or fault blocks. The circular plan of the Reynis Dyb seamount suggests it may possibly be a horst. It should be borne in mind, however, that the contouring of both these seamounts is based on but few soundings. Speculation as to their exact origin, therefore, is fruitless until more detailed hydrographic surveys are made of them. Both theories, volcano or horst block, however, are in harmony with the location of the seamounts on the insular slope, presumably a major fault zone.

4. The sea valleys crossing the insular shelf may have been eroded by streams when the shelf was exposed to subaerial erosion at the end of

the Pliocene epoch, or they may have been caused by faulting, like the sea valleys and fjords of the north coast of Iceland. Whatever the ultimate origin, it is not improbable that Pleistocene glaciation of the shelf played a part in giving them their present outlines and bottom profiles.

While their over-all straight outlines may have resulted from faulting, it is just as possible that they were produced by glacial erosion of the valley walls. The eastern wall of Skeidara Dyb, for example, could as likely be the result of glacial scour as faulting, provided the ice extended far enough out onto the shelf. According to Rutten and van Bemmelen (20), the long, steep southern face of Mount Esja, in western Iceland, is due not to faulting, as had been believed previously, but to glacial erosion entirely.

In addition, the low ridges and swells separating the basins in the sea valleys are suggestive of recessional moraines, marking temporary positions of stillstand of an ice front.

5. The wide, low ridges lying on the segments of shelf between the sea valleys could be either fault blocks or glacial moraines. Comparison of Plate II with Figure 2 - West Sheet shows considerable similarity between the ridges on the insular shelf and the smaller-sized fault-block ridges southwest of Skaftarjökull.

The second explanation, however, is more in harmony with the orientation of the ridges than the first. It is true that the ridges along the outer edges of Sidu Grunn and Oraefa Grunn, and across the middle sections of Myra Grunn and Kötlu Grunn, do follow the same general east-northeast trend. However, the ridges on the inner portions of Sidu Grunn

and Oraefa Grunn do not follow this trend but lie diagonal to it. If the west-northwest-trending ridge on the inner portion of Sidu Grunn and the north-northeast-trending ridge opposite it on Oraefa Grunn be projected in a curved line to connect across Skeidara Dyb, the arc thus described is seen to be roughly parallel to the arc described by the present front of Skeidarajökull and its terminal moraine. This presents the intriguing possibility that Skeidarajökull may once have extended out onto the shelf and deposited its moraine ridges there. It was with this concept in mind that the writer interpreted the rock notations southeast of Ingolfshöfði as glacier boulders rather than bedrock. A similar possibility might be presented for Breidamerkrjökull's forming the west-northwest-trending ridge on the east side of Oraefa Grunn as part of its terminal moraine.

If the entire shelf were covered during the period of maximum glaciation, the ridges near the outer edge of the shelf could be moraine ridges deposited by the coalesced ice sheet. The prevalence of gravel on these ridges, as well as on the diagonal ridges, helps support this hypothesis. It is probable that the waves and currents of the post-glacial sea would have winnowed out the finer material from the surface of the ridges, leaving a layer of gravel. Such an ice sheet may have been floating by the time it reached the edge of the shelf, but deposition from the calving ice front could still result in a terminal ridge.

6. The greater part of the sand on the shelf may be derived from the deposits left by shelf glaciation. The widespread occurrence of this sand, around all the gravel ridges and in all the basins of the sea valleys, can no doubt be attributed to distribution by tidal and turbidity

currents. As explained in Section II, the diurnal tidal wave approaching Iceland from the south becomes a wave of translation when it crosses the Icelandic shelf; that is, the water particles move in a straight line in the direction of approach instead of describing a vertical oscillation, and the tide becomes, in essence, a mighty stream of water moving across the shelf. The maximum current velocity, shown by the table of current data on B. A. 2980, is 0.6 knots, which is slightly more than one foot per second, the critical minimum velocity necessary to move sand. This velocity is plotted for one place only on B. A. 2980 ($63^{\circ} 35'$ North Latitude, $17^{\circ} 12'$ West Longitude). However, the strength of the currents south of Iceland is known to vary considerably with the winds, so it is not improbable that the critical minimum velocity is reached on other parts of the shelf when the tide is backed by a strong wind.

Likewise, as explained in Section II, turbidity currents may be expected to develop in the surf zone along the coast, especially during periods of stormy weather. The currents, moving down every available slope on the shelf, would eventually find their way to the outer edge and pour down the insular slope, unless they became entrapped in a hollow or basin deep enough to halt further progress. The sea valleys, with their enclosed basins, could thus receive many such currents and their load of fine sediments. It is a matter of conjecture, however, as to whether the basins are deep enough to completely halt the turbidity currents or whether they would merely slow them down, thereby causing them to drop the coarser constituents only of their sediment load. The fact that the bottom notations on the hydrographic chart show only sand in the basins suggests that the latter may be the case.

7. The suggestion has been made* that the large zones of mud at the head of Jökulsa Dyb and 5 miles southeast of Stokksnes may possibly be due to quiet water in the centers of large current eddies produced in the lees of Ingolfshöfði and Stokksnes. At present, however, not enough current data are available to determine if this is the reason for the occurrence of the mud zones or if they may be traced to some other cause.

* RICH, J. L., University of Cincinnati, Personal Communication.

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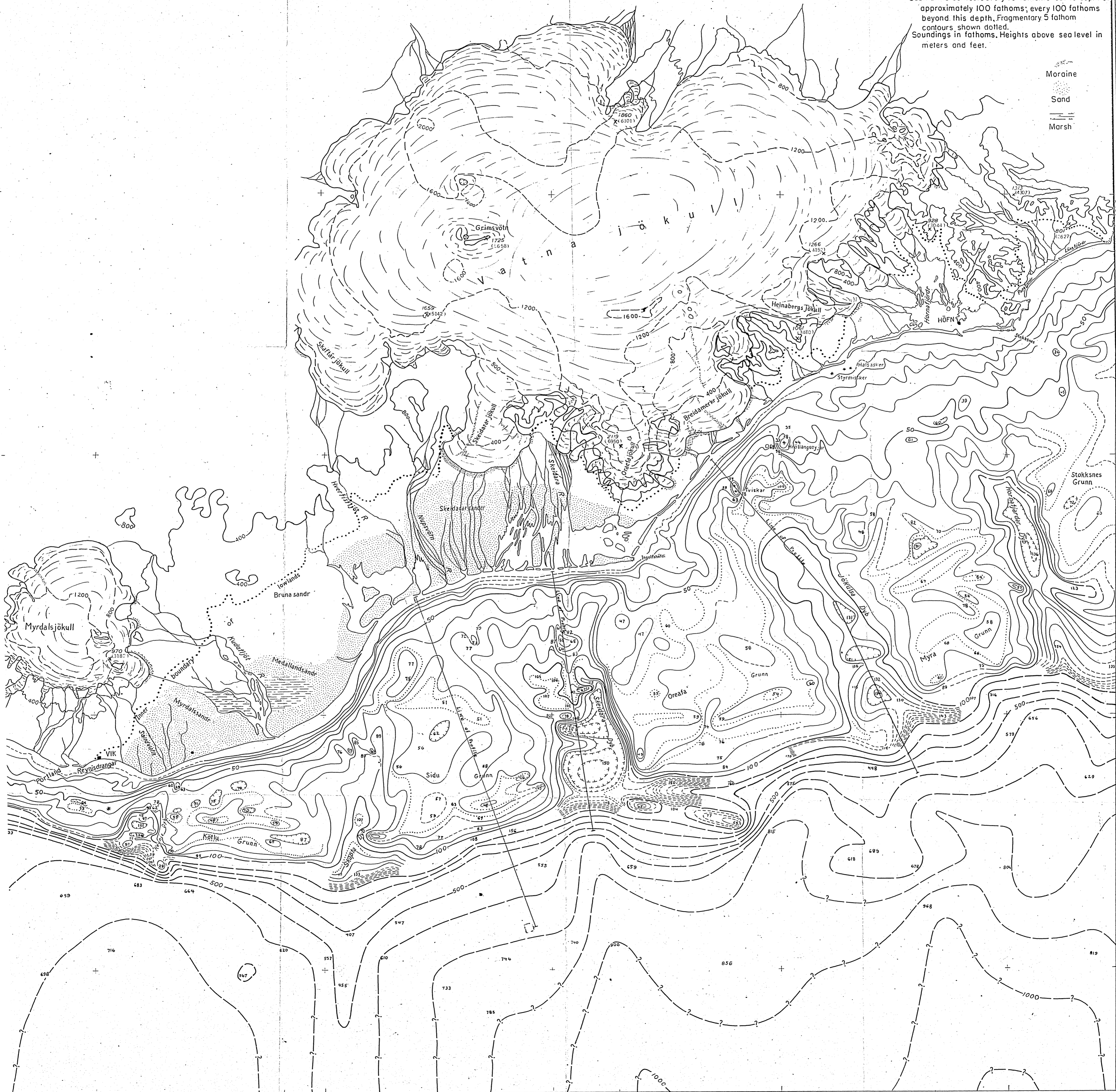
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SUBMARINE TOPOGRAPHY OFF THE SOUTHEASTERN COAST OF ICELAND

Scale 1:375,000
1 0 5 20 Miles

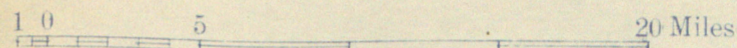
Topography contour interval 400meters,
Submarine contour every 10 fathoms out to depth of
approximately 100 fathoms; every 100 fathoms
beyond this depth, Fragmentary 5 fathom
contours shown dotted.
Soundings in fathoms. Heights above sea level in
meters and feet.

- Moraine
- Sand
- Marsh



BOTTOM SEDIMENTS OFF THE SOUTHEASTERN COAST OF ICELAND

Scale 1:375,000



Topography contour interval 400 meters,
 Submarine contours every 10 fathoms out to depth of
 approximately 100 fathoms; every 100 fathoms
 beyond this depth.

Soundings in fathoms, Heights above sea level in
 meters and feet.

- Moraine
- Sand
- Marsh

- S SAND
- G GRAVEL
- M MUD
- MS MUD AND SAND
- R ROCK

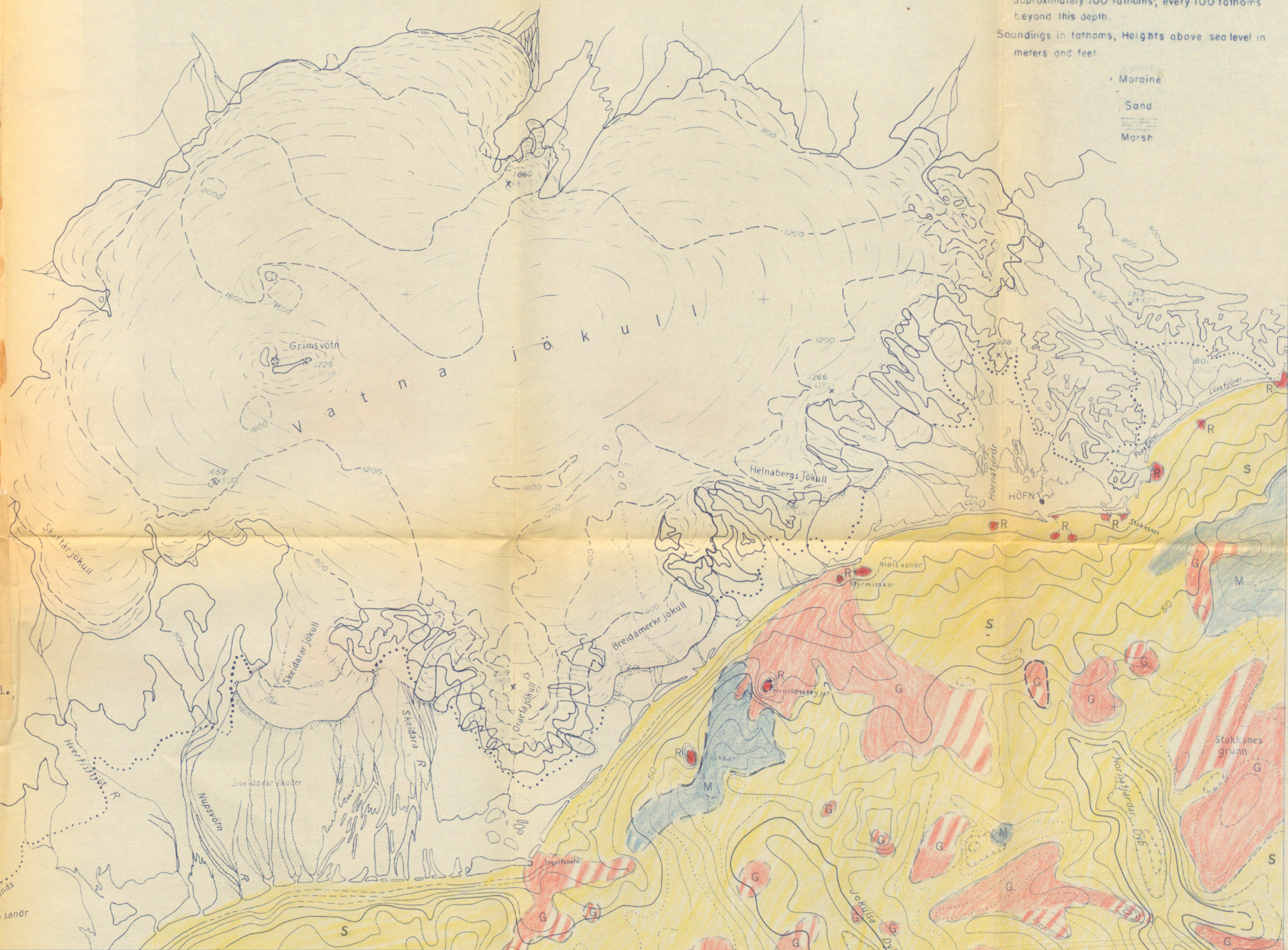
Banded color indicates bottom type
 inferred on basis of topography.

--- Contact between sediment zones.

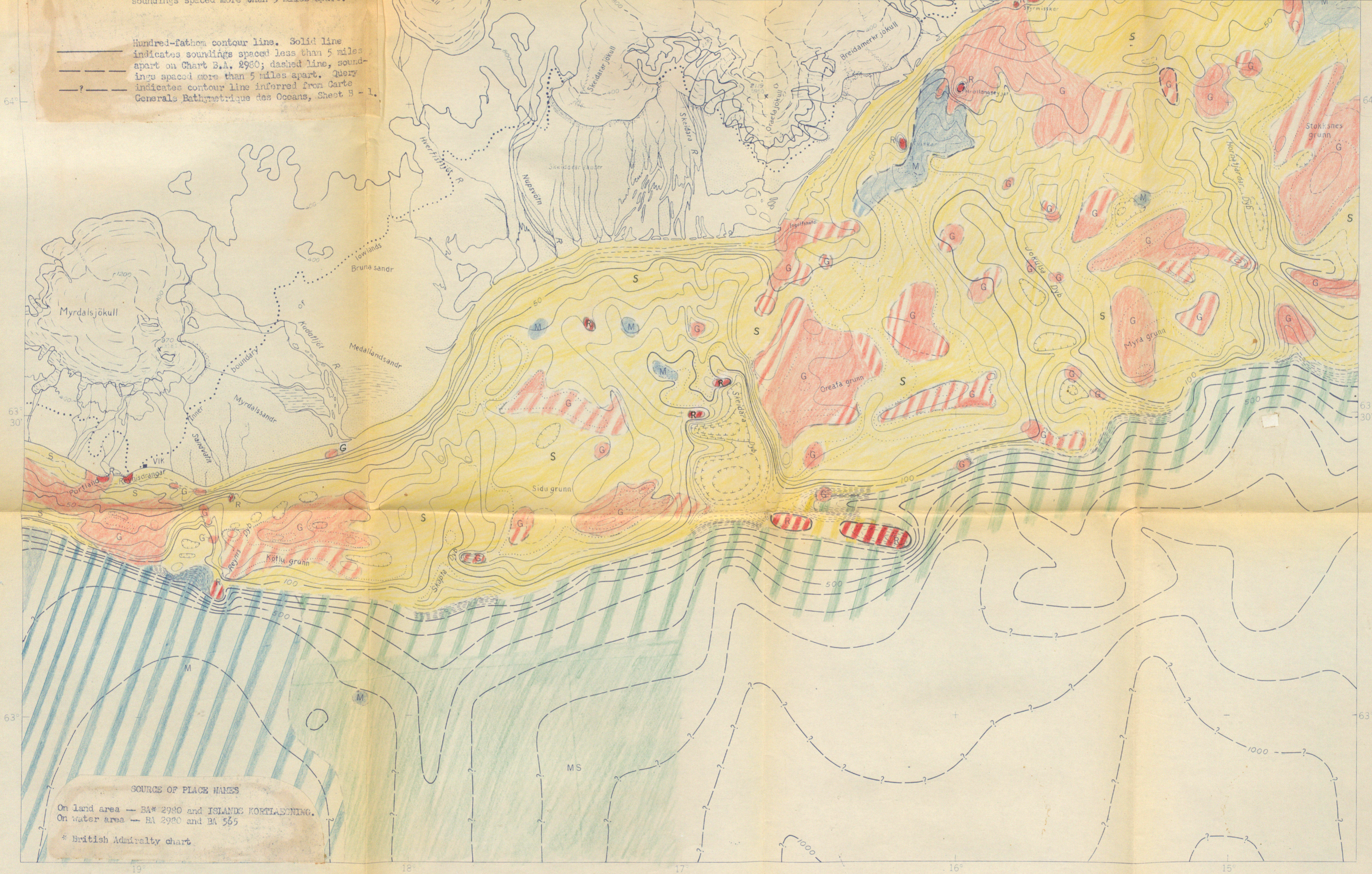
..... Fragmentary five - fathom line.

Ten-fathom contour line. Solid line
 indicates soundings spaced less than 5 miles
 apart on Chart B.A. 2980; dashed line
 soundings spaced more than 5 miles apart.

Hundred-fathom contour line. Solid line
 indicates soundings spaced less than 5 miles
 apart on Chart B.A. 2980; dashed line,
 soundings spaced more than 5 miles apart. Query
 indicates contour line inferred from Carte
 Generale Bathymetrique des Oceans, Sheet B - 1.



Hundred-fathom contour line. Solid line indicates soundings spaced less than 5 miles apart on Chart B.A. 2980; dashed line, soundings spaced more than 5 miles apart. Query indicates contour line inferred from Carte Generale Bathymetrique des Oceans, Sheet B-1.



SOURCE OF PLACE NAMES

On land area -- BA* 2980 and ISLANDI KORTLÆGNING.
 On water area -- BA 2980 and BA 565

* British Admiralty chart

S	SAND
G	GRAVEL
M	MUD
MS	MUD AND SAND
R	ROCK

Banded color indicates bottom type inferred on basis of topography.

--- Contact between sediment zones.

..... Fragmentary five - fathom line.

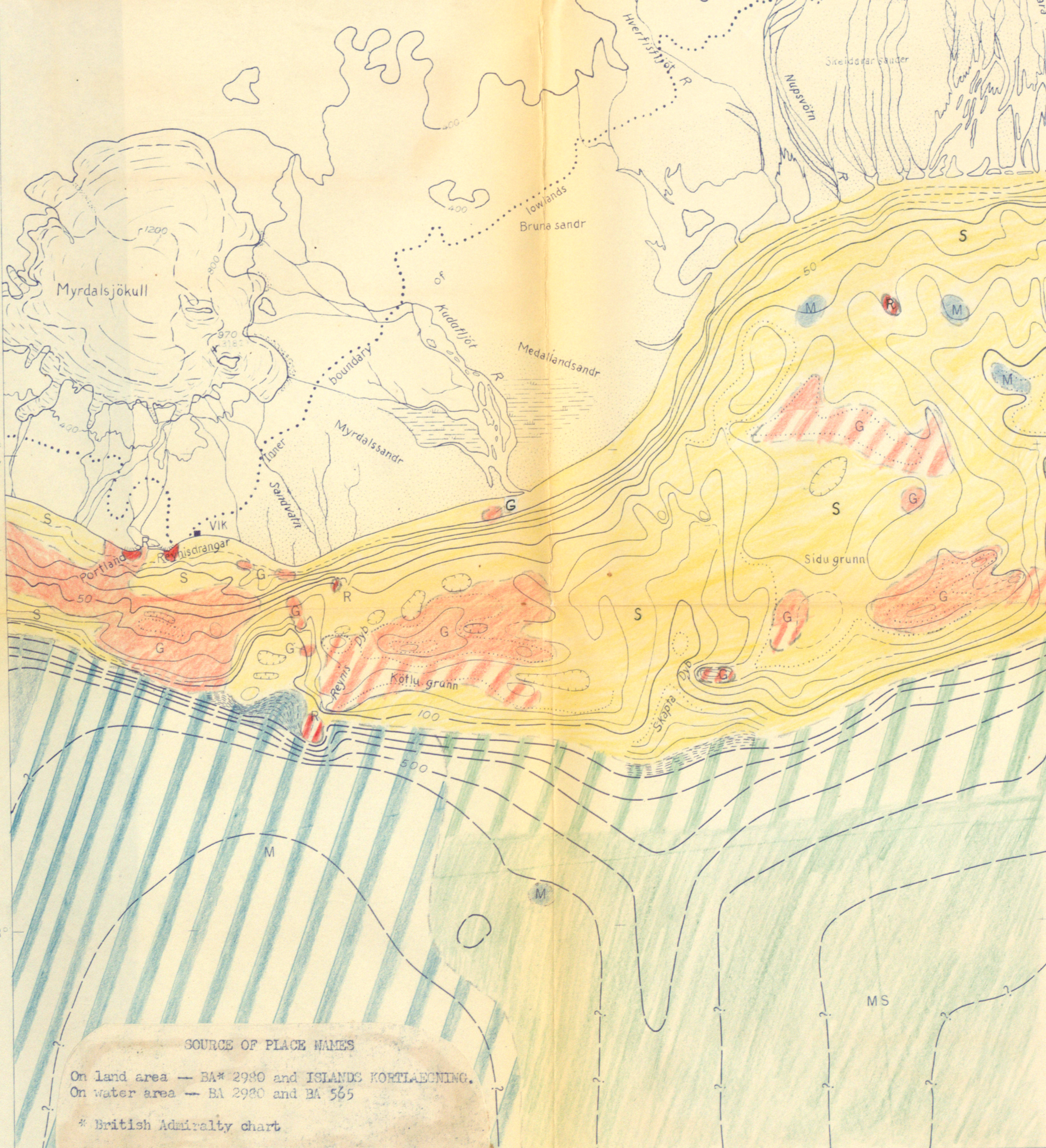
— Ten-fathom contour line. Solid line indicates soundings spaced less than 5 miles apart on Chart B.A. 2980; dashed line soundings spaced more than 5 miles apart.

— Hundred-fathom contour line. Solid line indicates soundings spaced less than 5 miles apart on Chart B.A. 2980; dashed line, soundings spaced more than 5 miles apart. Query indicates contour line inferred from Carte Generale Bathymetrique des Oceans, Sheet B - 1.

64°

63° 30'

63°



SOURCE OF PLACE NAMES

On land area -- BA* 2980 and ISLANDS KORTLÆBNING.
On water area -- BA 2980 and BA 565

* British Admiralty chart

M SEDIMENTS OFF THE SOUTHEASTERN COAST OF ICELAND

Scale 1:375,000

1 0 5 20 Miles

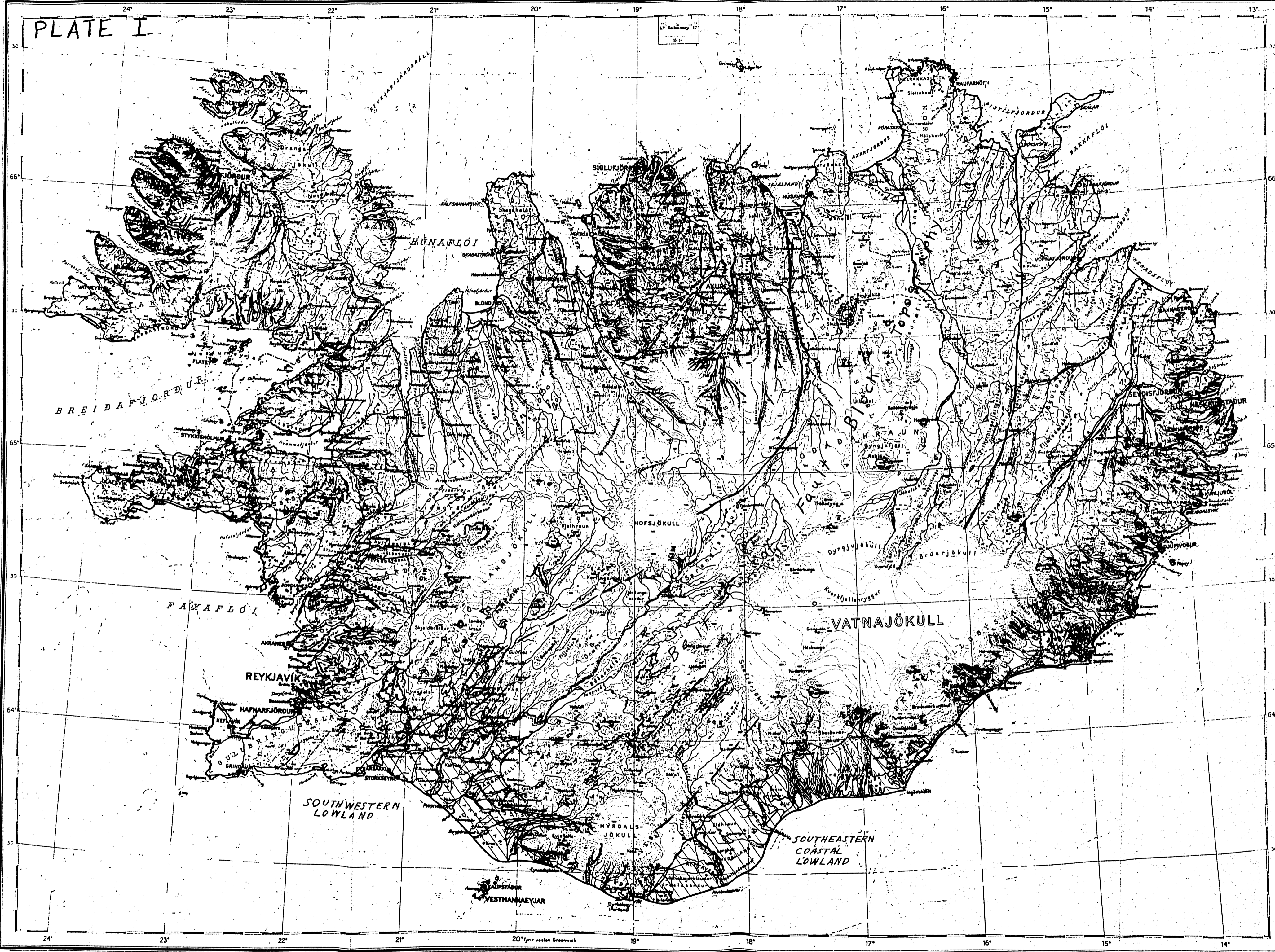
Topography contour interval 400 meters,
Submarine contours every 10 fathoms out to depth of
approximately 100 fathoms; every 100 fathoms
beyond this depth.

Soundings in fathoms, Heights above sea level in
meters and feet.

- Moraine
- Sand
- Marsh



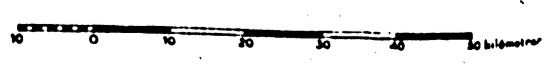
PLATE I



Communications revised to 1939

- | | | |
|-----------------------------|----------------------------|------------------------------------|
| ● KAUPSTADUR | ● KÖBSTAD | ● TOWN |
| ○ KAUPTÚN með kirkju | ○ HANDELSPLADS með kirkju | ○ MARKET TOWN with church |
| ○ KAUPTÚN án kirkju | ○ HANDELSPLADS án kirkju | ○ MARKET TOWN without church |
| ■ Verslunarsalur, Sýsluhúsi | ■ Handilsstafr, Fiskerhúsi | ■ Trading station, Fishing village |
| ✦ Kirkja | ✦ Kirke | ✦ Church |
| ■ Bær | ■ Gaard | ■ Farm |
| ■ (Lýðskil) Sýsluáskil | ■ (Gulpaund) Húsnámsáskil | ■ (Greenland) Farm, Húsnámsáskil |

1:1000 000



Heights and depths in metres
Contours at 100 metre intervals

- | | | |
|------------------|-----------------------|--------------------------|
| ✦ Vill | Fyr | Lighthouse |
| ○ Hver, Laug | Varm Kilde | Geysir, Hot spring |
| ○ Gígur - Eldgíg | Krater - Vulkanopalle | Crater - Volcano fissure |
| ○ Sýslumark | Sýslugraens | County boundary |
| ✦ Bú - Fast | Ána - Mandkúli | Bridge - Waterfall |
| — Ávegur | Kanngang | Road |
| --- Vægar gata | Ráttur | Brake path |

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