An account of the physical geography of Iceland : with special reference to the plant life / [Thorwald Thoroddsen].

THE BOTANY
OF
ICELAND

EDITED
BY
L. KOLDERUP ROSENVINGE
PH. D.
AND
EUG. WARMING
PH. D., SC. D.

PART I

2. AN ACCOUNT OF THE PHYSICAL GEOGRAPHY OF ICELAND
WITH SPECIAL REFERENCE TO THE PLANT LIFE

BY
TH. THORODDSEN
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(PUBLISHED BY THE AID OF THE CARLSBERG FUND)

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WITH 36 FIGURES IN THE TEXT

CONTENTS.

I. GENERAL TOPOGRAPHY. GEOLOGY.

ICELAND is a large island in the North Atlantic. It stretches from $63^1/_2{}^0$ to $66^1/_2{}^0$ N. lat. and from 13° 27′ to 24° 30′ W. long. fr. Gr.; consequently, the Arctic Circle touches its northernmost points, and as a result, along the northern coast, the midnight sun turns night into day for a short time during summer. In the most northerly districts the sun is above the horizon for a week; at Reykjavík the longest day is 20 hours 56 minutes, the shortest 3 hours 58 minutes. The distances from Iceland to the neighbouring countries are as follows: — to Norway 950 km., to Scotland 900 km., to the Færöes 450 km., to the east coast of Greenland 330 km., and to Denmark 1500 km. The length of the island from east to west is 490 km., and the breadth from north to south is 312 km. Its area is about 104,000 sq. km.

Iceland is a very mountainous country although it has not any true mountain-chains; it is most properly described as a continuous table-land with an average height of 700—1000 metres above sea-level; besides, there are only narrow borders of coastal land, valleys which cut into the table-land from all sides, and a few small areas of level land towards the south and west. Scarcely one-fifteenth of the country can be reckoned as lowland. Owing to its northern situation, its height above sea-level, and the resulting severe climate, only a relatively small part of the country is inhabitable. More than two-thirds of the entire area of the country is situated at so great a height above sea-level that almost no vegetation can thrive there. The sandy and stony deserts of the interior plateau, the lava tracts, and the glaciers are not fit dwelling places for human beings; therefore it is almost exclusively the coasts and the valleys which are inhabited.

Vatnajökull cover an area of about 8000 square km. The axis of elevation lies from NW. to SE., from somewhere near the head of Hvammsfjörður to Hornafjörður; it does not, however, consist of one continuous ridge, but of a series of snow-covered, dome-shaped mountains separated by broad stretches of more level ground. These snow- and ice-covered domes are strictly speaking a series of small plateaus which rise from the main plateau to an absolute height of 1400–2000 metres, as compared with 600—1000 metres above the plateau. The most easterly of the great glacier-bearing mountains is Vatnajökull which is separated from the much smaller Tungnafellsjökull (100 square km.) by Vonarskarð (1000 metres); between Tungnafellsjökull and Hofsjökull (1350 square km.) lies the broad stretch of level ground, Sprengisander (650 metres); west of Hofsjökull and between the latter and Langjökull (1300 square km.) lies Kjölur or Kjalvegur (600 metres); and between Langjökull and Eiriksjökull (100 square km.), Flosaskarð (800 metres). The plateau north of the last-mentioned ice-mountains abound in lakes and bogs. The interior plateau consists chiefly of deserts almost destitute of vegetation, but the surface varies somewhat in character in accordance with the geological nature of the underlying rock. Where basalt or dolerite forms the substratum, the surface is strewn with innumerable angular blocks of rock, split asunder by the action of frost; where tuff and breccia form the foundation, the surface is usually covered with gravel and fragments of slaggy lava which have been loosened from the breccia by the action of weathering. More than one-half of the plateau is overlain by more recent formations — lava, blown sand, volcanic ashes, glacial formations, clay and river-gravel. The lava-fields, taken together, cover a very large area in the interior and present a most desolate scene; as far as the eye can reach only a black, hardened mass is seen, and the dark colours are only here and there interrupted by mounds of reddish slag, smoking craters, scattered snow-drifts, and in the distance by glistening, white Jökull-domes; there is no sign of life and an oppressive silence reigns over the land.

The interior plateau is trenched by many valleys, chiefly towards the north and east; between these valleys long mountain spurs — the skeletal ribs of the eroded plateau — branch outwards toward the sea. Of these, the mountain-mass which extends towards the south, and is crowned at the top by Myrdalsjökull, is the most considerable. Towards the west the two volcanic mountain-chains

extend outward upon Reykjanes and Snæfellsnes. The mountain-chain on Reykjanes is broad and flat at the top; it is divided into several smaller plateaus (300—600 metres) with rows of craters and volcanic mountain-tops, and it sinks down more and more towards the west so that the extreme end of the peninsula consists chiefly of low-lying lava-fields with a few low, isolated mountain-tops. The mountain-chain which extends toward Snæfellsnes is higher (600—900 metres), but much narrower; it is also very vol-

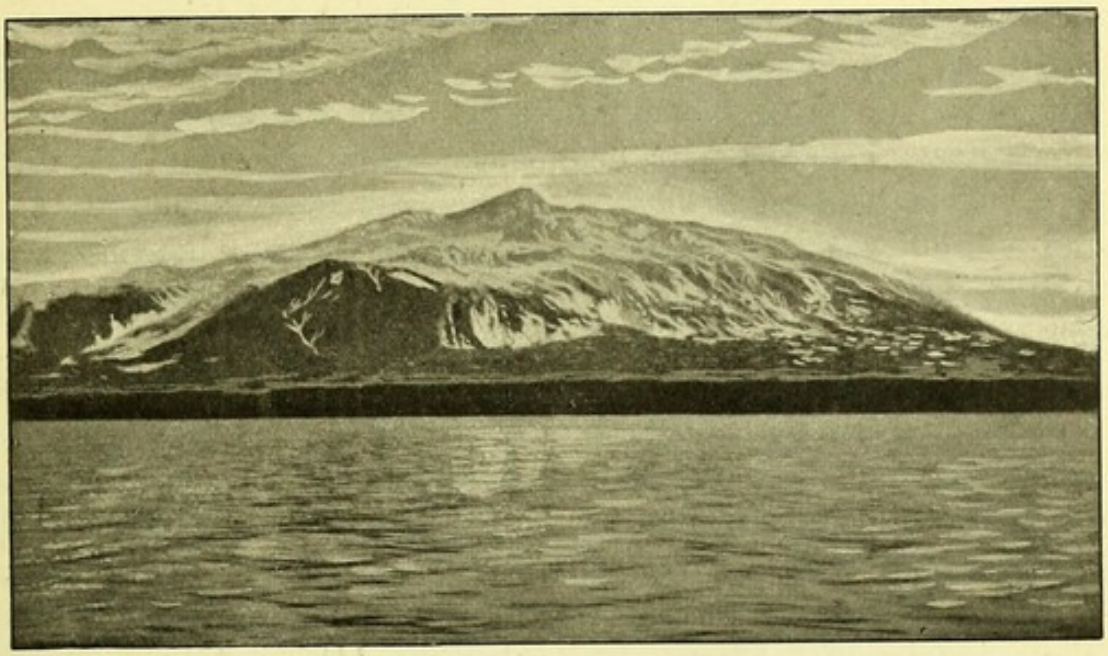

Fig. 1. Snæfellsjökull (West Iceland).

canic and terminates in the ancient, ice-capped volcano, Snæfellsjökull (1446 metres).

In North Iceland several great mountain-masses proceed from the high land outward upon the peninsulas, and from the head of the fjords long valleys extend into the country; by the extensive branching of the valleys, the mountains are divided into a number of ridges and peaks, which however when examined more closely, prove to have been cut out of an originally continuous plateau. Several valleys lead up from Húnaflói, of which the western are narrow, but the eastern (Víðidalur, Vatnsdalur, Blöndudalur) are broader and more fertile; these latter open out toward the low land (Thing) at the head of Húnaflói. The large peninsula between Skagafjörður and Eyjafjörður is occupied by mighty, steep mountain-masses which are intersected on both sides by numerous valleys, the largest (Öxnadalur, Hörgárdalur, Svarfaðardalur) being on the

east. On this peninsula occur the greatest heights in northern Iceland (Vindheimajökull, 1445 metres; Kerling 1350 metres; Rimar, 1261 metres). Broad, fertile and thickly-inhabited main valleys stretch up from the head of Skagafjörður and Eyjafjörður; east of Eyjafjörður, between the latter and Skjalfandi, the stern, wild mountains rise to a height of 1200 metres, and there Fnjóskadalur, which cuts through these mountains towards Eyjafjörður from the east, opens out. These mountains fall abruptly towards the east down towards Bárðardalur (70 km. long), but east of that valley the country becomes lower, and has a different geological structure and character; hitherto, basalt has been the dominant rock, but hereafter, for a long distance, the substratum is formed of tuff, breccia and recent volcanic formations. East of Bárðardalur the plateau gradually sinks down towards the sea, and inhabited spots occur, not only along the coast and in the valleys, but also here and there upon the high land itself (Myvatnssveit, 300 metres above the level of the sea; Fjallasveit, 450—500 metres). Upon these areas of the plateau there are many isolated mountains and mountain-ridges, volcanoes and lava-streams.

The eastern part of Iceland is called collectively Austfirðir. There the country is very mountainous towards the coast and indented by deep fjords which are bounded by high, precipitous rock-walls, basalt being now again the dominant rock. From Hjeraðsflói two long valleys, 80—90 km. in length, extend towards the south. These valleys, which unite lower down, are called Jökuldalur and Fljótsdalshjerað; the latter lies behind the fjord district of eastern Iceland and cuts it off from the interior plateau which is here somewhat lower than the coastal mountains, which reach a height of 10—1100 metres and even more. Towards the south there are two smaller Jökulls, Thrandarjökull and Hofsjökull í Lóni, with an area of 100 and of 80 square km. and a height of 1100—1200 metres respectively. Near Hornafjörður the character of the coastal land changes completely, because there the plateau, to its extreme edge, is buried beneath the snow and ice-fields of Vatnajökull. The low, narrow and sandy coastal border is irrigated by glacier-water streaming down from the numerous glaciers which advance through every cleft and valley. Here and there, along the edge of the snow-field, mountains and rocky promontories appear, and of the former the imposing volcano of Öræfajökull (2119 metres), Iceland's highest mountain, is the most noticeable; other promontories and mountains near the southern edge of Vatnajökull have a height of 1100—1500 metres.

North of the mountain of Lómagnupur (770 metres), which is a breccia-promontory rising steeply from a sandy flat, the glaciers recede from the coast and the plateau is continued as a low hilly edge as far as Mýrdalsjökull, the snow-masses of which cover the upper part of the above-mentioned southern spur of high land and which has an area of about 1000 square km., reaching a height of 1666 metres in the volcano of Eyjafjallajökull. Another very active and dangerous volcano, Katla, also hides itself beneath the glaciers of Mýrdalsjökull. West of this snow-field the plateau retires again from the coast; the deep valley of Markarfljót separates Mýrdalsjökull from Tindfjallajökull (1462 metres), and north of the latter lies the oblong, volcanic Torfajökull (1400 metres) and the famous volcano Hekla (1447 metres). North-west of Hekla and near Geysir, the plateau retires to its greatest distance from the coast (about 80 km.), but bends thence again towards the south-west, outwards towards the peninsula of Reykjanes.

The lowlands of Iceland cover only a small area; in the north and east there is no low land with the exception of the larger valley-mouths, e. g. at the head of Húnaflói, Skjálfandi and Fljótsdalshjerað and the extreme end of the peninsulas of Skagi and Melrakkasljetta. Larger lowland areas occur only in South and West Iceland; they are however small in extent compared with the mountainous country and the table-lands. Although the lowlands only comprise one-fifteenth of the entire area of the country, yet together with the valleys they are of very great importance because tolerably favourable climatic conditions and a closer vegetation, permitting fixed habitations and the rearing of cattle. are found almost exclusively there; the inhabitants of the few dwellings which occur scattered in the lower parts of the plateau must struggle with severe conditions and are almost entirely reduced to sheep-rearing alone. But by no means all the lowlands are grass-covered; large tracts of lava, glacier-gravel and blown sand are extremely poor in plant-life. On the south coast the country nearest to the sea is quite flat, from Hornafjörður to Reykjanes, but in many places this level land is so narrow that it consists only of an insignificant coastal border; in other places it widens out into larger plains and extends further into the country. Between Hornafjörður and Mýrdalsjökull, below Vatnajökull, the coastal country is formed by deposits from the numerous glacier-rivers and consists exclusively of sand and gravel; the lowland here is often flooded by branching torrential glacier-

rivers, so that no vegetation can thrive here. Below the southern edge of Vatnajökull the farmsteads are therefore confined to oases separated from one another by gravel-deserts and swollen glacier-rivers. In many places the people have been obliged to move their houses up on the mountain sides in order to avoid inundations caused by the glacier-waters, and here the mountain-sides facing south are covered with a luxuriant plant-growth, while the level country below is devoid of vegetation. The sandy tracts have different names, such as Breiðamerkursandur, Skeiðarársandur, Brunasandur, Mýrdalssandur, Sólheimasandur, etc. Of these the largest is Skeiðarársandur (about 900 square km.), and taken together they cover an area of about 2700 square km. Between Lómagnupur and Mýrdalsjökull the lowland becomes broader and is covered by extensive lava-fields, blown sand, gravel and volcanic ashes, as large volcanoes occur in the neighbourhood. The largest area of low land in Iceland lies between Eyjafjallajökull and the peninsula of Reykjanes and is about 4000 square km. in extent; it is hemmed in by tuff-mountains which in many places fall abruptly towards the plain. The lowest part of the lowland is only slightly raised above sea-level, but it rises gradually towards the interior where it ultimately branches off into different valleys; near Geysir it reaches its greatest height above sea-level, about 150 metres. The low land is not flat everywhere, some parts of it are hilly, and a few isolated mountains also rise from the plain. West of Hekla the lowland, by means of a gentle rise, is in direct connection with the interior plateau, to the great danger of the inhabited districts, as the blown sand, volcanic ashes and pumice dust which cover large areas of the interior have thereby free access to the lowlands; therefore, in these regions, during north-westerly storms, large tracts of grass-covered and inhabited land have been overwhelmed in the course of time. The lowlands consist chiefly of grassland, and nowhere in Iceland do farmsteads occur so closely together as here, these districts being well-suited to cattle-rearing. Three very well-supplied rivers run through the lowland, viz. Markarfljót with a large delta-land (Landeyjar), Thjórsá and Ölfusá, and besides these there are many smaller ones. The eastern part east of Thjórsá is called Rangárvallasýsla, the western Árnessýsla. At the head of Faxaflói there is another low area (about 1000 square km.) which on an average has a height of only 20—30 metres. It is bounded by steep, basalt mountains which are arranged in a semicircle around

the lowland which is very swampy and above which project numerous low, isolated, basalt hills. The eastern part is called Borgarfjörður and the western Mýrar. From the low land several wide valleys extend inwards between the mountains.

The north-western peninsula, as mentioned above, constitutes a small plateau by itself and is separated from the mainland by Breiðifjörður and Húnaflói; the isthmus which connects the peninsula with the mainland has a breadth of only 7 km., and rises to a height of 228 metres. The coast of north-west Iceland, which is much indented by fjords, is bounded everywhere by steep, dark mountain-sides which often rise abruptly, even vertically, from the sea to a height of 400—500 metres. The mountains are everywhere composed of horizontal, or slightly inclined, basalt-layers which are highly denuded by erosion, so that numerous small valleys, cirques, clefts, ridges and bastions occur as in other basalt regions of Iceland. By climbing the mountain-edge up in the highlands, and ascending to a sufficient height it will be seen that fjords and valleys have trenched the plateau with great regularity. The eye wanders freely over wide wastes, the valleys and fjords either disappear or are seen as insignificant clefts, and a monotonous table-land lies stretched out to view, the surface of which is broken only by low ranges of hills, and ice-striated basalt-masses with large stretches covered by angular blocks of rock and scattered snow-wreaths. It is often extremely difficult to traverse this kind of ground, across an ocean of rocky blocks, where the clay and the gravel between the blocks often occur as a slushy mass owing to the thawing of the numerous patches of snow. Only now and then can a solitary, stunted Alpine plant be seen maintaining a miserable existence in the shelter of the large blocks of rock. The plateau of the north-western peninsula has an average height of only about 600 metres, and where it is highest (800—900 metres) the snow drifts and consolidates into *névé*-domes — Gláma (about 60 square km.) towards the SW. and Drangajökull (about 350 square km.) towards the NE. The numerous valleys which lead up from the fjords and cut into this plateau are similar in character to the other Icelandic valleys in the basalt districts, so it will be convenient to describe their physiographical characters collectively. The bottom of the valley rises gradually in broad rock-terraces, upon the surface of which bogs and small lakes often occur, and it terminates amphitheatrically in a large cirque, down the steep rocky sides of which several streams fall in cascades.

The mouths of the contributory valleys are often situated at a higher level than the bottom of the main valley and along the mountain-sides a series of cirques are often found. Hundreds of streams carry gravel and rock-fragments down to the foot of the mountain and to the valley, and below each notch in the mountain there is, therefore, a flat cone of gravel which extends down the side of the mountain to the bottom of the valley; each little cirque and each notch has, like an hour-glass, according to the law of gravitation, emptied its contents upon the level land below. The foot of the mountain is covered with plants, but any aggregate of vegetation has rarely been able to extend higher than half-way up the mountain-side; only on ridges between clefts and hollows, where neither floods, rock-slips nor avalanches can do harm can the plant-covering extend upwards in longer tongues, while the upper half of the mountain-side consists but rarely of anything except bare rock-ledges or rock-faces or heaps of stones. On a closer investigation, a few individual plants will however be found seeking cover, shelter and foothold among the blocks of rock and in the crevices. In places where springs are trickling out in a row from between rock-strata there is often a luxuriant vegetation of yellowish-green mosses which form soil and pave the way for the higher plants. Even on the most precipitous valley-sides, sheep are seen scattered about seeking the mountain-plants which peep forth between the stones. Upon the north-western peninsula there are no lowlands. but only a narrow border of coastal land which is due to the action of the breakers at a time when the sea-level was higher than at present. Only the narrow coastal land along the sides of the fjords is inhabited, and the inhabitants are chiefly dependent upon the sea for subsistence. Where the land which fringes the coast becomes somewhat broader and the valleys more grassy, as along the north coast of Breiðifjörður, the inhabitants' chief means of sustenance is sheep-rearing; where the fjords are small, the mountains steep, and the coastal land has disappeared, as along the coast south of Cape Nord, the inhabitants maintain themselves almost entirely by the catching of birds upon the steep sea-cliffs.

Glaciers. The snow- and ice-covered mountains (Jökulls)[1] of Iceland, taken together, cover an area of 12700 square km. and

[1] In Iceland, by "Jökull" a glacier-bearing mountain is usually meant, but sometimes the term is used for the masses of snow and *névé* upon the mountain.

through their glaciers and glacier-rivers they exert a great influence upon the surface and climate of the country and upon the conditions of life of the inhabitants. The Icelandic climate is specially adapted to the development of large glaciers, for the air is raw and cold and moist, the amount of rainfall considerable and the summer-heat slight. The amount of precipitation is greatest towards the south-east and there the interior table-land is covered by the great Vatnajökull. The altitude of the snow-line varies from 400 to 1400 metres in the different parts of the country, and the level above the sea at which the glaciers end differs greatly; in the north on the north-western peninsula, and in the south near Vatnajökull, the glaciers descend almost to the sea, to 25 metres and 9 metres above sea-level respectively at the lowest points to which they descend. The great ice-mountains of Iceland are without exception closely associated with the plateau. Large areas of the highest part of the plateau are covered with *névé* which occurs as slightly-arching domes or undulating snow-fields of great thickness. Prominent mountain-peaks are rare; the latter do not appear until near the edges of the snow-fields and usually as outstanding summits of the underlying rock. The surface of these snow-fields is devoid of gravel; this does not appear until it does so at the extremities of the glaciers which are often quite black with it and with sand and blocks of rock. The large glaciers which descend from these *névé*-covered flats have, on an average, a very slight declivity; only in places where precipitous mountain-peaks project from the edge of the snow-field, do steep glaciers of small dimensions occur. The large glaciers of Iceland closely resemble the glaciers typical of Arctic countries; but there are a great many small glaciers which resemble those of the Alps. Several of the broad glaciers which descend from Vatnajökull cover a very considerable area (e. g. Dyngjujökull 400 square km., Bruarjökull 500 square km., etc.). Peculiar to Iceland are the so-called "glacier-torrents" (Jökul-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 ice-bergs. 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. Öræfajökull has, in the same manner, caused considerable destruction; while the waterfloods of Skeiðarárjökull, which were especially frequent during the 19th century, have done less material damage, as only uninhabited sandy wastes were inundated. Minor glacier-bursts are also occasionally due to lakes and rivers, which have been dammed by glaciers, suddenly breaking through their barriers and inundating the district. These glacier-bursts have a great effect upon the plant-life, because no permanent vegetation can exist upon gravelly and sandy flats which are constantly inundated by waterfloods carrying large pieces of ice; therefore very large stretches of lowland in the neighbourhood of such volcanoes and glaciers are destitute of plant-growth, for what little vegetation appears in the period between the glacier-bursts is quickly destroyed. The general physiographical conditions pertaining to the glaciers of Iceland may be best seen by a study of the table opposite.[1]

Snow-line. In Iceland it is not easy to determine the snow-line, owing to the great variability of the climatic factors. Because of the great annual and periodical variability of temperature and of the circumstances connected with precipitation, the snow-line also varies. In Iceland three kinds of height-levels connected with the vertical distribution of the snow, and dependent on climatological and orographical conditions, may be supposed to exist. The snow-line proper, which signifies the lowest limit of the permanent, continuous snow-covering of the mountains, is not subject to very great changes from year to year. Below this comes a zone of detached, more or less closely placed, patches of *névé* and wreaths of snow; these never melt entirely, but either are added to or else diminish according to the character of the year. Below this zone comes the most variable of the snow-coverings: scattered snow-drifts which to a greater extent than the others are dependent on orographical conditions. These snow-drifts may persist through a series of damp and cold years, but dwindle almost to nothing or disappear entirely in warm and dry years. The snow at Drangajökull upon the north-western peninsula may serve as an example. Here, on

[1] Here it should be noticed that many of the figures for the area of the Jökulls are approximate and given as a rough estimate, because the maps of a great part of Iceland, and especially of the plateau are still very imperfect.

Names of Jökulls	Approximate area in sq. km.	Greatest height above sea-level in metres	Altitude of snow-line in metres	Number of glaciers known	Altitude of inferior end of glacier in metres
Gláma	cir. 60	901	cir. 650	—	—
Drangajökull	350	890	—	7	—
— east side	—	—	400	—	30
— west side	—	—	650	—	25
Snæfellsjökull	23	1446	—	2	560
— north-east side	—	—	650	—	—
— south-west side	—	—	1000	—	—
Langjökull	1300	1400	—	31	—
— south-west side	—	—	900	—	600
— east side	—	—	1000	—	435
— north-west side	—	—	1000	—	628
— north side	—	—	1100	—	—
Eiríksjökull	100	1798	—	6	606
Ok	15	1198	900-1120	—	—
Hlöðufell	1	1188	960	—	—
Arnarfellsjökull (Hofsjökull)	1350	1700	—	19	—
— east side	—	—	—	—	552
— north side	—	—	1200	—	910
Mýrdalsjökull	1000	1666	—	20	—
— north side	—	—	1100	—	700
— south side	—	—	8-900	—	97
— east side	—	—	6-700	—	205
— west side	—	—	1000	—	220
Torfajökull	100	1200	950	—	—
Tindfjallajökull	22	1462	950-1000	5	570
Vatnajökull	8000	2119	—	41	—
— west side	—	—	1000	—	635
— south side	—	—	900	—	9
— north side	—	—	1300	—	600
— east side	—	—	950	—	700
Hofsjökull í Lóni	80	1200	850-950	1	—
Thrandarjökull	100	1200	900	—	—
Snæfell	15	1822	—	2	—
Tungnafellsjökull	70	1600	1300	2	—
Dyrfjöll	5	1131	600	—	—
Fönn	10	900	—	—	—
Kaldbakur	5	1161	—	—	—
Vindheimajökull	10	1466	—	1	—
Myrkárjökull	10	1200	—	1	—
Túnahryggsjökull	40	1200	—	4	—
Unadalsjökull	20	1200	—	—	—
	12686	—	—	142	—

the eastern side the snow-line stands at a height of 400 metres above sea-level, on the western side at an altitude of 650 metres. Upon the plateau itself, around the base of Drangajökull, there are numerous large, scattered wreaths of snow which taken collectively would cover a large area; they occur at an altitude of 250—500 metres. In the summer of 1886—87 there occurred, in addition, numerous wreaths at a lower level — in sheltered places even close to the sea-shore, especially at Snæfjallaströnd, where very long snow-drifts were lying on the terraces of the basalt beds. In these districts old banks of snow are usually very frequent at a height of 50—100 metres above sea-level; the climate also is very raw and the precipitation considerable; there are occasional snow-storms in the middle of summer, and drift-ice with cold, damp fogs and drizzling rain is a frequent visitor. The sea cuts into the land from all sides.

Above the snow-line proper there is naturally no vegetation, with the exception of a few individuals which maintain their existence on projecting rocks and "Nunataks" in the ice. In the region of permanent snow-drifts there occurs, only here and there, a poor and very scattered rocky-flat vegetation, but in the zone of the variable snow-drifts there may often be a vegetation of different species which is rather luxuriant, considering all things. According to my measurements in the years 1882—1898 the snow-limits were about as follows (the snow-limits given in the table on p. 203 may serve for comparison): —

	Snow-limit in metres	Lowest limit of the permanent snow-drifts in metres	Lowest limit of the variable snow-drifts in metres
Northern part of the north-western peninsula	400-650	250-500	50-100
Snæfellsnes	800-1000	cir. 700	500-600
Ódáðahraun	1400	1000	—
Mývatn	—	700-800	—
Peninsula NE. of Eyjafjörður	1000	450-500	200
Austfirðir	900-1000	500-550	300-400
Plateau between Vatnajökull and Mýrdalsjökull	1100	600-700	—
Arnarvatnsheiði NE. of Langjökull	1000-1100	600-700	500-600
The neighbourhood of the southern lowland	1000-1100	800-900	—

Rivers. Iceland possesses numerous rivers of considerable size; their volume is due to the damp climate of the land and to the great number of glaciers. The Jökulls serve as huge water-reservoirs, from which the majority of the larger rivers are supplied, and the glacier-plateaus also attract rain and other atmospheric precipitation, so that the supply is always uniform. The volume of water is greatest in the lower-lying districts because the plateau above 500—600 metres, to a great extent, is covered with lava, gravel and loose sand which absorb all the moisture; but it reappears further down, and below the 500 metre line there are extensive bogs both in the lowest part of the plateau, in the lowlands and in the valleys. In the lava-deserts both on the plateau and in the lowlands, the rain and melted snow disappear immediately, and large tracts are quite destitute of water; but at the edge of the lava numerous springs bubble forth from the earth. The water which at first is usually turbid and intermingled with glacier-mud, becomes filtered by passing through the lava, and is therefore very pure and clear in the springs. When there is no outlet, water is sometimes found in the lava-field itself, at the bottom of deep clefts; as for instance, the renowned, cold, crystal-clear water in the lava-clefts near Thingvellir. In early summer, during sudden thaw, while the frost-layer still persists in the ground, extensive gravelly and clayey flats on the plateau and in the lowlands are turned into morasses, but when the ice of the subsoil melts later in the summer outlets are again opened for the surface-water so that the gravel-fields are drained. In the valleys numerous springs make their way through the basalt along the mountain-sides, often in long rows between the layers, and can be detected by the green mosses which grow luxuriantly around them.

Icelanders draw a distinction between "bergvatn" (mountain-water) which is clear, and "jökulvatn" (milky-white glacier-water) which may have a muddy, yellowish colour or a chocolate-brown colour according to the amount and kind of glacier-clay carried in it. The amount of clay in the glacier-water is larger in summer than in winter and, again, the glacier-rivers are clearer and of less volume in the morning than later in the day. Differences in the weather — cold or warm or wet or dry years — have the greatest influence as regards the volume of water in the glacier-rivers. In dry and warm summers the clear rivers are but small, while the water carried by the glacier-rivers increases to double or three times the usual volume. As the glacier-rivers are so dependent upon the

melting of the snow their size varies from day to day and from year to year; many glacier-streams which disappear entirely during winter, carry in warm summers an immense volume of water. Almost all Icelandic glaciers rest on soft rocks (tuff and breccia) upon which erosive action is very active; therefore, the Icelandic glacier-rivers carry down an immense amount of rock in the form of mud, sand, gravel and blocks of stone; for this reason they are hardly ever found entering fjords or deep bays, these having quickly become filled up in cases where they formerly so entered, while the Jökulls (glacier-bearing mountains) are surrounded by large sandy and gravelly tracts which for the most part owe their origin to the rivers.

Taking the whole of the island into account, rivers containing glacier-water are decidedly in the majority. South of Vatnajökull clear water is almost unknown, as all rivers and brooks originate in the glaciers. There all the rivers flow down to the coast by short courses in torrential current, and during summer some of them are so broad that it takes hours to cross them — but then it must be remembered that it is necessary, in the middle of the river, to go a long way round, on account of the current and depth. On the flat, sandy tracts the rivers are constantly changing their course, and greater and smaller changes take place daily. All glacier-rivers branch abundantly.

In accordance with the slope of the land, the longest and largest rivers flow in South Iceland towards the south-west and south, and in North Iceland towards the north; the majority of them rise on the plateau at a height of 600—900 metres above sea-level, a fact which should be correlated with the limits of the glaciers in the interior. Although the Icelandic rivers carry a comparatively great volume of water yet they are not navigable, because of their usually steep fall, their torrential current, and their tendency to spread out and subdivide into numerous branches in the low land. The largest rivers of Iceland are as follows: — From the south edge of Vatnajökull rise Jökulsá í Lóni, Hornafjarðarfljót, Jökulsá á Breiðamerkursandi, Skeiðará and Núpsvötn; the last three are considered to be the most dangerous glacier-rivers of Iceland. From the west edge of Vatnajökull rise Hverfisfljót, Skaftá and the well-supplied Kúðafljót; this last also receives a large supply of water from Mýrdalsjökull. From the latter another river flows down — the short, but torrential Jökulsá á Sólheimasandi, also called

Fúlilækur, which often has minor "glacier-torrents" that carry down ice-pieces and stones. On the east side of the southern lowlands, Markarfljót flows into the sea; it rises in Torfajökull, but also receives well-supplied feeders from Mýrdalsjökull; in the low land it divides into four arms which enclose the largest delta-land of Iceland, the so-called Landeyjar. Thjórsá, Iceland's longest river

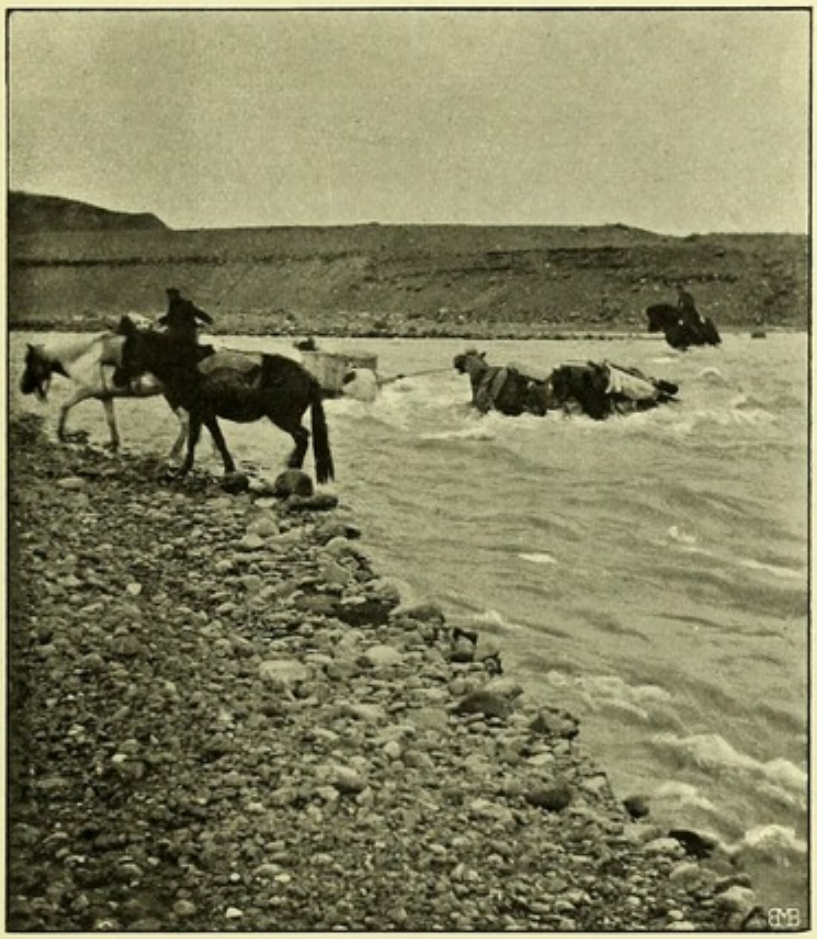

Fig. 2. The river Jökulsá á Sólheimasandi. A ford.

(200 km.) rises in Arnarfellsjökull, but receives about one-half of its water supply from Vatnajökull through its tributary Tungná; Thjórsá carries an immense volume of water and, in the cultivated district, is in several places one km. or more broad; above its mouth it forms an expansion or a saccate lagoon and is joined by a well-supplied arm of Markarfljót, named Thverá. The third and most westerly large river in the southern lowlands is Ölfusá which, for the longest part of its course (until the mouth of the tributary river Sog), flows under the name of Hvítá and issues from Hvítarvatn near Langjökull receiving, both on the plateau and in the cultivated district, many large affluents from both sides. In the neighbourhood

of Geysir, Hvítá forms the large waterfall Gullfoss. Towards the west, another river named Hvítá flows down through the district of Borgarfjord; it carries a great volume of water and its lower course is navigable. In the north-western peninsula there are no large rivers, but in North Iceland many such occur, among others Blanda, which issues from Arnarfellsjökull and flows into Húnaflói. From the same Jökull issues also Hjeraðsvötn which flows through the district of Skagafjörd and empties itself into the fjord by two

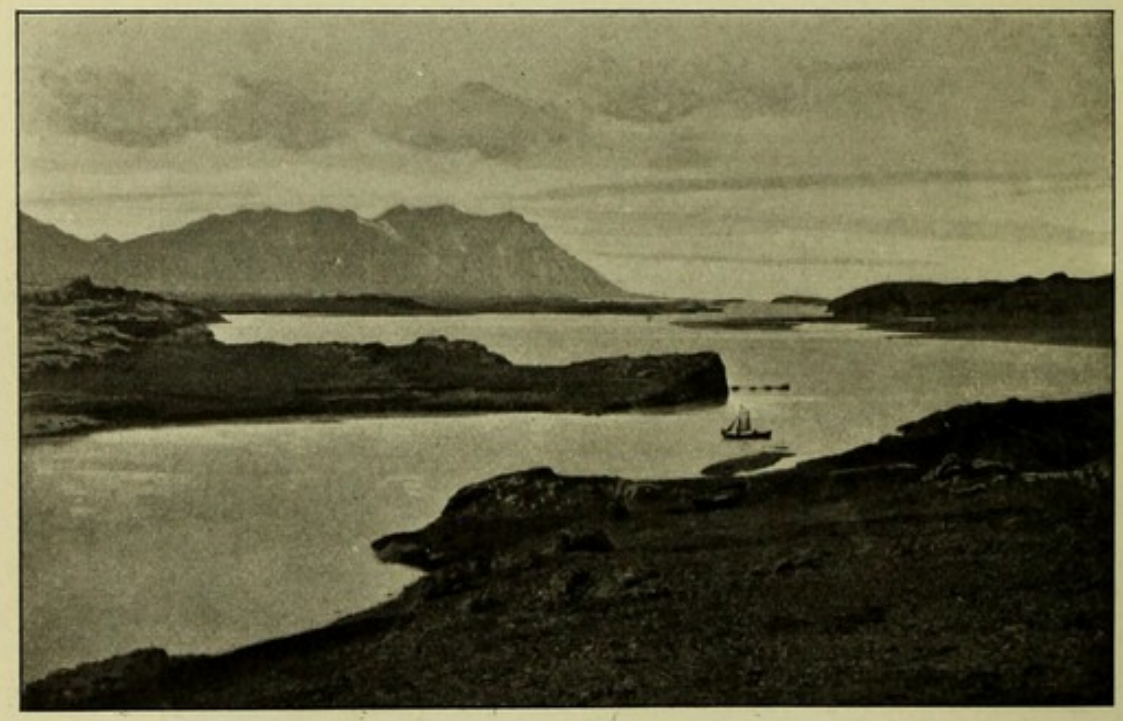

Fig. 3. The river Hvítá flowing through the district of Borgarfjord.

mouths. Three rivers of rather large volume — Hörgá, Eyjafjarðará and Fnjóská — enter Eyjafjörður. Then there is Skjálfandafljót which issues from Tungnafellsjökull and flows through the Bárdardalur; it has many waterfalls, among which Godafoss is the best-known. Jökulsá á Fjöllum, one of the best-supplied rivers of Iceland, empties into Axarfjörd and in its lower course falls through a deep cleft and forms Iceland's grandest waterfall, Dettifoss. In East Iceland two large rivers are noticeable, Jökulsá á Brú and Lagarfljót, both of which issue by many arms from the north edge of Vatnajökull and fall into Hjeraðsflói, after the latter river has expanded into a deep, oblong lake. Besides the numerous cataracts in the large rivers, there are also beautiful cascades (Fossar) in the smaller streams; of these the better-known are Hengifoss in Fljótsdalshjerad, Glymur in Botnsdalur, Dynjandi in Arnarfjörður in the north-western pen-

insula, and Skogafoss and Seljalandsfoss below Eyjafjallajökull. These cascades have a height of about 100 metres and more. The largest rivers, only, have been mentioned above, but in addition to these, hundreds of streams of greater or lesser volume occur, often with beautiful waterfalls and cascades in connection with picturesque clefts and rocks.

As mentioned above, the torrential and changeable glacier-rivers have a destructive influence upon the cultivation and vegetation of the plains. The greensward is torn off and large areas are covered by gravel, therefore the level country south of Vatnajökull is in several places turned into a desert almost destitute of vegetation except where special natural conditions afford a shelter from the destructive effect of the rivers. Where the action of the glacier-rivers is suddenly arrested by any natural phenomenon the level country again becomes quickly covered with plants. As an example may be mentioned the fact that Hverfisfljót, in the year 1783, was forced out of its bed by a great lava-stream, and a considerable stretch of land — Brunasandur — which had previously been irrigated by cold and torrential river-branches was freed from these, only a few clear streams of filtered glacier-water with a slight current issuing from the edge of the lava-streams and flowing down the level country; so that where in 1783 there was a gravelly and sandy flat without plant-life and without means of sustenance for human beings there is now a parish with seven farmsteads and abundance of meadows and pasture-lands for the sheep and cattle of the inhabitants. In itself the glacier-water is not inimical to vegetation; it is only the torrential current, the changeableness of the water-courses, and the low temperature of the water which have a destructive effect upon plant-growth; where these factors are not active, the glacier-water, with its contents of fine clay, is on the contrary a fertilizer; therefore in the neighbourhood of the mouths of the largest glacier-rivers, where there is only a slight current and the water has become warm on the way, fertile tracts of meadows are often found where the glacier-water is profitably utilized for irrigation. Water from rivers such as Thjórsá and Hvítá has, by analysis, been proved to contain an unusually large quantity of alkali and phosphoric acid.

Lakes. There are many lakes in Iceland, but the majority of them are of small size. The largest lakes — Thingvallavatn and

Thorisvatn — cover an area of only about 100 square km. each: the lake-surfaces occupy therefore only a very small part of the entire area of the country. The lakes are of very diverse origin, the basins having been formed by tectonic movements, ice-erosion, volcanic action and other natural agents. On the plateau where the outlet is slight, especially in the neighbourhood of the large Jökulls (ice-mountains) many lakes occur, in some places gathered in large groups, as Fiskivötn on Arnarvatnsheiði NW. of Langjökull, and Veiðivötn W. of Vatnajökull; the melting snow and ice from the glacier-edges disappear in the nearest lava-streams and sandy tracts and then reappear and gather into basins many kilometres away from the glaciers from which they originated. In other places the lakes occur in the immediate neighbourhood of the glacier-edge, as Hvítárvatn and Hagavatn near Langjökull and Langisjór near Vatnajökull; the glaciers project into these lakes and calve their ice-bergs there; the water in these lakes is milky-white as in the glacier rivers. In some places lakes occur in between the glaciers (Grænalón near Skeiðarárjökull) or are dammed up in valleys by glacier-tongues. The best-known lake in Iceland is Thingvallavatn (105 square km.); it is situated in a new volcanic district bounded on the S. and W. by steep tuff-mountains and on the N. and E. by lava-streams which originate from the volcano of Skjaldbreið; these streams have afterwards flowed down between the two well-known fissures — Almannagjá and Hrafnagjá. It was here that the Icelandic Althing met in the time of the Republic. It appears as if the basin of the lake of Thingvalla was originally formed by subsidence along lines of fracture from SW. to NE.; this lake has a depth of 110 metres. In North Iceland Mývatn is the best-known lake; it is formed in a depression in the lava-stream and has a depth of only 2—7 metres; its bottom is lava and several craters project above its surface like islands, while the surroundings are very volcanic. Mývatn has received its name from the mosquitoes (mý) which are often quite a plague there. As in Thingvallavatn, trout are plentiful in this lake, but it is especially known as the abode of numerous birds, especially many different species of ducks. The group of lakes called Veiðivötn consists for the most part of crater-lakes, of which the largest is called Stórisjór. In other places valley-lakes occur — deeply hollowed basins in the basalt — as Skorradalsvatn in Borgarfjörður and Lagarfljót in East Iceland, the surface of which latter lies 26 metres above sea-level while its bottom

lies 84 metres below the level of the sea. Lagoon-lakes, situated close to the coast, occur also, especially in North Iceland; the largest of them are Hóp, Höfðavatn and Miklavatn. According to the condition of the bars and the outlets the quality of the water of the lakes may often change quickly; sometimes they contain fresh water, sometimes brackish water, sometimes salt water. The fauna in these lakes is also subject to periodical changes. Sometimes marine animals immigrate through the outlets; at other times they disappear, and a freshwater fauna becomes dominant.

Fishing in the Iceland lakes is of great economic importance to the inhabitants. In the larger rivers and in many smaller streams, salmon is caught, and now the fishing is often rented out to English sportsmen, especially in south-west Iceland. Many rivers, and most of the lakes, abound in trout and salmon-trout (*Salmo alpinus* and *S. trutta)* which play a great rôle as a means of support of the inhabitants. The quantity of living organisms varies greatly according to circumstances; there appears to be most life in the shallow lakes, especially in those with lava-bottoms, in which warm or luke-warm springs are also sometimes found at the lake-bottom, around which plant- and animal-life collect. Some Phytoplankton (Diatoms) occurs in the lakes in South Iceland, but on the plateau and in North Iceland only Zooplankton (Daphnias) is found, and this is abundant. In Thingvallavatn, *Chara* and *Nitella* grow at a depth of 15—30 metres; in Mývatn there is a quantity of *Nostoc* which is found thrown up in great masses along the shores. In the lakes, there occur in addition, several species of *Limnæa* and *Pisidium*, and *Lepidurus* is frequently found in great quantities; there is, also, an abundance of gnat-larvæ and other larvæ which serve as food for the trout.

Geology. Iceland is almost entirely built up of volcanic rocks, none of which appears however to be older than Tertiary times. The foundation of the island is a depressed and broken basalt-plateau similar to the other Tertiary basalt-plateaus on both sides of the Atlantic Ocean, in East Greenland, the Færöes, Antrim in Ireland and on the islands of Mull and Skye. It is therefore assumed that in Tertiary times a continuous basalt-land extended across the Atlantic Ocean, that it subsided in Mid-Tertiary times and that Iceland and the Færöes are the remains of this land. In Greenland and on Skye the basalt rests on Jurassic strata, in Mull

and Antrim upon chalk; in Iceland, where the basalt formation has a thickness of at least 3000 metres, the underlying rock has not yet been found.

The principal rocks of which Iceland is composed are two, basalt and palagonite breccia; more than one-half of the surface and the rock-foundation of the country consists of basalt, but the palagonite formation, which is composed of breccias, tuffs and conglomerates of different age and which, taken as a whole, is younger than the basalt formation, forms an irregular band across the country, occupying an area somewhat smaller than that occupied by the basalt. Compared with these two formations, all other rocks and formations have quite an unimportant distribution. The basalt mountains, the precipitous walls of which often rise from the sea to a height of 600 – 1000 metres, are composed of layers of varying thickness, wedged in between each other; the thickness of the individual layers often decreases rapidly along a short distance until the layer disappears and gives place to another. In the basalt formation, beds of tuff and breccia sometimes occur between the basalt layers, but their amount is inconsiderable compared with that of the basalt. Dykes are frequent; the majority of them pierce down through the entire series of layers. Seen from a distance, the basalt-mountains with their steep, terraced walls, have a monotonous and gloomy appearance, but on closer inspection exhibit rather great variation. Some of the basalt layers are compact, others are coarsely crystalline, doleritic, porphyritic, amygdaloidal (with more or less completely filled vesicular cavities), slaggy, banded, etc. In some districts the basalt is cleft into beautiful columns; in others into more or less irregular, angular blocks; in others it has an almost slaty appearance. In the vesicular cavities of the basalt zeolites, quartz, chalcedony and calc-spar are often found. As a general rule the basalt layers have a slight inclination (3^0—5^0) from the coast inwards towards the tuff and breccia formations, which appear to fill a flat, saucer-like depression in the underlying basalt plateau; but many local deviations occur owing to dislocations and subsidences of larger or smaller areas of the underlying rock.

In the middle of the basalt-formation in Iceland (as also in the Færöes and in Ireland) rather considerable clay deposits are found with the impressions and remains of plants of Tertiary times; also lignite and compressed tree-trunks, all called in Icelandic "surtarbrandur." This plant-bearing formation attains its greatest thick-

ness (20—50 metres) in the north-western peninsula and was originally deposited at one level, but was afterwards broken up by dislocations, so that it now occurs at different levels above the sea. The surtarbrand formation consists of diversely coloured layers of clay and tuff with intercalated layers of lignite and coal-slate; in many places leaves and fruits are excellently preserved in it, especially near Brjánslækur on the northern side of Breiðifjörður, and at Tröllatunga and other localities near Steingrímsfjörður; in this

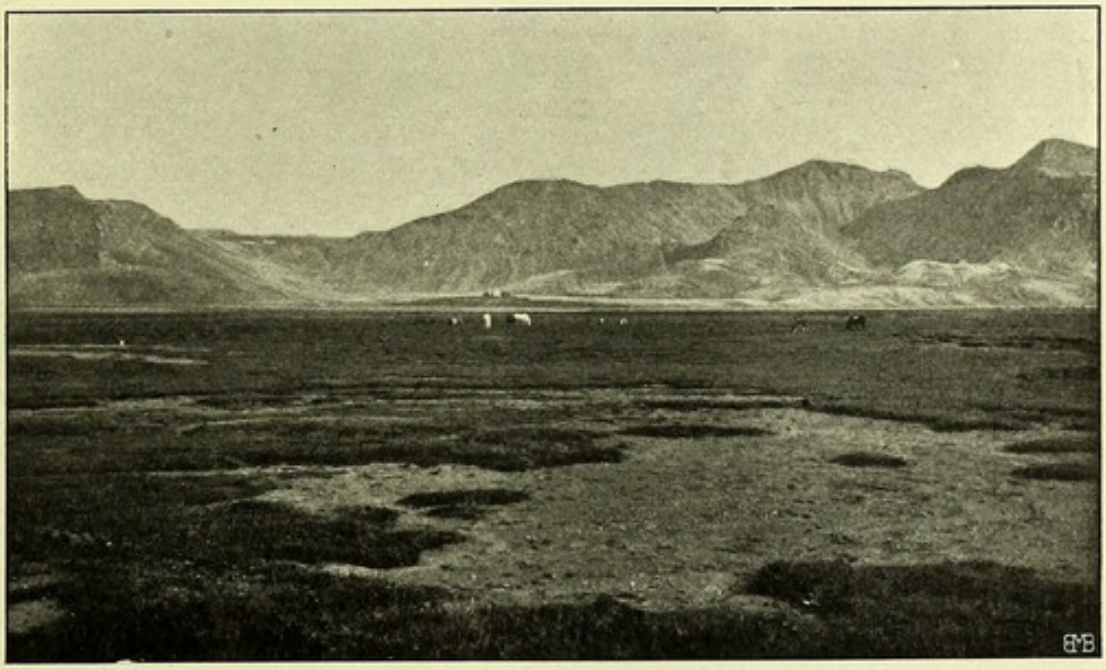

Fig. 4. Mountains near Kolviðarhóll (tuff and breccia).

last place it can be seen that large Tertiary woods have been destroyed by pumice-eruptions and lava-streams. According to O. Heer the mean temperature of the year in north-west Iceland, at the time of these Tertiary woods, was at least 9° C — probably somewhat more (11°—12°); now the average temperature for the year in these places is only 2°. The most common tree in western Iceland at that time was *Acer otopterix;* its leaves are found in abundance and excellently preserved in the clay-layers; there occurred in addition *Sequoia Sternbergi*, *Pinus Steenstrupiana*, *P. microsperma*, *P. aemula*, *P. brachyptera*, *Betula prisca*, *Alnus Kefersteinii*, *Ulmus diptera*, *Quercus Olafssonii*, *Liriodendron Procaccini*, *Vitis islandica*, *Rhus Brunneri*, *Dombeyopsis islandica*, etc.

The Palagonite formation is composed of different kinds of tuffs and breccias, and in its upper divisions there is much moraine material and scattered glacial gravel, as also some ice-striated lava-

streams. The tuffs have usually a brownish-yellow colour owing to the intermixture of palagonite, a brown dully-lustrous alteration-product of tachylyte or basalt-glass, which constitutes the greater portion of the ground-mass of the rock; therefore the whole formation is often called the palagonite formation. The tuffs consist of lava-dust and lava-fragments with an abundance of glass-pieces (palagonite, tachylyte), slag and bombs; loose anorthite-crystals are often abundant. The breccias are distinguished from the tuffs by being

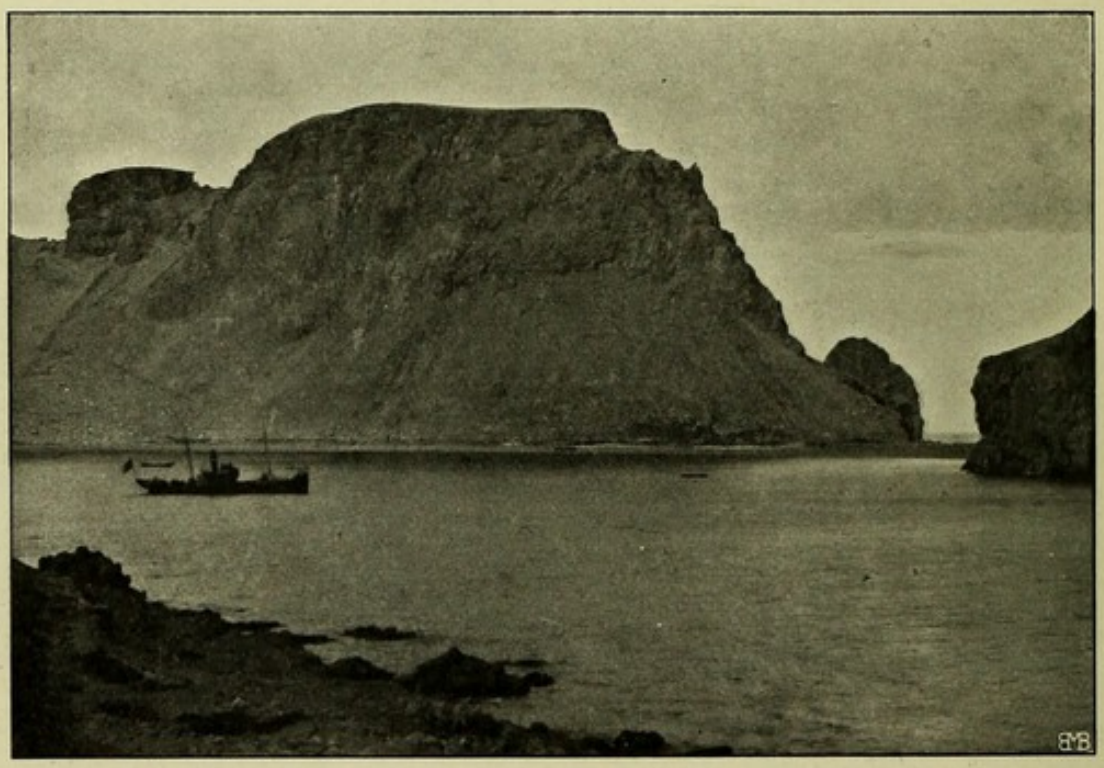

Fig. 5. Cliffs on Klifið (tuff and breccia). The Vestmannaeyjar.

more coarse-grained and containing larger, angular lava-pieces; the fragments consist of compact basalt, dolerite, pumice, slaggy lava and volcanic bombs; the separate fragments are often covered with a glassy crust. The palagonite formation is sometimes arranged in layers; sometimes not a trace of regular arrangement can be discerned. The tuffs and breccias have been formed by volcanic eruptions which chiefly ejected ashes and lava-fragments, and produced only a few lava-streams; the ruins of the numerous large volcanoes from which these eruptions proceeded may still be demonstrated. The palagonite formation is traversed by thousands of basalt dykes which branch and send out apophyses and intrusive sheets; very often the breccia and the tuff is filled with numerous hollow nodules and balls of basalt with a radially-columnar structure inside and

covered on the exterior with a crust of tachylyte. The tuff-formation appears to consist of several divisions the mutual relation of which has not, however, yet been elucidated.

All round Iceland, in both the basalt and the tuff formations, small patches of *liparite* occur. This rock occurs in small intrusive beds and dykes which, on account of their light colour, are distinguishable from the dark basalt and can therefore often be seen from a distance. The liparites vary very greatly both in colour and in structure, and in places where larger sections are exposed, the colouring is often richly variegated. Liparites are almost always accompanied by many closely allied, glassy rocks, especially pitchstones, which occur as dykes, perlites, sphærulites, obsidian and pumice. In south-east Iceland and on Snæfellsnes, veins of *granophyre* are found in some places. The rocky promontories on each side of the Bay of Lón in south-east Iceland consist of *gabbro*, probably of Tertiary age; this rock is also found under the névés of Vatnajökull, because many of the glacier-rivers carry down an abundance of pebbles of gabbro. The liparites and allied rocks, which on the whole cover an area of about 800 square km., are distributed all over the island, but most frequently in larger quantities in East Iceland. Liparite eruptions have taken place at all periods from the earlier Tertiary times to the present day; some volcanoes which have been active within historic times have ejected liparitic pumice. In the neighbourhood of Húsavík in North Iceland are found, near Hallbjarnarstadir, marine deposits with abundant shells of mussels and snails dating from the end of the Tertiary epoch, from the period called in England the *Red Crag;* these formations are found nowhere else in Iceland.

In central Iceland, where tuff and breccia form the foundation, large areas are covered by old *ice-striated lava-streams.* These lava-streams are distinguished from the lavas of the present day by their colour and structure. The modern lavas are usually dark in colour with a compact basaltic structure, while these ice-striated lavas have lighter colours and a doleritic structure. These dolerite-lavas, during the Glacial period and immediately after, flowed from dome-shaped lava-cones with large crater-openings, here and there still extant; or sometimes from large "Bedded Volcanoes" (Strato-Vulkane) the ruins of which — half destroyed by erosion — are still to be found here and there within the area of the palagonite formation. These ice-striated lavas are of different ages; some of them

have been produced before the surface assumed its present form, others have been formed after the country had in all essentials acquired the sculpture it has to-day; several of them have flowed down through valleys and hollows. Reykjavík is built upon such a doleritic lava-stream, and there the dolerite is much used for building purposes. In several places the glacial lavas are of considerable thickness (100—200 metres and more). Some larger volcanoes, which have been in eruption as late as within historic times (Eyjafjallajökull, Snæfellsjökull, Öræfajökull), began their activity even during the Glacial period and at that time discharged doleritic lava-streams. In several places in West and South Iceland large deposits of conglomerates occur, with rolled gravel and sand, alternating now and then with moraine material and ice-striated lavas; these resemble the "Nagelfluh" of the Alps and were perhaps formed in a similar manner.

During the Glacial period the whole island was wrapped in a sheet of inland-ice through which only a few small peaks projected here and there near the edges. The Jökulls (snow-fields) of the mainland probably extended on all sides down to the sea, for the bottom-moraines of that time are found everywhere, both on the plateau and in the lowlands; the lateral and terminal moraines which occur in the valleys and lowlands, date from a later period when the ice was retiring; it appears also that large masses of moraine-material occur here and there on the sea-bottom off the mouths of the fjords. The north-western peninsula was probably covered with a separate ice-sheet, from which numerous small glaciers, with intervening ridges free from ice, descended to the sea. The ice-sheet of the Glacial period had, on the interior plateau, a thickness of 700—800 metres. Ice-striated rocks occur all over the island, both in the high land, in the valleys, and in the lowlands, as also on islands and skerries. Large and small erratic blocks are found in thousands scattered over the whole of Iceland.

As mentioned above, it is assumed that Iceland, in the beginning of Tertiary times, was connected by a broad land-bridge with Greenland, the Færöes and Scotland; this land-bridge was a volcanic highland or plateau-land formed by innumerable lava-streams which originated principally from rows of craters and from fissures. The plateau, which had a height of 3000—4000 metres above sea-level, was towards the end of the Miocene period broken up and depressed; by this subsidence, perhaps in conjunction with

abrasion, the countries were separated and have never since been connected with each other. But Iceland was then, after the separation, considerably larger than it is now, the land extending 50—100 km.

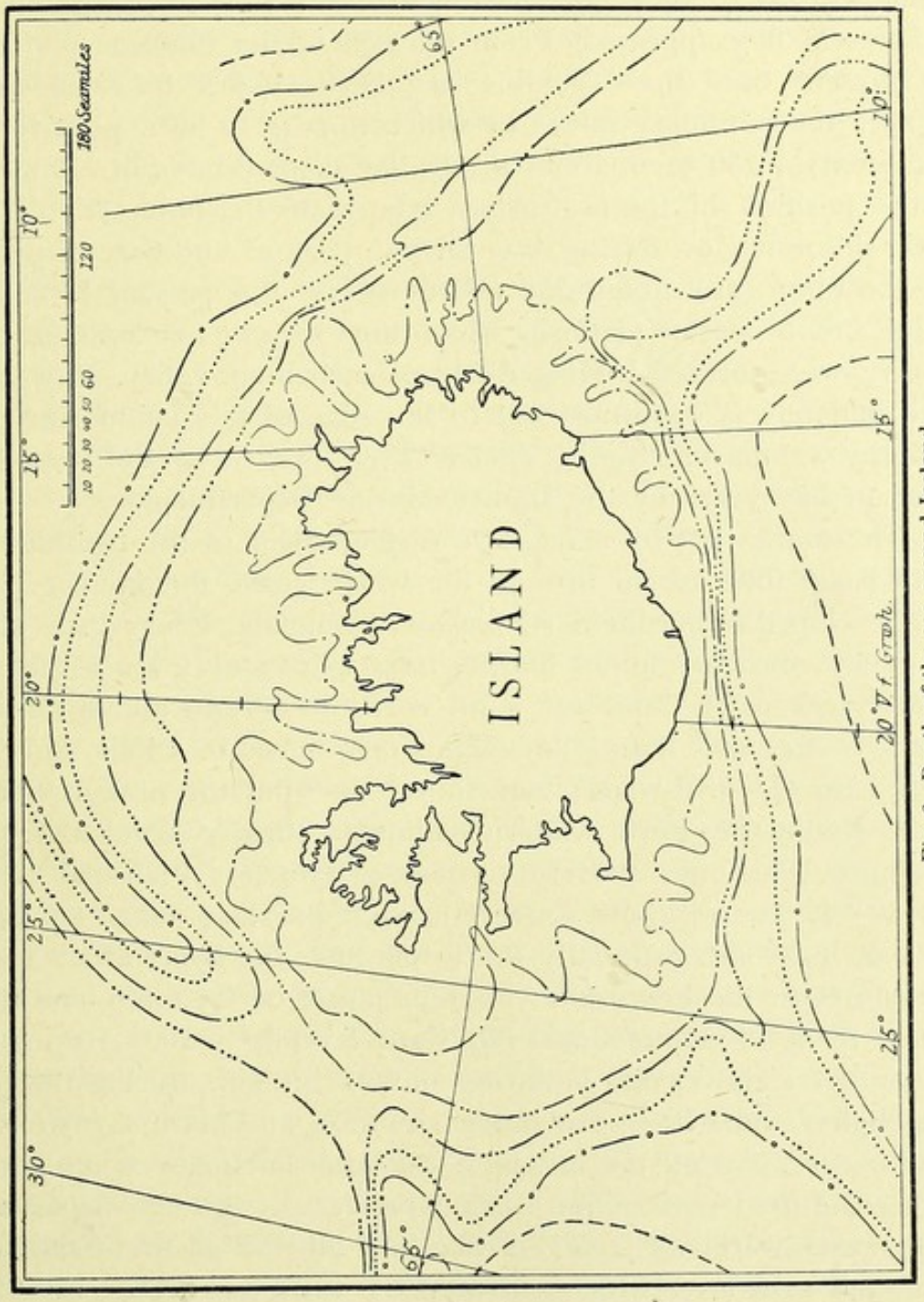

Fig. 6. Depth of the sea around Iceland.
The lines from the coast outwards indicate depths of 100, 300, 600, 700 and 1000 fathoms respectively.

further out on all sides. The subsidence continued gradually, but perhaps with less intensity than before, through Pliocene times, and the submarine coastal platform, which occurs around the whole island and is limited by the 100 fathom line, was simultaneously formed by denudation; the abrasive action ended in the Red-Crag time.

In the Pliocene period Iceland was fissured transversely by numerous lines of fracture which caused violent volcanic action, by which the tuffs and breccias of the palagonite formation were produced. Along the same lines the volcanoes of the Glacial period and of the present day appeared. From the end of the Pliocene period to the present time the coast-line has been subject to considerable changes the boundary-values of which appear to be a positive displacement of 150 metres and a negative displacement of 250 metres of the position of the sea-surface relative to the land. At the end of the Pliocene, or during the earliest part of the Glacial period, the coast-line sank about 250 metres below the present level, and in the broad coastal platform which thus became dry land, erosion-grooves were formed leading off from each main valley. Now, each fjord and bay is continued out to the edge of this submarine platform by submarine fjords, as has been proved by the soundings taken of late years by the Danish Marine Department.

The marks left by a negative displacement of the coast-line in post-Glacial times occur around the whole coast, but are especially well-developed round the north-western peninsula. Everywhere along the rocky coast are found marine terraces of gravel, coast-lines and surf-terraces marked on the solid rock; in several places remains of shells are also found and sometimes bones of whale and walruses, also old drift-wood; sometimes far from the present line of coast. Round the north-western peninsula occur distinct and well-developed coast-lines and surf-terraces at two levels (70—80 metres and 30—40 metres above sea-level); such are also found on other parts of the coast, especially the lower line; the upper line is rarely as distinct as the lower one; in some places on the main land there appear to be indistinct marks of a water-level up to 100—150 metres. In South Iceland caves, hollowed out by the surf during the time of a higher water-level, are rather common, and marine clay-formations occur upon all the low land, the latter having been submerged during the final part of the Glacial period. In the clay-deposits in south-western Iceland, *Yoldia arctica* and other High Arctic molluscs are found at a level which corresponds with the higher coast-line (70—80 metres); other shell-mounds, with a fauna which resembles the present one, correspond with the level of the lower coast-line (30—40 metres), *Saxicava* is especially characteristic of these shell-mounds. Since the Glacial period the coast-line has retreated, but with some oscillations, and even now several indications may be

observed affording evidence of an upheaval of the land in our own day. Shortly after the Glacial period the climate was somewhat milder than it is now; in northern Iceland abundance of *Purpura lapillus* has been found in shell-mounds, and this still lives in the sea south of Iceland, but not in the colder water along the north coast. In bogs on the northernmost headlands, where birch woods no longer thrive, remains of *Betula alba* are found, while *Betula verrucosa*, which no longer grows in Iceland, has been found in the bogs of South Iceland.

Volcanoes and Lava-streams. Iceland is one of the most volcanic countries in the world; as mentioned above, the island throughout has been built up by volcanic activity which began early in Tertiary times and has continued to the present day. There are records to hand of 138 eruptions from 30 volcanoes within historic times, but many eruptions undoubtedly took place in early times which either were not recorded or occurred in the inland wastes and snow-fields without being noticed by the inhabitants. At the present time, 130 post-Glacial volcanoes are known in Iceland, and several volcanic vents have undoubtedly still to be found, or else have been effaced or destroyed by erosion. All the numerous volcanoes have, in the course of time, since the Glacial period, discharged enormous quantities of lava, and the post-Glacial lava-fields of Iceland cover an area of about 11 200 square km.; they occur over the country in vast expanses around the volcanoes from which they have originated. The majority of these lava-fields have been produced not by one but by numerous eruptions at various times, and the greater part of the lava dates from pre-historic outbursts. The largest lava-stream which has been poured forth during a single eruption within historic times, is that which issued from the craters of Laki — a row of craters formed in 1783; this stream covers an area of 565 square km.; and its mass occupies about $12^1/_3$ cubic kilometres; it is probably the largest lava-stream upon the surface of the earth which, within historic times, has been known to flow out during a single eruption. The largest continuous lava-field in Iceland is Odáðahraun on the plateau north of Vatnajökull (600—1200 metres above sea-level); it was produced by numerous eruptions from more than 20 volcanoes, and covers an area of about 4000 square km. The lava-field, next in size, which originated from the many large craters near Veiðivötn, west of Vatna-

jökull, and extends down to the south coast near Eyrarbakki, covers an area of 1550 square km. In the low land this lava-field is covered by a thick layer of soil upon which dense settlements have arisen. In addition, extensive lava-fields (1530 square km.), which originated from 28 volcanoes, occur on Reykjanes; and upon the plateau on either side of Langjökull, there are also other large lava-fields (1030 square km.) of which Hallmundarhraun is the best known; in it is the lava-cavern, Surtshellir, which is $1^1/_2$ km. in

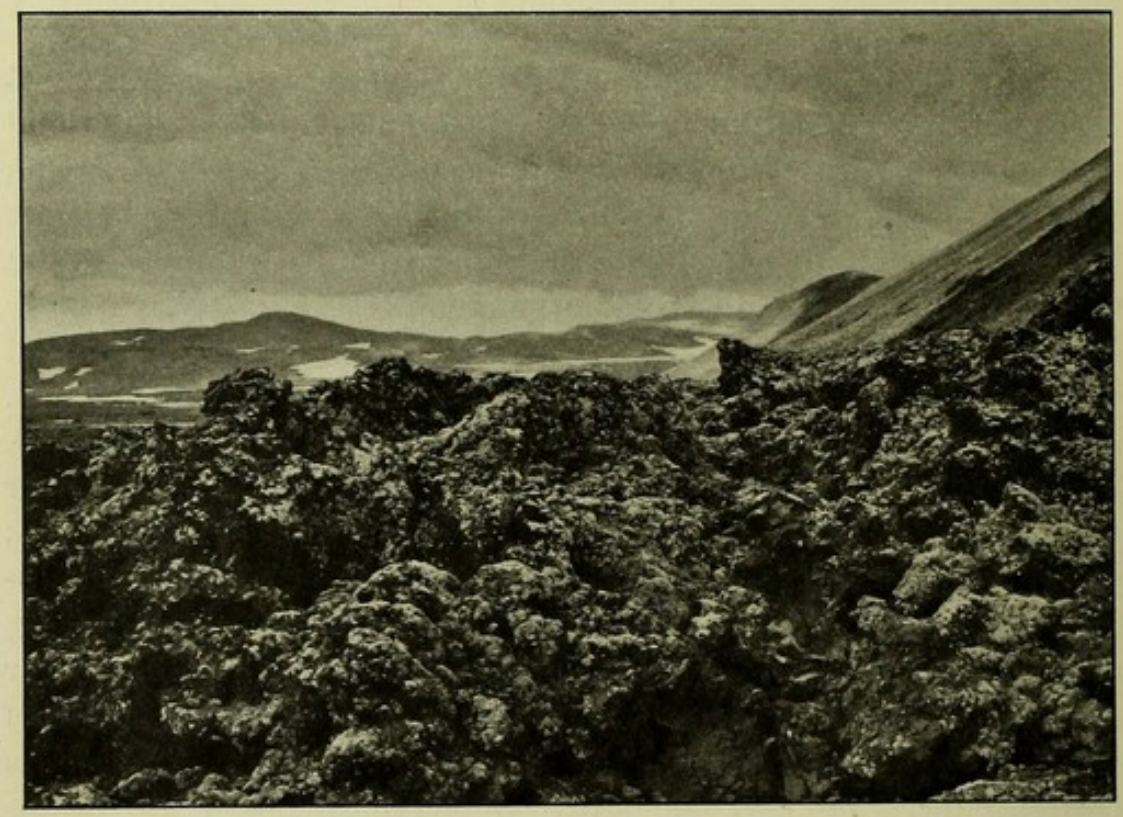

Fig. 7. Lava-stream (apalhraun); upon the outer south-west slope of Dyngjufjöll. (Phot. Heinrich Erkes.)

length. Large tracts of lava occur also around Hekla, near Mývatn, Kelduhverfi and in several other places.

The surface of the lava-streams varies greatly; often it is very rugged and jagged and is then, in Iceland, called *apalhraun,* and in the Sandwich Islands, *aa.* Such streams consist exclusively of porous and brittle lava and slaggy fragments heaped together pell-mell. Such lava-streams are comparatively narrow, with high edges which, seen from a distance, look like fences or ridges upon the level land. A lava-stream of this description is very difficult to cross, owing to the fragments being put together so loosely that they are disturbed by the slightest touch. Other lava-fields, especially the

large ones, have another variety of surface — lava-sheets — which may sometimes be level, but are more frequently broken and cracked in numerous directions; in Iceland they are known as *helluhraun*, in the Sandwich Islands as *Pahoehoe*. Upon the smooth surface, numerous tangled and twisted lava-ropes may be seen, bent in long curves following the undulating surface of the viscous lava. Sometimes this lava is compact, and without great irregularities of surface, but more frequently, by cooling, the surface has subsided and

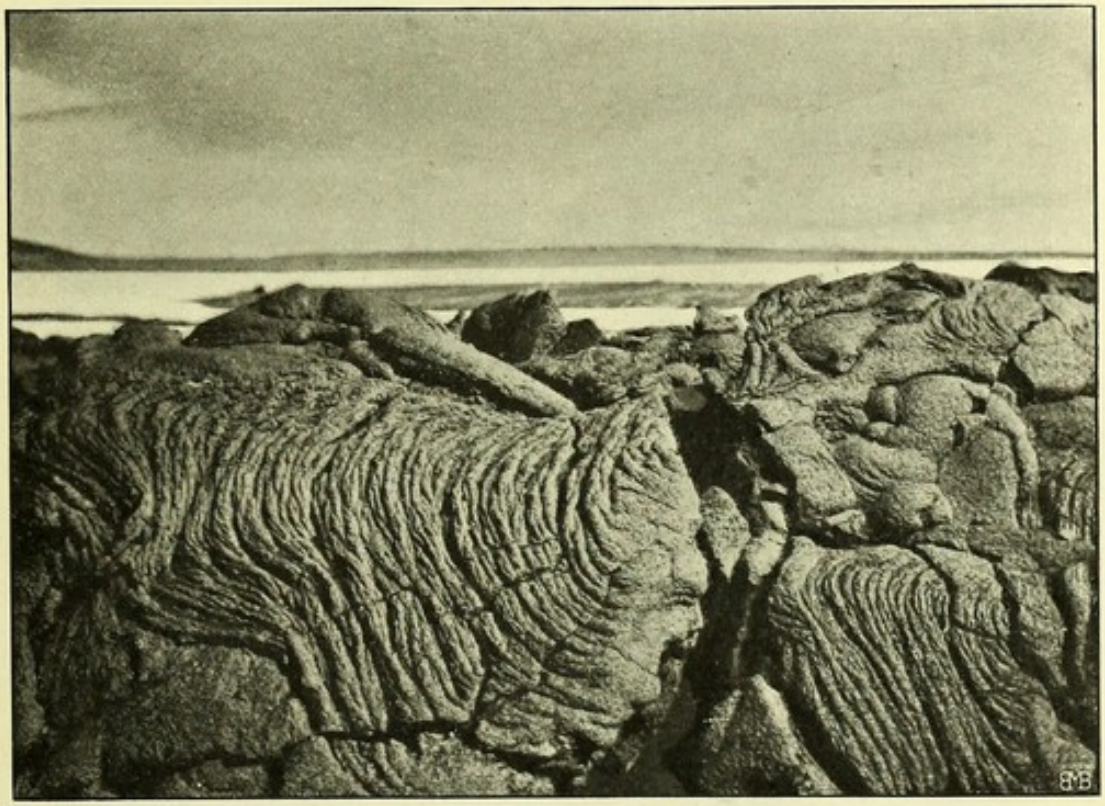

Fig. 8. Sheet-lava near Frambruni. Slope of Trölladyngja on Odáðahraun.
(Phot. Heinrich Erkes.)

broken into large pieces, forming a number of hills, ridges, embankments and cauldron-shaped depressions, giving to it the aspect of a rough sea with high waves. Sometimes the surface of this sheet-lava is arranged in knots, curls and folds, all as smooth as hardened pitch. Beneath the lava-sheets there are often empty spaces, like drain-pipes and tunnels, and sometimes large caverns. Both forms of lava are sometimes found combined in the same stream. Long clefts often occur in the lava-streams, and sometimes enormous cracks, which are due to the subsidence of the substratum. Of lava-clefts of this description Almannagjá near Thingvellir is the most famous. In Odáðahraun there are also lava-clefts, 10—15 km. in

length. Groups of small slag-cones (craters) and lava-kettles *(Hornitos)* are very common in the lava-fields; they are often gathered together in hundreds upon a relatively small area and without any regularity

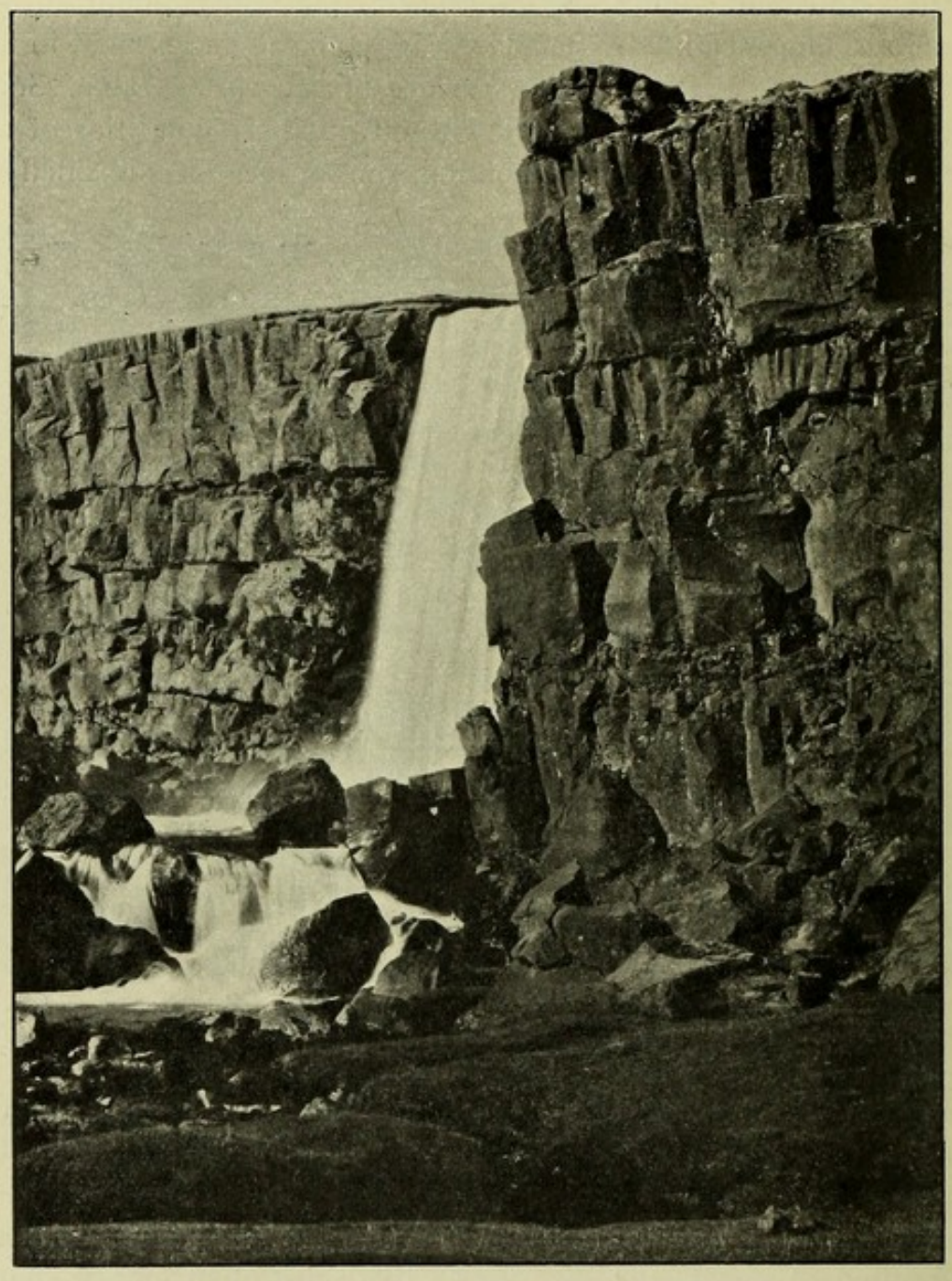

Fig. 9. Lava-streams in vertical section (Almannagjá).

of arrangement. These slag-cones are secondary formations, usually associated with lavas which have overflowed marshy ground and lakes, and have thereby absorbed quantities of water-vapour; they are of frequent occurrence near Mývatn, on Reykjanes, and especially at Landbrot.

Large areas of Iceland are, moreover, covered with volcanic ashes, slags and bombs ejected by volcanoes. During the eruptions, the fine ashes are often spread out over a large part of the country and are sometimes carried by the wind across the Atlantic Ocean. During the Katla eruption in 1625, the ashes were carried to Bergen in Norway, and in 1845, ashes from Hekla were carried as far as to Germany, and during the Askja eruption in 1875 the volcanic dust was carried to the west coast of Norway in eleven hours forty minutes, and in another ten hours they travelled as far as Stockholm. Ashes and slag are thrown up into the air to a great height; on April 21, 1766, the ash-column of Hekla had a height of 5000 metres above the summit of the mountain, and it has often been higher still. Lava fragments and bombs are shot into the air to a great height and often fall at a distance from the place of eruption; during the Hekla eruption in 1510, a man was killed by a volcanic bomb at Skálholt, 45 km. from the volcano; during the eruption of the same mountain in April 5, 1766, a volcanic slag, as big as a man's fist, was hurled to Viðivellir in Skagafjörður, 165 km. from the mountain. The fine dust which fills the air during great eruptions, causes peculiar refraction-effects in the air; thus, during the Laki eruption of 1783, dust-clouds and unusually brilliant sunsets were common over the whole of Europe, North Africa and a part of western Asia. The ashes fell in such quantities in Caithness in Scotland as to destroy the crops; that year is still spoken of by the inhabitants as "the year of the ashie." The shower of ashes, together with the red-hot scoriæ ejected in an eruption, often causes considerable damage to the inhabited land. Pastures are buried beneath them or are scorched, and the coppice-woods often suffer severely. Whether the damage done by the ashes to pastures is permanent or not greatly depends upon their nature; the heavy basaltic ashes are especially injurious, as they can only with difficulty be carried away by the rain or by irrigation. When, however, the layer of ashes is thin it gradually is absorbed into the soil, by the grass growing up above it. In the neighbourhood of larger volcanoes, several layers of ashes, one above the other, are found in the soil. The light, liparitic pumice-ash, which is rarer, is less injurious, as it is quickly carried away by water. Sometimes the ashes discharged by a volcano contain a great quantity of acids; during the Laki eruption of 1783, the ashes were so acid that they burnt holes in the burdock leaves, and left black patches on the

sheep's skins, and the hoofs of the sheep turned yellow when they walked amongst them; while the rain which fell from the dust-clouds, is said to have been so sharp and biting that it was painful where it fell on the hands and face. The volcanic eruptions, on the whole, have had a very injurious influence upon the plant-distribution in the volcanic regions of Iceland. During the eruptions a great number of sheep and cattle die from want of food or from its unwholesome nature, and of various diseases caused by the ashes eaten with the fodder. No eruption has however been so disastrous as the eruption of the Laki crater-rows in 1783. In the winter which followed, and in the spring of 1784, the sheep and cattle suffered from all kinds of diseases owing to the unwholesome food, and died by scores. On many farmsteads the entire live-stock died out, and the following year there died in the whole of Iceland 11,500 cattle, 28,000 ponies and 190,500 sheep — about 53 per cent of all the cattle, 77 per cent of the ponies and 82 per cent of the sheep. Then came a famine, which carried off 9500 of the inhabitants, about one-fifth of the total population of Iceland at that time.

In Iceland there are several types of volcanoes. Usually, by a volcano is understood a large hill or mountain, more or less conical in form, which is ignivomous, discharging lava-streams and ejecting ashes and fragments of lava. Volcanoes of this description occur in Iceland, but are not common; seven or eight such volcanic mountains are known, which resemble externally the well-known Italian volcanoes of Vesuvius and Etna, without however being so regular in form; they are built up of alternating layers of ashes, lava and slag, and usually resemble truncated cones with a crater at the top, and a considerable angle of inclination (at the base 8^0—15^0; at the top 20^0—35^0); the majority of them have their summits covered with snow and glaciers. Of these volcanoes the largest and best known are Öræfajökull, Snæfellsjökull and Eyjafjallajökull. Hekla is also built up of alternating layers of lava and tuff, but is not conical. Its shape conforms to an elliptical ridge, rent down its major axis, and studded with a row of craters along the line of fissure. Another type of Icelandic volcano are the dome-shaped "lava-cones" *(dyngja*, pl. *dyngjur)* — larger or smaller volcanoes, built up entirely of lava-streams, without any intermediate layers of tuff or slag. Volcanoes of this description, which are also found in the Sandwich Islands, are distinguishable from the country surrounding them as shield-shaped cones, and their altitude is low

compared with their extent. The largest have an altitude of 1400—1600 metres, and a diameter of 10—15 km. On such dome-shaped lava-cones the angle of inclination at the top of the mountain is only slightly greater than near the base, seldom exceeding 7^0—8^0, and more frequently still less, often only 1^0—2^0. The summit of such volcanoes consists of a circular or elliptical mouth or depression, often of large dimensions, some having a diameter of 1000 metres or more. The walls of the depression (crater) are usually

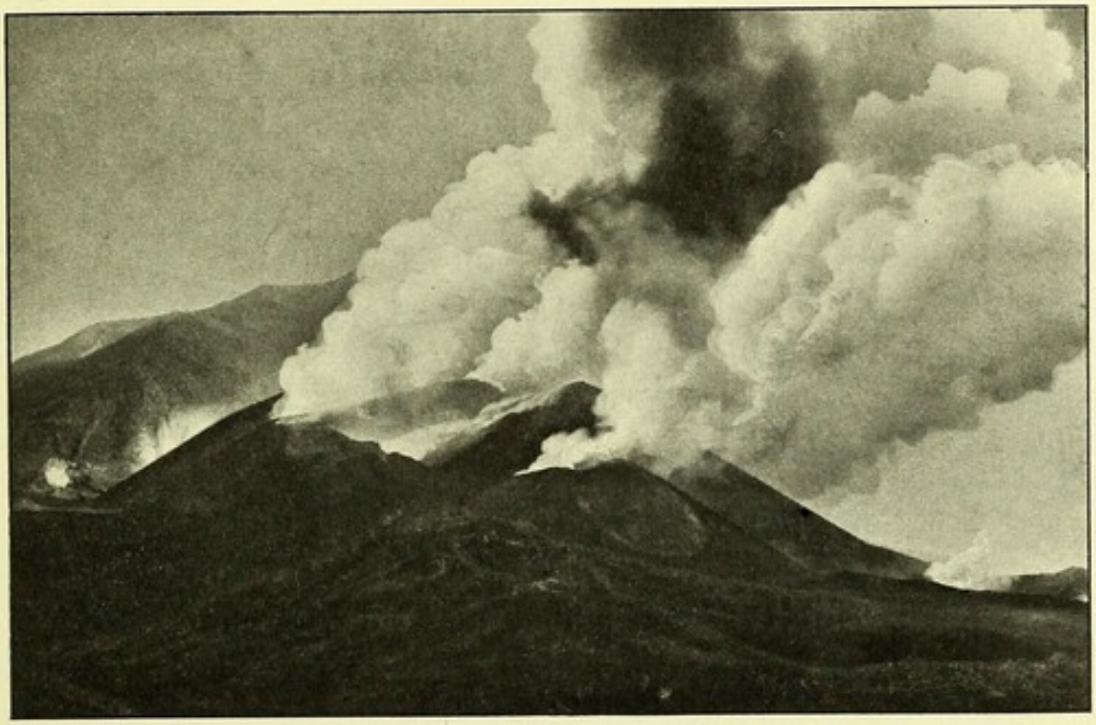

Fig. 10. Row of craters.

cleft by concentric fissures, so that the descent from the lip to the bottom of the crater is, as it were, a series of steps. The sides of these volcanoes are entirely covered with knotty sheets of lava, and long tunnels and caves are very common in the sides of the volcano. In some cases the depression is filled with lava to such an extent, that the only indication of the circumference is a ring of small lava-pinnacles and lava-ridges. The immense lava-waste of Odáðahraun was mainly formed by outpourings from this type of volcano, of which Trölladyngja (1491 metres) is the largest. Another well-known volcano of this description is Skjaldbreið near Thingvellir. Of post-Glacial lava-cones, 16 are known from Iceland. These lava-cones were also very common during the Ice Age.

The greatest amount of lava which has been poured forth in

Iceland, issued from volcanic fissures and crater-rows; these are not volcanic mountains, but rows of low craters established along the direct line of a fissure, more frequently upon level land. Of this kind of eruptive vent, 87 are known from Iceland at present. Each of the craters in such a chain occurs independently and is built up of scoriæ and lava. They are usually low, rarely exceeding a height of 100—150 metres, while the majority of them are even considerably lower; they are often very irregularly formed and composed of several rings. Some crater-rows are very long; they often attain a length of 5—10 km., and some are longer still, as for instance, the Laki crater-row of 1783, which has a length of 30 km., and contains about a hundred separate craters of various sizes. Some crater-rows are so small that they resemble toy-volcanoes. In some places the lava has welled up out of fissures in large streams without any visible craters. The largest of these fissures is Eldgjá, north of Mýrdalsjökull; it has a length of 30 km., and has poured out lava-streams sufficient to cover an area of about 700 square km. In some places "explosive craters" occur, cauldron-shaped depressions produced by a single volcanic explosion. The best known of these craters is Viti, on the side of Mount Krafla, north of Mývatn. It was formed by a sudden outburst on May 17, 1724. For a long time afterwards there was a large, boiling slough at the bottom of the crater, but this is now converted into a greenish-coloured quiescent lake. The majority of the volcanoes in Iceland are basalt volcanoes, and have poured out streams of basaltic lava, and ejected basaltic slag and ashes. Only in the neighbourhood of Torfajökull liparitic volcanoes occur — of post-Glacial origin, and of peculiar aspect — which have poured out lavas rich in silica. The interior of the lava-mass is grey or reddish brown, but the surface of it is jet-black, as it consists of obsidian, covered here and there by light, almost white, pumice. The largest liparitic lava-streams are those called Hrafntinnuhraun and Dómadalshraun. In some places streams of liparitic blocks in a half-melted condition have flowed out from craters in the mountain-sides, and several volcanoes have ejected liparitic pumice, as for instance, the volcano of Askja, 1875. Many volcanoes in Iceland are buried beneath the snow and the glaciers, and as mentioned above, when they break out into eruption, large masses of ice are melted and the glaciers burst, which causes the neighbouring level lands to be inundated by enormous floods of water, with huge fragments of ice tossing on

its surface. The Katla eruption, in this way, converted thickly inhabited and fertile tracts into deserts, and in 1362 Öræfajökull destroyed, in the same way, two parishes, sweeping away forty farmsteads with their inhabitants and live-stock and all else, out into the sea.

The best-known Icelandic volcano is Hekla. It has been the scene of 21 eruptions during historic times; next in importance comes the glacier-volcano Katla of which 13 eruptions are recorded.

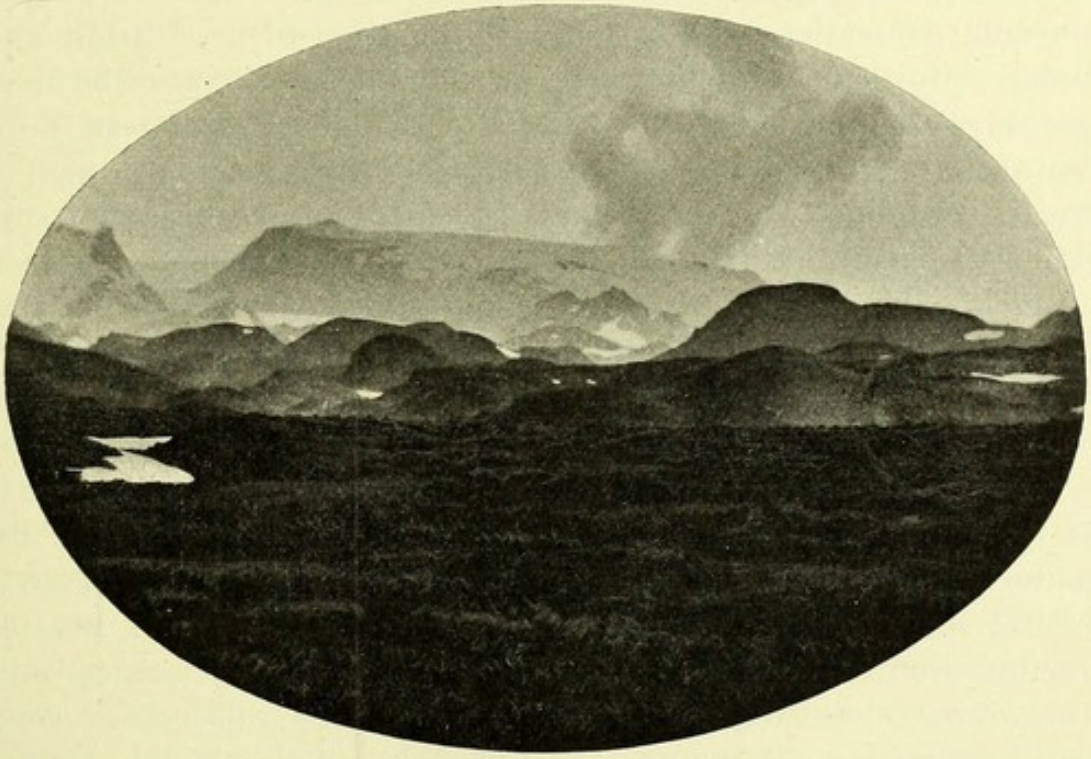

Fig. 11. Kverkfjöll, a volcano on the northern edge of Vatnajökull; seen from Hvannalindir. (Phot. J. P. Koch.)

Submarine eruptions have taken place some ten to twelve times near Eldeyjar off Reykjanes, whereby new islands have had their origin; but these have disappeared again. Several volcanoes are present beneath the ice-cap of Vatnajökull, but the foci of eruption are not known for certain. During the last two centuries, from 30 to 40 eruptions have been recorded from the snow-fields of Vatnajökull. During several of these eruptions the snow and ice on Skeiðarárjökull, on the southern side, partially melted, and enormous torrents of water were discharged. Occasionally Brúarjökull, on the northern side, has been very active. On Reykjanes there are numerous prehistoric volcanoes and rows of craters, and in three or four places eruptions have taken place since there have been settlements on

the island; one of the most active volcanoes on Reykjanes is called Trölladyngja. The best-known volcano near Mývatn is Leirhnúkur, but besides this, many smaller crater-rows and separate craters occur; the volcanoes near Mývatn were particularly active during the years 1724—30. In the centre of Odáðahraun rises the volcanic mountain-group Dyngjufjöll with the crater-valley of Askja; it is one of the largest volcanoes of Iceland. The crater-valley, which is surrounded by circular mountain-walls, covers an area of about 55 square km. In the south-eastern corner of it there is a deep volcanic depression with a lake; at the edge of the latter a new crater opened on March 29, 1875, and discharged an enormous quantity of pumice over the eastern part of Iceland and, as mentioned above, the dust was carried as far as to Scandinavia. The greatest eruption which has taken place during historic times in Iceland was the eruption of the above-mentioned crater-rows of Laki in 1783. The lava which poured forth filled valleys, altered the course of rivers and destroyed several farmsteads, fertile meadows and extensive pastures. North of Iceland submarine volcanic eruptions have occasionally taken place.

Almost all the volcanoes of Iceland are associated with fissures in the tuff and breccia areas of the palagonite formation. In the southern part of Iceland all the mountain-ridges, valleys and rivers exhibit a decided dependence on tectonic lines of deeply situated fracture from SW. to NE. Open fissures in the surface, all the numerous crater-rows, and the lines joining the volcanoes, have a similar direction. Moreover, hot springs — both alkaline springs and sulphur springs — are arranged along the same lines. In North Iceland, on the other hand, the tectonic lines and the fissures and volcanoes, have generally a direction from S. to N. Both these directions probably are combined in a curving band of fracture-lines which lies across the island. In the basalt plateaus of the west coast there are several cauldron-like fissures and concentric fractures, and along the southernmost of these depressions, which extend over both the tuff and breccia areas around Faxaflói, the volcanoes and hot springs are arranged in a semicircle.

Earthquakes are very frequent in Iceland not only in connection with volcanic eruptions, but also apart from them; in the latter case they are chiefly confined to three districts with well-marked natural boundaries. All the greater earthquake shocks are tectonic

in origin; that is to say, they are due to movements and subsidences of large tracts of land bounded by dislocations and fractures of the ground. In North Iceland, between Skjálfandi and Axarfjörður, where the new volcanic tuff district extends to the coast, violent earthquakes are frequent, especially in the neighbourhood of the trading-station of Húsavík. The earthquakes of 1755, 1872 and 1885 were especially serious and did great damage in these districts. At Faxaflói there is another earthquake-area where minor shocks are very common; they are usually most violent on Reykjanes, especially in the neighbourhood of Krisuvík, and at the extreme point of the peninsula, near the lighthouse. The third earthquake-area comprises the southern lowland area between Reykjanes and Eyjafjallajökull. This district has frequently suffered from violent and destructive earthquakes which have caused great loss of human life and of property. In modern times the earthquakes of 1784 and 1896 have been especially destructive. The former (Aug. 14—16) completely ruined 92 farmsteads, and damaged 372 houses and 11 churches. In August and September, 1896, the earthquake shocks were even more violent. Great chasms were rent in the earth, some as long as 15 km.; water-courses were altered and the position of hot springs changed; quantities of hugh fragments of rock were loosened from the mountain-sides; 161 farmsteads were hurled down, and 155 more were greatly damaged; in fact, every house in this area sustained some damage. By each of these violent earthquake shocks a limited tract of land was put in movement. Occasionally, North Iceland has been shaken by volcanic eruptions which originated under the sea off the north coast of the island; this was the case in the years 1838, 1899 and 1910.

Hot alkaline springs occur in hundreds in Iceland, scattered all over the country, sometimes singly, sometimes in groups. At the present time 677 hot and boiling springs are known in 162 localities, and the majority of them are closely dependent upon the fracture-systems of the island. Earthquakes exert great influence upon these springs; many disappear or are altered, and new ones are formed. The surfaces of the springs have any temperature up to boiling point. Tepid springs which can be used for bathing are called "laugar," boiling springs "hverar." Some of the latter throw up jets of water as Geysir does; but otherwise the boiling springs may be divided into five classes: (1) springs which are constantly

spouting, (2) intermittently spouting springs, (3) alternately spouting springs, (4) constantly boiling springs which do not spout, (5) springs with a high temperature and a quiet surface or which boil quietly in the middle. All the boiling springs deposit siliceous sinter. The most famous hot spring is Geysir, in the vicinity of Haukadalur in South Iceland, in the centre of a group of other boiling springs. This group of springs was mentioned for the first time in 1294 and has often undergone alteration by earthquakes, especially in 1630 and 1789. Geysir's eruptions now take place very irregularly and many days may intervene between them. At the end of the 18th and the beginning of the 19th century, Geysir's activity was at its maximum, and it could throw up fountains of water to a height of 50—60 metres, whereas now the water rarely rises above 30 metres. The neighbouring hot spring Strokkur, began its activity in 1789 and ceased during the earthquakes of 1896. At first Strokkur threw up higher fountains of water than did Geysir, not only boiling water and steam, but also cold water. Other large groups of hot springs are found near Reykir in Ölfus, in Reykholtsdalur, on Hveravellir on the plateau NE. of Langjökull, and in many other places.

Sulphur springs occur in abundance in the volcanic districts, but not outside the palagonite-formation; also alkaline springs are common in the basalt districts. The alkaline springs are found upon the level land, in valleys and upon mountain-sides where there is much underground water, but the sulphur springs commonly occur upon mountain ridges and other dry localities where the water has an outlet through the underlying lava, etc. Several of the solfataras deposit a considerable amount of sulphur in small heaps where the sulphurous vapours rise from the soil. Sulphur from Iceland had a commercial importance even in the 13th century, and the trade in sulphur was especially lucrative in the 16th century. Since that time the export of it has gradually decreased and now has entirely ceased. The sulphurous vapours which rise through the clefts and cracks in the earth have a great effect upon the neighbouring rocks, which are transformed and decomposed in various ways — coloured clays, gypsum, iron-alum (Halotrichit), etc. being formed. The mountains which have been penetrated by the hot sulphurous vapours are easily recognizable at a long distance, owing to their naked and discoloured appearance; they are always light-red, yellow and white in colour and are entirely destitute of plant-

growth. While plant-growth is abundant in the neighbourhood of the alkaline hot springs, from the vicinity of the sulphur springs it is almost absent. In places where surface-water or underground water is found, mud-holes are formed, or larger or smaller sloughs, in which clayey mud of various colours boils and bubbles; it is sometimes ejected a few feet upwards, whereby crater-like mounds are formed around the larger pits, bearing a weird resemblance to

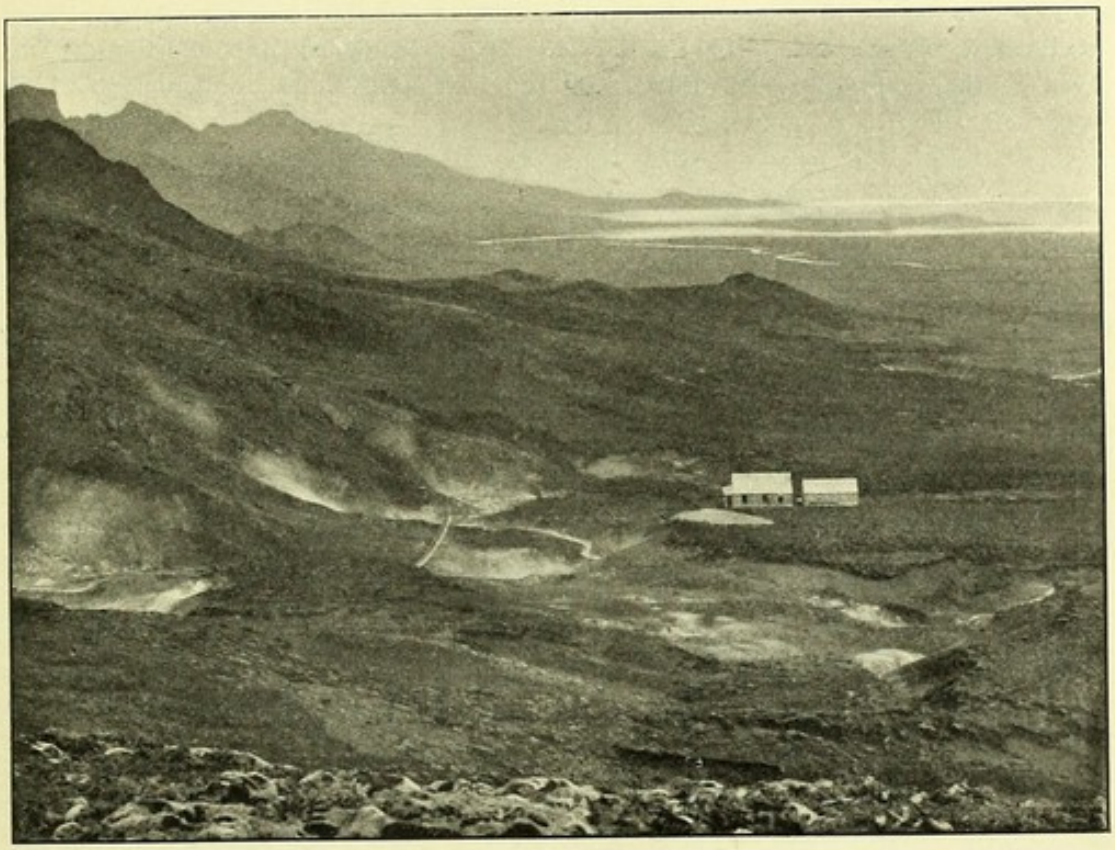

Fig. 12. Solfataras of Krisuvík.

large cauldrons of boiling porridge. The majority of the sulphur springs occur on Reykjanes, in Hengill, near Krisuvík and at Cape Reykjanes where the large slough of Gunna is well-known. Moreover, extensive sulphur-spring districts (Námufjall, Krafla, Fremrinámur) occur near Mývatn, and Kerlingarfjöll near Arnarfellsjökull is another, upon the interior plateau. Carbonic acid springs *(ölkeldur)* and Mofettes occur here and there, especially on Snæfellsnes in western Iceland; the best-known carbonic acid spring is found near Raudimelur in Hnappadal. Ores, metals and stones of any great commercial value are not found in Iceland. Here and there some lignite occurs which is utilized by the neighbouring inhabitants. The gathering of sulphur is no longer lucrative, but,

as already mentioned, in East Iceland calcareous spar is quarried at Helgustaðir near Reydarfjörður and is used by the makers of optical instruments.[1]

[1] For fuller notes on the Physical Geography and Geology of Iceland the reader is referred to the following papers by Th. Thoroddsen: Island. Grundriss der Geographie und Geologie: Justus Perthes, Gotha. 1906 (358 pages). Lýsing Islands, Köbenhavn, 1908—1911, in 2 vols (365 and 673 pages). Explorations in Iceland during the years 1881—98 (The Geographical Journal. London, 1899. Vol. XIII, pp. 251—274, 480—513). Vulcane im nordöstlichen Island (Mitteilungen d. k. k. Geogr. Gesellschaft, Wien, 1891, pp. 117—145, 245—289). Geological Map of Iceland. Surveyed in the years 1881—98. Edited by the Carlsberg Fund. Copenhagen, 1901, Scale 1 : 600,000.

II. CONDITIONS PERTAINING TO SURFACE AND SOIL.

After having thus given a brief, general survey of the orographical and geological conditions and having described the substratum and general structure of the island, we will now pass on to a description of the surface itself, with which plant-growth is more particularly associated. As mentioned above, Iceland is built up of basalt, tuffs and breccias, but basalt is the fundamental rock; the tuffs and breccias are, for the most part, nothing else but basalt split and pulverized. The mineralogical and chemical composition of the soil is therefore essentially the same over the entire island, provided the siliceous liparites are excepted which have no effect of any importance to the whole.

Seen from a distance, the basalt mountains usually appear to be steeper than they are in reality, and the small terraces or steps of the layers of basalt are not distinguishable in the higher part of the mountain from a distance except when they are snow-covered or when, as rarely happens, a scanty vegetation (especially mosses) has been able to gain foothold upon the narrow ledges. The rule is that the steps of the basalt mountains become broader as the base is approached. At the top the separate layers project as a narrow ledge which is only half, one, or two metres broad, but lowest down in the valleys, and nearest to the sea the separate layers form enormous terraces which may attain a breadth of $^1/_4$—$^1/_2$ km. or more. The upper surface of these broad terraces is covered with gravel and clay, and sometimes with a scattered plant-growth, or sometimes with a continuous vegetation, with bogs or swamps; there, enormous, elongated snow-wreaths may persist far into the summer. On basalt mountains erosion is more active on the sunny side, therefore the other side is steeper and more sparsely covered with plants. On the sunny side the average inclination is usually

only 20°—25°, but upon the other side 30°—35°. There are, however, a few basalt mountains which are much steeper than this: for instance Skessuhorn near Borgarfjörður, which has an inclination of 48°. In the numerous erosion-channels on the mountain sides, where gravel and stones are constantly rattling down and avalanches are frequent, it is difficult for the plants to gain foothold. The ridges between the mountain streams are therefore more closely covered with plants but, as already mentioned, a continuous plant-

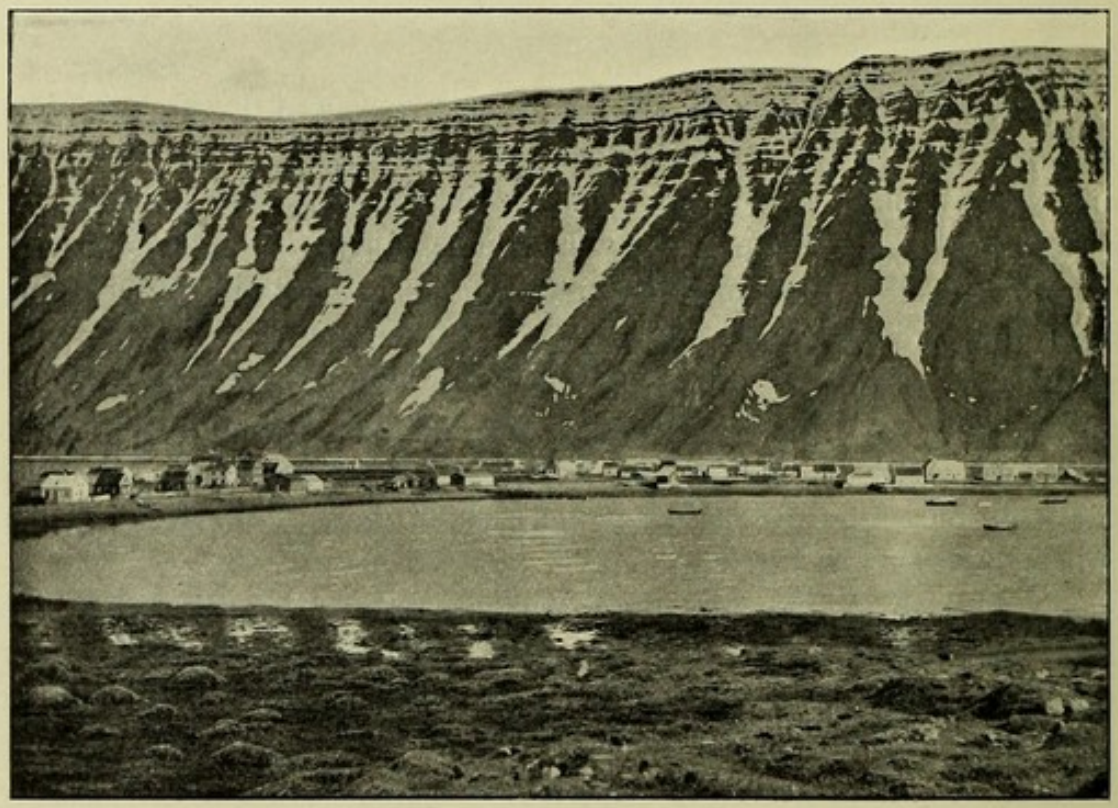

Fig. 13. Basalt mountains with snow-wreaths (Isafjörður).

covering rarely extends higher than half-way up on the basalt mountains. In olden times the mountain sides were in very many places clad with coppice woods, but these disappeared at an early date, partly owing to the havoc wrought by sheep and partly to man's lack of foresight. Now only some stunted shrubby birches are to be seen upon inaccessible cliffs, where they are beyond reach of man and beast, even with the utmost exertion. Upon mountain-sides deprived of their birch-copses, avalanches of snow and stones have suffered no hindrance, so that all soil and plant-growth have disappeared, thus turning the mountain-sides into naked, gravelly and rocky slopes. In some districts such changes have taken place

even as late as in the 19th century. Where the basalt mountains are not too steep nor the mountain-streams too torrential, the flat gravel-cones upon the valley sides, below the notches in the mountain, are often overgrown with plants. These gravel-cones often underlie the home-fields of the farmsteads.

In the fjord districts of Iceland the vegetation upon the basalt mountains differs considerably in passing from the sea inwards. Owing to the effect of the sea-water, the violent storms and the rawness of the climate, the outermost points are comparatively poor in plants, while the vegetation increases inwards towards the valley, and in the bottom of the valleys, especially on the north-western peninsula, remains of coppice woods are often found; but woods could not thrive out along the fjords, still less at the extreme points. Where the basalt does not occur as steep cliffs and is not covered by loose layers of clay, glacial gravel and soil it is usually strewn with loose sharp-edged fragments, split and torn off by frost. The severance of these fragments usually follows the cleavage of the basalt, and they are sometimes slaty and in thin plates, a condition which is especially common in the uppermost part of the basalt formation. Upon the split and torn basalt in the uppermost part of the mountains, plants have difficulty in gaining foothold, especially when the climate is as raw and stormy as is the case in Iceland. Therefore, large areas of the higher-lying basalt districts are extremely poor in plant-life even in places, where according to the situation, the conditions might be expected to be somewhat more favourable.

The landscape in the tuff and breccia districts has a different appearance. Basalt mountains usually have sharp, and breccia mountains soft outlines. Those areas of the cultivated districts and on the lower spurs of the highland which are built up of tuff and breccia have often a more or less undulating appearance; the mountains are broken down into numerous rounded ridges and protuberances with intervening stretches of level ground and valleys of irregular shape; but here and there are seen tabular mountains or promontories with steep sides and a flat surface, where the basalt or dolerite has covered and protected the tuff and the breccia. On the plateau, where through centuries storms have been continually altering the sculpture of the surface, the soft tuff-mountains have suffered in particular; here the tuff-ridges are connected into irregular chains which have been eroded in every possible way, and often resemble fantastic ruins with numerous sharp peaks, protuberances

and knolls separated by sandy areas and labyrinths of branched clefts and small valleys. Tuff mountains, owing to the loose nature of the rock, are relatively poor in water as the latter often disappears into the ground, and does not appear until at a distance from the mountain. This is especially the case with the tuff-mountains on the plateau where, during summer, not a single stream or spring is met with for long distances, but only large, deep, dry river-beds and water-courses filled with coarse gravel and large

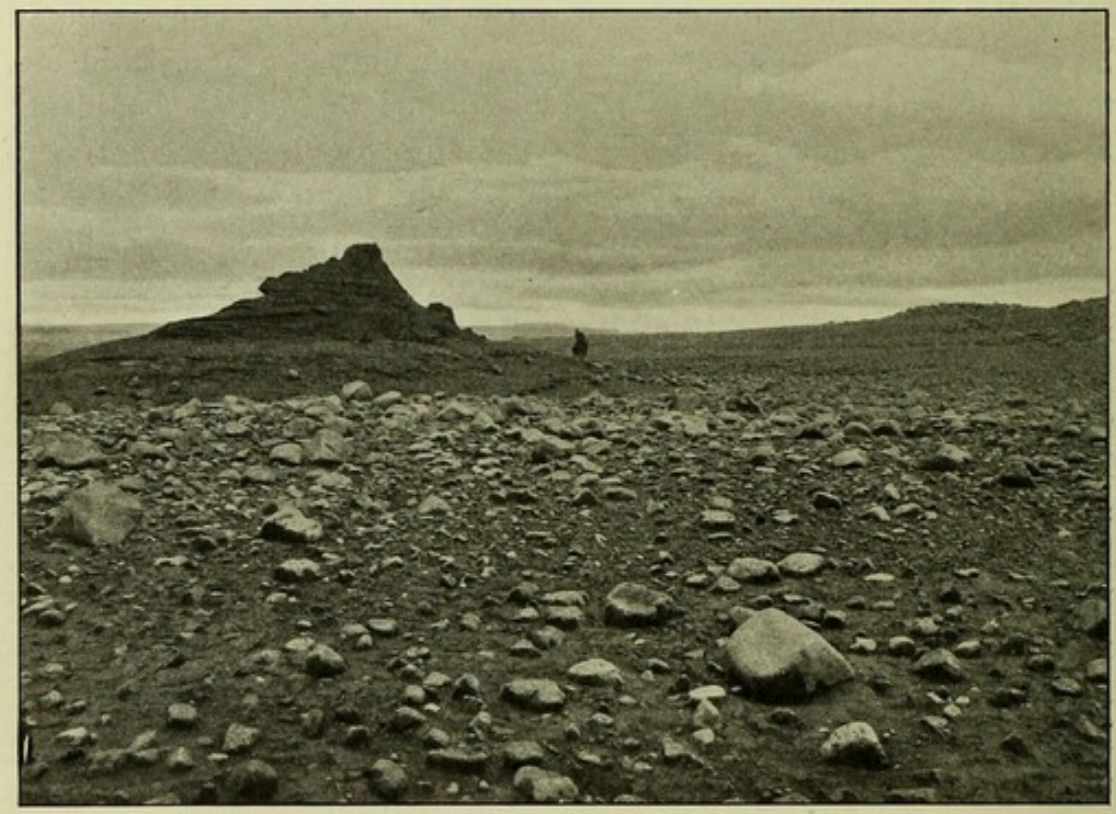

Fig. 14. Remaining portion of a "móhella" upon a wind-eroded gravelly flat (örfoka).

boulders. These river-beds are due to the melting of the snow in spring or during periods of thaw in winter when, for a short time, they are all filled with torrential floods of water.

The surface of the breccia mountains is usually concealed by loose, angular and porous fragments of lava which have been disintegrated from the breccia; the nature of the rock is often seen only in clefts and in a few prominent protuberances and projecting rocks. The power of resistance of the rock against the action of water and wind differs however greatly, because tuff and breccia are of all possible degrees of hardness, although a loose texture is the most common. Tuff is easily disintegrated, and water and wind

carry the finer palagonite-dust down into the valleys or to distant quarters of the island where it is deposited and retained by the vegetation, frequently forming thick layers (móhella). The heavier lava-fragments which have thus been deprived of matrix are left behind. On stretches of level ground the lava-gravel, thus loosened, sometimes attains a thickness of several metres. As a general rule the surface of the tuff-mountains is much affected by the action of water and air and along the sides of the fissures the effects may be traced far down. Sometimes these fissures are filled with zeolites, calcite or gypsum; and sometimes the mass which fills the fissures is harder than the surrounding rock so that the surface presents the appearance of a network of raised lines, while the tuff in the intervening spaces has been disintegrated and carried away. On the ridges and peaks of several tuff mountains the surface is, as it were, pock-marked with numerous small irregular hollows, channels and pot-holes which are probably due to the combined action of water and drifting sand. There are often a great number of clefts and fissures in the tuff-mountains which can sometimes be seen from a great distance because of the plant-growth which retreats to them to find shelter from the storm. On the whole the varied forms of surface in the tuff districts greatly influence the details of the distribution of the plants of the place.

As tuff is far more easily decomposed than basalt, soil is formed more quickly upon tuff-mountains in cases where external factors such as sand-drifts and storms do not interfere. Therefore on the tuff and breccia mountains of southern Iceland there is a thick coating of soil and a luxuriant plant-growth right to the verge of the mountain; this is rarely the case on basalt mountains. Even on steep mountain-sides of tuff and breccia there exists a luxuriant vegetation of various species. This is especially conspicuous in Mýrdalur (south of Mýrdalsjökull) where, for instance, the extreme point of Reynisfjall is densely covered with plants. A luxuriant vegetation is also found in Víkurklettar and in several other places. On the whole, as mentioned above, it is characteristic of the lower mountains, south of the great Jökulls, to be covered by a comparatively luxuriant plant-growth, while the level country is barren, owing to the destructive action of the glacier-rivers. In the case of the sea-fowl cliffs, where manure is supplied by the sea-fowl, such tuff-mountains are far more densely covered with *Cochlearia, Archangelica,* etc., than are the basalt mountains.

In Iceland all which lies above 500 metres is a complete desert; this is also true of great parts of all that lies between 300 and 500 metres; at this altitude there are, however, rather extensive bogs covered with *Carices* and *Eriophorum*, especially towards the west (N. W. of Langjökull). Larger and smaller desert-areas are also found lower down; in some places they extend even to the sea, but in such cases they owe their origin to special circumstances — the destructive influence of glacier-rivers, volcanic eruptions or blown sand. In many inhabited districts the greater part of the surface consists of a rocky flat with scanty vegetation; a dense plant-growth such as that found in meadows, bogs and heather-moors covers only a very small part of the entire surface of the island, perhaps not more than 1500—2000 square km.; but the amount so covered cannot be stated with any certainty. The interior plateau owing to its height above sea-level and its climatic conditions will probably never be of any greater importance, as regards the livelihood of the inhabitants, than it is at the present time. Considerable tracts of the lower-lying parts of the plateau (afrjettir), in spite of the very poor herbage, are used as summer-pastures for the hardy Icelandic sheep which are driven up into the mountains about the end of June and fetched home again in the middle of September. No small percentage, however, of these sheep perishes yearly by venturing too far into grassless wastes, falling into rivers and down clefts, being overcome by snow-storms, becoming a prey to foxes, etc.

The snow-line and the glaciers form the upper limit of plant-growth; but from thence down to about 500 metres above sea-level, individual plants usually occur widely separated; there are, therefore, virtually no habitations on the plateau. As the height of the snow-line in the different parts of the island varies greatly, so similar laws govern the occurrence of the habitations, which are closely associated with the plant-growth. The highest snow-line occurs in north-east Iceland, and there the habitations also extend furthest upwards. Three parishes are found on the plateau itself, viz. Mývatnssveit at 300 metres above sea-level, Fjallasveit at 400—500 metres, and Jökuldalsheiði at 500—530 metres. In the last two the number of the farmsteads and of the people has been subject to very great fluctuations. The inhabitants of these parishes maintain themselves almost entirely by sheep-rearing. In Mývatnssveit the conditions are however more favourable, as it is situated at a

lower level, is sheltered by several high mountains and has moreover a rich fishery in Mývatn. The district of Fjallasveit is chiefly covered with blown sand, and the plants growing on the sand-dunes and sandy flats, viz. *Elymus arenarius*, *Salix glauca* and *S. lanata* and *Carex incurva*, serve as fodder for the sheep, which thrive well. These plants are cut and gathered during autumn for winter-use. It is, however, difficult to keep cows; and on account of the weather, neither potatoes nor root-crops will thrive. The climate is also far more severe than at the coast; the annual mean temperature in Mödrudalur is — 0.8° C. In these districts the snow-line has a height of 1300—1400 metres above sea-level, and the highest limit at which habitations occur is 530 metres. On the north-western peninsula, to the extreme north the habitation-limit occurs at only 80 metres above sea-level, and the snow-line at 400 metres; more to the south, on the same peninsula, at about 130 metres, and the snow-line at 650 metres. For comparison with the height of the snow-lines given above I give in the following pages a list of the inhabited farmsteads situated at the highest levels in the different parts of the country, because they give an indication of the limit of the more densely plant-covered, inhabited country upwards towards the wide expanses, poor in plant-life, in the interior. The settlements in the uppermost valleys and in some parts of the plateau are by no means fixed; in years when severe weather occurs, with cold and damp summers, some of these farmsteads are abandoned, but are again inhabited when more favourable weather sets in. The areas above the populated districts, between these and the desert proper, are too poor in plant-life to be inhabited, but they are of great importance as summer-pastures for sheep and ponies.

Heights of the uppermost farmsteads above sea-level in metres.

Upon the northwestern peninsula.

Smidjuvík SE. of Cape Nord	80	metres
Skógar in Mosdal at Arnarfjörður	82	—
Hlidarsel at Steingrimsfjörður	128	—

Near Faxaflói.

Fornihvammur in Nordurárdal	170	metres
Gilsbakki in Hvítársida	175	—
Fljótstunga	232	—
Kalmannstunga	218	—
Hæll in Flókadal	174	—

Upon the peninsula of Reykjanes and in its immediate neighbourhood.

Vigdísarvellir NE. of Krisuvík	122	metres
Kolvidarhóll[1] near Hengill	262	—
Nesjavellir S. of Thingvallavatn	172	—
Svartagil N. of the above lake	182	—

Near the Southern Lowland.

Austurhlid on the way to Geysir	163	metres
Haukadalur N. of Geysir	104	—
Tungufell S. of Gullfoss	148	—
Stórinúpur in Hreppar	135	—
Galtalækur W. of Hekla	142	—
Selsund SW. of Hekla	155	—
Raudnefsstaðir NW. of Tindfjallajökull	239	—
Barkarstaðir in Fljótshlid	134	—

South of Mýrdalsjökull and Vatnajökull.

Höfdabrekka in Mýrdalur	128	metres
Svartinúpur in Skaptártunga	273	—
Holt in Sida	172	—
Eintúnaháls in Sida	227	—
Skaptafell (Bölti) in Öræfi	161	—
Viðidalur in Lón[2] E. of Vatnajökull	439	—

In the valleys of East Iceland.

Mýrar in Skriddal	183	metres
Kleif in Fljótsdal	126	—
Hákonarstaðir on Jökuldalur	310	—
Hauksstaðir in Vopnafjörður	195	—

Upon the plateau between Jökuldalur and Bárdardalur.

Víðirhóll on Jökuldalsheidi	533	metres
Lón	531	—
Möðrudalur on Möðrudalsfjöll	469	—
Viðidalur	462	—
Grímsstaðir	432	—
Viðirhóll	415	—
Reykjahlíd at Mývatn	292	—
Gautlönd	279	—
Krákárbakki	363	—
Svartárkot	409	—

In the valleys of North Iceland.

Ishóll in Bárdardalur	368	metres
Reykir in Fnjóskadal	223	—
Tjarnir in Eyjafjörður	223	—
Bakkasel in Öxnadalur	350	—
Gilhagi in Skagafjörður	227	—
Mardargnupssel at Svínadalur	395	—

[1] In reality only an inn for travellers.
[2] Not built until 1840; abandoned in 1842—1882; rebuilt 1883.

The surface of the interior plateau, with the exception of the glacier-covered areas, consists of deserts of stones, lava, gravel and blown sand. Where the underlying rock is basalt, the surface of the plateau is usually strewn with angular blocks of basalt, often in irregular heaps. Occasionally ridges are found, covered with gravel and blocks of glacial origin, but blocks split by frost are decidedly the more frequent upon these ridges. On the plateaus above the fjord districts of East Iceland, extensive areas are covered with angular blocks of basalt, but usually this layer of loose blocks is relatively thin. Similar conditions are met with in the north-western peninsula and on the mountains of North Iceland; but in the interior of the country glacial materials and the more recent formations preponderate. In that part, therefore, the greater part of the area consists of ice-striated ridges of dolerite, post-Glacial lavas, old bottom moraines and blown sand. Ice-striated streams of old dolerite-lava occupy vast areas in the interior. North of the great Jökulls the dolerite lavas may be traced continuously from Arnarvatn in the west to Snæfell in the east. Here and there the dolerite is covered with recent lava, and the closer the Jökulls are approached the thicker becomes the surface-layer of glacial gravel. As already mentioned, these monotonous, bluish-grey, stony deserts present an extremely desolate appearance. The only points upon which the eye can linger are scattered snow-drifts and large erratic blocks lying scattered upon the ridges. The landscape has undoubtedly remained for centuries unaltered in appearance; it must have looked as it does now, immediately after the snow-fields of the Ice Age had retired. There is no sign of life, and deep silence reigns over the land. The dolerite ridges, as has been already said, are covered with blocks rent by frost between which ice-striated domes protrude here and there. All the upper faces of the stones are dully polished and seamed by wind-abrasion. For days the traveller may see nothing else but gravel and ridges of rocks in endless succession like waves upon the sea; while as regards plants, only at intervals of 10 to 20 metres may a few stunted specimens of *Armeria maritima, Salix herbacea* and *Cerastium alpinum* be met with; the first-mentioned plant occurs most frequently. Here and there partially dried-up water courses and river-beds are found which are filled during the thaws of spring; and pools and small lakes are also occasionally met with hidden away in the low-lying ground between the ridges. In the immediate neighbourhood of the Jökulls,

where numerous glacier-rivers branch out upon the plateau, there are flats of rolled gravel and clay which are sometimes so steeped in water from the melting glaciers that they cannot be traversed.

On the interior plateau large areas (about 6500 square km.) are occupied by lava-streams — usually sheet-lava, with intervening tracts of slaggy lava. These lava-deserts are very poor in plant-life, and in the most highly-situated districts, they are almost entirely destitute of vegetation. Water is also very scarce, as the rain-water and the melting snow from the snow-drifts penetrate into the lava and do not reappear until far away as springs. The surface of these deserts consists of a hard, stiffened stony mass without a vestige of soil-covering, the hollows often filled with volcanic ashes and blown sand. The vegetation upon the lava-streams differs greatly on the plateau from what is found in the low-lying district, even if the lava-streams are of the same age; in the latter locality the oldest post-glacial lava-streams are often covered by a thick layer of soil, supporting heather-moors and coppice-woods; while on the plateau, lavas of the same age are quite bare. From Trölladyngja, a volcano in Odádahraun, an enormous lava-stream (Frambruni), 110 km. in length, has flowed down through Bárdardalur to Ullarfoss. Up at the volcano itself the lava, to a height of 1000 metres above sea-level, is entirely destitute of vegetation; lower down from Dyngjufjöll to Bárdardalur (800—200 metres), the vegetation becomes denser each step. The blown sand which has accumulated in the low-lying tracts, is here and there covered with lyme grass, which is soon followed by dwarf willows and heather. Down in Bárdardalur (160—100 metres) the lava is entirely covered with greensward and river-gravel so that only a few lava-peaks protrude. Near Lundabrekka a rather thick layer of peat is formed on the surface of the lava; otherwise the large lava-waste of Odádahraun (600—1200 metres) is almost destitute of plant-growth. The few plants which occur are especially met with where hollows in the low-lying tracts are filled with blown sand; most frequently some tufts of *Elymus arenarius* can be seen, and here and there a few specimens of *Silene maritima*, *Cerastium alpinum* and *Armeria maritima*. In places where the mountain streams from Dyngjufjöll have carried down a little clay, soil-formation has taken place to a small extent and extremely small specimens of *Salix herbacea* and *Polygonum viviparum* exist there. Lichens, which occur so frequently on low-lying lava-streams, are very rarely met with on Odádahraun, so the lava-surface is usually

quite destitute of covering; on the other hand, on lava-streams near Mývatn (above 300 metres above sea-level) lichens are very frequent. There, many species of phanerogams have also made their appearance, and both there and in Kelduhverfi the lava is often found to be covered by a thick carpet of moss. On Reykjanes scores of square km. of lava are entirely hidden beneath a soft greyish carpet of Grimmias.

Between Jökulsá á Fjöllum and Jökulsá á Brú, and between Kaldakvist and Skaftá, more recent tuffs appear upon the surface of very considerable tracts of the plateau, not covered by ice-striated dolerite-lavas or by modern, basaltic lavas. Where this tuff does not appear as bare peaks or steep mountain-chains, the surface is covered by lava-gravel disintegrated from the breccia, or else it is covered by blown sand, which is widely distributed, not only on the interior plateau but also in the lowlands. Blown sand is of varied quality and origin. It may be coarse or finer; it is sometimes so fine that it penetrates everywhere. During violent storms in sandy districts the fine dust is carried to the most remote quarters of the island and is deposited as a fine layer all over the surface: it even falls on vessels in mid-Atlantic. But naturally most dust falls in districts bordering on the tuff-belt or situated in it, as the dust chiefly originates from the tuff. The atmosphere in distant regions is often yellowish-brown because of the fine dust suspended in the air, and this dust-cloud is known in Iceland as "mistur." This tuff-dust has played a very important part in the formation of the Icelandic soil and subsoil, and it can be demonstrated almost everywhere. In the blown-sand districts proper, and in the neighbouring regions, where also larger particles of stone are put into motion, wind-blown sand has a great mechanical influence and is a mighty geological factor; its denudating effect upon the tuff mountains has been very great. Harder rocks are also affected by the sand; dolerites acquire a dull polish with irregular depressions, striations and furrows, while basalt is likewise sand-polished though to a less extent. Tuff and breccia mountains are always more highly disintegrated on the windward side, and the isolated fragments of basalt embedded in the breccia project further from the groundmass on that side than to leeward. When the wind is stormy, great masses of blown sand are constantly driven through the narrow valleys, which occur between the numerous sharp tuff-ridges east of Túngná, so that no vegetation can thrive there; only here and

there upon the highest ridges and peaks, which cannot be reached by the coarser grains of the drifting sand, are seen small patches of soil supporting mosses and a few phanerogams.

In Iceland blown sand consists almost invariably of decomposed volcanic rocks; quartz-sand does not occur in Iceland. The most common blown sand is palagonite-dust usually of a yellowish-brown colour, which when examined microscopically, is seen to consist of glass-particles, tachylite, palagonite, plagioclase, augite and various

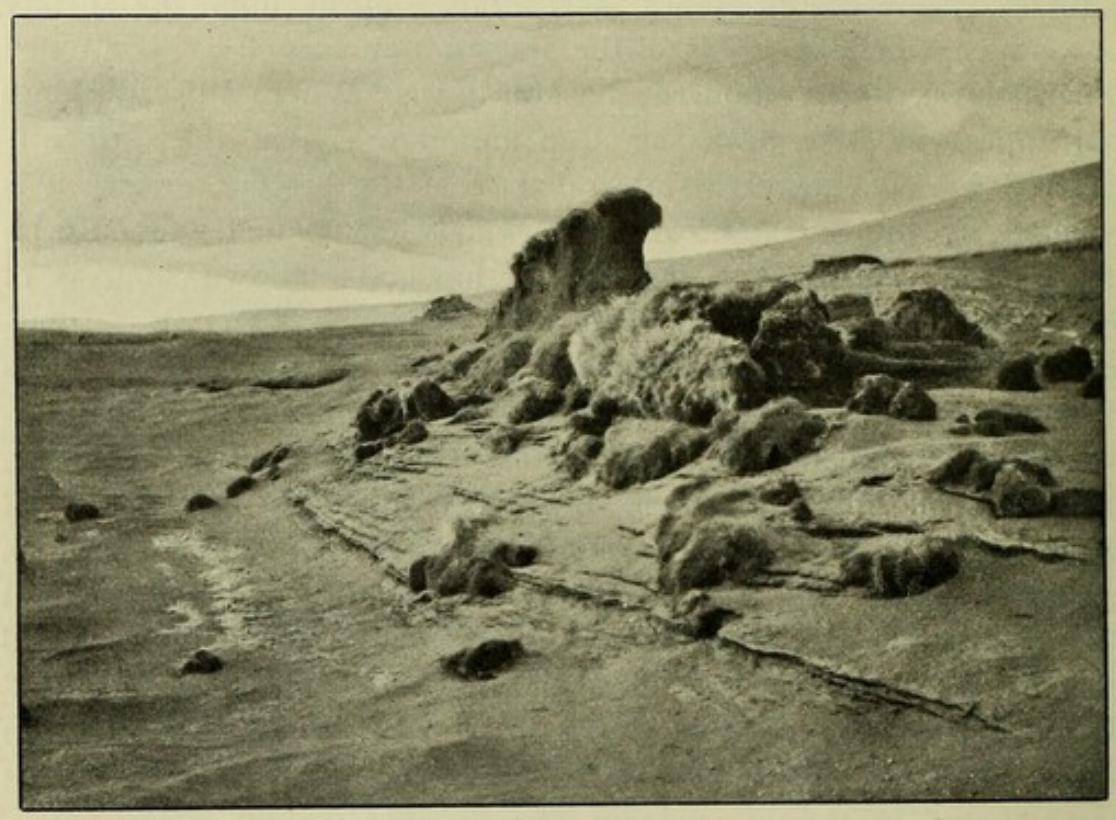

Fig. 15. Móhella in Króksdalur, not far from Sandmúladalsá. (Phot. Heinrich Erkes.)

finely decomposed zeolitic alteration-products. Volcanic ashes of recent date often occur as blown sand especially in the interior of the lava-wastes; they are heavier and less mobile, consequently, they are not dispersed in quantities beyond the volcanic districts. In the neighbourhood of the great glacier-bearing mountains, considerable tracts of level land are often covered with glacial clay, which when dried, crumbles into dust and drifts beyond the nearer surroundings. Around Dyngjufjöll, especially south-east of Askja, large areas are covered with blown sand, consisting of liparitic pumice-dust which all dates from the eruption of 1875. Moreover, stretches of blown sand consisting of decomposed mussel shells, i. e. calcareous dust, occur here and there along the coast of the north-western peninsula.

Owing to the variability of the wind-conditions, the dunes in the blown-sand districts are usually small and irregular in form; they are rarely higher than 3—4 metres, usually much less, and they are bound together by lyme grass and a few creeping dwarf willows. Sandy levels with low waves of sand are of general occurrence, and when moisture comes into play, the surface is cracked into numerous polygonal cakes by the action of desiccation or frost. The cracks are filled with drifted sand, so that the surface resembles a kind of mosaic.

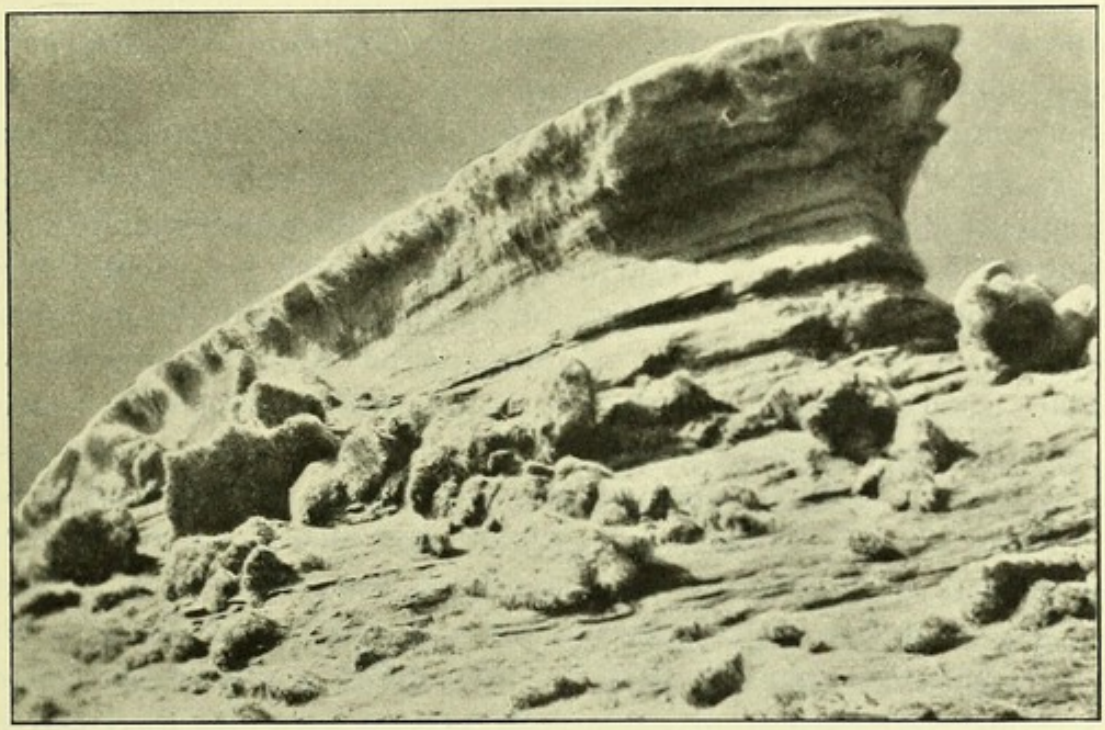

Fig. 16. Soil torn up by the wind. Large tracts in Landsveit are occupied by these loess-like formations. Here several square miles of land, which were formerly wood-covered, are torn up by the north-east wind. The district of Landsveit, west of Hekla. (Phot. Th. Thoroddsen.)

In tuff districts proper older and younger æolian formations are the thickest and most widely distributed, and often alternate with volcanic and glacial formations; but the tuff-dust is also carried to the basalt districts, where they initiate the formation of the loess-like layers known in Iceland as "móhella." Smaller layers of "móhella" occur everywhere in valleys and lowlands alternating with older and more recent glacial formations, with peat and lava-streams, but they decrease in thickness the further they are away from the large stretches of blown sand in the tuff districts. "Móhella" usually resembles a fine, easily crumbled, yellowish-brown or grey tuff, which is often traversed by stems of plants and red tuff-tubes which have been formed around the decayed stems; they

often alternate with layers of wind-polished stones, gravel, scoriæ or pumice, sometimes with clay. Where the blown sand is continuously moving, no vegetation can thrive, but when the fine dust and sand has blown away as far down as to the coarse gravel, Icelanders say that the sand is "örfoka," i. e. it cannot drift any longer (see Fig. 14). Then plants are again able to take root and new soil is gradually formed — until that also is blown away. The phenomenon of alternating periods of sand-drift and of vegetation, which has lasted through centuries, is nowhere so distinctly traceable as in Rangárvellir. Here the substratum is exclusively formed by "móhella," the thickness of which is unknown, but it must be considerable, probably 100 metres or more. Here the lowland plain abuts on the lava-fields of Hekla, whence quantities of volcanic ashes are blown down into the cultivated land. The lowland plain is intersected by deep, branching valleys, which are usually dry, but during the thaws of winter and spring large quantities of water have an outlet through these channels. From the plain a series of small terraces leads down to the bottom of these valleys, which often consists of a grass-covered, level stretch of land. The valley-sides offer favourable opportunities for studying the composition of the móhella: fine bluish-grey layers of sand alternate with reddish sand-layers penetrated by compounds of iron, and the embedded stones of varying sizes bear testimony to the strong erosive action of blown sand. In some layers soil and remains of plants occur, also clay-tubes formed around haulms of grasses. Here and there layers of pumice and scoriæ are also seen. No inhabited district at the present time is so exposed to being attacked and overwhelmed by blown sand as Landsveit in the southern lowlands. Here, during the nineteenth century, large stretches of grassland and many farmsteads were overwhelmed by drifting sand, especially in the years 1836 and 1880—1881. The substratum consists of old lava which formerly had a covering of móhella and greensward, now to a great extent torn up and destroyed by the masses of blown sand from the north-east. Sand storms cause deep channels and furrows in the soil, which constantly enlarge and by combining with others, gradually destroy the entire layer of soil, so that only a few massive fragments of móhella with hollowed sides and covered with greensward traversed by the fibres of plants, are left behind until they also succumb to the universal destruction. In large stretches of this district all greensward and soil have been torn off down to the naked lava-rock.

From here proceed broad, ramified channels containing blown sand, which are continued and widened, and which constantly encroach on the remaining piece of grassland. The north-eastern part of this district was formerly covered with heather and coppice wood, which the inhabitants, with incomprehensible lack of foresight, destroyed and used for fuel. Skarðsfjall, which stands in the centre of Landsveit, has protected the areas situated in its shelter towards the south-west. Some streams have also checked the advance of the drifting sand and have thus acted as a protection. Most of the blown sand which in various ways devastates the cultivated districts, originates from the wastes of the plateau. There is indeed enough and to spare of it, at least 3—4 thousand square km. of the interior being covered by blown sand of various thickness. On the plateau the blown-sand tracts appear rarely or never to become "örfoka," therefore they are almost always quite bare of vegetation with the exception of the scattered tufts of lyme grass and a few small willows in more favourable localities. In the elevated districts, the surface of which we have been describing, many plants cannot be expected to thrive. As we shall have occasion to mention later on, the highest part of the interior of Iceland, at a height of 650—1000 metres, is a waste extremely poor in plant-life.

The lowlands, as mentioned above, cover only a very small area ($^1/_{15}$) of the entire surface of Iceland; and a considerable part of this small area consists moreover of barren soil, of lava-streams, of stony rocks and ridges poor in plant-life, and of glacial and blown sand. Therefore the area which may properly be regarded as densely covered with plants, is very small compared with the entire area of the country, and with the present method of cultivation it could scarcely maintain the rural population if the mountains and parts of the plateau could not be utilized as pastures for sheep during the summer. The extent of plant-distribution differs, however, greatly in the different parts of the lowlands. While some of the districts are almost entirely or for the greater part covered by a dense vegetation of grass, sedges, heather or coppice-wood, as Ölfus, Flói, Skeið, Landeyjar, Mýrdalur, etc., great parts of other inhabited districts have not even half of their area grass-covered. Several inhabited areas in Skaftafellssysla, Mulasyslur and Thingeyjarsyslur contain very large tracts of rocky flats, poor in plant-life, lava-streams, sandy wastes, etc.; and in some districts only a very small fraction of the surface is of any use for the sheep- and

cattle-rearing of the rural population. The peninsula of Reykjanes, which is of no great elevation, more than half of its surface being below 100 metres, and which has a comparatively mild climate with a considerable rainfall, is, however, so poor in plant-life, that only 4 per cent of the area is grass-covered. The area bounded on the west by Lágaskarð and on the south by Hafnarfjörður is about 1635 square km., but of this only at most 69 km. is occupied by grassland. The greater part of the area of the peninsula of Reykjanes is covered by more recent lava-streams, and has a scanty vegetation; the inhabitants along the coast maintain themselves chiefly by fishing.

As it has already been remarked, the surface of the lowlands varies in character. It usually consists of loose masses, but sometimes also of solid rock which projects here and there through the more recent formations and the older and more recent lava-streams, as crests, ridges and hills. As mentioned above, in South Iceland large areas (2000—3000 square km.) are covered with glacial and volcanic sand, through which branching glacier-rivers flow. Although these sandy tracts originate mainly from river-gravel and sand, other constituents are also found intermixed in them, for instance tuff-dust, and volcanic scoriæ and ashes, where active volcanoes occur in the neighbourhood. On Mýrdalssandur volcanic slags and ashes predominate. River-gravel and glacial clay occur only upon the surface of changing river-beds. The vast Skeiðarársandur, on the other hand, is formed almost exclusively of rolled glacial-gravel mingled with fine sand and clay, which increases in amount the nearer the coast is approached. The various sandy tracts differ naturally somewhat as regards the quality of the material and the size of the grains, etc. Old lava-streams, also, extend over large areas of the lowlands; they are usually covered with soil which supports a luxuriant vegetation with heather-moors, coppice-woods and grasslands. In thickly inhabited districts such as Flói and Skeið, the substratum is of lava, and in the former district it is marshy, as it lies so low (at the level of the sea), that the water cannot drain off. Flói is jammed in between two river-deltas so that the rain-water cannot be drained away owing to the pressure of the bottom water, and in rainy years this district suffers greatly from water which has no outlet, so that the ground is quite boggy. The underlying lava protrudes from every hill and the soil is mixed with lava-fragments. The lowland tract of Flói gradually merges into the district of Skeið which

is situated upon the same lava-stream, but as the level above the sea is somewhat higher, the water most frequently penetrates into the lava, and the soil is sandy, hard and dry and covered with a good and vigorous growth of grass. The sedges disappear or retreat to small patches where the local conditions allow the accumulation of a greater amount of moisture. The thicker soil-layers upon the lava-streams, usually originate from tuff-dust (móhella), which has been carried thither and has gradually filled up all the depressions, and from glacial clay deposited by rivers. Several lava-streams with a thinner layer of soil support coppice woods — e. g. on Thingvallahraun, and Hvitárhraun — and heather, as on Reykjaheiði near Kelduhverfi, and others. In the lowlands the quantity of the plant-growth upon the lava-streams is closely connected with their age, and by the end of a century, a number of species has already settled down on a lava-stream, as may easily be seen upon the Skaftá-lavas of 1783 and the Leirhnúk-lavas of 1724—30; on the other hand, the lava-streams of Sveinagjá, which date from 1875, are still very poor in phanerogams.

In the most thickly inhabited districts the substratum of the soil generally consists of older and more recent glacial and alluvial formations, very often in connection with "móhella," volcanic ashes and lava-gravel. In the lowlands, which were covered by the sea at the close of the Glacial period, marine sand and clay layers are most frequently found immediately upon the basal rock. The clay, which was deposited by the glacial rivers of the Ice Age, often occurs in layers of considerable thickness; it is most frequently bluish-grey in colour and turns blackish-blue on being wetted; it is very tough and dense, and can often become rather hard. The clay contains a very insignificant amount of carbonate of lime, usually only 0.1—0.2 per cent, while the Danish Yoldia-clay, according to Johnstrup, contains 5—15 per cent of carbonate of lime. Along the rivers the banks of clay may often be traced for several kilometres without any disturbance being observed in the position of the layers, which is extremely regular and nearly always horizontal. The thickness of the clay-formations varies greatly; in the most highly situated parts of the lowland area and in the valleys, it is sometimes as much as 20—30 metres, further down from 5 to 15 metres. The thickness diminishes the nearer the coast is approached; but it may vary greatly. The clay occurs not only where rivers cut through, but also as a substratum below morasses. Marine sand

often occurs above the clay, and then more recent river-deposits, alternating with móhella, volcanic gravel, etc. Here and there, these formations are exposed at the surface and form an almost barren gravelly flat (melar), which, far into spring, is quite slushy, owing to the melting snow, which cannot drain away on account of the sub-surface ice and the clayey subsoil. In the eastern part of the southern lowland tract, under the boggy ground, occur enormous river-deposits (Landeyjar) — delta formations from Markarfljót and other rivers. But higher up, where the soil is drier (Rangárvellir), the subsoil is composed of thick móhella-formations; nearer to the sea occur fine sand and downs.

In several districts in the lowlands there are a great many rocky ridges (holt), which protrude through the morasses and grass-land. They vary in nature according to the character of the underlying rock, and generally consist of basalt or dolerite, rarely of palagonite-breccia. These ridges usually bear clear evidence of the action of the glaciers during the Ice Age. They are highly ice-striated and often have two distinct sides, one bearing traces of having been exposed to the direct force of the ice, while the leeward side is comparatively destitute of such marks. Their external form is sometimes dependent upon the direction of the inclination of the basalt-layers. In some places (Mýrar and Breidifjörður) they originate from fragments of a deeply sunk basal rock. The surface is usually stony, with solid rocks, larger loose stones, and smaller gravel; sometimes a great many erratic blocks are scattered upon the ridges. As regards plant-growth, these ridges should be characterized as rocky flats more or less covered with vegetation, and protruding like small islands above the grass-covered, usually boggy level lands. In several places the ridges, in olden times, have been clothed with coppice woods, but it is centuries since the coppice has been destroyed by sheep and goats. Such ridges are found scattered over a great part of the island in the lowlands and valleys, and often impart a characteristic feature to the landscape. The farm-buildings are often built upon them. In the low-lying marshy land of Mýrar, at the edge of Faxaflói, they occur scattered in hundreds in the bogs, and in the southern lowland district they are frequent in the eastern part of Flói and the upper part of Holt, while elsewhere large stretches of this lowland area are completely flat. In other districts they are so large that they are most properly described as small mountains (fell, hálsar). In the valleys the old moraines are often trans-

formed by the rivers, and converted into terraces, which form the substratum of bogs and grassland. The glacial moraine-gravel often extends far up the mountain-sides and forms here a substratum for soil and plant-growth. In other places in the valleys are steep rock-faces, stony slopes, heaps of large fragments of rock (urd), and the conical heaps of finer and coarser gravel brought down by the mountain-streams, which all help to give variety to the plant-formations. While basalt-mountains are slightly and slowly disintegrated, tuff-mountains are extremely liable to disintegration, hence the products of the latter, combined with the action of wind, glaciers and rivers, play a more important part. The contribution of the basalt towards soil-formation dates mainly from the Glacial period. As we have seen from the above, the substrata which support plant-growth are (1) firm ground, having a rocky base (basalt, liparite, breccia and lava); (2) loose soil, consisting of moraines, river-gravel, sand, clay, blown sand, volcanic ashes and tuff-dust (móhella); and (3) the products of the plants themselves: boggy soil composed of peat and humus.

The character of the subsoil below the humus-layer and the plant-covering is consequently in close relation to the chemical and mineralogical composition of the underlying rock. Over the greater part of Iceland the inorganic soil consists of decomposed basaltic rocks, the main mineralogical constituents of which are plagioclase (especially lime-felspars) and augite, but magnetite and olivine also occur, often in great quantities, and apatite and a small quantity of titanic iron. The chemical composition of the Icelandic basalts is rather uniform. On an average they contain 43—53 % of silica, 11—18 % of alumina, 11—22 % of iron (Fe 0 and Fe_2 0_3), 8—13 % of lime, 2—9 % of magnesia, 0.2—2 % of potash and 1—4 % of soda. Because anorthite, of the plagioclases, is very largely distributed in the Icelandic rocks, not only in the basalt, but also in the recent lavas and tuffs, these Icelandic rocks often contain a comparatively small amount of silica and a very considerable amount of lime and also alumina. The reason why the Icelandic soil is nevertheless poor in carbonate of lime may be found in the fact that the lime can only with difficulty be separated from its siliceous compounds, and because in the whole of the island, no sedimentary calcareous rocks are found, though such are of common occurrence in other countries. In districts where sulphurous acids sent out from fumaroles have affected the rocks, as is common in tuff-districts,

calcium sulphate (gypsum) is very common in the soil. The Icelandic basalts have not been investigated with regard to the amount of apatite contained in them, but judging from the abundance of phosphoric acid which often occurs in the waters of the large rivers, it must, in some places, be very considerable. In the districts where liparite is the main rock, the soil has not yet been investigated, but it must vary somewhat, on account of the varying composition of the rock, which contains much larger amounts of silica (65—78 %), potash (2—4 %), and soda (3—6 %) than the basalts. For the rest, the Icelandic liparites show evidence of their connection with the basalt-area in which they occur, by the fact that almost all of them are soda-liparites.

From Iceland there are as yet only a few soil-analyses to hand, and from a few districts only.[1] In calcined samples of fine soil from dry grasslands the main mass consisted of silica (37—48 %), alumina and peroxide of iron (38—50 %), while lime, magnesia, alkalies, present as silicates and other compounds, were found in quantities of from 7 to 14 %. The amount of carbonate of lime was but small, and varied from 0.5 to 1.7 %; in home-fields most frequently 1.5—1.7 %. On the other hand, the amount of phosphoric acid was larger (0.3—0.4 %) than in ordinary Danish soil. The soil samples were rich in humus and contained an unusually large amount of nitrogen considering the amount of humus — from 7 % to as much as 24 %. The amount of humus and also of iron compounds is larger than in ordinary Danish soil. Under unfavourable conditions of humidity the abundance of the organic substance found in the soil constitutes a danger, on account of the formation of protoxide of iron; and climatic conditions make the chemical changes in the materials of the Icelandic soil difficult and slow in wet tracts. The amount of the inorganic substances in the sand-samples gives a correct idea of the chemical composition of the solid basaltic rock.

Some analyses have been made of Icelandic plants. Firstly, of Icelandic hay, both hay from home-fields (tun; see Fig. 17) and hay from dry and from wet meadows. The analyses show that the Icelandic hay resembles mountain hay from the Alps. It contains a larger amount of fat than does the Danish hay; less cellulose;

[1] Analyses of Icelandic soil are found in P. Feilberg: Bemærkninger om Jordbund og Klima paa Island (Tidsskrift for Landøkonomi, 1881) and by A. Torfason in Búnaðarrit, Reykjavík, XX (1906), pp. 173—184; XXIII (1909), pp. 52—54. Also, in the recently published work by M. Gruner: Die Bodenkultur Islands, Berlin, 1912.

and a larger amount of ash.[1] Afterwards, many different species of plants were analyzed and compared with Swedish plants and the main result arrived at was very similar.[2] P. Feilberg writes: "Iceland is the land of the Cyperaceæ and of the coarser species of grass, but the sheep and the cattle which through generations have accustomed themselves to this coarse food, thrive well on it. The chemical contents of the fodder show that this is also possible, nor is there any reason why it should be otherwise."

In a damp and cold climate such as the Icelandic, the chemical changes in the material of the soil take place more slowly than the formation of vegetable matter, which accumulates and absorbs water where this is copiously present; thus the entrance of air is prevented, and heat is not generated. These circumstances give rise to the production of acid, boggy humus as in other northern countries with a cold and damp climate. Considerable areas in Iceland are covered with boggy soil, and there are also the very best conditions for the formation of peat and bogs. In some parts of the lowlands there are vast extents of bogs and swamps, as e. g. in Mýrar and Andakíll at the head of Faxaflói, and in Flói, Ölfus, Holt, etc. in the southern lowland tract; while larger and smaller swampy areas are found almost everywhere. In the lower-lying parts of the plateau there are also wide stretches of boggy land, e. g. Tvídægra, north-east of Langjökull; Miklumýrar, north of Hreppar, and many other places. In the majority of the districts the area of wet grassland, covered with Cyperaceæ and mosses, exceeds by far that of the dry grassland, but unfortunately as yet no measurements are to hand as regards the extent of the bogs.[3]

There are considerable peat-formations in the Icelandic bogs, but their thickness, distribution, plant-remains, etc. have not yet been investigated. In Skaftafellssyssel where glacier-rivers and volcanic

[1] Josep J. Björnsson: Um heygædi (Thjóðólfur, 1886, No. 40). P. Feilberg: Græsbrug paa Island, Kbhavn., 1897, pp. 14—17.

[2] St. Stefánsson and H. G. Söderbaum: Isländska foder- och betesväxter (Meddelanden från kgl. Landbruks-Akademiens experimentalfält. Nos. 74 og 83, Stockholm, 1902 and 1904). Also in Búnaðarrit, XVI. 1902, pp. 179—196; XVII, 1903, pp. 25—66; XXIV, 1910, pp. 1—48.

[3] M. Gruner's "Die Bodenkultur Islands," Berlin, 1912, came to my notice after I wrote the above; in it he estimates the entire bog area of Iceland at 10,000 square km. or about 10 % of the entire area of the island. According to this, as regards the extent of its bog area, Iceland is reckoned to be third among the Scandinavian countries (Finland 27.2 %, Sweden 12.6 %, Iceland 10 %, Denmark 5 % and Norway 3.7 %).

eruptions have constantly been influencing the soil-formation, peat is rare. In the peat there often occur quantities of stems, roots and branches of *Betula odorata*, and Francis J. Lewis[1] has found remains of *Betula verrucosa* in peat-bogs in South Iceland. Even in districts where birch-copses no longer thrive, as e. g. on Hornstrandir north of Jökulfirðir, birch-stems are found in the peat bogs. The Icelandic peat is largely utilized as fuel, and as regards its fuel-value it compares favourably with peat from other countries,[2] only the amount of ash is rather considerable, especially in peat from South Iceland, perhaps on account of the presence of volcanic ashes and blown sand. In the Icelandic peat-bogs there usually occur several, or a few, bands of volcanic ash of various thickness, usually basaltic ashes, but yellowish liparitic pumice-ash occurs also. In districts situated in the neighbourhood of active volcanoes the ash-bands in the bogs are very numerous. Bog iron-ore occurs also in the Icelandic bogs; in some places in rather considerable quantities. In olden times it was much used by the inhabitants, and for the smelting of the iron many coppice woods were destroyed. Parts of various boggy stretches — wet meadows — have great economic importance, and the hay (uthey) is largely used as fodder for sheep and cattle, especially as winter fodder for horses and sheep; the best part of it, only, is used for the cows, which live mainly upon hay from the home-fields (tun-hay). In 1910 about 14,300 tons (each ton 1000 kg.) of this uthey were harvested. Of the largest and most productive meadows of this kind may be mentioned Hvanneyri in the district of Borgarfjord, Forin in Ölfus and Safamýri in Holt. At the mouths of various large glacier-rivers are large and very fertile stretches of meadow-land, which either constantly or else at times are flooded by glacier water, e. g. in Lón in East Iceland, at Hvanneyri in Borgarfjord, and in several other places where a kind of marsh is formed by the deposited glacier-clay which contains fertilizing substances; in such places the river-water is no longer very cold, and has a very slight current or none at all. In water from Icelandic rivers the following substances of use for plant-food were found: the figures given are those for five million pounds of water (one pound = half kg.).[3]

[1] F. J. Lewis: Stratification of Peat Deposits in Iceland (Transactions of the Royal Society of Edinburgh, Vol. 47, Part IV (No. 26), Edinburgh, 1911, pp. 827—831).

[2] Analyses of Icelandic peat by A. Torfason are found in Eimreidin, XI (1905), pp. 40—41, and in Búnaðarrit, XX (1906), pp. 116—119.

[3] The analyses are found in P. Feilberg: Græsbrug paa Island, 1897, p. 22;

	1 Danish Streams	2 Hörgá	3 Eyjafjarðará	4 Hvítá (Borgarfjord)	5 Laxá from Mývatn	6 Hvítá (Arnessysla)	7 Thjórsá	8 Thjórsá; during the thaw of 1898
Nitrogen	15-20	1.37	4.65	1.35	110.00	4.9-14.12	4.5- 6.5	3
Potash	10-15	13.50	11.50	11.00	15.50	12.5-17.5	11.0-15.5	140
Phosph. acid.	0.6-1.0	1.05	5.00	4.35	35.00	1.5- 3.5	5.6-19.5	157
Lime.....	100-700	33.02	35.00	41.50	55.00	21-37	49-82	46

In several places river-water is utilized for irrigation, and irrigated meadow-lands were calculated to cover an area of 28.4 square kilometres in 1909.

The only cultivated soil in Iceland is that of home-fields (tun) around the farm-buildings. These home-fields are manured and levelled, but generally are not ploughed. The extent of the cultivated areas (tunes) of the whole of Iceland was in 1909 calculated to be 187.8 square kilometres; to this should be added 2.8 sq. km. for the cabbage and potato plots. There are often numerous knolls in the tunes, which render haymaking very difficult (Fig. 17). Therefore the improvement of the soil consists in the levelling of these knolls, which, however, reappear in several places after a time. The nature of the tunes and the quality of the soil naturally differ greatly according to cultivation and situation. The grass (tada) from the tunes consists mainly of Gramineæ, and, as already mentioned, is used as winter fodder for the cows. In 1910, 5145 tons of tun-hay (tada) were cut. Outside the home-fields there is also a great deal of dry grassland (harðvelli) covered with Gramineæ, which is chiefly used as pasture-land for sheep and cattle. In the soil of the tunes and the dry grassland a larger quantity of lime and phosphoric acid is usually found than in that of the wet meadow-tracts.[1]

As in other arctic and subarctic regions, "soil-flows" (Solifluktion) are a common phenomenon in Iceland, and they exercise, especially in mountainous regions, no slight influence upon the soil and plant-growth. The upper layer of the soil upon slopes and

and in Búnaðarrit, XXII, 1908, pp. 265 and 266. No. 1 is by Feilberg and Westermann, Nos. 2, 3, 4, 5 and 8 by Detlefsen and Meyer; Nos. 6 and 7 by A. Torfason. Nos. 5 and 8 appear somewhat doubtful.

[1] P. Feilberg in Tidsskrift for Landøkonomi, 1881, pp. 8—12.

mountains-sides is saturated with water from melting snow during spring, and slides slowly downwards; very often gravel and clay is by this arranged in bands down the slopes. Below large snow-drifts which persist till far into summer, or during the whole of summer, there is always water which soaks into the soil, and upon many mountain-sides, slow-flowing mud-streams are formed, which in shape and movement recall small glaciers. In other places the flowing

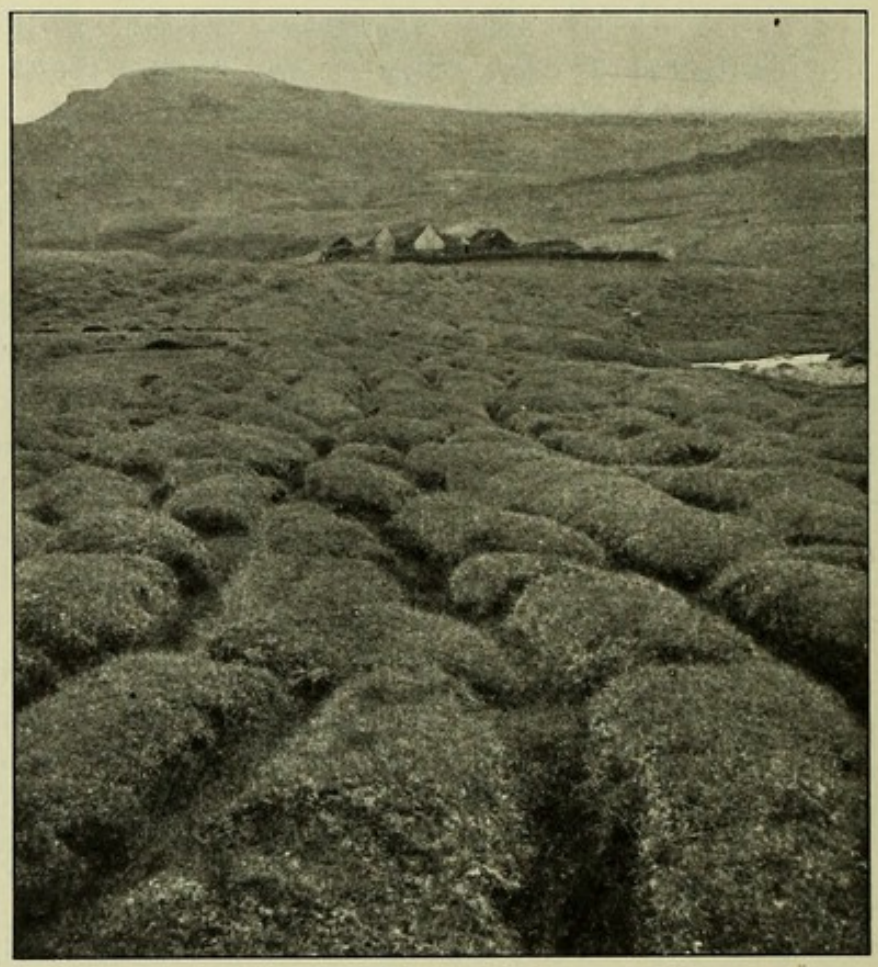

Fig. 17. An old Tun. Kjós near Reykjavík. (Phot. A. Hesselbo.)

soil forms small terraces, which are partially transformed into rows of knolls overgrown with plants. Sometimes the soil is loosened from the solid rock, or slides upon the ice of the subsoil; sometimes clayey streams flow down into depressions and valleys, and occasionally fragments of greensward, which had been resting upon a saturated substratum of sand and clay, are loosened. Frequently it can also be seen how water, flowing upon the ice of the subsoil down the slope, undermines the soil so that large pieces of greensward are put into motion, give way, and are torn asunder. It may also happen, where there is a thick layer of loose soil, that the

downward-flowing water, during thaw, tunnels below the ice-layer and forms subterranean channels, causing the upper layer to collapse and fall down into these hollows. In this way, after the volcanic eruptions of Askja in 1875, great damage was done to the soil on Jökuldalur; its enormous moraine-terraces were covered with pumice-gravel which froze into a thick layer that melted but slowly, because the white, glistening gravel reflected the rays of the sun; below this layer, the water dug out channels, 20—30 metres deep, through earth, sand and gravel, and caused catastrophes such as that mentioned above.

In this connection may be mentioned the influence often exerted upon the soil by the numerous avalanches and rock-slips of different kinds, and the very slow, creeping movement which may be observed in connection with gravel, stones and rocky blocks upon the mountain sides which, in the course of years, may become of very great morphological importance. During earthquakes it may happen that mountain-sides clad with grass and coppice are suddenly denuded of their surface soil, which slides down into the lowland plain. During the earthquake of 1896 a piece of swampy soil, 10,000 sq. metres in area and 2—3 metres thick, at Thjórsá in the neighbourhood of Krókur, thus slid down, being thrown into wavy folds and hummocks, although the slope of the ground was only 1—2°. The mountain of Skarðsfjall, which rises 227 metres above the plain, had, before the earthquake, a thick coating of soil, and was grass-covered to its verge; but after the earthquake it resembled a fruit which has been peeled. Thirteen landslips descended on the western side, leaving behind them large surface depressions, and strewing below mighty mounds of soil, clay, gravel and stones together with larger and smaller fragments of torn greensward. These landslips must, in the course of time, have had an enormous influence upon the soil and the plant-growth of many districts where earthquakes are very frequent. All over the island are often seen, along the mountain-sides, marks of ancient huge earth- and rock-slips that could only have occurred during earthquakes.

Level tracts with their surfaces cracked into polygonal cakes (rudemarks) are extremely common in Iceland, and fine specimens of such may be seen as, for instance, in the neighbouring districts of Reykjavík. They have a peculiar effect upon plant-distribution on the rocky flat. "Rudemarks" are usually formed only on flat land where the soil consists of gravelly clay — especially clay inter-

mixed with a large quantity of tuff-dust (móhella). The surface is divided into squares or more or less regularly formed polygons, by bands of small stones or gravel, while the clay of the interior of the squares or polygons is destitute of stones. The surface resembles a net — the meshes of which are formed by irregular bands of gravel. Usually it is only the gravel which supports plant-growth; there the plants can find shelter between the stones, while the middle of the clay-cakes is too wet for plant-growth. But when the "rude-mark" becomes drier, vegetation may gradually extend over the

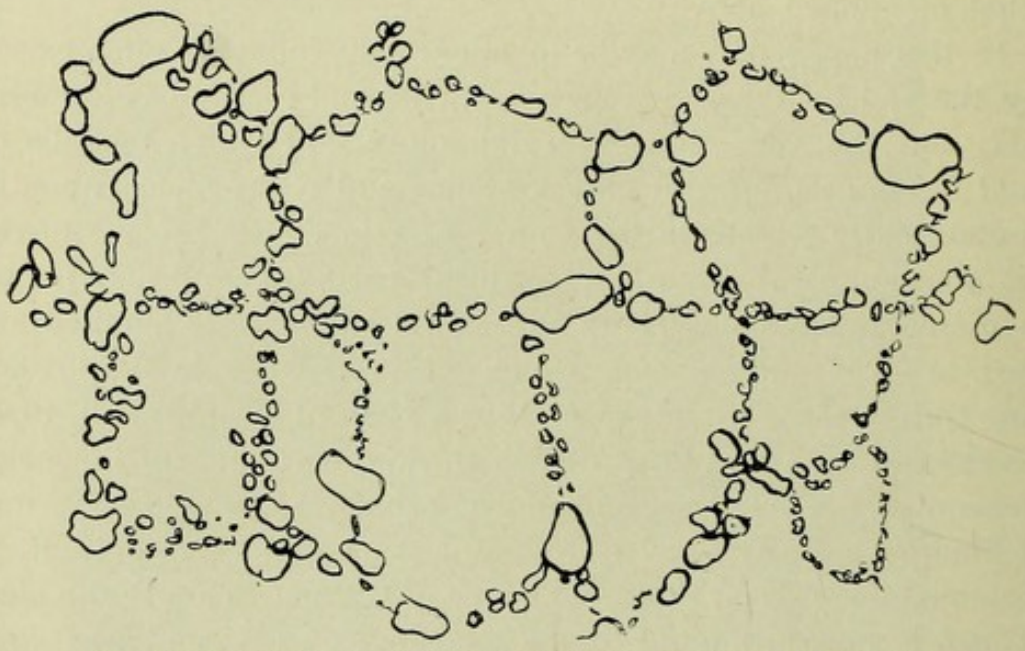

Fig. 18. Portion of a "rudemark" in the neighbourhood of Reykjavík, showing the position of the stone and gravel bands. (Drawn by Th. Thoroddsen.)

cakes of clay, first forming a scattered growth upon them and ultimately soil and a plant-carpet, especially when tuff-dust and drifted soil have settled on the surface. The polygonal cakes vary greatly in form and size, but generally they have a diameter of only ½—1 metre. The knolls (þúfa, pl. þúfur; see Fig. 17), which play such an important part with reference to Icelandic vegetation and agriculture, stand in close genetic relation to the "rudemarks" and we will therefore try to give an account of the way in which they both have probably originated, but questions bearing on this point require to be elucidated by the experimental investigations of persons living on the spot. My investigations in Iceland have confirmed me in my opinion that the Icelandic þúfur — as already mentioned — stand in a close genetic relation to the "rudemarks" and that sub-surface ice is an essential condition for the formation of both;

where for some reason or other no ice-layer is formed in the ground, neither "rudemarks" nor knolls seem to occur.

The depth at which this ice is present in spring differs greatly in the different parts of the island, and — according to the weather — in the different years. In the northernmost districts this ice may remain throughout the summer for years during cold and damp periods. As a rule, in the first half of June, frozen ground is met with at a depth of 1—1½ metres over the greater part of the island; on the plateau a thicker or thinner layer of this sub-surface ice is no doubt always present throughout the summer, and there, in several places, it gives rise to the formation of swamps, bogs and lakes, as the melting snow and ice cannot drain off. In some districts with very warm ground, where hot springs or other secondary effects of volcanoes occur, the ground is never frozen.

As is well-known clay and clay-soil develop, by contraction, numerous intersecting clefts; such cracks are also formed during winter by the action of frost, and in severe winters loud cracks are constantly being heard, announcing the rending of the ground. The surface layer of soil is therefore traversed by a network of numerous rents and cracks which divide the clay-soil into irregular fragments or a number of prisms. On closer investigation these cracks are not only found to occur on gravelly and clayey flats, poor in plants, but also in the clay-humus of the home-fields; some of them are as fine as hairs, others have a breadth of 2—3 cm. Both these factors, the sub-surface ice and the cracks in the ground, are necessary to the formation of "rudemarks" and knolls, and to these should be added two other very important factors, viz. frost and unequal surface-evaporation.

When, in spring, the snow melts on the cracked and netted surface of a flat consisting either of clayey gravel or of plant-covered clay-soil, and the flat itself thaws at the surface, the water percolates through the ground and the cracks, but cannot escape on account of the sub-surface ice so that the entire layer of soil becomes saturated with water. Where the flat consists exclusively of sand and gravel, without any mixture of clay, the entire soil-layer is evenly saturated and the surface of the water can sometimes rise to a level with that of the ground. Evaporation then takes place evenly over the entire surface, and when the sub-surface ice melts, the surface-water drains away or evaporates, and nothing further happens. But on a clayey gravel-flat intersected by a network of

cracks, the circumstances are somewhat different. During spring the ground is partially thawed; it freezes in the night and thaws during the day. The sub-surface ice forms a downward limit which does not permit the water to drain away, and uniform circulation and evaporation at the surface are prevented in a "rudemark" by ice-formation in the many cracks, originally full of water, which together with the sub-surface ice as a base form a vascular- or cell-system over the entire flat, and this system lasts at least for some time. The water from the melting snow and ice on the surface collects mainly in the cracks and depressions, where it freezes during the night; this is best observed on a knolly flat, which during the thaw of spring produces an entire network of small water-canals. The water cannot penetrate downwards on account of the ice in the cracks or, if they should be free from ice, it will yet remain for a long time in them, for as the water-layer is thicker there than upon the polygonal cakes, the evaporation is slower. The heating of the sun and consequent evaporation of water is therefore greater on the cakes, so that the wet from below, from the slowly thawing parts of the ground and the ice of the subsoil is drawn up into the centre of the cakes. A clayey soil with particles of a certain size has great capillary power and can absorb water and draw it up in great quantities.[1] The power of absorption of the clay-soil is greatly increased when it is covered by soil, humus and plant remains. During spring, frost and thaw alternate constantly and daily. The "rudemark" freezes in the night, at least partially, and thaws in the morning; in the course of the day the water rises in the individual clay-prisms owing to the rapid evaporation from the surface, but in the night it freezes, expands and raises the central part of the cake. This occasions a constant wandering of the particles of the clay soil upwards into each clay-prism, and by the constant pressure exerted by the frozen soil throughout a long period, the heavier particles are sorted out, and as they are less mobile, they are left behind or pushed to the sides. This sorting-out of the coarser material is the most characteristic feature of the "rudemark." The enormous pressure due to the freezing process is well known. As will be mentioned again later on, in several places in the Iceland mountain-bogs there are opportunities of observing how the frozen

[1] The air contained in sandy clays in a dry condition may amount to 40 % of their volume, and by infiltration, as large a volume of water may replace the air. See A. G. Högbom in Geol. Förhandl., Stockholm, 1905, XXVII, p. 22.

water inside the knolls can rupture a greensward, 10—20 cm. thick, and traversed with plant-roots. This pressure from below, repeated for years in a "rudemark," must gradually push and force the gravel aside so that it lodges at last in the cracks which, while they are filled with ice, form a kind of wall around each clay-prism. Thus the stones are placed in the neutral territory between the small centres of power, and form a boundary to each cake, the upper edge of which boundary appears upon the surface while the lower reaches down to the ice in the subsoil. Below the level of this ice the gravel is irregularly dispersed in the clay; it is regularly arranged only in the surface-layer above the ice. In the summer, when the soil has thawed and the sub-surface ice melted, the water drains off, and the "rudemark" dries. Everybody who has travelled in Iceland during spring knows what an enormous difference there is between the clayey gravel-flats in which the horses sink deep down while the ice of the subsoil still hinders the draining off of the water, and the same flats in summer when they are dry, so that horses can gallop across them. During summer the clay-polygons become somewhat depressed. Many of them are however slightly arched during the summer also and retain for a long time a considerable amount of wet in their interior. Clay which easily absorbs water and expands is well known to Swedish geologists[1] who call it "jäslera," and recently it has been connected with "rudemarks."[2] In the neighbourhood of Reykjavík (Melar) some well-defined "rudemarks" have developed in clay soil where a water-containing layer at a depth of about $1^1/_2$ metres rests on a thick "móhella" through which water can penetrate only with difficulty, and which therefore freezes in winter into a plate of sub-surface ice. Where the ground consists of clayless sand no "rudemarks" are developed, nor where the subsoil is so porous that water cannot accumulate and form sub-surface ice proper.

In my opinion the knolls which are of such common occurrence in the home-fields of the farmsteads (see Fig. 17) are developed in a similar manner. These knolls are usually larger or smaller elevations of earth which occur together in numbers; the surface-layer consists of humus and plant-remains, but the interior is formed

[1] A. G. Högbom: Om s. k. jäslera och om villkoren för dets bildning (Geol. Fören. Förhandl., Stockholm, XXVII, 1905, pp. 19—36).

[2] E. Bergström: En märklig form af rutmark från barrskogsregionen i Lappland. Geol. Fören. Förh., XXXIV, 1912, pp. 339—340.

of the clay soil, which projects into them like a kernel and forms the main part of their volume. The knolls have usually a diameter of $^1/_2$—2 metres and a height of $^1/_4$—$^1/_2$ metre; sometimes they are somewhat smaller; or they may be larger. The form varies, but is usually oblong. When the knolls are large the channels (kargatthyfi) between are but narrow. The thicker soil-layer together with the greensward-covering and the vegetation, are intersected by a network of cracks similar to that in the "rudemarks:" These cracks divide the ground into numerous pieces of various shapes which behave, as regards the sub-surface ice and the moisture, as the "rudemark." The knolls are dependent on the crack-systems of the substratum. In the knolls the ascending stream of clay and humus particles must be stronger than in the cakes of the rudemark as the greensward, rich in humus, has a very great capillary attraction and an enormous water-capacity — it can absorb water to the extent of 50—60 % of its volume; therefore during the evaporation from the surface it absorbs water vigorously, not only from the thawing ground below, but also laterally from the channels between the knolls filled with water during the spring thaw: in spring the greensward upon the smaller knolls is as saturated with water as a sponge. Bands of volcanic ashes, which were present in the ground or in the greensward before knoll-formation began, become bent upwards in curves according to the form of the knolls — a fact which, among others, is a proof of the local pressure from below in each knoll. In spring, during the melting of the snow, the channels between the knolls are often half filled with water which cannot escape, while the tops of the knolls are dry, sometimes even very dry owing to evaporation, so that the vegetation upon them is totally different from that upon the sides of the knoll. Sometimes large knolls have a kernel of ice far into the summer. The formation of knolls does great damage in the peasants' home-fields and great trouble is taken in levelling them, but they may reappear comparatively quickly if the ground is not thoroughly drained, so that the surface-water and the water from the melting ice of the subsoil are immediately carried away. In this connection it should be mentioned that where a snow-covering during spring protects the ground for a long time against the action of frost and thaw, no knolls are formed.

Knolls of the kind described above occur in thousands also in uncultivated grasslands with clayey móhella-soil, on heather moors and on grass "móar", and here, also exclusively upon somewhat flat

land[1] and in places where the water, for some reason or other, cannot drain off. Here the soil is usually much thinner than in the home-fields but nevertheless it has a very great power of absorbtion during the process of surface-evaporation; the greater part of these knolls consists of móhella-clay. On an entirely bare clay-flat no knolls are found, and the separate cakes in the „rude-mark" rise but slightly in the middle during spring, but not until they are plant-covered and clad with greensward do they bulge and retain their convexity. On a closer investigation it is probable that several transitional forms will be found between "rudemarks" and knolly flats, but investigators have not as yet made this matter a subject for study. Where similar plant-formations (heather and "móar") occur upon slopes or mountain sides upon which the water easily finds outlets, knolly flats are absent, and "rudemarks" are never found in such localities. Upon mountain-sides small eminences of various kinds may sometimes be observed which are due to underlying stones or ridged mud-flows, etc., but never "thufur" proper. Nowhere have I seen any indications of "rudemarks" or "thufur-marks" being at all connected with mud-flow phenomena.

On the plateau peculiar knolls of usually large size are found which the inhabitants of the different districts call "rústir," "haugar" or "dys." These knolls are, as a rule, of irregular, oblong form, and are bare of vegetation on the top, where they consist only of humus and clay. It can be seen that the ground has bulged and the knolls are cracked at the top. In some places there are evident proofs of this being the case: bands of the original soil are seen to lie upon the top of the knoll while the clay and gravel within have poured out of the cracks between the bands. In the neighbourhood of Ulfsvatn on Tvidægra, at a height of 460 metres above sea level, I investigated such knolls in 1898; they were 1—1½ metres in height, 15—20 metres in length and 8—10 metres in breadth. The sides were covered with heather, but Cyperaceæ grew in the intervening spaces. Similar knolls occur in several other places in the interior of Iceland, but only in one more place did I observe

[1] Dr. H. Jónsson describes a heather-covered "rudemark" where the cracks between the cakes were covered with *Grimmia hypnoides*, but the cakes themselves with *Calluna* and *Empetrum*. This peculiar vegetation — the brownish heather-vegetation divided into numerous polygons by the greyish moss-bands — occurred only upon level ground (Botanisk Tidsskrift, XXVII, 1905, pp. 43 and 44).

them to be as large as those at Ulfsvatn, viz. in East Iceland on the plateau south-east of Snæfell, at a height of 690 metres above sea-level. This was in 1894, but the inclemency of the weather prevented me from making a halt at the place. Here, also, several of the knolls had burst and discharged a large quantity of clay-soil. This form of knoll occurs especially at the edge of the bogs where the foot of the knoll stands in water during the melting of the snow: where the supply of water is too abundant these knolls do not occur. It is a fact peculiar to all knolls, both in the lowlands and on the plateau, that they consist of móhella-soil and humus intermixed with clay; this is true also of the "rudemarks" with the exception that more gravel and stones are found in them than in the plant-covered ground. As mentioned above, there is no direct connection between the mud-flow phenomena and the "rudemarks" and knolls, but it may happen that a flat with either of these surface-forms is afterwards affected by mud-flows; this is then a secondary phenomenon. Where subsoil-ice is absent, as for instance in the neighbourhood of the hot springs which are scattered in hundreds all over the country, I do not remember to have seen "rudemarks" or "thufur" proper. Upon the plateau itself "rudemarks" are rather rare, but, on the other hand, various mud-flow phenomena are common; thus, stones are often seen arranged in bands on the slopes, and in various other ways which, however, I regret to say, have not as yet been more closely investigated. On basaltic plateaus covered with coarse basalt-gravel and blocks of rock, patches of clay are now and then seen which appear, in the middle, to have thrust up from below and spread out slightly on all sides.

Besides these knolls there are many other similar eminences in the gravel-covered ground which are called knolls, but are due to quite different causes and have a different origin. Sometimes nodules on the greensward are due to the form of the substratum, as where a thin layer of soil occurs upon lava, or upon a stony and rugged bottom. In blown sand, knolls are formed around roots of *Elymus arenarius, Halianthus peploides* and other plants. Where the ground-water stands very high, as in many extensive boggy tracts, so that the entire surface freezes into an ice-cake, only small knolls of organic material are seen, formed of moss and Carices. On hard grassland, on gravelly flats and similar places, small

knolls are formed of the rootlets, leaf-rosettes, etc. of various plants. Sometimes knolls are formed of organic material in places where a small spot is constantly manured, e. g. the so-called "bird-knolls" on higher levels, where bird of prey are in the habit of alighting, and the characteristic Icelandic "dog-knolls" (hundaþúfur) along the roads where the dogs are wont to stop, which almost all travellers in Iceland have for companions.

III. CLIMATE.[1]

ALONG the coast of Iceland, generally speaking, a decidedly insular climate prevails, the conditions of which are determined by the wind-distribution over the North Atlantic and by oceanic currents. The climate has an oceanic character, the summer being cool and the winter usually mild — but it may become very cold when northern winds prevail and the Polar ice blockades the coasts. The air is usually damp, and storms are very frequent and violent. The climate varies, however, rather considerably in the different parts of the coast, and there is also a considerable difference between that of the coast and the interior.

[1] Meteorological observations from Iceland are published annually in "Meteorologisk Aarbog," 2. Del. Bilandene. København (Annuaire Météorologique. Publié par l'Institut météorologique Danois. Deuxième partie. Les colonies), in Danish and French. See also. Eléments météorologiques des îles Féroé, de l'Islande et du Groenland. Copenhague, 1899. The climatological observations from Iceland have, as yet, been worked out to a small extent only, and there exist no larger and more exhaustive accounts of the climate of Iceland; only some small, but valuable, papers are to hand by V. Willaume-Jantzen (Climat du littoral islandais. Congrès maritime international de Copenhague, 1902; and some articles in "Salomonsens Leksikon," 1899, and in "Atlanten," 1904); use has been made of these in this paper. The climatological means which are given in this paper have been calculated and classified at the Meteorological Institute in Copenhagen in 1910, and were previously published, 1911, only in my book on Iceland "Lýsing Islands," in which there is a section (vol. II, pp. 327—394) giving an account of our present knowledge of the climate of Iceland and its weather-conditions during historic times. Among older papers on the climatology of Iceland may be mentioned J. Thorstensen, Observationes Meteorologicæ, 1823–1837, in Islandia factæ. Hafniæ, 1839; J. F. Schouw, Nogle Bemærkninger om Vejrliget paa Island i Vinteren 1824—25 (Tidsskrift for Naturvidenskaberne. København, 1826, IV, pp. 259—262); Mag. Pedersen, Undersøgelse om Barometrets daglige Middeloccillation paa Island (Overs. Vid. Selsk. Forh., 1845, pp. 65—69); and lastly observations by H. J. Scheel from Akureyri, 1811—13 (Annals of Philosophy. Edited by Th. Thomson, Series 1, Vol. XI, London, 1818, pp. 96—103 and 169—175), and observations by A. O. Thorlacius from Stykkisholm, published in "Journal of the Scottish Meteorological Society," 1869, 1873, etc. Articles on the winds, drift-ice and other more special subjects will be mentioned subsequently in footnotes to the text.

The climate of Iceland, owing to oceanic currents, is much milder than could be expected from the position of the island. As is well-known the temperature of the air varies greatly at the same latitude on the eastern and western sides of the North Atlantic. Stykkisholm in Iceland lies about 65° N. lat. as also Brönö in Norway and Angmagsalik on the east coast of Greenland, but the temperature varies greatly in these three places as shown in the following table: —[1]

	February	July	Average for year
Brönö	— 1.4° C.	12.8° C.	5.2° C.
Stykkisholm	— 2.7° C.	9.7° C.	2.8° C.
Angmagsalik	— 10.8° C.	5.4° C.	— 2.6° C.

The above table shows, among other things, the great influence exerted by the cold, ice-carrying current in Denmark Strait. On the whole, oceanic currents have a great effect upon the climate of Iceland. The west coast has its temperature raised by the Gulf Stream. One branch of this passes Cape Nord and continues its course along the north coast where it becomes cooled, but has still a comparatively high temperature which is distinctly felt at Grímsey. Another branch of the Gulf Stream comes from the south up towards the south and east coasts where it meets the cold Polar current which comes down along the east coast of Greenland and at Iceland divides into two branches. Of these branches the one broad branch turns down through Denmark Strait, while the other flows down towards Langanes, and thence southwards along the east coast of Iceland to South Iceland where it passes between the coast and the warm current outside. The conditions connected with these currents exert a great influence upon the temperature of the ocean off different parts of the coast and thus upon the flora and fauna of the ocean, which differ greatly according to whether they are under the influence of cold or warm water. Thus, the algal vegetation along the north-eastern coast of Iceland has a different character — is more Polar — than towards the south-west; this applies also to the fish fauna, and the deep-water, spot-bound fauna, as well as to the plankton.

The temperature of the surface-water of the ocean varies therefore in no slight degree off the different parts of the coast. During winter the temperature of the ocean-water off the east coast, where the influence of the Polar current is greatest, is on an average 0.8°

[1] Julius Hann: Handbuch der Klimatologie. Stuttgart, 1908, I, p. 181.

(Papey); off the north coast 2° (Grímsey); off the west coast 1° (Stykkisholm); and off the south coast 4.1° (the Vestmannaeyjar); but it varies rather considerably with the increased or decreased

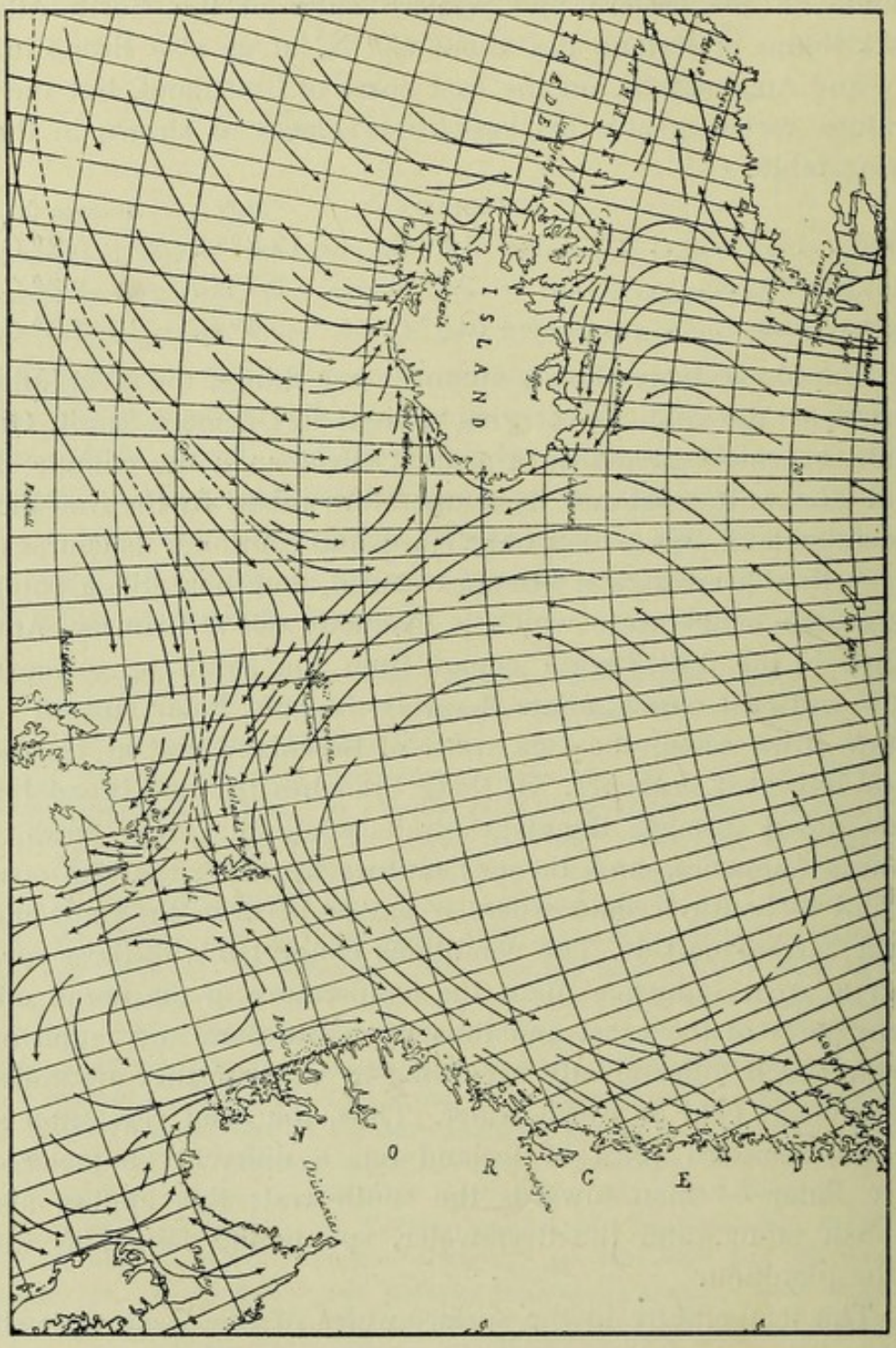

Fig. 19. Reduced photographic reproduction of Ryder's chart of the North Atlantic Ocean.

proximity of the Polar ice. The mean summer temperature of the ocean round Iceland is 5.8° at Papey, 6.1° at Grímsey, 9.7° at Stykkisholm, and 10.4° at the Vestmannaeyjar. For further particulars consult the following table: —

Table I. Mean Temperature of the Surface Water of the Ocean round Iceland for the Period 1872—1906. (Centigrade scale used.)

Name of Station	January	February	March	April	May	June	July	August	September	October	November	December	Winter	Spring	Summer	Autumn	Average for year
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Stykkisholm..	0.9	0.3	0.4	1.7	4.7	8.2	10.4	10.6	9.1	6.3	3.7	1.8	1.0	2.3	9.7	6.4	4.9
The Vest-mannaeyjar	4.1	4.1	4.5	6.1	7.7	9.5	10.9	10.8	9.1	6.8	5.1	4.1	4.1	6.1	10.4	7.0	6.9
Papey.... ...	0.7	0.4	0.5	1.5	3.1	4.8	6.0	6.6	6.2	4.3	2.6	1.3	0.8	1.7	5.8	4.4	3.2
Grímsey.....	1.8	1.4	0.7	1.3	2.6	4.2	6.6	7.4	6.9	5.3	4.1	2.9	2.0	1.5	6.1	5.4	3.8

The temperature-conditions of the coastal districts correspond very closely with those of the ocean. The north-east coast has, on an average, a mean winter-temperature of from — 2° to — 4° C., a summer temperature of 6° to 7½° C., and a mean for the whole year of 1° to 2° C.; while the south-west coast has a winter temperature of 0° to — 2° C., a summer temperature of 9° to 10° C., and one for the whole year of 3° to 4°. When the Greenland drift-ice blockades the coast, the difference between these temperatures is considerably greater. In the severe ice-year, 1881, the difference between the temperature on the isle of Grímsey and in the Vest-mannaeyjar, from January to March, was 10½° to 14° C., while normally in these months it is only 3½° to 5½°; in the same months (in 1881) the difference of temperature between Stykkisholm and the Vestmannaeyjar was 7° to 10° C., while normally it is only 3° to 4°. Therefore the temperature varies very greatly from year to year, and so also does the mean of the different months. For instance, take the month of March: at Stykkisholm the highest mean temperature in a period of 33 years was 2.9° C.; and the lowest mean in the same period was — 13.3° C. From this it will be seen that the Polar current, and especially the drift-ice, exercises a great influence upon the climate in Iceland and thereby upon the vegetation and the means of sustenance of the people. When the Polar ice arrives at the north coast the temperature immediately falls: when in May and June the people who live in South Iceland see that it is snowing on the mountains, they at once take it as a sign that the dreaded drift-ice is about to blockade the coast of

North Iceland. So long as the ice drifts backwards and forwards along the coast, the weather continues to be very changeable and stormy; but once the ice has been grounded on the land, the weather becomes more settled, although colder. The parts of the coast which are most subject to be blockaded by the drift-ice are the north and east sides of the north-western peninsula, especially Strandasysla, and Langanes and Melrakkasljetta. In these districts the effect of the presence of the drift-ice is shown both in the wider extension of the snow-wreaths and in the character of the vegetation. On the east coast of the north-western peninsula, south of Cape Nord (also called Cape Horn) there is no vestige of coppice-wood, while this occurs luxuriantly on the western and south-western side of the peninsula, and at the heads of the fjords. Cabbage and potato plots are also absent along this coast, north of 65° 40' N. lat.; while small plots of cabbages occur frequently in Aðalvík on the north-western coast of the peninsula at 66° 25' N. lat. Even at the head of Hunaflói the influence of the drift-ice is evident: *Chamænerium latifolium* which flowers every year on the plateau, 600—700 metres above sea-level, flowered only twice during eleven years (1878—88) at Midfjörður. In the districts which are most exposed to the effects of the Polar ice, the herbage is extremely poor owing to the constant coldness of the springs and the rawness of the summers; the frequent snow-falls even at midsummer, make hay-making precarious, so that the sheep and cattle — and thereby the inhabitants — are liable to suffer want.

During the nineteenth century the coast of Iceland has been free from ice on an average about one year in every four or five; but no rule can be formulated for the arrival of the Polar ice on the coast of Iceland; sometimes it remains absent for many years; sometimes it visits the coast several years in succession. The ice arrives at different times — as a rule from January to April; if it arrives early, it usually drifts away soon without doing any great damage, but if it arrives near the time of spring, it often remains till far into summer, and causes much inconvenience, hindering navigation and fishing, spoiling the hay-harvest, etc. But it almost invariably drifts away at the end of August, and for the last four months of the year the coast is almost always free from ice. As a rule, the Polar current first carries the drift-ice to the north-western peninsula of Iceland, off Cape Nord, and the main mass is carried out through Denmark Strait; but that part of the ice which besets

Hornstrandir (the coast down either side of Cape Nord), is carried by the coastal current (the Irminger Current) along Strandasysla into Hunaflói, from thence outwards along the east coast of this fjord, then further eastwards along the entire north coast, past Langanes and on, down to the east and south coasts, where it either melts or else drifts away into the open sea. The ice which comes to South Iceland always comes from the east, never from the north-west. In severe ice-years the drift-ice may blockade the whole of the south coast as far as to Cape Reykjanes; on the other hand, it very rarely happens that any drift-ice enters Faxaflói and more rarely still that any icebergs drift past the north-western fjords into Breiðifjörður; the ice is not known to have been grounded on the land, down past Patriksfjörður, for the last 200 years. The most severe ice-year known was the year 1695; in that year drift-ice surrounded the whole island with the exception of Snæfellsnes — a fact unparalled in the history of the country. In most of the places the ice occurred in such quantities in that year that open water was not visible from the highest mountains. As usual the ice drifted from North Iceland to South Iceland and then southwards and reached Thorlakshöfn as early as April; from thence it drifted into Faxaflói as far as Hítárós, and from the north-west the ice drifted past Látrabjarg into Breiðifjörður. In the beginning of May it was possible to walk and ride everywhere outside all the fjords of North Iceland. It sometimes happens that the drift-ice drifts to Langanes and then down to the east coast without touching the north coast.[1] The Polar current bears great quantities of drift-wood to the northern coast of Iceland, most frequently to the neighbourhood of Cape Nord and Langanes. The greater part of this drift-wood starts probably from Siberia; that of most common occurrence is *Larix sibirica*, *Picea obovata*, *Abies sibirica*, *Pinus cembra*, *Pinus silvestris*, *Populus tremula*, *Salix vitellina*, and others.[2]

[1] Th. Thoroddsen: Den grönländska drifisen vid Island (Ymer. Stockholm, 1884, pp. 145—160). C. Ryder: Isforholdene i Nordhavet, 1877—1892 (Tidsskrift for Søvæsen, 1896). V. Garde: Isforholdene i de arktiske Have in Nautisk Meteorologisk Aarbog of 1898 and subsequent years (in Danish and English). W. Meinardus: Periodische Schwankungen der Eisdrift bei Island (Annalen der Hydrographie und Maritimen Meteorologie, 1906).

[2] J. G. Agardh: Om den Spetsbergska Drifvedens ursprung (Övers. af Kgl. Vet. Ak. Förh., 1869, No. 2, pp. 97—119). A. G. Nathorst: Två somrar i norra Ishafvet. Stockholm, 1900, I, p. 345. Th. Thoroddsen: Ferðasaga af Vestfjörðum (Andvari, XIII, 1887, pp. 164—168) and Ferðabók, II, 1914, pp. 63—70. Compare Geografisk Tidsskrift, IX, p. 45. E. Olafsson: Rejse gennem Island (1772), I, pp. 508—513. O. Olavius: Oekonomisk Rejse gennem Island (1780), pp. 126—146.

The drift-ice also carries to the coast of Iceland fragments of rock which are not found in Iceland (gneiss, granite, talc-slate, mica-slate, etc.), and also gravel, clay and earth from other Arctic countries. Moreover, the warm water of the Gulf Stream sometimes carries drift-material with it from southern parts, e. g. mahogany, sugar-cane, "nuts" of *Entada Gigalobium, Mucuna urens, Guilandina Bonducella,* etc.

The weather of the North Atlantic Ocean depends upon the winds, which also exercise a great influence upon the currents around Iceland. The mean atmospheric pressure in the North At-

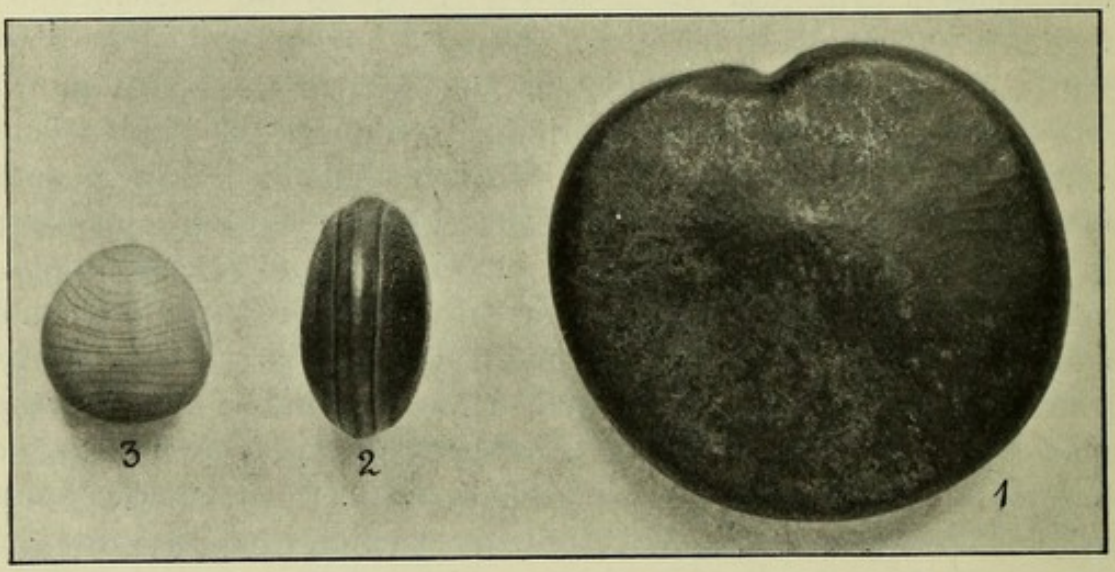

Fig. 20. Seeds of *Entada Gigalobium* (1), *Mucuna urens* (2), and *Guilandina Bonducella* (3).

lantic is generally lowest to the south-west of Iceland but there is, in addition, another centre of low barometric pressure north-east of Iceland; on the whole, the direction of the winds over Iceland is determined by this. In West and North Iceland the majority of the winds blow from SE., E. and NE., while on the east coast winds from the NE. and NW. are nearly equally numerous (20 % and 17 % relatively) because here both the above-mentioned centres of low atmospheric pressure try to prevail. This is true of the average condition only, because in reality the wind-conditions from day to day are very variable, as the ocean here is constantly visited by moving centres of depression. The barometer in Iceland is subject to very great changes. In Reykjavík the barometer, during a period of 28 years, has oscillated between 789 mm. and 697 mm.; at Stykkisholm, during one of 33 years, between 789 mm. and 700.3 mm.; in the Vestmannaeyjar during a period of 29 years, from 789 mm. to

Table II. Atmospheric Pressure along the coast of Iceland for the Period 1872—1906: 700 mm. +, reduced to 0° C., and to sea-level.

Name of station	January	February	March	April	May	June	July	August	September	October	November	December	Winter	Spring	Summer	Autumn	Average for the year
Stykkishólmur. From 1/6 1873 to 31/12 1906.																	
Mean Atmospheric Pressure....	49.0	51.6	54.4	57.2	60.7	58.9	57.4	57.4	54.5	54.7	52.5	48.9	49.8	57.4	57.9	53.9	54.8
Mean of maximum pressure ...	66.8	65.5	66.4	63.6	65.7	65.2	62.5	63.9	62.9	67.6	64.7	65.2					57.9
Mean of minimum pressure....	36.8	36.4	40.5	47.6	51.3	52.4	51.4	50.5	47.4	45.7	42.5	40.8					52.0
Absolute maximum pressure ...	85.2	89.1	88.5	79.4	83.5	78.8	74.0	73.6	75.0	82.7	80 3	83.6					89.1
Absolute minimum pressure ...	5.7	0.3	12.3	18.0	30.3	25.2	30.7	24.0	14.8	20.6	13.2	3.7					0.3
Vestmannaeyjar. From 1/7 1877 to 31/12 1906.																	
Mean Atmospheric Pressure ...	49.3	51.9	53.1	56.3	60.4	59.4	57.3	56.7	54.4	54.5	50.9	48.1	49.8	56.6	57.8	53.3	54.4
Mean of maximum pressure ...	63.9	65.8	66.8	61.9	64 0	64.9	61.6	64.1	64.7	61.6	61.8	55.3					57.2
Mean of minimum pressure....	36.1	37.3	37.9	47.5	54.9	54.5	52.4	50.1	49.0	45.2	41.2	41.4					51.9
Absolute maximum pressure...	88.5	87.5	89.0	80.2	83.0	77.9	71.9	75.3	74.8	80.2	81.4	79.2					89.0
Absolute minimum pressure ...	6.4	699.2	15.7	18.0	30.3	23.6	33.7	32.3	18 1	15.5	5.6	5.5					699.2
Berufjörður. From 1/12 1872 to 31/12 1906.																	
Mean Atmospheric Pressure....	50.4	53.3	54.9	58.2	61.1	59.5	57.7	57.4	55.5	55.2	53.4	50.5	51.4	58.1	58.2	54.7	55.6
Mean of maximum pressure ...	65.9	67.2	65.8	64.1	65.4	65.9	62.2	63.8	64.6	66.1	63.8	63.9					58.1
Mean of minimum pressure....	37.1	39.4	40.8	47.5	52.4	53.9	51.3	50.5	48.6	46.2	44.0	44.1					53.1
Absolute maximum pressure.	87.8	88.7	87.7	80.5	83.2	77.7	72.9	73.8	76.7	79.9	80.0	81.4					88.7
Absolute minimum pressure . .	7.8	4.9	16.0	18.0	28.1	31.3	35.9	34.5	21.3	21.0	13.7	6.2					4.9
Akureyri. From 1/7 1873 to 31/12 1906.																	
Mean Atmospheric Pressure....	50.7	53.3	55.6	58.5	61.5	59.4	57.8	57.9	55.5	55.9	53.9	50.6	51.5	58.5	58.4	55.1	55.9
Mean of maximum pressure ...	68.4	67.0	66.7	65.3	66.8	66.1	62.5	64 6	63.7	68.1	64.7	65.9					58.4
Mean of minimum pressure....	38.1	38.7	43.3	49.2	52.1	53.2	51.6	51.0	48.0	47.3	45.0	43.3					52.5
Absolute maximum pressure...	85.6	89.0	88.2	83.8	83.9	77.6	73.2	74.3	77.2	83.5	81.2	81.5					89.0
Absolute minimum pressure ...	8.8	5.7	15.2	19.6	30.1	26.0	34.8	28.6	18.4	17.1	15.3	8.1					5.7

Table III. Prevailing Winds expressed as percentages.

Name of station	January	February	March	April	May	June	July	August	September	October	November	December	Average for the year
Vestmannaeyjar ($^1/_7$ 1877 to $^{31}/_{12}$ 1906).													
N.	13	13	18	13	10	4	7	10	11	18	17	17	12
NE.	3	4	3	3	2	2	1	2	1	4	4	3	3
E.	19	22	24	27	27	24	20	23	26	21	20	18	22
SE.	9	8	8	10	10	14	13	9	10	9	8	8	10
S.	10	10	9	9	8	9	5	5	9	8	9	10	8
SW.	16	13	9	7	8	10	9	9	11	8	12	14	11
W.	8	9	7	7	8	9	13	8	6	6	6	7	8
NW.	3	3	4	5	4	4	7	4	4	4	4	3	4
Calm	19	18	18	19	23	24	25	30	22	22	20	20	22
Papey ($^1/_8$ 1873 to $^{31}/_{12}$ 1906).													
N.	11	15	13	12	10	5	5	8	7	12	14	11	10
NE.	11	13	18	26	27	24	26	24	19	16	15	12	20
E.	4	7	6	8	9	13	10	10	8	8	6	6	8
SE.	5	5	5	6	5	6	6	5	6	5	4	5	5
S.	7	7	6	8	7	10	10	8	8	5	6	7	8
SW.	19	17	12	12	14	18	13	12	20	14	15	17	15
W.	9	6	5	3	4	5	5	3	5	5	6	7	5
NW.	24	20	24	15	13	5	6	10	14	24	25	27	17
Calm	10	10	11	10	11	14	19	20	13	11	9	8	12
Stykkishólmur ($^1/_6$ 1873 to $^{31}/_{12}$ 1906).													
N.	5	5	5	6	6	5	5	9	6	8	6	7	6
NE.	14	17	18	17	16	10	10	12	15	19	20	14	15
E.	21	23	24	25	21	18	21	21	19	22	21	24	22
SE.	16	15	15	15	14	14	10	10	15	17	16	14	14
S.	13	11	9	10	11	13	9	9	13	11	9	10	11
SW.	16	15	12	6	6	8	6	5	10	9	12	16	10
W.	5	4	5	6	8	12	15	11	7	4	5	4	7
NW.	1	1	1	1	4	7	8	6	2	1	1	1	3
Calm	9	9	11	14	14	13	16	17	13	9	10	10	12
Grímsey ($^1/_7$ 1873 to $^{31}/_{12}$ 1906).													
N.	8	8	9	7	8	5	8	7	6	6	8	9	7
NE.	16	18	18	19	20	12	13	12	13	19	21	16	17
E.	15	19	20	26	27	27	28	27	23	21	20	16	22
SE.	20	21	20	16	10	11	9	12	17	18	15	20	16
S.	7	7	5	4	2	3	2	2	5	6	6	8	5
SW.	9	6	5	3	2	3	2	2	5	6	7	8	5
W.	14	12	12	10	9	10	10	10	13	11	13	12	11
NW.	5	5	5	5	9	10	11	12	8	6	6	6	7
Calm	6	4	6	10	13	19	17	16	10	7	4	5	10

699.2 mm.; at Berufjord during a period of 34 years, from 788.7 mm. to 704.9 mm.; and at Akureyri, during one of 33 years, from 789 mm. to 705.7 mm. The paths of the moving centres of depression lie especially frequently south of Iceland so that one centre of depression after the other crosses the Atlantic from the west with a main direction of east or north-east; sometimes nearer, sometimes further from Iceland. This movement of low pressure centres causes the wind to veer towards the sun, especially from S. or SE. through E. and NE. Table III shows that at Stykkisholm, very frequently the winds blow from S. and SW. (such form 11 % and 10 % respectively) which is due to the fact that Denmark Strait also provides a path for the moving centres of depression; they come from the south and cause on Iceland a veering of the wind with the sun from SE. or S. through SW. It is probably these centres of depression which cause the rather frequent winds from the W. and SW. at Grímsey and Papey respectively. There may, however, occur longer periods in which the winds of Iceland are rather constant, the lowest atmospheric pressure over the North Atlantic remaining at the same place. The wind-conditions are generally favourable for Iceland, the warm air from the Atlantic Ocean is carried in over the land, while it is rare for cold winds to be thus brought during winter. According to observations taken at Stykkisholm on the west coast, the warmest winds there are the SE., S. and SW. while the greatest cold is caused by the N., NE. and E. winds. The difference between the temperature induced by the warmest and by the coldest winds is on an average 9°—10° C. in the months of December to April, and 4°—6° C. in the other months. The temperature may show great differences according to whether northerly or southerly and easterly winds are the prevalent ones for any length of time; thus, the mean temperature at Stykkisholm in March 1856 was + 4.3° when southerly winds prevailed, and in March, in the ice-year 1881, the mean temperature was — 13.3° when easterly winds were prevalent.[1] Conditions pertaining to the atmospheric pressure over the Atlantic, which is specially

[1] V. Willaume-Jantzen: Climat du littoral islandais, 1902. N. Hoffmeyer: Die Vertheilung des Luftdruckes über den nord-atlantischen Ocean während des Winters und deren Einfluss auf das Klima von Europa (Zeitschrift für Meteorologie. Wien, 1878. Bd. XIII. Nr. 22). N. Hoffmeyer: Etude sur les tempêtes de l'Atlantique septentrional. Copenhague, 1880. G. Rung: Répartition de la pression atmosphérique sur l'ocean atlantique septentrional. Copenhague, 1894. V. Garde: Vindkort over den nordligste Del af Atlanterhavet (Nautisk-meteorologisk Aarbog for 1899. København, 1900. S. 25—46).

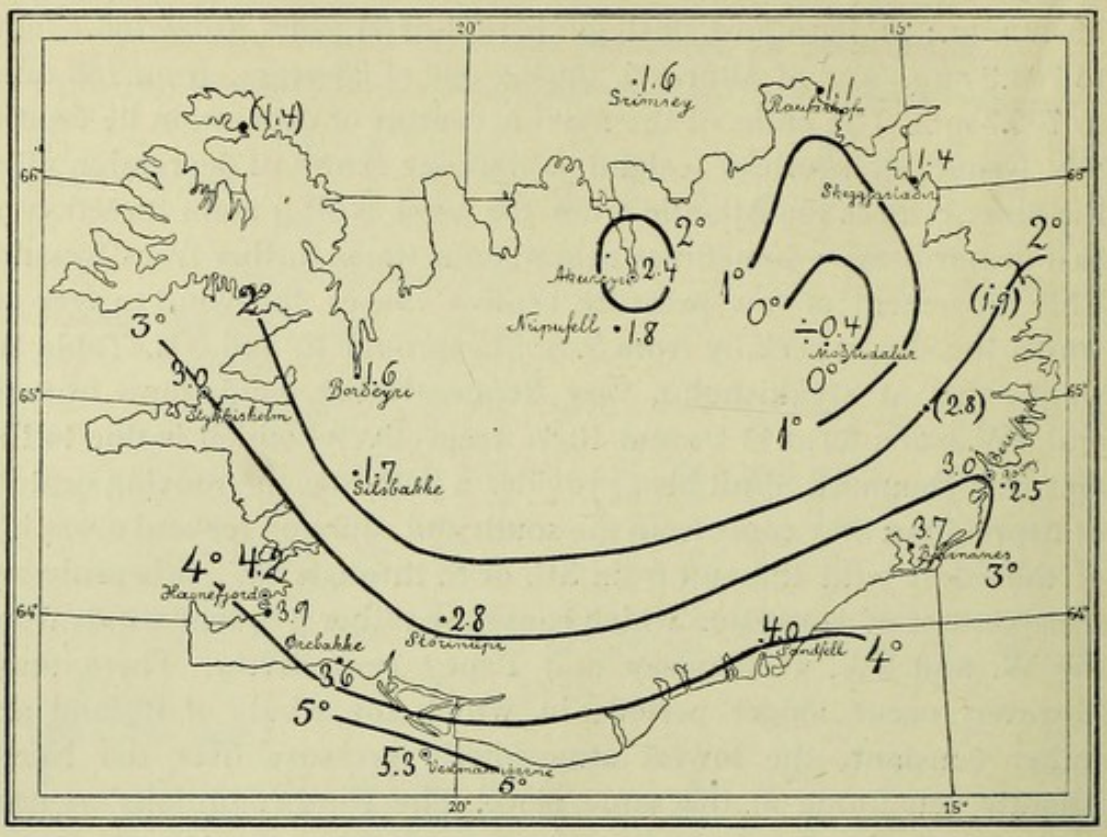

Fig. 21. The mean annual temperatures of 28 years (1874—1901). (V. Willaume-Jantzen.)

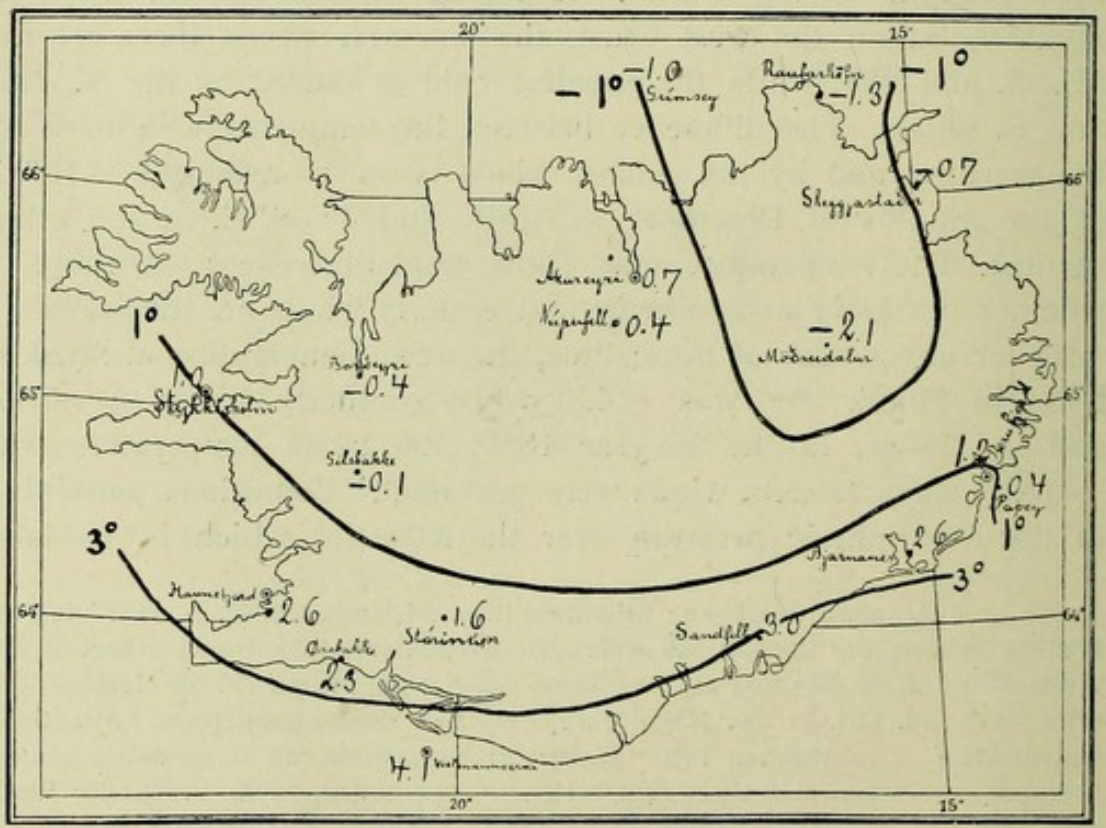

Fig. 22. The meanspring temperatures for the period 1874—1901. (V. Willaume-Jantzen.)

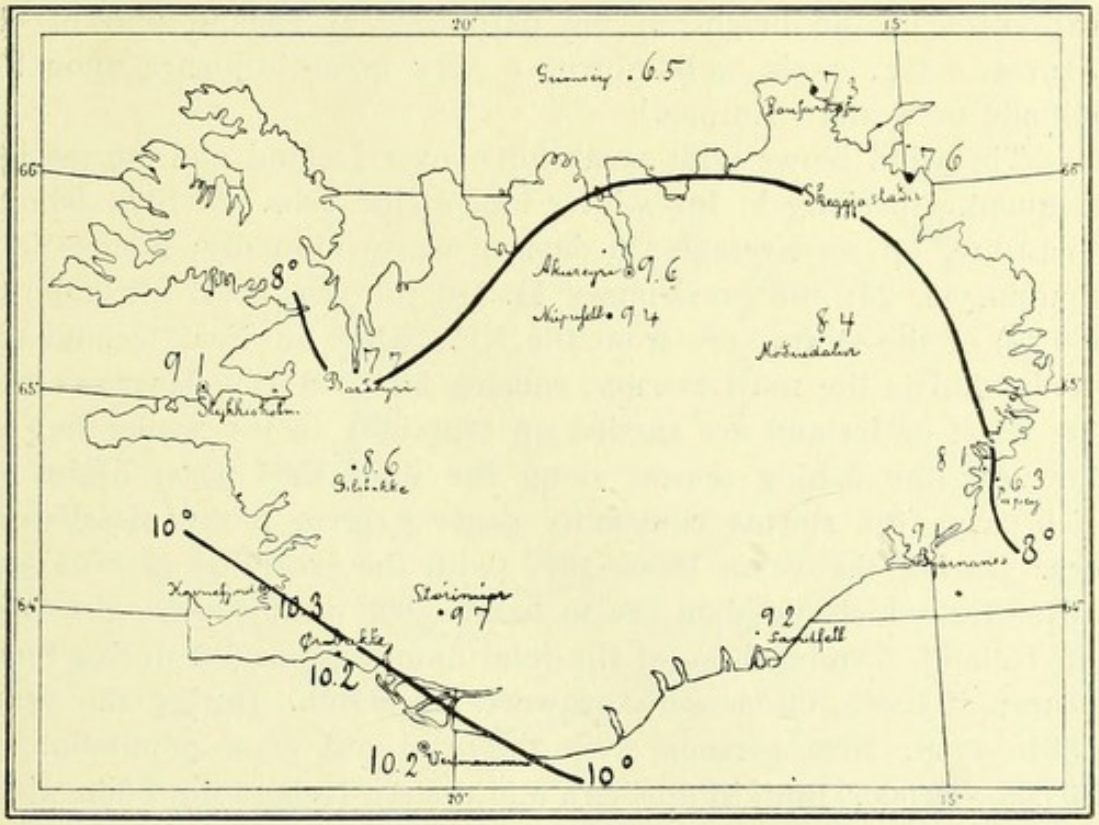

Fig. 23. The mean summer temperatures for the period 1874—1901. (V. Willaume-Jantzen.)

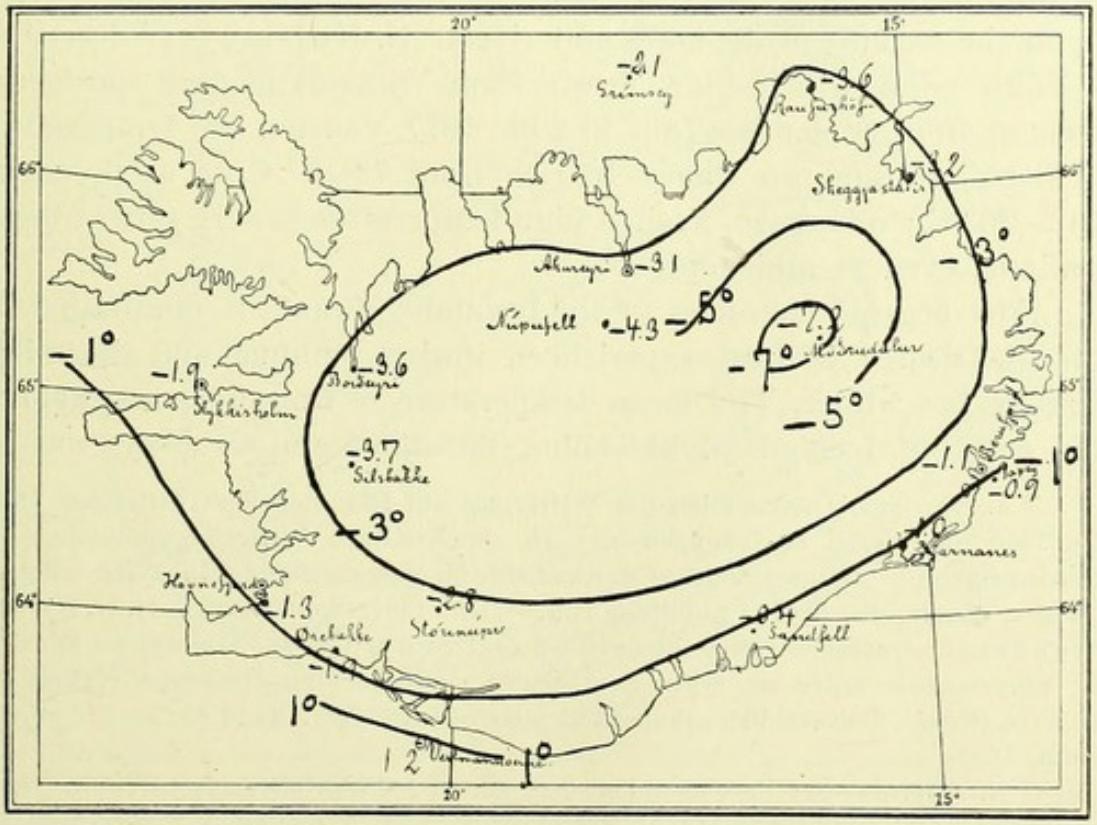

Fig. 24. The mean winter temperatures for the period 1874—1901. (V. Willaume-Jantzen.

expressed in the height of the barometer at Iceland and in the Azores, have, as is well-known, a very great influence upon the climate of western Europe.[1]

The wind blows with great force over Iceland and storms are frequent, especially in the winter half of the year. At Stykkisholm there are, on an average, 50 days of storm annually; in the Vestmannaeyjar 25; and on Grímsey 11. On the west coast the majority (60 %) of the storms are from the NE., while in East Iceland the NW. wind is the most stormy, causing 50 %. As the fisheries along the coast of Iceland are carried on especially in the winter half of the year (the fishing season along the south-west coast begins in February), the storms constantly cause a great many disasters at sea. During the years 1850—1877 (with the exception of 1853 and 1875, for which no data are to hand) 2008 people were drowned off Iceland, forming 3 % of the total number of deaths during those years; of these, 60 % were drowned in March. During the years 1881—1910, 2096 persons were drowned out of a population of 70,000—80,000. Both in northern and eastern Iceland the Föhn wind, which blows down from the Jökulls of the plateau, is fairly common during winter and causes a sudden rise of temperature, resulting in the melting of the snow in the lowlands and of the ice upon the surface of the lakes and rivers. N. Hoffmeyer[2] describes a Föhn wind which blew down from Vatnajökull over south-east Iceland from September 18th to 26th, 1877, causing the temperature at Berufjord and on Papey to rise from 7°—8° C. to as much as 18°—20° C.; otherwise, such a high temperature is very rare at these stations, even at midsummer.

The oceanic character of the Icelandic climate is manifested in the low degree of heat experienced during summer and the mildness of the winter. The mean temperature of the coldest days along the coast of Iceland (Stykkisholm, Berufjord and Grímsey) was in

[1] J. Hann: Die Anomalien der Witterung auf Island in dem Zeitraume 1851 bis 1900 und deren Beziehungen zu den gleichzeitigen Witterungsanomalien in Nordwestevropa (Sitzungsberichte d. Akademie d. Wissenschaften in Wien. Math.-naturw. Klasse. Band 113, Abteilung II a, Wien, 1904. S. 183—269). H. H. Hildebrandsson: Quelques recherches sur les centres d'action de l'atmosphére IV. Sur la compensation entre les types des saisons simultanés en différentes régions de la terre (Kungl. Svenska Vetenskapsakademiens Handlingar, Band 45, No 11. Stockholm, 1910).

[2] N. Hoffmeyer: Vejrforholdene paa Island i Vinterhalvaaret 1877—78 (Tidsskrift for populær Fremstilling af Naturvidenskaben, 5. Række, V Bind, 1878, pp. 161—172).

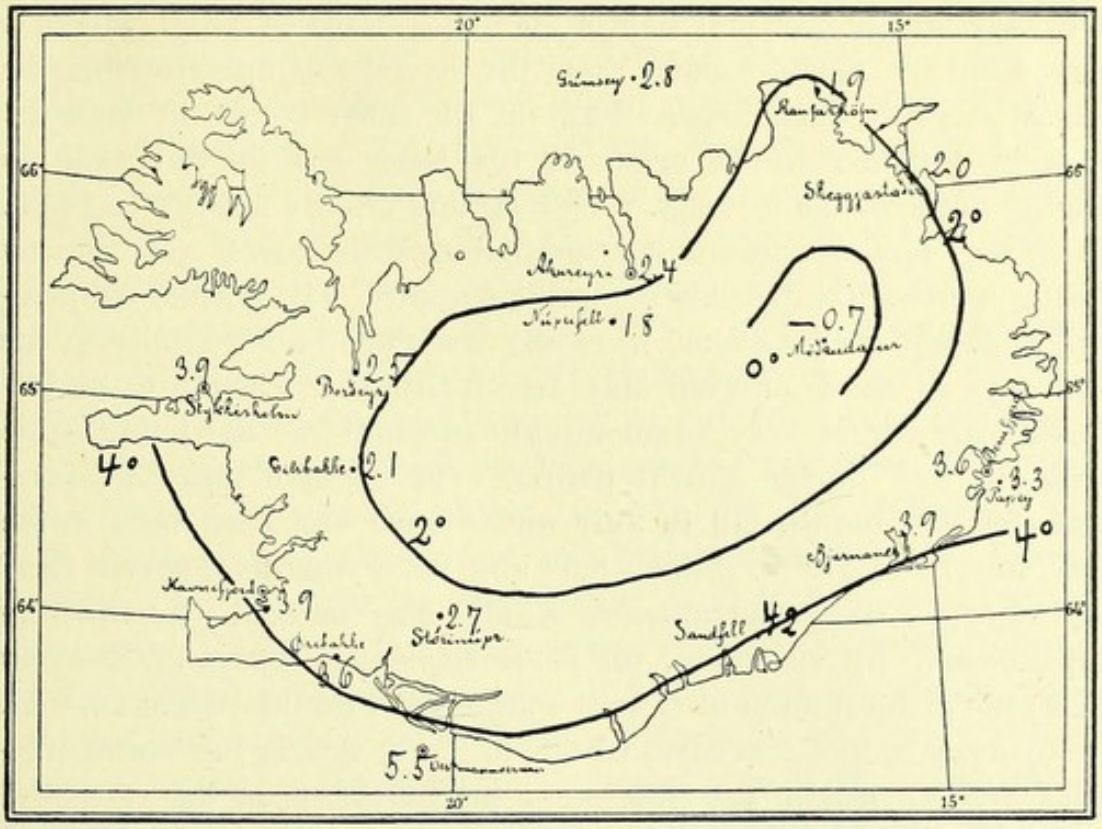

Fig. 25. The mean autumn temperatures for the period 1874—1901. (V. Willaume-Jantzen.)

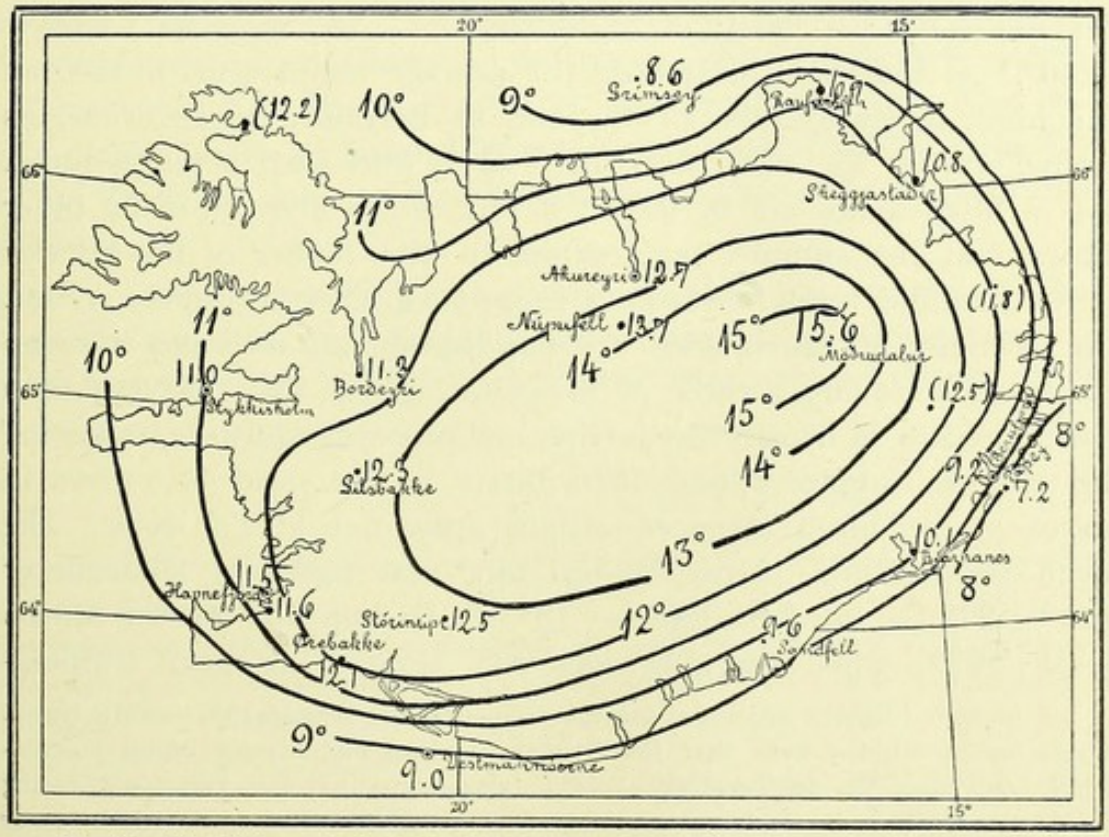

Fig. 26. The differences between the summer and winter temperatures of 28 years (1874—1901). (V. Willaume-Jantzen.)

February and in the first half of March — 2° to — 4° C., which is only from 1° to 3° colder than the average temperature of the coldest days in Copenhagen; but, on the other hand, the warmest days in Iceland, which occur in the latter half of July and in August have, on an average, a temperature of only from 7° to 10° C. There are, however, numerous oscillations from year to year, mostly during winter, less frequently during summer. The normal temperature is below zero (Celsius) from the last days in November to the first days in April, or even May 1st on Grímsey. Therefore the Icelandic summer is very unfavourable to plant-life, the temperature being so low during growth-period. The highest mean temperatures for any month fall in July and August and even these reach only to 11°—12½° C. (Papey 8.5° and 9.6°; Vestmannaeyjar 12.7° and 12.3°) — the temperature of a mild May or cool September in Copenhagen. By exception, on some days, the heat may be very great; the greatest amount of heat registered at Berufjord was 26.3° C., on Grímsey 26.2° C., at Stykkisholm 22.9° C., and in the Vestmannaeyjar 21.2° C. But in the interior of the island — in the valleys — a higher temperature (27°—28° C.) has occasionally been registered. The lowest temperature registered at Berufjord was — 23.1°, in the Vestmannaeyjar — 20.9; at Stykkisholm — 26°, and on Grímsey — 30°.[1] At the coast in Iceland the average temperature of the day and night rarely exceeds 15° C., and at Berufjord there occur, as a rule, during the year, only four days with such a temperature, but in Mödrudalur six to seven; a fact which shows among other things that the summer temperature is often higher in the interior of the country, while the cold there is also greater during the winter. On ascending to the interior districts the climate is found to be no longer so decidedly oceanic as along the coasts, and the vegetation also increases in density the further one proceeds upwards, following the valleys. Coppice-woods often thrive at the head of valleys in places where birch-coppices cannot grow out at the coast. The mean temperature of the coldest day and night in Mödrudalur was — 29° C., at Berufjord — 19° C. During the period March 6—12, 1892, when the cold was very severe, the mean tempera-

[1] All these figures are those for the cold, drift-ice winter 1880—1881. But it should be mentioned here that the Grímsey station had no maximum thermometer, and that the temperature — 30° C. was one which was registered during the day. In reality the cold had probably been greater, because in the same winter I noted early in the morning of some days, at Mödruvellir in Hörgárdal a temperature of — 32° to — 36° C.

ture in the Vestmannaeyjar was — 7° C., at Berufjord — 11½° C., on Grímsey — 15½° C. and in Mödrudalur — 24½° C.

The mean temperature for the whole island, according to the observations to hand, is 2½° C., but the real temperature is undoubtedly considerably lower, because only one station on the immense plateau was included. The mean temperature of the winter on the north and east coasts ranges between — 1° and — 3½° C., and of the summer between 6½ and 8° C., of South Iceland the mean temperature for the winter ranges between 0° and — 2° C., and the summer temperature between 9 and 10°. The difference between the summer and winter temperatures increases with the distance from the sea, as shown in Fig. 26. The difference is greatest between the plateau and the Vestmannaeyjar. The mean temperature for the year in Mödrudalur is — 0.4° C., and in the Vestmannaeyjar 5.3° C.; the mean summer temperature of Mödrudalur 8.4° C. and of Vestmannaeyjar 10.2° C.; and the winter temperature of Mödrudalur — 7.2° C., and of Vestmannaeyjar + 1.2° C.; thus the winter in Mödrudalur is 8° colder than in the Vestmannaeyjar. The south coast is the warmest part of the country, and in the Vestmannaeyjar the mean temperature of none of the months is below freezing point. The mean temperature for the year on the south coast is as follows: — Bjarnanes 3.7° C., Sandfell in Öræfi 4°, Eyrarbakki 3.6°, Havnefjord 3.9° and Reykjavík 4.2°. The climate of the coast of Iceland is said to be mildest below Eyjafjöll and in Mýrdalur, but no observations are to hand from these two places.

Table IV. Account of the Air Temperature along the coasts, in the interior districts, and on the plateau, according to the seasons.

	Number of stations	Winter	Spring	Summer	Autumn	The year
The Vestmannaeyjar	1	1.2	4.1	10.2	5.5	5.3
South-west coast (Stykkisholm-Eyrarbakki)	3	—1.7	2.0	9.9	3.8	3.5
South-east coast (Sandfell-Berufjord)	4	—0.8	1.8	8.2	3.8	3.3
North-east coast (Skeggjastaðir-Grímsey)	3	—3.0	—1.0	7.1	2.2	1.3
Interior districts (with the exception of Mödrudalur)	5	—3.5	0.4	9.0	2.3	2.1
Plateau (Mödrudalur)	1	—7.2	—2.1	8.4	—0.7	—0.4
The whole island	17	—2.4	0.8	8.7	2.9	2.5

Table IV shows that the climate of the interior districts is more continental than that at the coast, the summers being warmer and the winters colder. The differences in the temperature of the stations at the head of a fjord is greater than of those situated outside; Berufjord, for instance, is warmer than Papey. There are, however, exceptions to this in places where cold currents and drift-ice exert an influence; thus Bordeyri at the head of Húnaflói has the same annual temperature as Grímsey, — Raufarhöfn and Skeggjastaðir are even colder, being much influenced by the Polar currents.

During a period of 33 years (1873—1906) there have been on an average 166 frosty days annually at Stykkisholm, 109 in the Vestmannaeyjar, 158 at Berufjord and 192 on Grímsey. At Stórinupur near the southern lowlands, at a height of 135 metres above sea-level, during a period of 20 years, there have been on an average 200 frosty days. The frost appears early and disappears late. Frosty days are frequent till far into early summer, but in South and West Iceland midsummer is usually free from frost. On Grímsey it freezes in all the months of the year, but in July and August there are on an average only two frosty days monthly; at Berufjord, in the Vestmannaeyjar and at Stykkisholm, July has been free from frost during a period of 33 years. On the northernmost peninsulas and in districts situated at the highest levels there is no doubt that none of the months is entirely free from frost. When drift-ice lies along the coast in North Iceland the ground is usually frost-bound throughout summer, and in the vast extents of bog-land on the plateau, at a height of 400—500 metres the sub-surface ice never thaws entirely.

Table V shows the temperature at all the meteorological stations in Iceland during the years 1874—1901. The observations from the chief stations extend over a period of more than 25—28 years; at other stations 15—22 years and in some 5—12 years. For the sake of completeness some observations from three stations have been included, although they cover a period of 2—3 years only. Table VI gives many more and fuller information regarding temperature-conditions at the main stations during a period of 33 years (1872—1906).

The climate of Iceland is very damp although the precipitation is not considerable; it is, however, much greater than in Denmark. Sleet and drizzling rain are of constant occurrence, but the amount of precipitation on a single day is rarely sufficient to be of any con-

Table V. Mean Temperature in Iceland for the Period 1874—1901.

	Number of years	January	February	March	April	May	June	July	August	September	October	November	December	Winter	Spring	Summer	Autumn	Average for year
Stykkishólmur	28	—1.9	—2.3	—2.2	0.9	4.4	8.1	9.9	9.4	7.3	3.6	0.8	—1.5	—1.9	1.0	9.1	3.9	3.0
Borðeyri	12	—3.7	—4.0	—3.9	—0.3	3.0	6.8	8.1	8.1	6.1	2.3	—0.9	—3.1	—3.6	—0.4	7.7	2.5	1.6
Gilsbakki	7	—3.9	—3.7	—3.8	—0.4	4.0	7.9	9.4	8.6	6.1	1.6	—1.4	—3.5	—3.7	—0.1	8.6	2.1	1.7
Grímsey	27	—2.1	—2.8	—3.8	—1.2	1.9	5.4	7.1	7.0	5.8	2.4	0.1	1.4	—2.1	—1.0	6.5	2.8	1.6
Akureyri	19	—3.2	—3.2	—3.5	0.8	4.7	9.0	10.4	9.3	6.3	2.0	—1.0	—3.0	—3.1	0.7	9.6	2.4	2.4
Núpufell	5	—4.4	—3.9	—4.0	0.8	4.5	9.3	9.5	9.4	6.0	1.5	—2.2	—4.5	—4.3	0.4	9.4	1.8	1.8
Raufarhöfn	12	—3.8	—4.0	—4.9	—1.0	1.9	6.1	8.2	7.5	4.9	2.4	—1.5	—3.1	—3.6	—1.3	7.3	1.9	1.1
Skeggjastaðir	5	—3.7	—3.3	—4.2	—0.5	2.5	7.3	8.2	7.4	5.9	1.3	—1.3	—2.7	—3.2	—0.7	7.6	2.0	1.4
Möðrudalur	15	—7.8	—7.0	—7.2	—2.1	2.9	8.2	9.9	7.2	3.9	—1.4	—4.7	—6.8	—7.2	—2.1	8.4	—0.7	—0.4
Berufjörður	28	—1.3	—1.2	—1.8	1.3	4.1	7.1	8.7	8.4	6.7	3.2	0.9	—0.8	—1.1	1.2	8.1	3.6	3.0
Papey	27	—1.1	—1.1	—1.9	0.5	2.7	5.2	6.7	6.9	5.9	3.1	1.0	—0.5	—0.9	0.4	6.3	3.3	2.5
Bjarnanes	8	—1.2	—0.8	—0.9	3.2	5.4	8.2	9.8	9.2	7.3	3.6	0.8	—0.9	—1.0	2.6	9.1	3.9	3.7
Sandfell	5	—0.7	—0.1	—0.1	3.4	5.8	8.6	9.8	9.2	7.4	4.0	1.2	—0.3	—0.4	3.0	9.2	4.2	4.0
Vestmannaeyjar	25	1.1	1.4	1.4	4.1	6.7	9.2	10.9	10.5	8.3	5.2	3.1	1.1	1.2	4.1	10.2	5.5	5.3
Stórinúpur	18	—3.0	—2.4	—2.5	1.7	5.6	8.9	10.8	9.3	6.7	2.2	—0.7	—3.1	—2.8	1.6	9.7	2.7	2.8
Eyrarbakki	21	—2.1	—1.5	—1.6	2.4	6.1	9.3	11.0	10.3	7.5	3.0	0.2	—2.1	—1.9	2.3	10.2	3.6	3.6
Hafnarfjörður	22	—1.5	—0.9	—0.9	2.7	6.1	9.3	11.0	10.5	7.6	3.5	0.7	—1.5	—1.3	2.6	10.3	3.9	3.9
Reykjavík	27	—1.1	—0.8	—0.5	3.1	6.4	9.7	11.2	10.6	7.8	3.9	1.2	—1.2	—1.0	3.0	10.5	4.3	4.2
Aðalvík	2	—4.8	—4.1	—3.8	—1.1	3.1	7.1	9.6	7.5	5.9	2.1	—1.8	—3.3	—4.1	—0.6	8.1	2.1	1.4
Kóreksstaðir	3	—3.3	—3.1	—3.9	—0.2	3.2	7.9	9.9	8.2	6.3	1.5	—0.9	—2.9	—3.1	—0.3	8.7	2.3	1.9
Valþjófsstaður	3	—2.8	—2.9	—3.5	1.7	4.9	8.9	11.2	9.4	7.2	2.9	—0.7	—2.5	—2.7	1.0	9.8	3.1	2.8
Mean for the northern half of Iceland		—3.8	—3.8	—4.2	—0.4	3.3	7.6	9.0	8.2	5.8	1.7	—1.3	—3.3	—3.6	—0.4	8.3	2.1	1.6
Mean for the southern half of Iceland		—1.2	—0.8	—1.0	2.4	5.3	8.2	9.8	9.3	7.2	3.5	0.9	—1.0	—1.0	2.2	9.1	3.9	3.6
Mean for the whole island (17 stations)		—2.6	—2.4	—2.7	0.9	4.3	7.9	9.4	8.7	6.5	2.6	—0.3	—2.2	—2.4	0.8	8.7	2.9	2.5

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Winter	Spring	Summer	Autumn	Average for year
Stykkishólmur																	
From 1/6 1873 to 31/12 1906.																	
Mean temperature	— 2.0	— 2.4	— 2.2	0.7	4.3	8.2	9.9	9.3	7.3	3.5	0.7	— 1.4	—1.9	0.9	9.1	3.8	3.0
Highest mean temperature	0.9	0.9	2.9	4.8	7.1	10.2	12.4	12.0	9.8	6.8	3.2	1.5					4.0
Lowest mean temperature	— 8.6	— 9.6	—13.3	— 4.1	1.5	5.8	8.1	6.4	5.4	0.4	— 2.0	— 7.9					1.3
Absolute maximum temperature	9.7	8.9	9.6	12.3	19.9	19.9	22.9	22.0	16.2	15.1	11.4	10.4					22.9
Absolute minimum temperature	—26 0	—22.5	—25.0	—21.0	— 8.2	— 2.0	0.8	— 1.2	— 4.7	— 8.6	—17.9	—21.1					—26.0
Mean maximum temperature	0.6	0.1	0.6	3.4	7.2	11.1	12.7	12.0	9.7	5.7	2.9	1.0					
Mean minimum temperature	— 5.0	— 5.5	— 5.3	— 2.1	1.6	5.5	7.3	6.7	4.7	1.0	— 2.0	— 4.3					
Vestmannaeyjar																	
From 1/7 1877 to 31/12 1906.																	
Mean temperature	1.3	1.3	1.4	4.0	6.3	9.0	10.6	10.2	8.2	5.1	3.0	1.2	1.3	3.9	9.9	5.4	5.1
Highest mean temperature	3.2	3.7	5.4	6.5	8.7	10.4	12.7	12.3	9.9	7.3	5.6	3.6					5.9
Lowest mean temperature	— 1.7	— 2 4	— 3.0	2.4	4.0	7.2	9.1	9.0	6.3	2.7	0.4	— 3.2					4.1
Absolute maximum temperature	9.7	10.4	10.6	12.4	16.1	21.2	19.6	18.5	16.4	13.1	10.9	10.0					21.2
Absolute minimum temperature	—17.4	—15.2	—20.9	—13.3	— 9.5	— 0.8	2.7	— 0.3	— 2.6	— 6.6	—16.1	—16.0					—20.9
Mean maximum temperature	3.8	3.9	4.3	6.9	9.8	12.7	14.1	13.8	10.8	7.3	5.4	4.0					
Mean minimum temperature	— 1.8	— 1.8	— 1.6	1.1	3.8	6.8	8.2	7.6	5.8	2.2	0.3	— 1.5					
Berufjörður																	
From 1/12 1872 to 31/12 1906.																	
Mean temperature	— 1.3	— 1.3	— 1.5	1.3	4.0	7.2	8.7	8.3	6.8	3.2	0.9	— 0.7	—1.1	1.3	8.1	3.6	3.0
Highest mean temperature	1.6	1.9	2.4	5.2	7.1	9.4	10.3	10.7	8.9	5.3	3.6	2.1					4.2
Lowest mean temperature	— 8.5	— 5.7	— 9.4	— 3.3	1.7	4.7	6.4	6.1	4.6	0.6	— 2.4	— 6.7					1.0
Absolute maximum temperature	13.2	12.3	12.2	14.9	20.4	25.4	26.3	23.5	20.5	16.4	12.4	11.5					26.3
Absolute minimum temperature	—23.1	—19.3	—21.9	—18.3	—10.8	— 4.2	0.8	— 2.9	— 5.8	—10.3	—17.4	—20.4					—23.1
Mean maximum temperature	1.7	1.6	1.6	4.4	7.8	11.3	12.8	11.9	9.7	5.6	3.4	1.9					
Mean minimum temperature	— 4.1	— 4.2	— 4.9	— 1.7	1.1	4.1	5.9	5.5	4.2	0.7	— 1.8	— 3.5					
Papey																	
From 1/8 1873 to 31/12 1906.																	
Mean temperature	— 0.9	— 1.2	— 1.7	0.5	2.7	5.4	6.8	7.0	6.0	3.1	1.1	— 0.4	—0.8	0.5	6.4	3.4	2.4
Highest mean temperature	1.7	2.0	2.4	4.7	4.9	7.5	8.5	9.6	7.9	5.1	3.4	2.1					3.7
Lowest mean temperature	— 8.3	— 5.3	— 8.8	— 3.1	— 0.2	3.0	4.5	4.2	3.8	0.2	— 2.2	— 6.4					0.1
Grímsey																	
From 1/7 1873 to 31/12 1906.																	
Mean temperature	— 2.0	— 3.0	— 3.6	— 1.2	1.7	5.5	7.0	6.8	5.7	2.5	0.0	— 1.3	—2.1	—1.0	6.4	2.7	1.5
Highest mean temperature	1.6	1.2	1.4	3.3	5.1	8.5	10.1	10.8	8.5	4.7	2.8	2.1					3.1
Lowest mean temperature	—13.1	—10.7	—16.5	— 7.1	— 0.7	1.7	3.7	2.2	3.7	— 0.3	— 3.8	— 9.0					— 0.8
Absolute maximum temperature	9.5	8.8	9.6	10.8	16.0	21.0	19.6	26.2	18.3	12.9	11.2	9.9					26.2
Absolute minimum temperature	—30.0	—25.0	—30.0	—23.8	—12.2	— 6.9	— 3.0	— 3.0	— 5.0	—11.0	—17.5	—20.4					—30.0
Mean maximum temperature	0.5	— 0.3	— 0.6	1.2	4.1	8.5	9.9	9.6	7.9	4.2	2.0	1.1					
Mean minimum temperature	— 4.8	— 5.6	— 6.0	— 4.0	— 0.5	3.0	4.8	4.7	3.1	— 0.3	— 2.7	— 4.1					

sequence. As the rainfall, however, is often accompanied by storms, the weather is frequently very unpleasant for man and beast. It is especially in South Iceland that complaints are heard of the storms of sleet during autumn, when everything becomes saturated with moisture and rain penetrates into the houses through every chink and crevice. The humidity is more considerable in South than in North Iceland, which is shown for instance by the fact that houses with turf walls must be rebuilt more often in the southern districts. A cold, damp, whitish fog, accompanied by sleet, is very characteristic of the northern headlands, especially when the Greenland ice drifts backwards and forwards along the coast; then fog may shroud the coast for weeks and extend far into the valleys. The fog persists for a long time also in other places along the coast, especially in East Iceland. The amount of cloud also is generally great, especially in North Iceland.[1]

The amount of rainfall varies greatly in the different parts of Iceland, and in most places it is generally greatest during autumn and winter; on Grímsey, however, it is greatest during summer and autumn. The precipitation is greatest along the south and southeast coasts: in the Vestmannaeyjar 1320 mm., and at Berufjord 1166 mm. The greatest amount of annual rainfall in the Vestmannaeyjar was 1587 mm., and at Berufjord 1737 mm. Along the west coast the rainfall is much less, and still less in North Iceland, being at Stykkisholm 656 mm., but on Grímsey only 345 mm. At Stykkisholm there are, however, on an average 207 rainy days, but on Papey only 135, consequently, a much greater amount of rain falls there at a time. At Berufjord the greatest amount of rainfall within 24 hours was $109^1/_2$ mm. (July); at Stykkisholm 51.9 mm. (January); and on Grímsey 34.3 mm. (November). Heavy showers and sudden torrents of rain do enormous damage to the soil-layer on the mountain-sides, which are usually woodless and unprotected, and occasion numerous rock-slips which have often proved very disastrous to property and human life. The frequency of fogs differs greatly at different parts of the coast, but it is most frequent along the southern part of the east coast where the warm and cold ocean currents meet. At Berufjord there are on an average 171 foggy days annually; here fogs are frequent at all the periods of the year, but they occur most frequently during summer. On Papey (in the neighbourhood

[1] Amount of cloud (0—10): Vestmannaeyjar 6.2; Stykkisholm 6.7; Berufjord 6.7; and Grímsey 8.3.

Table VII. Amount of Precipitation along the coas

	January	February	March	April	May	June
Stykkishólmur						
From 1/6 1873 to 31/12 1906.						
Mean precipitation	78.2	65.5	45.0	34.6	38.6	39.4
Highest amount for the month	184.0	217.2	116.6	67.0	132.0	104.8
Lowest amount for the month	17.5	6.0	10.7	4.2	2.0	10.7
Greatest amount of precipitation during 24 hours	51.9	50.1	19.2	17.6	19.8	19.8
Number of days with snow	16	14	13	8	3	0.4
— fog	0.3	0.5	0.4	0.7	2.0	1.3
— frost	26	25	26	19	9	1
— storm	6	6	6	4	4	2
— precipitation	21	19	18	16	15	15
Vestmannaeyjar						
From 1/7 1877 to 31/12 1906.						
Mean precipitation	133.6	108.5	110.2	92.1	77.9	86.1
Highest amount for the month	225.6	195.1	239.0	198.1	149.1	145.6
Lowest amount for the month	34.5	29.6	26.1	15.0	11.5	30.0
Greatest amount of precipitation during 24 hours.	41.8	54.8	62.6	33.6	46.9	34.4
Number of days with snow	9	8	8	4	1	0.2
— fog	2	2	2	3	5	8
— frost	20	18	17	10	3	0.1
— storm	4	3	3	2	1	0.5
Berufjörður						
From 1/12 1872 to 31/12 1906.						
Mean precipitation	122.8	95.6	76.1	88.0	70.8	71.3
Highest amount for the month	258 7	214.9	231.6	222.9	237.6	168.2
Lowest amount for the month	26.6	4.6	2.6	15.0	0.0	17.9
Greatest amount of precipitation during 24 hours.	57.2	59.0	62.6	44.8	52.6	108.1
Number of days with snow	8	8	9	5	3	0.4
— fog	11	11	11	14	17	19
— frost	24	22	25	18	10	2
Papey						
From 1/8 1873 to 31/12 1906.						
Number of days with precipitation	14	13	12	12	9	8
— snow	7	7	7	5	3	0.5
— fog	9	9	10	12	13	16
Grímsey						
From 1/7 1873 to 31/12 1906.						
Mean precipitation	21.5	22.2	22.5	15.9	19.3	21.8
Highest amount for the month	58.0	112.0	73.8	37.5	98.7	59.0
Lowest amount for the month	1.2	0.6	2.4	1.2	3.0	3.2
Greatest amount of precipitation during 24 hours.	16.5	20.4	13.8	16.1	28.1	21.4
Number of days with snow	7	8	8	7	5	2
— fog	1	1	2	4	6	7
— frost	25	24	27	24	17	5
— storm	2	1	1	0.3	0.2	0.4

f Iceland in millimetres for the Period 1872—1906.

July	August	September	October	November	December	Winter	Spring	Summer	Autumn	Average for year
38.0	39.2	72.7	71.5	69.6	63.6	207.3	118.2	116.6	213.8	655.9
90.4	129.6	149.3	152.2	126.7	125.5					
4.9	3.2	20.1	19.4	20.4	11.7					
19.1	24.4	50.5	31.8	34.4	23.6					
0.1		1	4	10	14	44	24	1	15	84
1.6	1.3	0.7	0 3	0.4	0.3	1	3	4	1	9
	0.1	1	13	20	26	77	54	1	34	166
1	2	4	5	5	5	17	14	5	14	50
14	14	18	18	19	20	60	49	43	55	207
81.6	77.9	142.6	135.5	132.2	141.4	383.5	280.2	245.6	410.3	1319.6
153.2	226.7	215.9	241.2	244.0	296.1					1586.8
10.1	13.2	48.3	61.7	50.9	50.6					946.4
49.5	51.4	54.8	59.4	58.0	41.4					62.6
		0.3	2	4	8	25	13	0.2	6	44
8	6	5	4	2	2	6	10	22	11	49
	0.4	1	8	13	19	57	30	0.1	22	109
0.3	0.3	2	2	3	4	11	6	1	7	25
69.3	79.2	128.0	118.0	113.9	132.8	351.2	234.9	219.8	359.9	1165 8
180.9	225.5	314.4	267.7	245.9	331.4					1737.1
0.7	8.1	6.1	9.7	9.3	1.8					571.5
109.5	64.5	72.5	55.9	56.2	83.4					109.5
	0.1	0.5	3	6	7	23	17	0.5	9.5	50
21	18	16	12	11	10	32	42	58	39	171
	0.3	2	13	18	24	70	53	2	33	158
8	8	11	12	14	14	41	33	24	37	135
0.1		1	3	5	6	20	15	1	9	45
17	16	12	11	10	8	26	35	49	33	143
34.5	38.8	41.7	44.7	36.8	24.9	68.6	57.7	95.1	123.2	344.6
128.5	139.0	75.0	185.9	154.0	66.9					
1.2	0.8	7.4	13.4	4.2	0.0					
19.9	20.2	32.0	32.3	34.3	17.6					
0.5	0.4	2	6	9	9	24	20	3	17	64
10	8	4	2	0.5	0.3	2	12	25	6	46
2	2	4	17	21	24	73	68	9	42	192
0.2	0.2	1	1	2	2	5	1.5	0.8	4	11

of Berufjord) there are 143 foggy days. In other places fogs are much rarer; for instance on Grímsey there are on an average 46 foggy days, the majority of which occur during summer, while at Stykkisholm there are only nine. Along Hornstrandir fogs are very common especially during ice-years, but from this locality no observations are to hand.

The amount of snow varies greatly according to situation and height above sea-level, and from year to year. In North Iceland snow often persists for a long time during winter, but in south-west Iceland the weather is always stormy and unsettled; consequently, in the lowlands the winter-snow rarely persists for a long time. Frost and thaw often alternate daily. In South Iceland it often happens during winter that no snow is to be seen for months in the lowlands. On the other hand, it rains very often, and the precipitation which falls here as rain, produces on the plateau considerable masses of snow. By way of exemplifying the durability of the snow-covering, I give the results of my observations — the number of days with snow-covering — in Reykjavík during the winters of 1889—1892 and 1893—1895 in the following table: —

	1889—90	1890—91	1891—92	1893—94	1894—95
September	0	0	0	2	0
October	2	4	1	2	1
November	9	10	10	5	2
December	23	12	26	27	23
January	31	13	25	14	18
February	15	13	29	28	3
March	16	30	24	14	8
April	0	2	6	0	5
	96	84	121	92	60

In these five winters it snowed for the first time on Oct. 28, Sept. 28, Oct. 24, Sept. 19 and Oct. 31 respectively; for the last time on March 20, April 18, April 26, March 30 and April 18. Very often the snow persisted for a day or two only. The longest period during which the ground was covered continually with snow, was in the winter of 1891—92, viz. 63 days, from Jan. 19 to March 21. In all these winters the neighbouring Akrafjall, which has an altitude of 364 metres was often entirely snowless. In several places in North

Iceland the snow-covering persists so long during winter, that all intercourse between the farmsteads takes place on snow-shoes, and goods are transported on sledges, but in South Iceland sledges are hardly ever seen and still less snow-shoes. Snow may fall in any of the summer months, but in South Iceland it is only rarely that there is snowfall of any consequence during summer. In the northernmost districts it happens now and then, especially when Polar ice is in the vicinity of the island, that it snows so heavily for some days during mid-summer, that haymaking is suspended and the cattle must be stabled for a shorter or longer time. On the plateau snow-storms accompanied with frost occur now and then in July and August, and upon the great ice-mountains (Jökulls) it often snows in all months of the year. During a period of 30 years it snowed on an average 84 days annually at Stykkisholm, 44 days in the Vestmannaeyjar, 50 days at Berufjord, 45 days on Papey and 64 days on Grímsey. The amount of snow, as already mentioned, varies greatly according to the year. Snow-storms during winter have often caused great disasters by destroying thousands of sheep and many human lives. The annals of Iceland give us much information of such disasters, and numerous written records of many centuries show that the climate of Iceland has not changed since its first colonization in the year 874.

Hail is fairly common during winter, but rare during summer. On Grímsey it hails about twenty-four times annually; in the Vestmannaeyjar twenty times, at Stykkisholm five times and on Papey twice. The hail-stones are as a rule small, rarely larger than grit; but during volcanic eruptions, they are much larger, and often include grains of volcanic sand or ashes. Thunder is very rare and occurs as a rule only in winter. The registered thunderstorms average two in the year in the Vestmannaeyjar, and only one at Stykkisholm and Berufjord, while none have ever been registered on Grímsey. On the whole, thunderstorms are extremely rare in northern Iceland; thus at Audkula vicarage, in the district of Húnavatnssysla, thunder was heard once only between 1857 and 1873. Thunderstorms are more common along the southernmost part of the coast (Eyjafjöll, Landeyjar, Rangárvellir) where they occur sometimes during the summer also. The volcanic eruptions are almost always accompanied by thunder and strong electrical discharges.

The climatic conditions we have hitherto been considering, have naturally been those connected especially with the coasts and the

inhabited districts, because there alone permanent meteorological stations are found. The climate of the uninhabited plateau is far less known. Although it is possible, from the climate at the coast, to draw fairly definite conclusions as regards the climate of the interior, derived from the height above sea-level and the distance from the coast, yet almost all accurate investigations and observations from the plateau are wanting. The only climatological station on the plateau is Möðrudalur (469 metres above sea-level), and it will be seen that the climate there is far more severe than at the coast (see Table IV), from which again may be concluded how very severe must be the winter up at the Jökulls in the centre of the island, at a height of 1000—1400 metres; the climate in the interior is certainly far more continental than at the coast. The winter in Möðrudalur (mean temperature — 7.2° C.) is almost twice as severe as in the inhabited districts of North Iceland at any height up to 100 metres above sea-level, with a mean temperature of — 3.5° C. The spring of Möðrudalur is very cold with a mean temperature of — 2.1° C., and the mean autumn temperature is also below zero (— 0.7° C.), but the summer is as warm as at the coast. On Oðádahraun and north of Arnarfellsjökull the winter is beyond doubt very severe, with perhaps a mean temperature of — 10° or less. That the frost persists for a long time is seen by a few small oases, where the snow does not thaw until during July and where a miserable vegetation appears only for a period of two months. On the plateau the storms blow with great force, driving sand, gravel and small rock-fragments across the desolate plains and ridges of rock, thereby striating and polishing them; as mentioned above, the wind also carries great quantities of tuff-dust and blown sand from the plateau down to the valleys and lowlands. During summer it may sometimes become fairly warm in the middle of the day, but, in the interior of the plateau, it usually freezes during the night, so that small water-courses and pools of water are ice-covered early in the morning. Snow-storms occur now and then, and sand- and rain-storms and fogs are very common. The large Jökull-domes in the centre of the plateau often appear to form a climatic boundary, the weather frequently being opposite in character to the north and south of them. Thus, there is often bright sunshine on Arnarvatnsheiði, north of Langjökull, while south-easterly storms of rain are raging over the plateau south of the same Jökull; conversely it may be warm sunshiny weather on the

southern side, while fogs, with sleet and cold, extend from Húnaflói to the plateaus north of Langjökull. In a similar manner the mountain ranges on Reykjanes and Snæfellsnes exert great influence upon the local weather-conditions in the districts on either side of them. Apart from this, the weather often varies greatly in the different parts of the coast — a storm may be blowing on the south coast, while it is calm on the north coast. Northerly winds usually bring snow or rain to North Iceland, while they bring clear weather upon the south coast; southerly winds bring rain or snow-squalls to South Iceland and almost always an overcast sky, while simultaneously it is clear weather in North Iceland. The weather may differ in the fjords: a storm may be blowing out of the fjord, while it is calm outside, and vice versa. Sudden and strong gusts of wind blowing down from the mountains are often dangerous in some fjords, and in mountainous districts, highly intersected by valleys and ravines, the conditions of weather in the different districts are very capricious. On the whole, the weather-conditions on Iceland are very variable and unreliable in character.

IV. ACCOUNT OF THE GENERAL DISTRIBUTION OF PLANT-LIFE.

In connection with the description of the physiographical and climatic conditions, I shall now try to give a very brief account of the distribution of plant-life on the rocky substratum of Iceland. The following should be regarded merely as an attempt towards a description of the main features for general orientation. It is expected that later on in this work a more accurate and detailed account of the plant-geographical conditions will be given, and the ecological conditions and the different plant-formations will be described and analysed by different specialists.

Geological investigation has proved that Iceland in early Tertiary times was in all probability connected with Greenland and with Scotland across the Færöes by a land-bridge of volcanic, especially basaltic, rocks; the depression of this land-bridge had probably occurred and the countries been separated even in the Miocene period. During Pliocene times Iceland was somewhat larger than it is now, but subsidence continued; during this period the submarine coastal platform was formed, which occurs around the whole island, and also the now submarine fjord-grooves which lead off from the mouths of the present-day fjords. At the end of Pliocene times the climate gradually became colder until the Glacial period laid a continuous snow-covering over the whole island. Some botanists are of the opinion that a land-bridge connected Iceland and the Færöes with Greenland and Scotland during post-Glacial times also, but this hypothesis is highly improbable as it is at variance with many geographical and geological facts which are enumerated in the works cited below.[1] No geologist who is closely acquainted with the

[1] Th. Thoroddsen: Hypothesen om en postglacial Landbro over Island og Færøerne, set fra et geologisk Synspunkt. Ymer, Stockholm, 1904, pp. 392—399. Endnu nogle Ord om Landbro-Hypothesen. Ymer, 1906, pp. 93—101. Naturwissenschaftliche Rundschau, XXI Jahrg., No. 31. Island, Grundriss der Geologie und

geology of Iceland has been able to find any support for this hypothesis.

The Tertiary vegetation — probably from Eocene and Miocene times — which, as already mentioned, is found in the clay beds and in the so-called "Surtarbrand" in the middle of the basalt formation, was probably much altered in character even in Pliocene times, but unfortunately from this period there has as yet been found only a few small and undeterminable fragments of plants (conifers). When the Glacial period buried Iceland beneath an icy covering the Tertiary flora died out entirely, and the present flora must consequently have immigrated after the Glacial period and perhaps even partially during it, in intervening milder periods when the glaciers retreated slightly. As yet there are no real proofs to hand of an interglacial period in Iceland when the country was entirely free from ice and partially plant-covered.

As already mentioned, only a very small part of Iceland is really plant-covered. The continuous carpets of vegetation are only of slight extent compared with the considerable area of the island, and even in low-lying, inhabited districts large areas are occupied by rocky flats, Grimmia-heaths, sandy stretches poor in plant-life, lava-streams, etc. This is of course primarily due to the northerly situation of the island and the climatic conditions. The climatological chapter shows that the climate of Iceland is raw and cold. The winter is long, but generally not very severe; the summer is comparatively short and cold and the weather is usually changeable and damp; during spring, cold winds and sea ice accompanied by fogs do great damage as they often occur in the beginning of the growth-period. In many places the plants — many of which are evergreens — are protected from the cold of winter by a lasting snow-covering, but, as we have seen in the above, in several districts, especially in South Iceland, this snow-covering is variable and of short duration so that plant-growth suffers greatly under the influence of the cold wind; it is easily seen that there is great difference in the vegetation of the bare gravelly flats where the snow drifts off and of the depressions and localities in the shelter of rocks where the snow persists. Differences in the temperature and weather conditions of the different years according to whether Polar ice visits the coast or not, are of the greatest importance to plant-life.

Geographie, Gotha 1906, pp. 229 – 242. Islands Fjorde og Bugter (Geografisk Tidsskrift, XVI, 1901, pp. 58—82).

The snow-coverings in the lowlands generally melt away in April and the period of growth begins in May. But the time for the appearance of the plants differs considerably throughout the extent of the island, not only according to position and height above sea-level, but also on account of the conditions of weather in different years.

In south-west Iceland, in the neighbourhood of Reykjavík, in somewhat favourable years a few species flower at the end of April, e. g. *Saxifraga oppositifolia* and *Arabis petræa*, but in the beginning of May a great many plants are in bloom, e. g. *Salix herbacea*, *Alchimilla alpina*, *A. vulgaris*, *Draba incana* and *Silene acaulis*, somewhat later and until the middle of the month *Caltha palustris*, *Cardamine pratensis*, *Armeria maritima*, *Rumex acetosa*, *Oxyria digyna* and at the end of the month *Ranunculus acer*, *Taraxacum vulgare*, *Cerastium alpinum*, *C. vulgare*, *Thalictrum alpinum*, *Arctostaphylus uva ursi*, *Pinguicula vulgaris*, *Betula nana* and others. The common flowering period begins in June; and June and July are the months richest in flowers. For the rest, the flowering period is highly dependent on the weather; it may be delayed in colder years, especially in ice-years, but on the other hand, during prolonged periods of thaw in winter some flowers may open in February and March. On the northernmost points of land and on the plateau the time for flowering is naturally somewhat later.[1]

The number of plant-species found in Iceland cannot yet be stated with any certainty, but later in this work the lists and collections will be critically investigated and new species added to the list.[2] The number of species of known phanerogams and vascular

[1] For observations regarding the time of flowering in East Iceland in 1893 and 1894 see Helgi Jónsson: Vinter- og Vaar-Ekskursioner i Øst-Island (Botanisk Tidsskrift, 1895, pp. 274—275 and 292—294), and in the neighbourhood of Reykjavík in 1873—1875 see Th. Thoroddsen's notes in Grönlund's Karakteristik af Planteväxten paa Island, pp. 17—18. Moreover, there are some notes on the subject which have not as yet been published; but they make no difference as regards the general sketch of the spring-flowering given here.

[2] The chief floristic works on Iceland are the following: — St. Stefánsson: Flóra Islands, Köbenhavn, 1901. W. Lauder Lindsay: Flora of Iceland. (New Philosophical Journal, New Series, Edinburgh, July, 1861; 40 pages). C. C. Babington: A Revision of the Flora of Iceland. (The Journal of the Linnean Society, Vol. XI, London, 1871, pp. 282—348). Chr. Grönlund: Bidrag til Oplysning om Islands Flora. Höjere Kryptogamer og Fanerogamer. (Botanisk Tidsskrift, 2. Række, IV, 1874, pp. 36—85). Chr. Grönlund: Islands Flora, Köbenhavn, 1881. Chr. Grönlund: Afsluttende Bidrag til Oplysning om Islands Flora. (Bot. Tldsskr., XIV, 1885, pp. 159—217). H. F. G. Strömfelt: Islands kärlväxter. (Öfversikt af Kgl. Vetensk.

cryptogams may, I think, be estimated at 400—450. Chr. Grönlund in 1884 enumerated 366 species (340 + 26); E. Rostrup in 1887, 409 species (381 + 28); E. Warming in 1888, 417 (388 + 29); St. Stefánsson in 1890, 423 species (395 + 28), but in "Islands Flora," 1901, only 359 species; Helgi Jónsson recorded in 1896, 435 species, but in 1904, 360 species. It is thus seen that the number of the species differs somewhat according to the different authors; the reason for this I shall not enter into more closely here. For comparison it may be mentioned that the number of species known from the Færöes (Ostenfeld, Botany of the Færöes) is about 300 species of phanerogams and vascular cryptogams, from Greenland (E. Warming, 1888) 386 species, from Denmark about 1450 species, from Norway 1500. In the following I give an account for comparison and orientation; it is based on E. Warming's statistics (1888) and gives an excellent general idea of the subject, but it will probably be somewhat modified in its details on a later revision of the material. Warming records, according to what was known at that time of the flora of the island, that of circumpolar species there were found in Iceland 64, in Greenland 96 and in the Færöes 36; of sub-boreal and sub-alpine species in Iceland 70, in Greenland 87 and in the Færöes 33; and of temperate zonal species in Iceland 151, in Greenland 82 and in the Færöes 134. Of species which occur both in Europe and in America 48 are found in Iceland, 16 in Greenland, 47 in the Færöes; of those common to America, Europe and Spitzbergen 3 are found in Iceland, 5 in Greenland, 2 in the Færöes; in common with America alone Iceland has two species only, Greenland 21 and the Færöes none; in common with Europe there occur in Iceland 42, in Greenland 19 and in the Færöes 54 species. Greenland has 222 species in common with Iceland, but 137 with the Færöes; on the other hand, Iceland and the Færöes

Akad. Förhandlingar, Stockholm, 1884, pp. 79—124). E. Rostrup: Bidrag til Islands Flora. (Bot. Tidsskrift, XVI, 1888, pp. 168—186). Stefán Stefánsson: Fra Islands Væxtrige, I—III. (Vidensk. Meddelelser fra Naturh. Foren. i Köbenhavn, 1890, pp. 166—181; 1894, pp. 174—212; 1896, pp. 118—153). O. Gelert og C. Ostenfeld: Nogle Bidrag til Islands Flora. (Botan. Tidsskrift, XXI, 1898, pp. 339—348). Helgi Jónsson: Bidrag til Øst-Islands Flora. (Bot. Tidsskr., XX, 1896, pp. 327—357). Helgi Jónsson: Floraen paa Snæfellsnes og Omegn. (Bot. Tidsskr., XXII, 1899, pp. 169—207). Helgi Jónsson: Liste over Karkryptogamer og Fanerogamer i Syd-Island. (Bot. Tidsskr., XXVII, 1905, pp. 62—82). As regards older botanical literature, see Bibliogr. in E. Warming: Den danske botaniske Literatur fra de ældste Tider til 1880 (Botanisk Tidsskrift, XII, pp. 42—131, 158—247) and in Th. Thoroddsen: "Landfrædissaga Islands," Vol. 4, Copenhagen, 1904.

have 237 species in common. Of the higher plants in Iceland the majority of the species belong to the Cyperaceæ (44) and the Gramineæ (40), and these two families are also most characteristic of the inhabited land and of the greatest importance as regards the sustenance of the inhabitants. Of Compositæ there are 25 species, of Caryophyllaceæ 24, Cruciferæ 22, Juncaceæ 17, Filices 17, Rosaceæ 16, Scrophulariaceæ 13, Papilionaceæ 12, etc.[1] The lower plants have not yet been closely investigated; there are known, however, 300 species of mosses, 233 species of lichens and 543 species of fungi, 452 of which are parasites; on *Betula odorata* have been found 54 species of parasites, on *Salix lanata* 14 species, on *Dryas octopetala* 11, and on *Betula nana* and *Salix glauca* 10, etc. The mushrooms, of which many occur, are as yet but slightly known.[2]

Naturally, nothing is known as to how many species have immigrated into Iceland since the first colonization of the island in 874, but we may take for granted that the number is considerable. Even by the first "Landnámsmen" several species were undoubtedly imported from Norway and perhaps also from the islands along Scotland. In the Sagas we read about live-stock (cows, horses, sheep and swine) being brought to Iceland and in the fodder brought along with them there were certainly several foreign seeds. Some of the immigrants for religious reasons, brought earth with them from Norway from the site of their former temple (Hof). Then the settlers also used foreign seed for cereal crops, on the cultivation of which they were very keen at first. Moreover, different species may have been introduced along with articles of commerce and in other ways. Of imported species, which during later centuries have gained a firm footing and have become naturalized, the most common are *Urtica urens, U. dioeca, Cirsium arvense, Spergula arvensis, Carum carvi, Lamium intermedium, Senecio vulgaris* and some others.

[1] Eug. Warming: Tabellarisk Oversigt over Grönlands, Islands og Færöernes Flora, 1887. (Vidensk. Meddel. fra den naturhist. Foren., 1887, Köbenhavn, 1888).

[2] Chr. Grönlund: Islandske Naturforhold med særligt Hensyn til Mosvæxtens Betydning for Landskabet (Tidsskrift for populære Fremstillinger af Naturvidenskaben, 5. Række, IV, 1877, pp. 321—356). Bidrag til Oplysning om Islands Flora, Lichenes, Hepaticæ og Musci (Bot. Tidsskr., IV, 1870, pp. 147—172; 2. Række, III, 1873, pp. 1—26). Afsluttende Bidrag til Oplysning om Islands Flora, Musci, Hepaticæ, Lichenes (Bot. Tidsskr., XIV, 1885, pp. 159—217). Tillæg til Islands Kryptogamflora, indeholdende Lichenes, Hepaticæ og Musci (Bot. Tidsskr., XX, 1895, pp. 90—115). Islandske Svampe samlede 1876 af Chr. Grönlund (Bot. Tidsskr., XI, 1879—80, pp. 72—76). E. Rostrup: Islands Svampe (Bot. Tidsskr., XIV, 1885, pp. 218—229; XXV, 1903, pp. 281—335).

Lastly some 40—50 foreign species have been found which have not yet gained a permanent footing in the flora, some of which will probably again disappear.

There can be no doubt that the vegetation has been modified in various ways since man with his cattle-rearing came upon the scene; sheep have especially exerted a great influence upon the coppice-woods and other vegetation; in the few places to which sheep cannot gain access, e. g. in distant valleys surrounded by glaciers and rivers of great volume, on islands in the middle of waterfalls or torrential rivers or in lakes the vegetation is usually far more luxuriant than in other places. In Viðidalur in Lón I had the opportunity of noting an example of the change effected by sheep-rearing. The locality in question is situated 439 metres above sea-level and has a southern exposure; it is surrounded by glaciers and deep river-gorges impossible for sheep and cattle to cross. Formerly the valley had been inhabited for a short time, but in 1840 it was deserted by the inhabitants. I visited the valley in the cold summer of 1882 and found there a very luxuriant vegetation; all the plants had a height quite unusual in Iceland. At the bottom of the valley the grass and the different species of willow usually reached to the horse's belly; especially were *Salix phylicifolia, Geranium silvaticum, Bartsia alpina* and *Archangelica officinalis* of considerable size; there was almost a wood of *Archangelica* which reached a height of 1—2 metres. The old ruins of the huts which were destroyed in 1840 by an avalanche were overgrown with *Archangelica officinalis* and *Salix phylicifolia,* and from the old fire-place a willow, belonging to the latter species, had grown out, about 2 metres in height, with stem 3—4 cm. in diameter. In 1883 the valley was again inhabited. I revisited the place in the summer of 1894 and found the conditions greatly changed owing to cultivation and the influence of sheep and cattle. That tract of land upon which the above-mentioned species had reached their highest development was now laid out as a manured home-field (tun), overgrown by species of grass characteristic of manured fields. These grasses had not, however, yet gained mastery over the wild vegetation; the single plants of grass stood far apart, so that the field only yielded 64 cwt. hay per annum, while in the coastal districts a well cultivated field of the same size would have yielded 240 cwt. Besides, the soil was quite intersected by subterranean portions of former plants, roots of willows, etc. This vegetation would therefore in all probability quickly become

predominant if the farm were to be abandoned. Small willow-shrubs *(Salix phylicifolia* and *S. glauca)* had grown out from several pieces of turf which had been used for making the walls of the houses. On account of the large number of sheep the plant-growth of the whole valley had degenerated. The luxuriancy had entirely disappeared; no plants of any height were to be seen, the willow shrubs had become smaller and flatter in growth, as during winter the sheep nibble off the uppermost shoots which protrude through the snow; here it had not been possible to procure sufficient hay for winter-fodder, therefore, during winter the sheep had been left to shift for themselves with the result that they had attacked the willow coppices and a neighbouring birch coppice in Kollumuli.

But the destruction of the coppice-woods has exerted the greatest influence upon the vegetation. The Icelandic author Ari frodi (born 1067) says in his "Islendingabok" that when the first settlers came to Iceland it was wooded from the sea to the mountains or inner plateau ("milli fjalls ok fjöru"). But this statement is doubtless due to exaggeration. Arngrimur, the Abbot of Thingeyrar, writes in 1350 about Iceland "woods do not occur except birch, and that is low in growth." At the first colonization of Iceland many mountain-sides were probably coppice-clad right to the verge, likewise many ridges, gravelly stretches and old lavas on the plains, which are now bare. The coppices spread over a great part of the coastal districts and the valleys, but nowhere extended up on the plateau above a height of 600 metres, and probably even at that time the northern peninsulas and the extreme points of land were woodless. In the lowlands also many tracts of sand, bogs and new lavas were undoubtedly bare of wood as in the present time, and probably not more than 4000—5000 square km were covered with coppice at the beginning of the 10th century. The birch stems found in the bogs also show that the trees of olden times were not larger than those now found in the best preserved patches of wood. From the Sagas it can be seen that even during the first centuries the woods had suffered greatly. Space was cleared for farms and home-fields, and the best stems were used as laths for the support of the turf-roofs, etc., of smaller houses, although the greater part of the building-wood was imported from Norway, at any rate in districts where there was not easy access to drift-wood which at that time was found in quantities along the northernmost coasts. Moreover, trees were recklessly felled for fuel and in addition, wood in olden times

was largely used for the smelting of bog iron-ore and for charcoal for smith's work. Even as late as 1870 charcoal was used in every farmstead during hay-making for the purpose of beating out and sharpening the scythes. Numerous remains of ancient charcoal-pits are still to be seen in many places where no woods are found today. Burning woods are several times mentioned in the Sagas. They were set on fire either accidentally or also maliciously for revenge or out of mischief. But for centuries the sheep and goats have been the worst enemies of the woods; during winter when the snow is lying on the ground they procure their means of sustenance chiefly from the woods, nibbling off all the buds and gnawing the branches and stems. Even in the middle of the 13th century the greater part of the woods had disappeared from the inhabited districts, and the remnants have since that time been gradually diminishing. It is a wonder that woods still exist in Iceland to such an extent that, including shrubs, they cover an area of about 454 square km.[1] In the beginning of the 15th century all the coppice-woods had disappeared from Hunavatns and Skagafjardarsyslur, but in Eyjafjardarsysla some remains of woodland persisted till the beginning of the 19th century. Now the whole stretch of land from Eyjafjördur to Hrutafjördur is devoid of wood. Even in the middle of the 18th century woods, fairly high in growth, existed in several places from which they have now disappeared; they were greatly damaged by the Katla and Laki eruptions of 1755 and 1783 respectively.

Generally speaking, it may be said that the same kind of vegetation prevails throughout the island; taken as a whole, there is no great difference between north and south, high and low. The character of the flora is the same everywhere, although on a closer inspection it will be seen that the composition of the plant-formations varies somewhat, and that certain species are peculiar to, or specially common in, certain districts. The different species vary extremely as regards the number of their individuals; true, the largest areas are covered with a continuous carpet of grasses, sedges, dwarf-willows, heathers and Grimmias, but some species characteristic of rocky flats, such as *Armeria maritima*, *Polygonum viviparum*, *Cerastium alpinum*, *Salix herbacea*, *Silene maritima*, *Oxyria digyna*, *Sibbaldia procumbens* and others, occur widely distributed as scattered individuals throughout the island from the coast to the snow-line. Ac-

[1] Landshagsskyrslur fyrir Island, 1911, Reykjavik, 1912, p. 89.

cording to St. Stefansson's "Flora Islands," where 359 species are described, 197 species are common all over the island, 37 common in a few districts, 72 species are rather rare, and 53 species very rare.

As already mentioned, the vegetation has a homogeneous character throughout the island, and — according to our present knowledge — there are only a few species which are especially characteristic of certain parts of the island. East Iceland (Múlassýslur) is most noticeable in this respect; also, plant-geographically, Austur-Skaftafellssysla, which stretches as a narrow ribbon along the southern edge of Vatnajökull as far as to Skeidarársandur; this extensive sandy tract forms a limit for several of the eastern species. *Campanula rotundifolia* is a common characteristic plant in East Iceland, but very rarely so in other places; I found the most westerly individuals of this species on Brunasandur towards the southwest, and at Hólkná in the district of Thistilfjord towards the north, but it is very common east of these boundaries. *Saxifraga aizoides* is very common in East Iceland, but has not been found elsewhere — I found it in a most south-westerly direction at Øræfi and in a most north-westerly direction near Vidirhóll at Fjallasveit. *Trientalis europea* grows in various places in the coppice-woods of East Iceland, but nowhere else; *Alchimilla fœröensis* is also common in East Iceland, but has not been found elsewhere. *Cerastium Edmondstonii* has been found in some places in East Iceland and in one locality in Skaftafellssysla. *Saxifraga Cotyledon* grows along the south-eastern coast from Foss in Sida to Eskifjord, and two species of rose, *Rosa pimpinellifolia* and *R. canina*, grow along the same stretch of coast and nowhere else; the former was found in three habitats, westernmost at Seljaland and easternmost at Reydarfjord; the latter was found only at Tvisker on Breidamerkursandur. *Lychnis flos cuculi* grows along the south coast from Eyjafjöll to Øræfi and has not been found in other districts.

In South and South-west Iceland several species are common which either are not found or are very rare in other districts. *Spiræa ulmaria* is common from Borgarfjord to Lónsheidi, rare in other places, and not found in Mulasyslur; *Brunella vulgaris* is very common in South Iceland, but very rare in other places; *Plantago lanceolata* is also common in South Iceland, but has otherwise been found only in a few places in North Iceland near hot springs. *Succisa pratensis* is characteristic of South Iceland and is especially common in Vestur-Skaftafellssysla, west of Brunasandur. *Valeriana*

officinalis, Vicia sepium, Galeopsis Tetrahit and *Sanguisorba officinalis* occur only in southern and south-western Iceland. *Anthyllis vulneraria* is fairly common in south-west Iceland, but has otherwise been found only in one place in East Iceland (Njardvik); *Cakile maritima* is common in the sea-sand in south-west Iceland and in the southern part of the north-western peninsula, but has not been found elsewhere. *Lathyrus paluster, L. pratensis* and *Veronica anagallis* have been found only in south-west Iceland, and *Haloscias scoticum*, also, does not grow in other places with the exception of the islands in Breidifjördur where it occurs rather frequently, and on the islands in Hornafjord; *Hydrocotyle vulgaris* occurs near hot springs in South Iceland, especially in the district of Borgarfjord, but has not been found elsewhere; *Zostera marina* is very common in south-west Iceland, but is rare in other places.

The plant life of the north-western peninsula is as a rule poor in species and not very characteristic. *Fragaria vesca* has not been found there, although it is fairly common all over the island; *Cornus suecica* grows in some places in Vestfirdir and near Breidifjördur, but has not been found elsewhere, and *Melampyrum silvaticum* has been found only in wooded valleys near Isafjord. *Papaver nudicaule* appears to be more common on the north-western peninsula than in other parts of the island. In North Iceland only a few characteristic plants occur. *Pleurogyne rotata* is, however, very common in North Iceland, but rather rare in other places; *Milium effusum* also is especially characteristic of the northern districts. *Phyllodoce coerulea*, which is so common in Greenland, is also fairly common on the northern mountainous peninsulas on either side of Eyjafjördur westwards as far as Fljót, but has not been found elsewhere; *Primula stricta* has been found only near Eyjafjördur, and *Antennaria alpina* and *Erigeron uniflorus* have been found only on mountains in North Iceland.

Moreover, it may be mentioned that, here and there, a few otherwise rather rare species, by occurring in great abundance in certain localities, give a characteristic appearance to the landscape. Thus, in Selvogur *Anthyllis vulneraria* occurs so abundantly that during the flowering period large tracts are quite yellow; in Eyjafjördur and in Hrappsey considerable areas are closely covered with *Viola tricolor*. In Trostansfjördur the whole strand is densely overgrown with *Cakile maritima*, which, although rather common in western Iceland, occurs nowhere so abundantly as here. An

unusually large quantity of *Viscaria alpina* grows at Ulfsvatn (400 metres above sea-level). An old lava-stream, south of Krakatindur and NE. of Hekla is almost exclusively overgrown with *Oxyria digyna*, which otherwise occurs rather rarely on lava. The neighbourhood of Eyjafjördur is characterized by a great abundance of *Gentiana*, and the neighbourhood of Lake Myvatn by its rich vegetation of *Nasturtium palustre* and *Pleurogyne rotata; Erysimum hieracifolium*, which is otherwise rather rare, occurs abundantly and as large specimens on the islands in Myvatn; *Succisa pratensis* is very numerous in Sida. A few rare plants have been found only in very far distant habitats, at opposite sides of the island, thus, *Ophioglossum vulgatum* at Gunnuhver at the extreme point of Reykjanes, and at Bjarnarflag near Myvatn. *Drosera rotundifolia* grows here and there near Breidifjördur and Faxafjördur and otherwise only in the extreme north between Eyjafjördur and Skagafjördur, *Cirsium arvense* occurs in a few localities which are as far apart as Grindavik and the Vestmannaeyjar towards the south, and Eyjafjördur towards the north.

In Iceland as in other arctic or subarctic countries with a coastal or insular climate there is comparatively but a slight difference in the vegetation of the lowlands and of the plateau, of the mountains and of the valleys; it is very difficult to arrange the species according to their altitudinal zone. Almost throughout the island, and everywhere where plant-life can thrive at all, plant-formations and plant-associations, with a few modifications, occur with a gradually increasing or decreasing luxuriance and number of species according to situation only. With the exception of the highest situated tracts, close to the snow-line, the distribution of the plants and the differences in the vegetation appear to be in a higher degree dependent on local climatic conditions, such as snow and other atmospheric precipitations, wind, conditions of soil, inclination, more or less sunny exposure, streams and springs rather than on the height above sea-level. A luxuriant vegetation with a lowland character often extends very far upwards on the mountains on the sunny side, or where a suitable degree of moisture and a protective snow-covering afford favourable conditions of life for the vegetation, while in the immediate neighbourhood, and often at a far lower level, cold sharp winds or sand-drifts have destroyed almost all plant-life and laid the land waste. Exceptionally favourable localities are afforded for plants in some places near hot springs

on the plateau. Some plant-formations such as birch-coppices and heather-moors, do not, however, extend to the highest levels, and many species disappear on approaching the snow-line; on the other hand, others, as mentioned above, are distributed in great abundance all over the island, from the sea-level to the snow-line.

The Icelandic climate affords good conditions of life for mosses, therefore Iceland has a luxuriant moss-vegetation which is not only shown in the great extent of the Grimmia-heaths, but proofs of it are seen in various other ways in nature. On the interior plateau in the most barren localities small green oases are often seen, consisting exclusively of mosses; on the abrupt faces of rocks they form bright green cushions around springs; and at the numerous waterfalls of Iceland there is a luxuriant moss-vegetation, rich in forms; blocks of rock and steep rock-faces are often covered with mosses, as also the numerous cracks in the lava-streams; and the damp rock-clefts are often rich in different species. Under various conditions of nature, various species of mosses are the dominant ones, and form various characteristic societies.

A considerable number of lowland species have an upper limit on mountains and plateau, but this has not as yet been thoroughly investigated. On the other hand, very few highland plants have a lower limit; the majority of the plants which grow near the snow-line thrive just as well in the neighbourhood of the sea. In many districts, and in some places on the northern peninsulas towards the North Atlantic, plant-associations with well-marked plateau-characters are seen in the vicinity of the sea; this is especially the case with associations of *Salix herbacea*, *Sibbaldia procumbens* and *Gnaphalium supinum*, which are otherwise peculiar to the plateaus. Of the commonly distributed species probably very few occur exclusively on the plateau; of such plants only *Ranunculus glacialis* is known; it grows in many localities near the snow-line and has doubtless only rarely been found below 300 metres. *Pedicularis flammea* has a similar distribution, but in some places it grows perhaps further downwards. Otherwise there are only a few rarer species which have been found only on mountains and plateau, but it is possible that on a closer investigation these may also be found at a lower level. Of these may be mentioned *Carex pedata*, *Poa laxa*, *Catabrosa algida*, *Sagina nivalis*, *Draba alpina*, *Ranunculus pygmæus*, *Diapensia lapponica*, *Campanula uniflora*, *Antennaria alpina* and *Erigeron uniflorus*. Of common plateau-plants which also occur in

the lowlands may be mentioned, *Carex rostrata*, *C. lagopina*, *C. saxatilis*, *C. rigida*, *Eriophorum polystachyum*, *Luzula arcuata*, *Salix herbacea*, *Alsine biflora*, *Papaver nudicaule*, *Draba nivalis*, *Arabis alpina*, *A. petræa*, *Saxifraga cæspitosa*, *S. oppositifolia*, *S. nivalis*, *Epilobium anagallidifolium*, *Gentiana nivalis*, *Sibbaldia procumbens*, *Gnaphalium Norvegicum*, *G. supinum*, and others. As already mentioned, many of the most common plateau-species are distributed on rocky flats throughout the country, both at high and at low levels; for instance, *Silene maritima* is as common along the coast as at the highest levels in the interior wastes, as also *Polygonum viviparum*, *Cerastium alpinum*, *Armeria maritima*, *Draba alpina*, *Oxyria digyna*, and several others. Therefore, speaking generally, it is not easy to distinguish the species of the rocky flats of the plateau from those of the lowland. The main difference consists especially in the more scattered growth of the individual plants and their partially stunted appearance on the plateau; moreover, in the lowlands several species are found intermixed with the above, often abundantly, which rarely appear on the plateau, for example, *Dryas octopetala*. Further, where the situation is favourable, very luxuriant patches may occur on the rocky flat of the plateau, at any rate in the centre of the island below 600—700 metres. As we have already seen, the altitude of the snow-line differs greatly in different districts, consequently, the characteristics of the plateau vegetation are met with at different altitudes in different parts of the island. In central Iceland the plateau-character often does not begin until at 600—800 metres, but on the northern peninsulas and headlands the plateau-vegetation often descends to an altitude of 300 metres, and in some places even lower. On the lower-lying parts of the plateau, especially in the neighbourhood of large glaciers, from which the melting snow and ice has not sufficient outlets, there are often found groups of lakes and extensive stretches of boggy and swampy land with a luxuriant vegetation of mosses and sedges. Such swampy tracts are found among other places on Tvidægra (450 metres), in the neighbourhood of Grimstungnaheidi (500 metres), Miklumyrar near Hreppar (400—500 metres), Eyjabakkar near Snæfell (650 metres), Fljótsdalsheidi (400—500 metres), and several other places. The vegetation of these plateau-bogs is as yet very little known.

All the highest mountain summits and plateaus are covered with snow and ice, but along the edge of the plateau and in a few places upon the plateau itself there are several rather high mountain tops

which are snowless during summer. On these wind-blown rock-summits the plants generally encounter very unfavourable conditions, therefore many of the summits are quite bare of vegetation; on others a few lichen-crusts are seen on stones, or small Grimmia-cushions in clefts; and again on others a few scattered phanerogams are found. So far as is known, there are almost no notes regarding the plants on the mountain summits of Iceland, as the latter are rarely ascended by botanists, but geologists, on the other hand, are obliged to climb the mountains. I shall therefore take the opportunity here of inserting some fragmentary notes from my diary regarding the plants I found on the mountain-summits, with the heights measured. These notes were not intended for publication; I had put them down in my diary for my own information, but although they are fragmentary, they may be useful in showing that there is nothing specially characteristic in the vegetation of the mountain-summits. On the north-western peninsula: Kikafell near Brjámslækur (560 metres), Grimmias, *Salix herbacea, S. phylicifolia, Arabis petræa, Armeria maritima, Ranunculus glacialis, Silene acaulis,* all in flower July 22, 1886. Vattarfjall (401 metres), *Papaver nudicaule, Silene acaulis, Armeria maritima.* Bæjarfell near Steingrimsfjord (316 metres), *Silene acaulis, Armeria maritima, Cerastium alpinum, Polygonum viviparum, Empetrum nigrum, Saxifraga cæspitosa.* Drangaháls (315 metres), *Salix herbacea, Polygonum viviparum, Oxyria digyna, Rhodiola rosea.* Dalsheidi near Snæfjallaströnd (660 metres), mosses, *Silene acaulis, Salix herbacea, Gnaphalium supinum, Sibbaldia procumbens.* Klofningsheidi (606 metres), Grimmias, *Salix herbacea, Ranunculus glacialis, R. pygmæus.* Uxaskard near Látrar (Eyjafjord) (518 metres), *Oxyria digyna, Salix herbacea, Armeria maritima, Ranunculus glacialis.* Hafursey near Myrdalsjökull (587 metres), Grimmias, *Salix herbacea, Silene acaulis, Polygonum viviparum.* Lodmundur (1097 metres), NE. of Hekla, Grimmias, lichens, *Salix herbacea, Silene acaulis, Cerastium alpinum, Saxifraga cæspitosa, Carex rigida.* Skálafell near Ölfus (578 metres), *Salix herbacea, Cassiope hypnoides, Armeria maritima. Arabis petræa.* On the plateau towards the west: Thristapafell near Eiriksjökull (714 metres), *Salix glauca, Armeria maritima, Cerastium alpinum, Silene acaulis, Salix herbacea.* Strútur (921 metres), on the summit no plants, but 130 metres further downwards, *Arabis alpina, A. petræa, Saxifraga hirculus, S. hypnoides, S. oppositifolia, Pedicularis flammea.* Botnssulur (1108 metres), only some lichens and Grimmias and *Salix herbacea* and

Empetrum nigrum — a miserable stunted specimen of each of these two species, 2 and $2^1/_2$ cm. in height respectively. On the plateau towards the east: Kjarrdalsheidi near Lón (665 metres), *Salix herbacea, Polygonum viviparum, Oxyria digyna, Ranunculus glacialis,* all small and stunted. Markalda (961 metres) near the eastern edge of Vatnajökull, *Polygonum viviparum, Armeria maritima, Salix herbacea, Saxifraga nivalis.* Litla Snæfell (1133 metres), *Salix herbacea, Oxyria digyna, Arabis alpina, Ranunculus glacialis.* On Hlidarfjall near Myvatn (790 metres) where I was together with Grönlund in 1876, we noted the following plants: — *Alsine biflora, Draba nivalis, Saxifraga cernua, Cassiope hypnoides, Pedicularis flammea, Oxyria digyna*[1].

All that is situated outside the glacier-bearing mountains in the centre of Iceland at an altitude of 650—1100 metres may justly be regarded as a desert; seen both from a geological and geographical point of view the country here is desert-like in character, and in spite of considerable precipitation the plants suffer from drought, because the water disappears immediately over large areas owing to the porous nature of the rocky substratum — lava, tuff, volcanic gravel and sand. The few plants which grow in these wastes occur widely scattered; at a height of 900—1000 metres above sea-level a few lichens and mosses are seen only here and there, and at long intervals a few specimens of the hardy *Armeria maritima, Silene maritima* and *Polygonum viviparum* and in places where blown sand occurs a few tufts of *Elymus arenarius*; at a height of 1000—1100 metres one may ride for miles without coming across a single phanerogam. In addition to want of water, the frequent storms, often of sand and snow, check plant-growth during the short summer; moreover, a rather dry Föhn wind often blows across the wastes north of the great Jökulls, having already deposited its moisture upon the great plateaus of the Jökulls. Somewhat lower down, at an altitude of 700—900 metres, a few more species are met with as scattered individuals, e. g. *Silene acaulis, Arabis alpina* and *A. petræa*, and here and there a few haulms of *Luzula arcuata, Poa glauca* or *Festuca ovina*; moreover, a few scattered cushions or tufts of lichens *(Stereocaulon)* or mosses *(Grimmia)* occur.

Scattered here and there in these extensive wastes are sometimes

[1] See also Chr. Grönlund's list of plants from Heljardalsheidi and Hrafntinnuhryggur, and the list of plants collected by Johnstrup on Dyngjufjöll (Karakteristik af Plantevæksten paa Island, 1884, pp. 28 and 29).

found, at intervals of a whole day's journey, some small oases with a denser vegetation, in places where water is present, especially springs which issue from under the edge of the lava-streams. I propose to give here the names of some of these oases and their height above sea-level, and add some notes on their vegetation, which is generally very little known. As almost no notes are published on the vegetation of the plateau I shall avail myself of this opportunity to give a list of the species I collected on some of these oases, as they have never been visited by botanists. Some of these plant-covered patches are only a few square metres in extent, and the largest of them are perhaps as much as a square km. in area[1]. These oases often originate around hot springs, the temperature of which need not be very high — somewhat higher, however, than the mean temperature of the locality at which they rise. Thus NW. of Vatnajökull there are oases near Gæsavötn, 929 metres above sea-level, where the springs have a temperature of 5—7° C., and near Marteinsflæda (744 metres) with spring-temperature of $35^1/_2{}^0$ C. and near Hitalaug (672 metres) with a temperature of $33^1/_2{}^0$ C. Gæsavötn is the most highly situated of all the oases that I visited in 1884; plant-growth occurs here in connection with pools and springs; along the margins the vegetation is formed by mosses and *Salix herbacea* with scattered specimens of *Polygonum viviparum*, *Saxifraga stellaris*, *Oxyria digyna*, *Armeria maritima*, *Cerastium* and *Poa*, while *Carices* and *Eriophorum* form a fringe along the water's edge. Here I collected the following plants: — *Equisetum arvense* var. *alpestre*, *Calamagrostis stricta* var. *borealis*, *Aira alpina*, *Poa pratensis*, *P. pratensis* var. *alpigena*, *Poa alpina* var. *vivipara*, *Carex incurva*, *Eriophorum Scheuchzeri*, *E. angustifolium*, *Salix phylicifolia*, *S. herbacea*, *Polygonum viviparum*, *Oxyria digyna* f. *pygmæa*, *Armeria sibirica*, *Saxifraga stellaris* f. *pygmæa*, *S. decipiens* var. *grönlandica*, *Ranunculus hyperboreus*, *Cerastium arcticum*, *C. trigynum*[2]. From here I went to Hvannalindir near Kverkfjöll, the nearest oasis towards the east, but it took nevertheless two days (17, 18 Aug.) to reach it, travelling along the northern edge of Vatnajökull; along the whole of this stretch of land there were almost no plants, until at Jökulsá, 734 metres above sea-level, I found in the gravel a fairly large quantity of *Chamænerium latifolium* and *Oxyria digyna*.

[1] In my work "Island, Grundriss d. Geographie u. Geologie", 1906, there is a map showing the desert-boundaries and the oases known.

[2] Determined by Prof. Joh. Lange.

In Hvannalindir (656 metres) there occur along small streams a great many grasses and an abundance of tall specimens of *Archangelica officinalis*, but unfortunately I was prevented by a snowstorm from collecting plants there. At Vadalda at the springs of Svartá (674 metres) were found *Archangelica officinalis* and *Juncus balticus*. At Herdubreidarlindir (471 metres), north of the lofty mountain of Herdubreid, a rather rich vegetation occurs as a border along springs and branching streams while the surroundings consist of gravel quite bare of plant-life. Here I collected the following plants[1]: — *Equisetum variegatum*, *Phleum alpinum*, *Calamagrostis stricta* var. *borealis*, *Festuca rubra* var. *hirsuta*, *Eriophorum Scheuchzeri*, *Juncus arcticus*, *J. triglumis*, *Luzula multiflora*, *Tofieldia borealis*, *Platanthera hyperborea* var. *major*, *Salix phylicifolia* var. *angustifolia*, *S. lanata*, *S. herbacea*, *Achillea millefolium*, *Erigeron uniflorus*, *Hieracium murorum*, *Galium verum* var. *aspera*, *Thymus serpyllum* var. *prostratus*, *Bartsia alpina*, *Pirola minor*, *Archangelica officinalis*, *Parnassia palustris*, *Cerastium vulgatum*, *Silene maritima*, *Epilobium alsinefolium*, *Chamænerium latifolium*, and *Alchimilla alpina*. On Odádahraun itself there are otherwise only extremely small plant-covered patches. In Hrútsrandir near Kollótta Dyngja (653 metres), there occurred on a bottom of *Salix herbacea* a few small individuals of *Polygonum viviparum* and *Salix glauca* and far out on a neighbouring lava-stream a single specimen of *Taraxacum officinale* — the only one for miles round. Along some mountain-streams in the south-eastern corner of Dyngjufjöll small patches of a similar vegetation were found, only *Salix glauca* was far more vigorous here. Otherwise no continuous oases are found in the higher parts of Odádahraun, but only a few very widely separated desert plants, and in some places *Elymus arenarius* on blown sand. Towards Bárdardalur the vegetation increases gradually, and the sandy tracts, as far upwards as 500 metres above sea-level, are covered with *Elymus arenarius*, *Salix lanata* and *S. glauca*, and further downwards till about 450 metres, *Achillea millefolium* grows in abundance on the sand. In Miklimór between Sudurárbotnar and Alftakíll (about 450 metres) there is a considerable vegetation of different kinds of plants and even around Svartárvatn (409 metres) there is a rather rich vegetation like that on the sandy tracts of the lowlands.

On the north-eastern part of Vatnajökull east of Jökulsá and close to the glaciers, oases occur — separated by stretches of stony

[1] Determined by Prof. Joh. Lange.

deserts — which are as yet very little known, e. g. Thorláksmyrar, Mariutungur and Eyjabakkar (672 metres). I visited the last locality in 1894 and found there extensive areas covered with Cyperaceæ, cotton-grass and other plant-growth. In Fjallasveit, east of Jökulsá, a parish situated up on the plateau at an altitude of 400—500 metres, the population of which is solely dependent on sheep-rearing for their sustenance, very large tracts are covered with blown sand which in many places is densely overgrown with *Elymus arenarius, Salix lanata, S. glauca* and *Juncus balticus*, while *Carex incurva* grows abundantly on damp sandy flats. Near the farmstead Vidirhóll (415 metres) I collected in 1895 the following plants: — *Juncus balticus, J. triglumis, J. trifidus, Elyna Bellardi, Carex incurva, C. capitata, C. capillaris, C. vulgaris, C. rigida, C. rariflora, Poa pratensis, P. annua, Phleum alpinum, Festuca rubra* var. *arenaria, Calamagrostis stricta, Trisetum subspicatum, Selaginella spinulosa, Salix lanata, S. glauca, Saxifraga aizoides, Gentiana tenella, Pleurogyne rotata.*

North of Hofsjökull, at an altitude of 600—800 metres, similar barren wastes occur, as around Odádahraun, consisting of ice-striated doleritic lava, and here also the individual plants occur widely separated, but, in the neighbourhood of stream and lakes, the oases are larger both in number and size. The vegetation of these oases is generally confined to small swamps and pools and sometimes to rather extensive mountain-bogs; in the pool-vegetation *Eriophorum* is usually dominant, but sometimes *Carices* are in the majority. In mountain bogs numerous large knolls (dys) often occur which are usually dry at the top and covered with mosses and various rocky-flat plants, but wet below and overgrown with swamp-plants. Dry tracts between the swamps are generally covered with Grimmia-heaths which sometimes pass into lichen-heaths. Of the oases occurring in these districts may be mentioned: Sydri Pollar, Nyrdri Pollar, Geldingaá and Laugafell (with hot springs), and southwards near Sprengisandur, on the eastern side there is Nyidalur, and on the western side Nauthagi and Arnarfell with an unusually luxuriant vegetation which has been described by St. Stefánsson[1], who also describes the plant-formations near Laugafell and Geldingaá. In Nydri Pollar (704 metres) I collected in 1896 the following plants: *Poa alpina, P. flexuosa, Carex rigida, Eriophorum angustifolium, Salix lanata, S. glauca, S. herbacea, Pedicularis flammea, Tofieldia*

[1] Geografisk Tidsskrift, XVI, 1902, pp. 230 and 231.

borealis, *Alsine biflora*, *Cerastium trigynum*, *Saxifraga Hirculus*[1]. In Sydri Pollar (729 metres) I collected in the same year the following plants: — *Equisetum variegatum*, *E. arvense*, *Carex rigida*, *C. lagopina*, *C. rariflora*, *C. pulla*, *Juncus arcticus*, *J. biglumis*, *Eriophorum Scheuchzeri*, *E. angustifolium*, *Poa alpina*, *P. flexuosa*, *Phleum alpinum*, *Aira alpina*, *Festuca rubra* var. *arenaria*, *Calamagrostis stricta* f. *borealis*, *Salix glauca*, *S. lanata*, *S. herbacea*, *S. phylicifolia*, *Betula nana*, *Polygonum viviparum*, *Rumex acetosa*, *Arenaria ciliata*, *Cerastium alpinum*, *Silene acaulis*, *Cardamine pratensis*, *Tofieldia borealis*, *Montia rivularis*, *Thalictrum alpinum*, *Pinguicula vulgaris*, *Armeria maritima*, *Saxifraga decipiens*, *S. Hirculus*, *Pedicularis flammea*, *Erigeron uniflorus*, *Thymus serpyllum* var. *prostrata*, *Veronica alpina*, *Dryas octopetala*, *Vaccinium uliginosum*, *Empetrum nigrum*, *Bartsia alpina*[2]. As already mentioned, on Tvidægra there are extensive stretches of bog-land and a considerable vegetation of various species. In 1898 I collected here, near Ulfsvatn (453 metres), the following plants: — *Juncus biglumis*, *J. triglumis*, *J. trifidus*, *Luzula spicata*, *Eriophorum angustifolium*, *E. Scheuchzeri*, *Carex alpina*, *C. atrata*, *C. dioeca*, *C. lagopina*, *C. pulla*, *C. rigida*, *C. sparsiflora*, *Aira cæspitosa*, *A. flexuosa*, *Anthoxanthum odoratum*, *Festuca ovina*, *F. rubra*, *Phleum alpinum*, *Poa alpina*. *P. glauca*, *Trisetum subspicatum*, *Coeloglossum viride*, *Salix glauca*, *S. herbacea*, *Polygonum viviparum*, *Alsine verna*, *Cerastium alpinum*, *C. trigynum*, *Silene acaulis*, *Viscaria alpina*, *Ranunculus acer*, *Thalictrum alpinum*, *Cardamine pratensis*, *Draba incana*, *Geranium silvaticum*, *Saxifraga cæspitosa*, *S. Hirculus*, *S. stellaris*, *Potentilla verna*, *Alchimilla vulgaris* f. *filicaulis*, *Sibbaldia probens*, *Vaccinium uliginosum*, *Bartsia alpina*, *Pinguicula vulgaris*, *Thymus serpyllum* var. *prostrata*, *Gentiana nivalis*, *G. tenella*, *Galium silvestre*, *Hieracium alpinum*, *Taraxacum lævigatum*. In the same year I collected near Hvalvatn (378 metres) the following species: — *Juncus triglumis*, *J. trifidus*, *Eriophorum angustifolium*, *Carex chordorrhiza*, *C. dioeca*, *C. Goodenoughii*, *C. lagopina*, *C. pulla*, *C. rariflora*, *C. rigida*, *Aira cæspitosa*, *A. flexuosa*, *Anthoxanthum odoratum*, *Festuca ovina*, *Phleum alpinum*, *Poa glauca*, *Tofieldia borealis*, *Loiseleuria procumbens*.

South of the great Jökulls the vegetation generally extends further upwards on the plateau than to the north of them, but here also there are vast deserts of gravel, lava and blown sand, with a few widely separated oases, but it is especially the tracts between

[1] Determined by O. Gelert.
[2] Determined by O. Gelert.

Thjórsá, Skaftá and Mýrdalsjökull which are desert-like in character, and here there are also several bare tuff-ridges with numerous peaks. The sand is constantly drifting through the valleys and destroying all vegetation; only upon the highest ridges and peaks, which cannot be reached by the coarser grains of the drifting sand are seen several yellowish-green patches of mosses, and also along streams and around springs the moss-vegetation is sometimes fairly luxuriant and forms rather large green patches in places where very few or no phanerogams have been able to gain a foothold. Around Tjaldvatn (588 metres) in Veidivötn there is a considerable vegetation of different species; in 1889 I collected here the following plants: *Carex rigida*, *Poa pratensis*, *Festuca ovina*, *Salix glauca*, *Montia rivularis*, *Ranunculus acer*, *Batrachium paucistamineum*, *Thalictrum alpinum*, *Koenigia islandica*, *Empetrum nigrum*, *Rhodiola rosea*, *Parnassia palustris*, *Chamænerium latifolium*, *Hippuris vulgaris*, *Euphrasia latifolia*. Near Thorisvatn (591 metres) which is situated in the centre of large sandy deserts quite bare of vegetation, I found only *Salix glauca*, *Chamænerium latifolium* and *Carex rariflora*. On Blesamyri (535 metres) near Tindfjallajökull I found *Carex rigida* and *C. rariflora*. Near Hitalaug (650 metres) east of Torfajökull, in the neighbourhood of hot springs I found *Coeloglossum viride*, *Saxifraga stellaris*, *Sibbaldia procumbens*, *Pirola minor*, *Vaccinium uliginosum*, *Veronica alpina*, *Gnaphalium Norvegicum*, *G. supinum*, *Hieracium alpinum*. Near Hvannabotnar (434 metres) in the neighbourhood of Skaftá I collected: — *Equisetum palustre*, *Luzula campestris*, *Carex rigida*, *Calamagrostis stricta* f. *borealis*, *Anthoxanthum odoratum*, *Sibbaldia procumbens*, *Epilobium lactiflorum*, *E. Hornemanni*, *Gnaphalium Norvegicum*. Though the above list is naturally very incomplete owing to the author having had other work in hand (geographical survey and geological investigations) which left him no time for thorough botanical investigations or collections, yet these notes have been included here as these parts of the plateau are very difficult of access and are hardly ever visited by naturalists.

Outside the deserts in central Iceland, and nearer to the sea, there are also many, large and small, high-situated rocky areas and broken groups of rocks, pieces of plateau, and isolated peaks in the numerous mountain-spurs which extend between the branching valleys and fjords. The vegetation of these rocks is also very little known, but it resembles very much that of the plateau, only, it is usually richer in species. Highest up on the mountains, at an alti-

tude of 600—800 metres, there are usually gravelly tracts with scattered individuals of rocky-flat plants, such as *Silene acaulis, S. maritima, Cerastium alpinum, Luzula arcuata, Polygonum viviparum, Armeria maritima, Ranunculus glacialis, Saxifraga nivalis, S. oppositifolia* and others. In small damp hollows where the snow persists for a long time there is often a characteristic dense growth of *Salix herbacea*, which almost entirely conceals the moss-covering of the ground, together with *Sibbaldia procumbens, Gnaphalium supinum, Oxyria digyna* and *Polygonum viviparum;* in some places these are associated with several other plants. In other places there are small patches of Grimmia-heaths with scattered specimens of *Pedicularis flammea* or *Cassiope hypnoides.* Here and there streams and bogs occur with *Carex rigida, C. lagopina, C. rostrata, C. incurva* and others, but most often with *Eriophorum angustifolium* and *E. Scheuchzeri.*

As has been seen from the preceding notes on the vegetation of the plateau it is not easy to determine the altitudes or upper limits of the different plant-regions. Of the Scandinavian upper zones, the region of conifers is entirely absent, but, on the other hand, we may be justified in speaking of a birch-region, of an osier-willow region, and perhaps a lichen- or moss-region, but these regions pass into one another in many ways, and overlap. During the period after the Ice Age (the *Purpura-lapillus* Period) when it was warmer than it is now, the birch grew everywhere in the lowlands even on the northernmost headlands, but it had already retired from the latter at the time the first settlers came to the island, and since then, as we have already seen, its distribution has been considerably limited owing to the interference of man and sheep. The present Polar limit of *Betula odorata* in Iceland has not been fully investigated, but judging from what I saw on my journeys it appears, on the east coast, to extend across Vopnafjördur to the west coast of Melrakkasljetta, across Axarfjördur and Skjálfandi to Eyjafjördur near the mouth of the valley of Fnjóskadalur. The stretch of land between Eyjafjördur and Hunaflói is now devoid of birch coppices, although these occurred there in olden times; how far out they extended at that time upon the peninsulas between the fjords is not known. From Hunaflói the northern limit of the birch extends from Steingrimsfjördur to Isafjardardjup. This is, however, only quite a provisional limit; the subject requires to be investigated more closely. As regards the upper limit of the birch, it differs considerably in different parts of the island; it extends highest in Thingeyjarsysla

— near Myvatn to 550 metres. Birch coppices occur on the mountains of Vindbelgur (540 metres) and Dalfjall (550 metres). In olden times there were in Króksdalur and Yxnadalur — a continuation of Bárdardalur — considerable woods up to 450 metres. On the south coast the birch coppices do not as a rule extend so far upwards on the mountains; in Kollumuli near Lón birch coppices oc-

Fig. 27. Woods in Hallormstad; June 1909.
(Phot. A. Hesselbo.)

cur, however, at a height of about 500 metres, but, nowhere else along the south coast did I find birch coppices at that altitude. The forest of Nupsstadaskogur, south of Vatnajökull, reaches to an altitude of 400 metres, Bæjarstadaskógur in Øræfi to 320 metres, and coppices in Haukadalsheidi to 380 metres, but in the southern lowlands the limit for birch coppices usually occurs at a height of 200—300 metres; in some places at a slightly higher, in others at a slightly lower level. According to the Ordnance map the upper limits of the coppice-woods in South Iceland are as follows: —

Skaftafell in Øræfi	280	metres
Jökulfell (Bæjarstadaskogur)	320	—
Nupsstadaskogur	400	—
Thorsmörk	320	—

Markhlidar	250	metres
Burfell near Thjórsárdal	300	—
Skridufellsskogur	220	—
Tungufellsskogur	260	—
Haukadalsheidi	380	—
Uthlidarhraun	320	—
Laugardalsskogar	280	—
Thingvallaskogar	200	—
Botnsskogur	200	—
Skorradalur	150	—
Svinadalur	200	—
Husafellsskogur	260	—
Hvitársida	300	—

Although it is possible that birch coppices may be met with in some places at a somewhat higher level yet the limits will be approximately those given above. On the north-western peninsula, birch coppices occur mostly on the southern side at the head of the valleys and fjords which extend upwards from Breidifjördur and face the sun; but the birch coppices extend hardly anywhere higher than 200—300 metres, and usually occur at far lower levels. There is also a good deal of birch coppice at the branch-fjords of Arnarfjord, in Dyrafjord and at the southern fjords of Isafjardardjup, especially at Hestfjördur. North of Isafjardardjup I nowhere saw birch coppices proper, although a few individuals of *Betula odorata* occur in some places in Adalvik; nor are birch coppices known to occur on the east coast from Cape Nord to Steingrimsfjord.

To the birch region belongs also *Sorbus aucuparia* which occurs as scattered individuals both in the birch coppices and outside them; I do not think the mountain ash extends so far up as does the birch; I did not observe it at higher altitudes than on Sluttnes in Myvatn, 290 metres above sea-level. *Betula nana* occurs now and then in birch woods, but grows most commonly on heather moors and in bog-lands; it rarely forms coppices proper. It extends higher on the mountains than *Betula odorata*; I found it, for instance, in Sydri Pollar, 729 metres above sea-level. *Juniperus communis* is fairly common in birch coppices and on heather moors; the highest altitude at which I found it was in Yxnadalur near Odádahraun, 488 metres above sea-level. The heather moor is closely associated

with the birch region, and it probably rarely extends higher than 300—400 metres above sea-level as an aggregate plant-formation; but several of the different species of which the heather-moor is composed extend far higher up on the mountains without forming any heath-like associations, occurring as a few individuals only. I found *Vaccinium uliginosum* at the highest level (729 metres) near Sydri Pollar, and also *Dryas octopetala* at the same place; *Empetrum nigrum* extends to a similar height, and I came across a stunted specimen even on the top of Botnssulur at an altitude of 1108 metres. *Cassiope hypnoides* extends to a great height also; it is found, among other places, on Hlidarfjall at 790 metres above sea-level, and may perhaps extend even higher. *Loiseleuria procumbens*, on the other hand, did not occur at a higher level than 400—500 metres. *Calluna vulgaris*, *Arctostaphylus uva ursi* and *Vaccinum Myrtillus* were found near Myvatn at an altitude of about 400 metres, but I do not think they extend higher than the limits of the heather moor.

Above the upper limit of the birch region an osier or a willow region may be said to occur — in the centre of the country at an altitude of 500—800 metres, in other places somewhat lower — where willows are dominant among the woody plants, although they have their greatest distribution at a far lower level, in the birch region itself. At this altitude they do not form any coppice proper, but occur as flat expanses of low prostrate shrubs. Above the birch region it is especially *Salix herbacea*, *S. lanata* and *S. glauca* which are the dominants; *Salix phylicifolia* retires, although small specimens of the latter also are now and then met with even at this altitude. *Salix lanata*, and to some extent *S. glauca*, occupy large areas of the lower parts of the plateau, e. g. in Fjallasveit, Myvatnsöræfi, Sudurárbotnar, and several other places; they are of great importance to sheep-breeding, and in some places quantities of willow leaves are gathered as winter-fodder for sheep and cattle; in the lowest part of this zone *Betula nana* occurs now and then. In the centre of the country above 800—900 metres and up to the snow-line at an altitude of 1000—1400 metres, mosses and lichens are undoubtedly the dominant plants, although a few widely scattered phanerogams also occur. *Salix herbacea* extends also through this region to the snow-line; here and there, the most hardy of the previously mentioned rocky-flat plants occur as somewhat scattered individuals, but the main vegetation consists of mosses, although these do not occur in any great abundance compared with the vast

areas. Mosses often form an edging or fringe around loose stones on gravelly flats or also cushions on heaps of stones or in rock-crevices. On the highest situated and most inhospitable rocky and gravelly tracts, where storms are constantly driving sand and gravel across the surface, not even mosses can thrive, and the ground is quite bare. A few species of lichens *(Cladonia* and *Cetraria)* are sometimes found in the moss cushions, but usually they occur only as crusts on blocks of rock. Here and there on clayey soil in depressions crusts of liverworts occur, especially *Anthelia nivalis*, often associated with *Grimmia hypnoides* and *Salix herbacea*; round pools and along streams, cushions of bright green mosses are often seen, in which some flowering plants have sometimes found a home. In other parts of the country, the three regions mentioned here occur at a lower level, since they are correlated with the altitude of the snow-line in the different parts of the country.

V. A SKETCH OF THE CHIEF PLANT-FORMATIONS OF ICELAND.

We will now give a brief account of the commonest and, from a geographical point of view, most important plant-formations of the land-vegetation of Iceland, without, however, entering into details or into local deviations of the different plant-associations. This account is based partly on my own observations and partly on those published by others; I have especially made use of Dr. Helgi Jónsson's numerous excellent descriptions of the vegetation-forms of Iceland. Here I shall confine myself to the purely geographical distribution without entering more closely into relations of causation, or into questions of general ecology, which will no doubt be exhaustively discussed later on. The division into plant-formations and -associations is as yet, in many respects, dependent upon individual opinion. In the following, with the exception of a few deviations, I am adopting Dr. H. Jónsson's main divisions. Dr. Jónsson is the most experienced investigator of the vegetation of Iceland, and has described the plant-life from many more parts of Iceland than has anyone else. But much work remains to be done by future investigators; the vegetation-conditions from more than one-half the total area of the island are still to be described, and so many local variations, and such varied associations occur within the larger formations that it will be a long time before the details from everywhere are well-known. The following is only a brief account for the general orientation of the larger plant-formations and of the chief points regarding the distribution of the higher plants according to present knowledge[1].

[1] Besides the above-mentioned works on the flora of Iceland, there are the following descriptions of the vegetation: — Chr. Grönlund: Karakteristik of Planteväxten paa Island, sammenlignet med Floraen i flere andre Lande (Naturhistorisk Forenings Festskrift, 1890 [printed 1884], pp. 107—145). C. H. Ostenfeld: Skildringer af Vegetationen paa Island (Botanisk Tidsskrift, XXII, 1899, pp. 227—

The Vegetation of the Coast-line. The halophilous plant-associations along the greatly extended coast-line of Iceland have, as in other places, a rather heterogeneous soil consisting of fine and coarse strand sand, large pebbles or boulders, blown sand and rocks of basalt and tuff. Very generally round the coast there is seen upon low rocks[1], at the foot, a belt of *Verrucaria maura*; then come grey, yellow and green patches of several kinds of lichens; above this level only a few plants occur, mostly scattered individuals of *Cochlearia officinalis*, *Plantago maritima*, *Armeria maritima* and *Glyceria distans*. On steep, lofty coast-cliffs *Cochlearia officinalis* and *Rhodiola rosea* often occur in great abundance, also *Silene maritima*, *Armeria maritima*, *Cerastium alpinum* and various species of *Poa* and *Festuca*; to these should be added *Haloscias scoticum* in south-western Iceland and especially on the islands in Breidifjördur. As is well-known, there are several large sea-fowl cliffs along the coast of Iceland, but their vegetation has not yet been investigated; H. Jónsson has investigated only a few smaller sea-fowl cliffs in Dalasyssel and "sea-fowl-grass-slopes" (Fuglegræslier) in Skaftafellssyssel. According to H. Jónsson (1905, p. 37) the grass-covered mountain-slopes in South Iceland frequented by sea-fowl differ from the common grass-slopes, among other things in the abundant occurrence of *Poa pratensis* and *Stellaria media*; the occurrence of *Festuca elatior* and *Avena elatior* on "sea-fowl-grass-slopes" is also characteristic of the latter. The vegetation of the lofty sea-fowl cliffs appears principally to consist of the same plants as are found on common coast-cliffs, for instance, *Cochlearia*, *Rhodiola*, *Archangelica*, as also *Oxyria* and *Stellaria*; all growing luxuriantly. Owing to the soil being manured there is an immigration of many other species, especially from the grass-slope and the grassland; these species grow as luxuriantly in rock crevices and on ledges as in the most well-manured home-fields. Collections of plants from these sea-fowl cliffs have never been made; the plants being extremely difficult of access.

253; XXVII, 1905, pp. 111—122). Th. Thoroddsen: Planteverdenen paa Island (Salmonsens Leksikon, IX, 1899, pp. 606—607). Helgi Jónsson: Studier over Øst-Islands Vegetation (Bot. Tidsskr., XX, pp. 77—89). Vegetationen paa Snæfellsnes (Vidensk. Medd. fra naturh. Foren. i København, 1900, pp. 15—97). Vegetationen i Syd-Island (Bot. Tidsskr.. XXVII, 1905, pp. 1—82). Vegetationen paa Island (Atlanten, 1904, pp. 41—50). Gróðrar- og Jarðvegsrannsóknir (Búnaðarrit XX, 1906, pp. 146—181; XXIII, 1909, pp. 41—54). Fyrirlestur um gróður Islands (Búnaðarrit, XXI, 1907, pp. 6—20). Bygging og líf plantna, København, 1907, pp. 289—300.

[1] Cf. Eug. Warming: Dansk Plantevækst, I, København, 1906.

On the strand sand, especially in South Iceland, there is a fairly characteristic vegetation of *Halianthus peploides*, *Cakile maritima*, *Atriplex patula*, *Stenhammaria maritima* and *Potentilla anserina*; often, each of these species occurs separately and in abundance, but sometimes they are found intermixed in various ways. *Cakile maritima* usually occurs nearest to the sea, and *Potentilla anserina* at the highest levels, occupying large areas, and occurring so abundantly that the ground is quite interwoven by its creeping shoots. On the strand sand are also seen in small numbers *Cochlearia officinalis*, *Matricaria inodora*, *Silene maritima*, *Polygonum aviculare*, *Stellaria crassifolia*, *S. media*, *Capsella bursa pastoris*, *Glyceria distans*, *Festuca rubra*, *Elymus arenarius*, *Carex incurva*, etc. On the vast sandy stretches along the south coast blown-sand formations are frequent nearest to the sea; here *Halianthus peploides* and *Elymus arenarius* occur in tufts; above this belt of sand dunes, tracts are found occupied by a vegetation richer in species and consisting of *Potentilla anserina*, *Festuca rubra* var. *arenaria*, *Thymus serpyllum*, *Galium verum*, *Achillea millefolium*, *Juncus balticus*, and several others. But below the glacier-bearing mountains (Jökulls) the strand sand quickly merges into glacier sand, which forms sandy wastes extremely poor in plant-life.

At several places along the coast of Iceland salt-marshes are found, overflowed by salt water, for example in Borgarfjördur, Myrar, Hornafjördur and Lón. In Myrar the dominant species are *Glyceria maritima*, *Agrostis alba*, *Plantago maritima*, *Stellaria crassifolia*, moreover *Heleocharis uniglumis*, *Triglochin maritima*, *Juncus bufonius*, several species of *Carex*, etc. H. Jónsson found that in some places two-thirds of the area was occupied by *Glyceria maritima* and one-third by *Agrostis alba*, each species occurred separately in patches; some thick-leaved *Plantago maritima* occurred, however, in the *Glyceria patches*[1].

The Vegetation of the Fresh Water. Plant-life occurs very sparingly in running water, and where strong currents are felt it is usually absent. Nor do plants appear to thrive in glacier-rivers; this is probably due to the low temperature of the water and the current. In slowly flowing river-arms on level land, in rivulets and brooks there is often a considerable quantity of green algæ (*Zygnema* and *Spirogyra*), both at the bottom and upon the surface; in South Iceland *Enteromorpha intestinalis* is common in streams. The fol-

[1] Bunadarrit, XX, 1906, pp. 150, 151.

lowing mosses are found on stones in rivulets and brooks: *Fontinalis antipyretica* very frequently, also *F. gracilis* and *F. thulensis*, *Amblystegium Kneiffii*, *A. ochraceum*, *Hypnum rusciforme* var. *atlantica*, and others[1]. The vegetation of lakes and pools is much richer and differs considerably according to the depth of the water and the nature of the bottom, etc. The plankton of the Icelandic lakes has as yet been very little investigated; there are only a few notes to hand from Myvatn and Thingvallavatn. In Myvatn zooplankton only was found; Thingvallavatn contained phytoplankton in which diatoms were dominant[2]. In deep lakes there is usually very little or no vegetation at greater depths, only in places where it is shallower does plant-life occur. In Thingvallavatn, however, there are large areas covered with *Chara* and *Nitella*, especially at a depth of 13—30 metres, and they extend even down to 38 metres[3]. Where the lakes are shallower various species of *Potamogeton* and *Myriophyllum* and also *Batrachium paucistamineum* are common. Near the margin and in smaller pools the most common, and usually dominant, species are the following: *Heleocharis palustris*, *Equisetum limosum*, *Carex rostrata*, *Menyanthes trifoliata*, and in the southern lowlands *Glyceria fluitans* is common; to these should be added *Hippuris vulgaris*, *Eriophorum angustifolium*, *Sparganium minimum*, *S. submuticum*, *Ranunculus hyperboreus* and *R. reptans*, *Subularia aquatica*, *Callitriche hamulata* and *C. verna*, *Limosella aquatica* and several others, the occurrence of which varies somewhat according to the quantity of the water, the conditions at the bottom, etc. Where *Equisetum limosum* occurs in abundance it is cut annually and used for fodder for milch cows. In Myvatn and in other lakes in Thingeyjarsysla *Nostoc*-lumps are found in abundance, often thrown up on the shore in very great quantities. Sometimes in warm summers large areas of Myvatn become turbid; this phenomenon is known by the inhabitants as "leirlos" — it is said to be very injurious to salmon-trout, their gills becoming filled with the fine particles — when this occurs they retreat in great numbers to the eastern shore of the lake, where the water is purer and clearer owing to the numerous springs which here issue from the lava[4].

[1] H. Jónsson, 1900, p. 17, 1905, p. 7.

[2] C. H. Ostenfeld and C. Wesenberg-Lund: A Regular Fortnightly Exploration of the Plankton of the two Icelandic Lakes, Thingvallavatn and Myvatn. (Proc. R. Society Edinburgh, Vol. 25, Part 12, 1906, pp. 1092—1167).

[3] B. Sæmundsson in Andvari, 1904, p. 89.

[4] Dr. H. Jónsson informs me that the so-called "leirlos" is probably due to Blue-green Algæ perhaps *Aphanizomenon flos aquæ*.

Springs (kaldavermsl, dy[1]) are very common in Iceland, and are found in almost every valley below the mountain-sides or appear in rows upon the ledges of the basalt-layers. The peculiar vegetation connected with these streams is widely distributed below the mountain-sides and often occurs in the midst of other formations or high up on the mountain-sides in narrow zones in places where other vegetation is wanting. This vegetation is characterized especially by the fresh bright-green colour of the mosses; *Philonotis fontana* is everywhere the dominant plant, but many other species of moss also occur, especially *Pohlia albicans* var. *glacialis*, and various species of *Bryum*, *Amblystegium*, and several other genera. Several phanerogams occur among the mosses, the most common are *Epilobium alsinefolium*, *E. Hornemanni*, *Cerastium trigynum*, *Montia rivularis*, *Saxifraga stellaris*, and *Catabrosa aquatica*, sometimes associated with *Ranunculus hyperboreus* and *Caltha palustris*, *Marchantia polymorpha*, etc. As this spring-vegetation usually occurs close to bogs and swampy tracts, there are often transitions to bog- and swamp-vegetation.

Vegetation around Hot Springs. Peculiar to Iceland is the characteristic vegetation near hot springs. The heat of the soil and the hot water create exceptionally favourable conditions for plant-life, so that species which otherwise do not grow in Iceland can thrive here, and species from South Iceland which do not otherwise grow in North Iceland also occur here near hot springs. It is to be regretted that the vegetation connected with these springs has been more closely investigated in a few places only[2]. It is especially the rich algal flora, which for instance is of great importance as regards the separation of silica from the hot water, which requires investigation. The vegetation around the hot alkaline springs is usually very luxuriant and may extend over fairly large areas, because the aqueous vapour floats above the surroundings and descends as a continuous, drizzling rain of tepid water. The plant-associations may differ somewhat according to local conditions, as to whether the surroundings are damp or dry, gravelly or rich in humus. Where the surroundings of the springs consists of a hard grass-bottom, the following

[1] In Iceland the word "dy" is also applied to small pools in swampy tracts.

[2] Plant-life near the hot springs has been investigated especially by C. Ostenfeld, Bot. Tidsskr., vol. 22, 1899, pp. 299—245; by Chr. Grönlund: Karakteristik af Planteværten paa Island, pp. 33—35 and by Japetus Steenstrup and F. M. Liebmann, Forhandl. v. d. skandin. Naturforskeres 2. Møde 1840, København, 1841, pp. 336 – 340.

plants are common: *Potentilla anserina*, *Leontodon autumnalis*, *Trifolium repens*, *Brunella vulgaris*, *Gnaphalium uliginosum* and *G. silvaticum*, *Hydrocotyle vulgaris*, *Ranunculus acer*, *Sagina procumbens*, *Spergula arvensis*, *Plantago major*, *P. maritima* f. *pygmæa*, *Polygonum persicaria*, *P. aviculare* and various Gramineæ, and sometimes *Vicia cracca*. Where it is damper occur *Epilobium palustre*, *E. alsinifolium*, *Cardamine multicaulis*, *Montia rivularis*, *Limosella aquatica*, *Juncus lamprocarpus*, *J. bufonius* and some *Carices*. The composition of these groups of species differs however considerably at the different kinds of springs. Of vascular plants the following have been observed exclusively near alkaline hot springs: *Hydrocotyle vulgare*, *Gnaphalium uliginosum*, *Veronica anagallis*, *Polygonum persicaria;* rare outside the range of influence of hot springs are *Galeopsis tetrahit*, *Plantago lanceolata*, *P. major* and *Blechnum spicant*. Moreover, C. Ostenfeld enumerates eight species of mosses which have been found only on warm soil, and three species which are especially connected with a warm ground. In North Iceland some species grow only near hot springs, which in South Iceland thrive also outside the area of the warm soil, for instance, *Brunella vulgaris*, *Plantago lanceolata*, *Cardamine multicaulis* and *Drosera rotundifolia*. In the outlets from both the warm and hot springs an abundance of algæ often occurs — often in a great heat — which have not as yet been investigated. Near solfataras vegetation is extremely sparse, and in the immediate neighbourhood of the sulphurous-acid fumaroles no plant-life can thrive, therefore only bare clayey flats occur there. *Ophioglossum vulgatum* grows only near solfataras; in 1882 I found at Bjarnarflag near Myvatn scattered, but numerous, specimens of it on clayey ground which had a temperature of 27°C. — it occurred together with *Sagina procumbens* and *Poa pratensis*; and in 1883 I found it near Gunnuhver on Reykjanes also on warm clay in the neighbourhood of sulphur springs. In both localities it occurred together with the otherwise rare *Riccia bifurca* and *Chomocarpon commutatus*. C. Ostenfeld found it on Reykjanes in the neighbourhood of steaming holes, "first a crust was found held together by a *Stigonema*-species, then a great many Muscineae of which the most characteristic were *Riccia bifurca* and *Chomocarpon commutatus*. Amongst them occurred some other mosses: *Pohlia nutans* v. *filicaulis*, *Fossombronia Dumortieri*, *Bryum ventricosum*, *Fissidens osmundioides* and *Philonotis fontana*, moreover, the characteristic *Ophioglossum vulgatum* var. *polyphylla*" (loc. cit. p. 240).

Ostenfeld also describes the vegetation near the boiling mud-pools, and writes: "Close to the mud-pools the ground is quite bare, and not until some distance from them do plants begin to appear; nearest to them occurred *Agrostis alba* forming a net-work with its long rhizomes, and beyond this came a dense, low carpet of *Sagina procumbens*, *Cerastium vulgatum*, *Plantago major* (dwarf-form), *Stellaria media* and a great abundance of *Grimmia hypnoides*; somewhat further off many other plants occurred." "The vegetation near the outlet of the large mud-pool Gunna was characteristic and peculiar; here the damp ground (about 30°C.) was covered by a pure, green carpet of *Nardia crenulata* in which only one other plant occurred, viz. *Juncus bufonius*; within there was firm soil the particles of which were held together by moss-protonema. The moss-carpet became brownish-red where the ground was drier, but it was only *Nardia* which changed colour; some mosses occurred, however, along the outer edge ....., but only as a subordinate component" (loc, cit. pp. 239, 240). Near numerous solfataras in the neighbourhood of Myvatn, on Odádahraun, Kerlingarfjöll, Torfajökull, and in several other places no vestige of plant-life occurs.

Vegetation on Wet Soil (bogs, pools, swamps and wet meadows). Bog- and swamp-land (myrar) is very extensively distributed in Iceland, both on the plateau and in the lowlands and valleys; these tracts are also of great economic importance, as in the inhabited districts the grass is cut for hay, and the hay (úthey) is used as winter-fodder for sheep and ponies. In Iceland the swampy meadow-tracts are divided according to their water-content into two main divisions, myri (pl. myrar) and flói (pl. flóar); the soil of the former is firm and tough owing to the interwoven roots and rhizomes; in the latter the soil is rotten, and more loosely connected, so that cattle thrust their legs through it and easily get stuck fast; in the former the surface is saturated with the ground water, but in the latter the water reaches to the surface or slightly above it, consequently here pools of all sizes abound. Upon the flat surface of the "myrar" small cone-shaped knolls usually occur, and in "flóar" water-channels and swampy holes are often found between the knolls. The vegetation is far denser and more continuous in the former than in the latter. The dominant species in the swampy "flói" are *Carex chordorrhiza*, *Eriophorum angustifolium* and *Scirpus cæspitosus*, and frequently occurring species are *Carex rostrata*, *C. saxatilis*, *C. Goodenoughii*, *C. limosa*, *C. rariflora* and several other *Carices*, as also

Menyanthes trifoliata, *Equisetum limosum*, *Heleocharis palustris*, etc. Upon the knolls, which are dry, many other plants occur, often *Betula nana*, *Vaccinium uliginosum*, *Salix glauca*, etc. The ground-vegetation consists of several species of mosses, *Amblystegium*, *Sphagnum*, *Hylocomium*, and others. On the mountains *Eriophorum*-bogs are very frequent and *Carex*-bogs of rarer occurrence, but in the lowlands the reverse is the case. Moss bogs with different aquatic

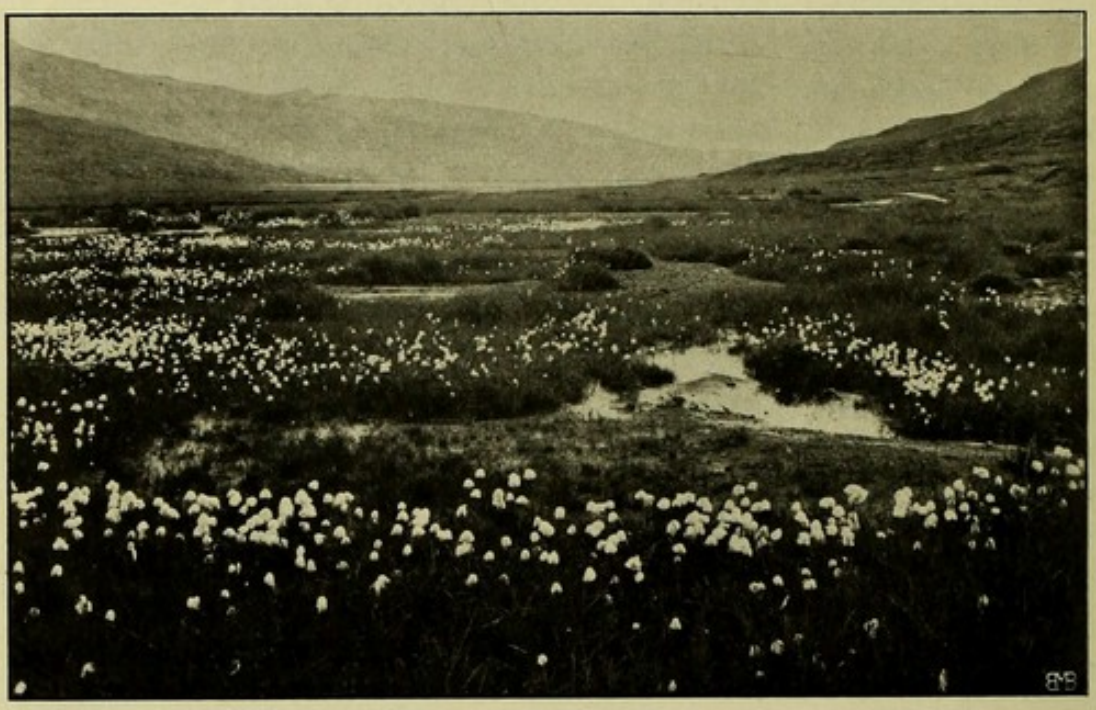

Fig. 28. Geitabergsvatn. Flooded meadow with *Eriophorum* and *Carex*. (Phot. A. Hesselbo.)

vegetation, as at the above-mentioned springs, often occur in these swampy tracts, and pools with *Equisetum limosum*, *Hippuris vulgaris*, *Menyanthes* and *Sparganium*. The Icelandic "myrar" are richer in species and have a denser vegetation than the "flóar." The dominant plants are *Carex cryptocarpa* and *C. Goodenoughii*, but in addition many other species of *Carex* occur, viz. *C. rariflora*, *C. canescens*, *C. microglochin* and others, moreover, *Eriophorum Scheuchzeri*, *Equisetum palustre*, *Comarum palustre*, which are characteristic of wet meadows, *Caltha palustris*, *Parnassia palustris*, *Cardamine pratensis*, etc. Almost everywhere the above-mentioned genera and many others are associated with a moss-bottom. Sometimes some *Gramineæ*, *Polygonum viviparum*, *Euphrasia officinalis*, etc. occur upon the knolls, and in south-west Iceland, here and there on moss-covered knolls, *Drosera rotundifolia*. From the outer edge of the

water-saturated tracts, where the ground is becoming drier, are easy transitions to other plant-formations, such as grassland, heather-moor, etc.

Rocky flats. Of all plant-formations, the rocky-flat-formation occupies the largest area in Iceland, and is the one which characterizes by far the greatest part of the island. In favourably situated localities nearest the coast it passes into a "herb-flat" (Urtemark) with

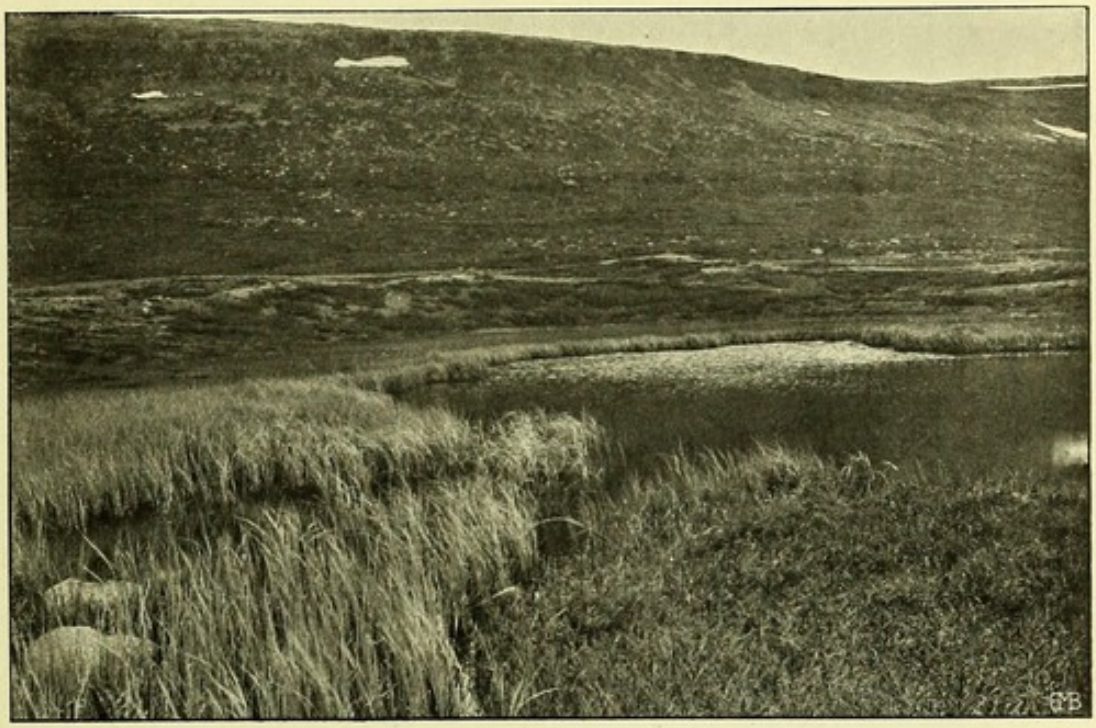

Fig. 29. Lake near Armuli, with *Carex rostrata*.
(Phot. A. Hesselbo.)

a dense vegetation of different plants, and with some mosses and lichens; but usually the plants are too scattered to have any influence worth mentioning upon the appearance of the landscape. The vegetation of the rocky flat, which includes a great proportion of all the plant-species of the island, may be divided into many sections according to soil-conditions. On climbing higher up on the plateau we find that species and individuals become fewer in number and more scattered in growth, and as already stated, in the highest parts of the plateau only a few stunted, widely separated plants occur. On rocky flats situated at high levels mosses play an important part, especially *Grimmia hypnoides*, which gradually forms soil for higher plants; now and then some fruticose lichens are found intermixed with the mosses, and in many places on the

plateau patches of *Anthelia nivalis* occur. The rocky-flat-formation appears to be an original, late Glacial formation from which a great many distinct formations have developed, the different species having become associated according to their conditions of life. The outer limits of the rocky flat are the Grimmia-heath and the "herb-flat," but transitional stages to heather-moor and grassland often occur. As sub-divisions or nearly related formations the following may be mentioned: — gravelly flats (melar), stone-covered ridges (holt); fallen blocks and debris upon mountain slopes (urd, pl. urdir), steep cliffs (hamrar), gravelly river-plains and river-terraces (eyrar), sandy tracts of various kinds, clayey flats and lava-streams.

Gravelly flats (melar) also occupy large areas in the lowlands; the soil-conditions differ somewhat, but generally the gravel is mixed with clay and then the surface often cracks into polygonal cakes and forms a "rudemark" (p. 257). These "rudemarks" greatly influence plant-distribution, as the plants generally resort to the gravel bands between the cakes, where they find shelter and protection. Sometimes gravelly flats are so poor in plant-life that they appear quite bare and naked; sometimes they are so densely covered as almost to form a "herb-flat." The most common plants on gravelly flats in the lowlands are *Cerastium alpinum*, *Arabis petræa*, *Draba hirta*, *Silene acaulis*, *S. maritima*, *Armeria maritima*, *Salix herbacea*, *Sagina nodosa*, *Spergula arvensis*, *Arenaria ciliata*, *Alsine verna*, *Thymus serpyllum*, *Dryas octopetala*, *Papaver nudicaule*, *Oxyria digyna*, *Rumex acetosella*, *Trisetum subspicatum*, *Poa glauca*, *Festuca ovina*, *Agrostis alba*, *Luzula multiflora*, *L. spicata*, etc. Naturally all the above-mentioned species do not occur together; in some places a great many of them may occur, while in other places a very few, perhaps only three or four, may be found. The vegetation is also somewhat dependent upon neighbouring plant-formations. Usually mosses or lichens are very sparsely present upon these gravelly flats in the lowlands; only here and there small Grimmia-cushions occur.

On stone-covered ridges (holt) there is usually a greater variety as regards soil and situation than on the gravelly flats, and the vegetation there is sometimes fairly luxuriant and conspicuous especially in early summer when *Silene acaulis*, *Dryas octopetala* and *Thymus serphyllum* are in bloom; these are very common there, and also the majority of the plants of gravelly flats. Moreover, the following are noteworthy: *Alchimilla alpina*, *Saxifraga cæspitosa* and *S. oppositifolia*, *Viscaria alpina*, *Empetrum nigrum*, *Sedum acre*

and *S. annuum*. As the environment of the ridges differs greatly — sometimes bogs, sometimes dry grassland, sometimes heather — the vegetation on the ridges also differs somewhat in the different districts owing to immigration from these plant-associations. Mosses

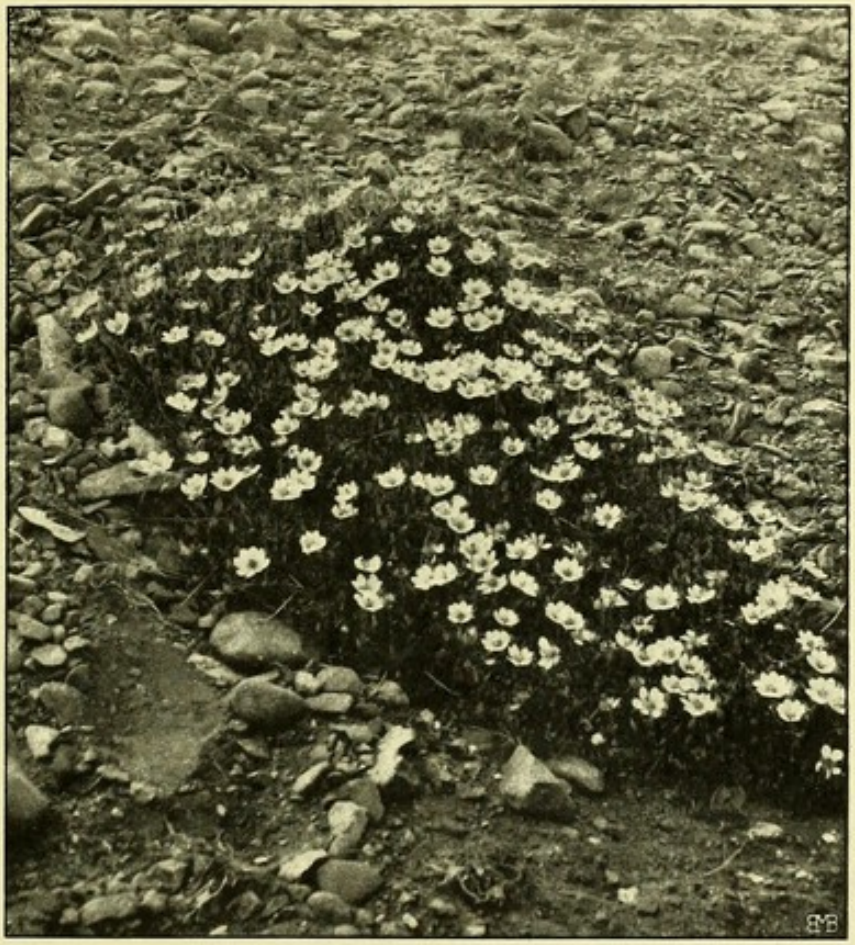

Fig. 30. *Dryas octopetala* (Vallanes; June 26, 1909).
(Phot. A. Hesselbo.)

are few in number, but there is often an abundance of crustaceous lichens, chiefly various species of *Lecideas* and *Lecanoras*, which often impart a strongly variegated appearance to the rocky boulders.

River gravel has one characteristic plant all throughout Iceland, viz. *Chamænerium latifolium*, the splendid, purple flowers of which occur in large patches upon gravel-tongues between branching rivers, and can be seen from a distance. Besides plants common to gravelly flats several willows often occur here, viz. *Salix glauca*, *S. lanata* and *S. phylicifolia*, and also *Saxifragaceæ*, *Galium verum*, *G. silvestris*, and others. Clayey flats with a denser vegetation and a soil rich in humus frequently occur at the outer edges of gravelly

flats; they have a characteristic vegetation consisting of *Koenigia islandica*, *Sedum villosum*, *Juncus alpinus*, *J. biglumis* and *J. triglumis;* moreover, *Epilobium palustre*, *Spergula arvensis*, *Sagina procumbens*, *S. nodosa*, *Stellaria crassifolia*, *Polygonum aviculare*, *Equisetum palustre*, *Triglochin palustris*, *Agrostis alba*, *Luzula spicata* and some other species occur frequently, which are distributed according to the water content, etc. of the clayey flats.

The vegetation of mountain-slopes is often only an extension of that of the rocky flats, with the difference that greater variations occur at the base of the mountains, the conditions there being more highly diversified: the stony tracts alternating with bogs, springs, grass-slopes, heather-moors, coppice-woods, etc. But frequently mountain slopes consists mainly of downward-gliding gravel-masses or angular rock-fragments, with little or no vegetation, the stone-covering being too unstable to permit plants to gain foothold; in other places are heaps of loose blocks of rock (urd) or solid rock-terraces or -faces; in many places mountain-streams excavate channels or deep ravines, and at the base of mountains they cause the formation of broad gravel-cones with branching streamlets with mosses and other plants connected with springs, or with transitions to bog-formations. On the rock terraces there is sometimes a soil-layer which, according to the conditions of moisture, supports either Gramineæ or Cyperaceæ. Therefore, on mountain-slopes, many different plant-formations are found in patches close to one another in many transitional stages. In the rock-detritus on mountain slopes which are not too steep, plants common on rocky flats occur, but none that are really characteristic; the following have been noted: *Silene acaulis*, *S. maritima*, *Alchimilla alpina*, *Dryas octopetala*, *Thymus serpyllum*, *Cerastium alpinum*, *Armeria maritima*, *Saxifraga cæspitosa*, *S. hypnoides*, *S. stellaris*, *Potentilla maculata*, *P. anserina*, *Sedum acre*, *Erigeron alpinus*, *Veronica saxatilis*, *Poa glauca*, *P. alpina*, and several others. Nor are there many characteristic plants in the vegetation of the rock-faces. Tuff and breccia mountains are generally richer in plants than basalt mountains, their surfaces having many more crevices and hollows in which plants can gain foothold. The following plants occur on steep mountain-sides: *Archangelica officinalis*, *Rhodiola rosea*, *Haloscias scoticum*, *Polypodium vulgare* and *Woodsia ilvensis*, also *Cochlearia officinalis*, especially on sea-fowl cliffs; *Saxifraga Cotyledon* grows only on rocks in south-eastern Iceland. Moreover, in rock-clefts various ferns occur, most frequently *Cystopteris*

fragilis, but also flowering plants, such as *Sedum annuum*, *Oxyria digyna*, *Plantago maritima*, *Saxifraga cæspitosa*, *Poa glauca*, *Festuca ovina*, and others. On damp rock-faces near large waterfalls these same species are met with, often as large, well-developed specimens (H. Jonsson, 1905, p. 30); also *Poa alpina* f. *vivipara*, *Aira alpina*, *Saxifraga hypnoides*, *S. stellaris*, *S. nivalis*, *S. cæspitosa* and several

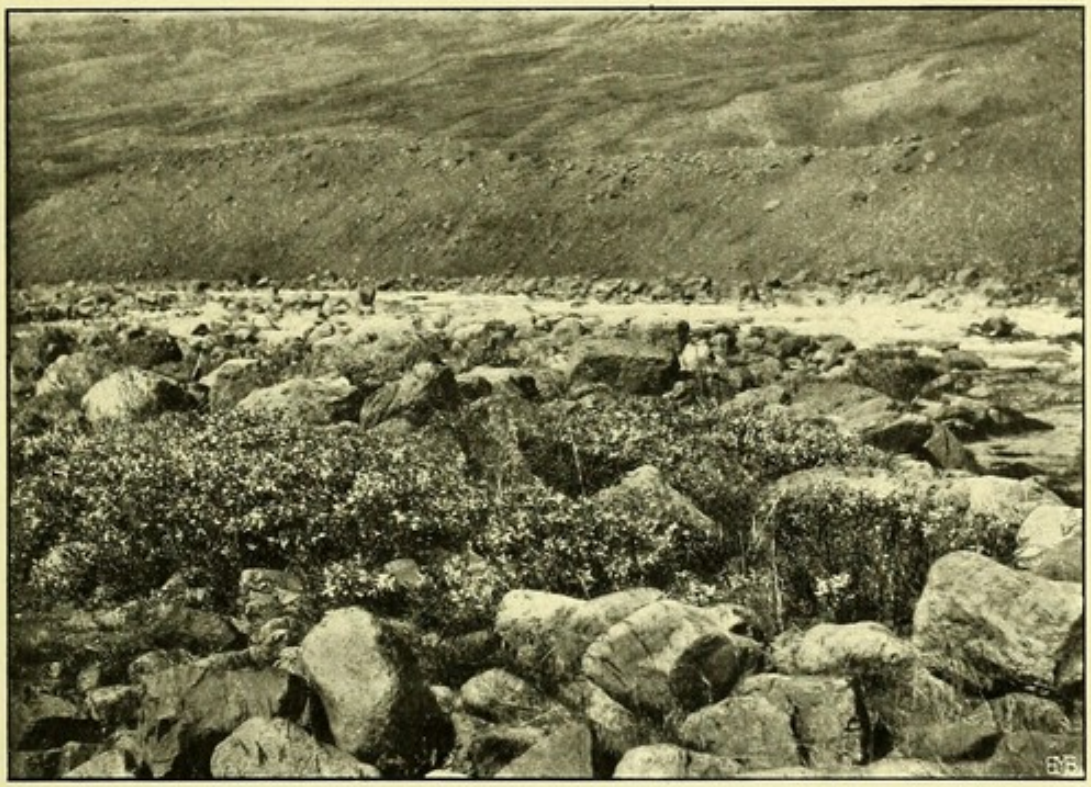

Fig. 31. The river Thverá in Öxnadal. *Epilobium latifolium* and *Aira* on a small gravel-island in the river; July, 1909.
(Phot. A. Hesselbo.)

species of mosses. Nowhere is seen so mixed and variegated a plant-society as on extensive, fairly densely plant-covered mountain slopes where the majority of the plant-formations are met with, in patches, side by side. On a talus of fallen blocks and débris (urd) there is often a considerable vegetation of lichens, mosses and liverworts. In some places, especially far up on the mountains, the sloping heaps of rock-fragments are poor in plants; in other places they carry a rich vegetation of ferns or willows and birch shrubs and heather, with a variable admixture of herbaceous plants from different formations, with no special character, the vegetation resembling closely that which occurs in ravines and lava-clefts.

Where the conditions of life are specially favourable; where the

situation is suited to plant-life with southern exposure, an adequate supply of water, shelter from sharp winds, and intense sunlight during spring a "herb-slope" (Urteli[1]) or "herb-flat" (Urtemark) is formed which on the one hand passes gradually into a rocky-flat formation, and on the other into a birch coppice; it chiefly contains the plants of these two formations, but the growth is dense and luxuriant, so that the ground often appears to be entirely covered by the closely-placed plants. Dicotyledonous flowering plants are the most important, grasses are absent or of subordinate importance. The soil consists of clay or gravel mixed with humus, upon which mosses sometimes occur. Such herb-slopes are found in patches on mountain-sides, on basalt-terraces or on the inclines below rocks, in large ravines and in sheltered, sunny hollows; they often form beautiful carpets, in which the various species usually occur intermixed with each other. As a rule, the dominant species are *Geranium silvaticum*, *Spiræa ulmaria*, *Archangelica officinalis*, *Angelica silvestris*, *Geum rivale*, *Bartschia alpina*, *Alchimilla vulgaris*, *Brunella vulgaris*, *Rubus saxatilis*, *Vicia cracca*, *Myosotis arvensis*, *Leontodon autumnalis*, several species of *Hieracium*, *Rumex acetosa*, *Ranunculus acer*, *Poa*, *Agrostis* and *Aira*; intermixed with these occur several other species, but less frequently. In some parts of the island other characteristic species are frequently noted in "herb-slopes," for instance in East Iceland, *Campanula rotundifolia* and *Saxifraga aizoides*, and in some places in South Iceland *Valeriana officinalis* and *Lychnis flos cuculi*.

Sand-covered tracts (sandar). As already mentioned, sandy tracts occupy vast areas — several thousand kilometres surface — in Iceland, both in the lowlands and on the plateau. The physical conditions of these "sandar" differ somewhat, therefore their vegetation, although usually homogeneous and poor in species, may now and then vary somewhat in details. The vast sandy wastes below the glacier-bearing mountains (Jökulls) of South Iceland are mainly formed of glacio-fluvial gravel and sand, but also partly of volcanic ashes and scoriæ, while there are wide stretches upon which both the fine and the coarse gravel is mixed with clay. Sometimes extensive stretches are occupied by alternating clayey flats and pebble-covered river-beds; there are also tracts strewn with ice-striated boulders, and extensive areas, especially on the plateau, covered

[1] Urteli (herb-slope) and Græsli (grass-slope; see p. 335) denote plant-covered slopes where dicotyledonous flowering plants and grasses are dominant respectively.

with blown sand. Where the sand-covered tracts reach the shore their outermost border supports a halophilous vegetation which, at a short distance from the coast, is replaced by the common plants of sandy soil and rocky flats. On gravelly tracts of sand in the lowlands the following plants are the commonest: *Silene maritima*, *Armeria maritima*, *Festuca rubra*, v. *arenaria*, *Carex incurva*, *Agrostis alba*, *Juncus balticus*, *Elymus arenarius* and *Potentilla anserina;* also *Galium verum* and *Thymus serpyllum*, often occurring in patches. Although the vast stretches of glacial sand in South Iceland have a fairly variable surface yet they are extremely poor in plant-life; owing to "glacier-bursts," and to glacier-rivers constantly causing floods and changing their courses, the vegetation has rarely the chance of development. On Skeidarársandur (cf. H. Jónsson, 1905, pp. 20—22) the following plants occur widely scattered: *Chamænerium latifolium*, *Arabis petræa*, *Silene maritima*, *Saxifraga oppositifolia*, *S. cæspitosa* and *Poa glauca*, also small patches of *Grimmia hypnoides;* but there are, in addition, large stretches quite naked and entirely destitute of plant-life. The main part of Myrdalsandur is a desert almost devoid of vegetation; far apart occur a few specimens of *Arabis petræa*, *Silene maritima* and *Elymus arenarius;* usually there is no vestige of plant-life, and one may ride for hours without seeing a single plant. In a few localities in Breidamerkursandur and Skeidarársandur there is open grass-vegetation in small oases where the sandy gravel from some cause or another has for some length of time escaped inundation by the ice-cold glacier water; in such places, in addition to *Chamænerium latifolium* there occurs usually *Agrostis alba*, *Poa alpina*, *P. glauca*, *Aira alpina*, *Calamagrostis stricta*, *Festuca ovina*, *F. rubra* v. *arenaria*, *Carex incurva*, *Juncus balticus*, *J. triglumis*, *Luzula spicata*, *Salix lanata*, *Oxyria digyna* and others. As may be seen, there is nothing specially characteristic in the vegetation of these tracts of glacial sand and if they were rescued from the destructive effect of the glacier-rivers, they would quickly become covered by the various plant-formations of the level country; we have already mentioned one such instance, when Brunasandur in 1783 was rescued from the inundations of glacier-rivers by a lava-stream, which pushed a large river aside.

Blown sand supports a somewhat more peculiar flora, the characteristic plant being *Elymus arenarius*; but where it is very mobile, as e. g. on the plateau in the neighbourhood of Fiskivötn and between Tungná and Skaftá, no plant-life can thrive on it.

Where the sand becomes more stable, or there is shelter, *Elymus arenarius* appears, often associated with *Festuca rubra* v. *arenaria;* not until the sand becomes somewhat fixed do other species appear, e. g. *Juncus balticus*, *Carex incurva*, *Agrostis alba*, *Festuca ovina*, *Silene maritima*, *Salix lanata*, *S. glauca* and occasionally *Halianthus peploides* in localities not too far away from the coast. Extensive

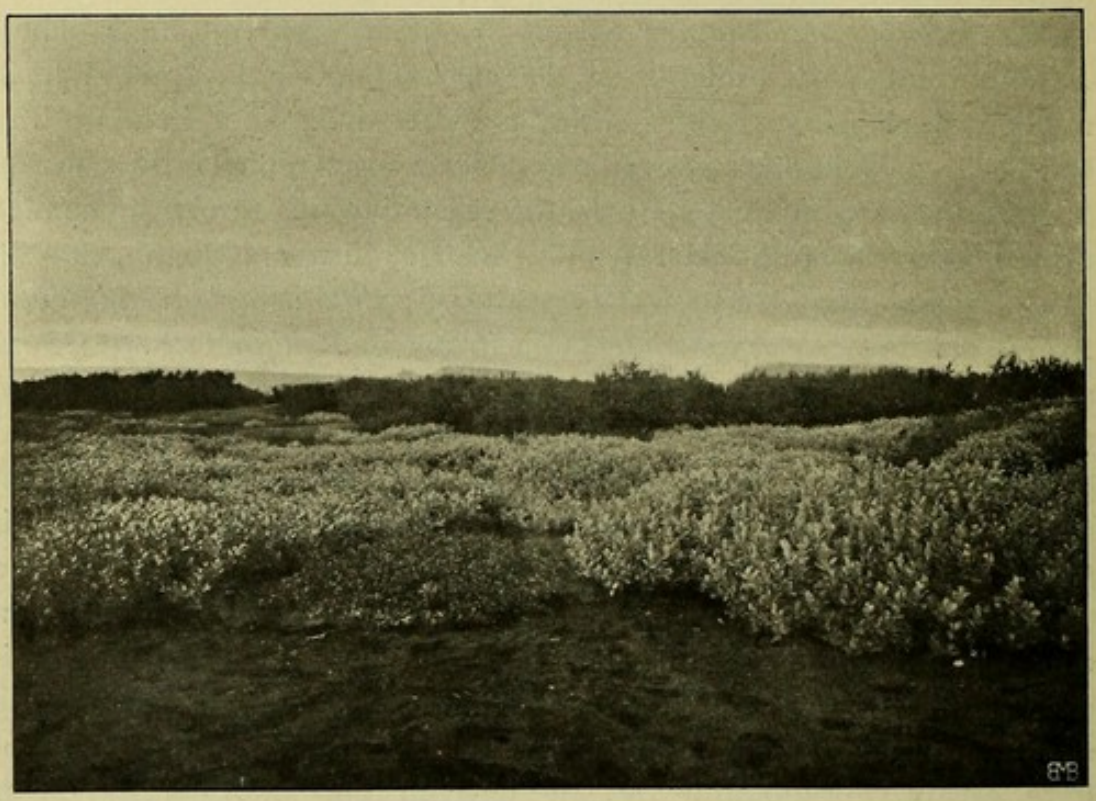

Fig. 32. *Salix lanata* and, in the background, *Betula odorata* growing in black blown-sand (volcanic ash) near Jökulsá, between 'As and Svinadal; July, 1909. (Phot. A. Hesselbo.)

tracts are covered with different *Salices*, especially in Fjallasveit, where in some places on sandy flats *Carex incurva* also occurs in abundance; moreover, in Myvatnsöræfi, Sudurárbotnar, Rangárvellir, and several other places. Where the soil is broken up and removed by sand-storms as deep down as to the underlying gravel, as in several places in the southern lowlands in the neigbourhood of Hekla, small tufts of *Festuca rubra* and *F. ovina* are the first to appear, then come *Juncus balticus*, *Equisetum arvense*, *Agrostis alba*, *Silene maritima*, *Salix lanata* and *S. glauca*; then gradually several species of grasses make their appearance until at last a grassy willow-flat is formed which makes an excellent sheep pasture. Here and there on the plateau are damp flats of old blown-sand inter-

sected with clefts, rent by frost, which are filled with *Grimmias* and *Salix herbacea*.

The flora of the lava-streams cannot be referred to any single plant-formation, because according to the age and the progessive development of the vegetation, the lava may bear on it all possible kinds of plant-formations. Nevertheless in Iceland several plants

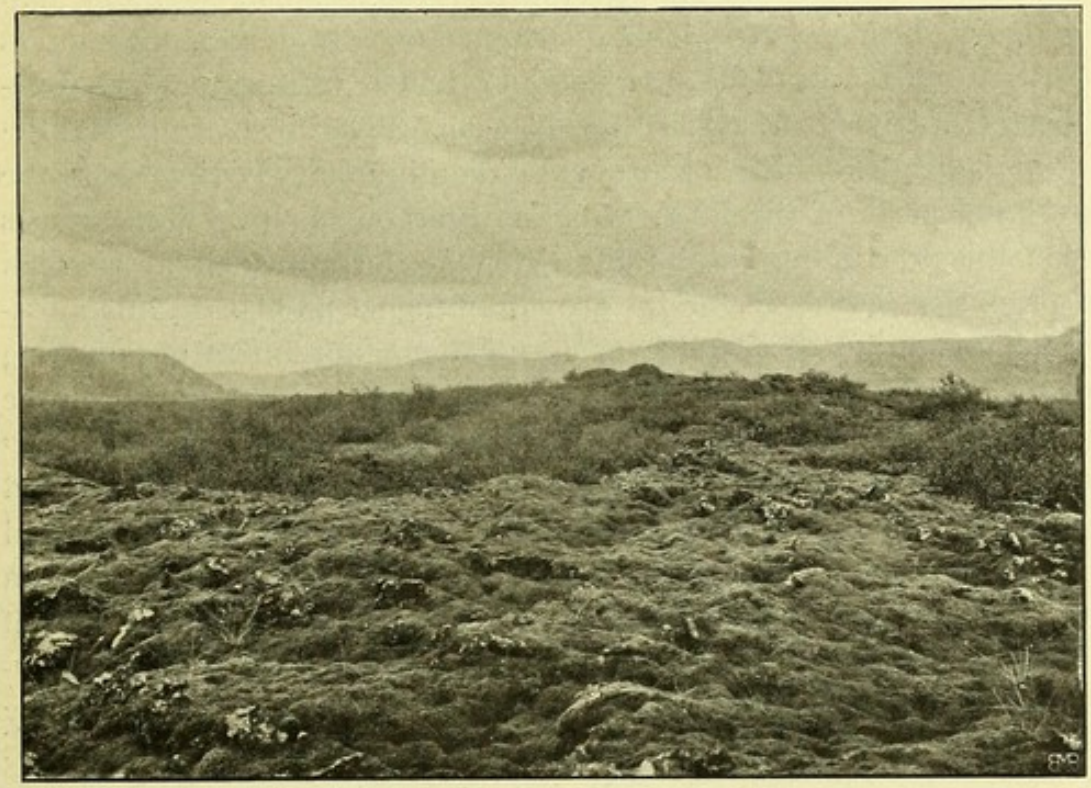

Fig. 33. Lava-field in Nordrárdal in the district of Borgarfjord (Aug. 3, 1909). The lava is covered to a depth of one foot with a layer of *Grimmia hypnoides*. Projecting parts of the lava are covered with crustaceous lichens. Here and there a tuft of *Festuca ovina*. Birch coppice in the background. (Phot. A. Hesselbo.)

are more particularly associated with lava-streams and have there found shelter in the numerous clefts and depressions, where conditions of life are especially suitable for them. *Paris quadrifolia* is found only on lava-streams, and also ferns are found, in abundance and often as very large specimens. *Aspidium filix mas, A. spinulosum, A. lonchitis* and *A. phegopteris* very rarely occur in other habitats than lava-clefts; *Athyrium filix femina*, *Woodsia ilvensis*, *Polypodium vulgare, Aspidium dryopteris* and *Cystopteris fragilis* are also common in lava-clefts, although they are also met with fairly often in other localities, between blocks of rock and in rock-clefts. *Milium effusum* occurs also most frequently in lava-clefts. On lava-

streams there is a good opportunity of studying the development of the different plant-formations and plant-societies because, at the beginning, every lava-stream is virgin soil, where plant-life must break entirely new ground. The first establishment of vegetation is due to mosses and lichens; on the 23-years-old Krakatindshraun Dr. H. Jónsson found twelve species of mosses, three of lichens and one alga. Two of the lichen-species, *Stereocaulon alpinum* and *Squamaria gelida*, were widely distributed on lava-domes, the mosses usually occurred in clefts, but nowhere had a moss-carpet yet developed (H. Jónsson, 1905, pp. 55—56). The next stage is the *Grimmia*-heath, which occurs as a continuous covering over the low-lying parts of the lava, while crustaceous lichens form crusts upon the protruding points; the *Grimmias* form the soil-layer which is primarily necessary for the growth of higher plants. In this moss-foundation occur several lichens and scattered specimens of flowering plants from different associations. After this the development on the lava-streams in the lowlands proceeds in various directions according to the surface-conditions of the lava, the nature of the rock and other circumstances, such as the greater or less amount of drifted sand or humus which has settled upon the surface, and whether a supply of water is available, etc. Consequently, in the course of time a lava-stream may support either a heather-moor, a coppice-wood, a "herb-flat", or grassland, or all these plant-formations may be simultaneously present on the same lava-stream. Rocky-flat formations proper, do not occur on lava-streams, except very rarely, when the lava-streams become covered with gravel brought down by mountain streams or glacier rivers. On the plateau the vegetation on a great many of the lava-streams does not go beyond the lichen-stage, on others a considerable number of *Grimmias* are present, but almost never as a continuous covering, such as they form in many places in the lowlands and especially on the peninsula of Reykjanes. On the other hand the lava-streams of the plateau are frequently covered with drifted sand and support a sand-vegetation which at higher levels consists of *Elymus arenarius* and at lower levels of different *Salices*. There are a few instances of old, partially blocked and sand-covered lava-streams in the valleys, in localities where water was abundantly present, forming the substratum of swampy grassland with peat. Thus, in the course of time, a lava-stream may give rise to almost any formation[1].

[1] For further information regarding plant-life on lava-streams see H. Jóns-

The Grimmia-heath formation is co-ordinate with the rocky-flat formation, but is not so widely distributed by a great deal as is the latter. As already mentioned, it reaches its fullest development on the lava-streams in the lowlands, especially in the peninsula of Reykjanes, where it occupies vast areas; but it also occurs on many other lava-streams. Where there are sand-drifts *Grimmia*-carpets occur very sparsely or are entirely absent, as *Grimmia hypnoides*, the most common species, cannot thrive in drifting sand; therefore extensive areas around Hekla, Fiskivötn and several other places are practically bare of mosses. On the vast lava-fields on the plateau mosses occur very sparingly. In several places the *Grimmia*-heaths on the lava-streams of the lowlands are comparatively quickly transformed into soil for higher plants, which are fairly numerous even in the Grimmia-carpet; generally the latter, in the course of time, passes into heather-moor; sometimes into patches of grassland. In several places the Grimmia-heath covers, with its characteristic grey carpet, stony mountain-slopes, and areas strewn with rock fragments, and, as is the case with the rocky flat, forms the foundation of a scattered vegetation of many different species, without any special character, but dependent upon the plant-formations of the neighbourhood. Usually the Grimmia-heath develops more quickly into heather-moor or grassland than does the rocky-flat formation, owing to the abundant material for soil-formation supplied by the mosses. Grimmia-heaths occupy large areas in the lower part of the plateau, but very few flowering plants are found there in them; on the other hand, lichens often occur numerously, especially *Cetraria* and *Cladonia*, not however so numerously that they form a lichen-heath proper, which occurs in Iceland only in patches, and is of no great importance. In the highest parts of the interior of Iceland the Grimmia-heath formation is of much less importance than in the lower part of the plateau.

Grassland. Ground covered chiefly with grasses or grass-like plants may be classified under four heads: grass-slopes (Græsli); knolly grassland (Græsmo); flat uncultivated grassland; and home-fields, artificially manured soil. Grass-slopes (Græsli). The lower

son: Gróðrarsaga hraunanna à Islandi (Skirnir, 1906, pp. 150—163); Vegetation paa Snæfellsnes (Vid. Medd. Nat. Foren., 1900, pp. 81—84), and Vegetation i Syd-Island (Bot. Tidsskr., 27 Bd., 1905, pp. 53—61). C. H. Ostenfeld: Skildringer af Vegetationen paa Island (Bot. Tidsskr., 22 Bd., 1899, pp. 245—253). Chr. Grönlund: Karakteristik af Plantevæxten paa Island, pp. 30—32.

slopes of mountains are often grass-covered, especially when the rock is tuff or breccia; in South Iceland the tuff mountains are often entirely grass-covered, at least on the southern side, and sometimes they are covered with a thick layer of soil without knolls proper, which occur only on the clay ground of the lowlands. But sometimes wavy rows of small knolls, or narrow ripple-like ledges occur in the lowest part of the grass-slope, and sometimes above these, for a great distance up, the surface of the soil is undulating and wave-like; this is undoubtedly due to mud-flows in the clayey soil-covering. On basalt mountains the grass-vegetation extends upwards in tongues or occurs in patches in depressions or on ledges, separated by considerable tracts of stones and gravel. On such a grass-slope, in addition to the grasses, many other kinds of herbaceous plants are more or less numerously represented. In South Iceland, according to H. Jónsson, the following are the dominant species: *Agrostis vulgaris, A. canina, Anthoxanthum odoratum, Festuca ovina, Poa alpina, P. nemoralis, Geranium silvaticum, Trifolium repens, Brunella vulgaris* and *Leontodon autumnalis*; less common, but often occurring locally in great abundance: *Spiræa ulmaria, Linum catharticum, Rubus saxatilis, Gentiana campestris, Myosotis arvensis, Parnassia palustris*, and many others; in Fljotshlid *Carum carvi* is very common and in Myrdalur and Sida *Succisa pratensis.* The vegetation is rich in species and is rather mixed, although grasses preponderate. In other parts of the country where basalt is dominant the grass vegetation of the mountain-slopes consists of similar species, but is not so luxuriant as in South Iceland. The following species are common: *Agrostis vulgaris, A. alba, A. canina, Anthoxanthum odoratum, Nardus stricta, Aira flexuosa, A. cæspitosa, Phleum pratense, Poa alpina, Hierochloa borealis, Festuca rubra*, etc. A special *Nardus*-association and an *Anthoxanthum*-association often occur.

Knolly grassland (Græsmo). By this is understood dry, extremely knolly stretches of clayey ground intermixed with humus, occurring on level land and in valleys with a mixed vegetation of Gramineæ, Juncaceæ and Cyperaceæ; it may therefore differ considerably in appearance, according to which of these families predominates. When grasses predominate the "Græsmo" resembles grassland, but sometimes *Juncus trifidus* and *Elyna Bellardi* are so dominant that large stretches attain a brownish tint like that of a heather-moor. Usually, the vegetation of the knolls differs from that of the depressions; in the depressions, mosses and some *Carices*

are often met with, but upon the knolls there are *Elyna Bellardi* and *Juncus trifidus*; sometimes these are intermixed with mosses and lichens. In some places *Juncus balticus* predominates, in others *Luzula* or *Agrostis*, *Aira cæspitosa*, *Trisetum subspicatum* and other grasses.

The dry uncultivated grassland without knolls (hardvelli, vallendi) usually has for a substratum coarse sand, river-gravel, pebbles, etc., with a thin covering of humus, and a low and rather open vegetation which chiefly consists of Gramineæ *(Festuca*, *Aira*, *Poa* and *Agrostis)*, but these are abundantly intermixed with *Juncus balticus*, *Luzula multiflora* and *L. spicata* and *Elyna Bellardi*; *Festuca rubra* is sometimes a dominant species. Of dicotyledonous plants the following are common: *Leontodon autumnalis*, *Thalictrum alpinum*, *Draba verna*, *Galium verum*, *Euphrasia officinalis*, *Viola tricolor*, *Gentiana campestris*, *Achillea millefolium*, *Rhinanthus minor*, and others.

The home-field (tun) is the manured grassland round the farm-buildings. It is usually enclosed and generally abounds in large knolls. In 1909 the area of the home-fields throughout the island was estimated at 188 square kilometres. The hay (tada) from these home-fields is kept chiefly for winter-fodder for cows. The cultivation of the home-fields differs greatly, which again influences the vegetation, other plant-associations occurring in patches in the grass-covered area of the home-field; these are especially dependent upon the degree of moisture contained in the different parts of the field. In really well-cultivated home-fields throughout the country the vegetation is everywhere homogeneous. The Gramineæ are dominant, especially *Aira cæspitosa*, *Poa pratensis* and *Festuca rubra*; moreover *Festuca ovina*, *Poa trivialis*, *P. annua*, *Agrostis vulgaris*, *Alopecurus geniculatus* and *Anthoxanthum odoratum* are very common, and intermixed abundantly with these occur *Ranunculus acer*, *Taraxacum officinale*, *Rumex acetosa* and *Polygonum viviparum*. The home-fields are often quite yellow with *Ranunculi* (*R. acer* and *R. repens*); in many places *Trifolium repens* and *Rhinanthus minor* also occur abundantly. In some places *Viola tricolor* is abundant in home-fields, especially in Eyjafjördur, and *Geranium silvaticum* in some places in Myrdalur, and in other places *Vicia cracca*, etc. In addition, many other plants are found in patches, according to the dampness of the soil and the care given to the cultivation of the home-fields; in dry and sandy grassland there often occur an abundance of *Galium verum*, *G. silvestre*, *G. boreale*, *Achillea millefolium*, *Leontodon autumnalis*,

Armeria maritima, as also *Luzula*, *Elyna*, etc.; in damp home-fields are found *Caltha palustris*, *Cardamine pratensis*, *Koenigia islandica*, *Montia rivularis* and different *Carices*. Moreover, a great many species often immigrate from the plant-formations of the neighbourhood; in some places, in badly kept home-fields, even swamp vegetation and willow-coppices or heather may be met with in patches. The

Fig. 34. Outer edge of the home-field (tun) of the farmstead Hnausar in Vatnsdal *Matricaria inodora* and *Capsella Bursa pastoris*; in the background *Rumex domesticus*; July 28, 1909. (Phot. A. Hesselbo.)

farm-buildings are, as a rule, in the centre of the home-field, and around them there is almost always a characteristic vegetation consisting of *Alopecurus geniculatus*, *Glyceria distans*, *Ranunculus repens*, *Poa annua* and *P. trivialis;* quite near to the home and stables grow *Stellaria media*, *Capsella bursa pastoris*, *Polygonum aviculare*, *Rumex domesticus*, etc. Around farmsteads in the vicinity of the sea, and on islands, are often found in addition *Cochlearia officinalis*, *Cakile maritima* and *Atriplex patula*. In Iceland the walls and roofs of peasants' houses are generally built of turf and are therefore overgrown with various grasses, especially *Glyceria distans*. Flowering plants also often occur upon houses; they vary in the different districts; in south-west Iceland *Matricaria inodora* grows luxuriantly

on the roofs and in some places *Achillea millefolium*; in various districts *Rhodiola rosea* has been planted on the walls, and in the northermost districts *Cochlearia officinalis* often occurs in abundance upon the houses, and in some places *Saxifraga rivularis*. At their base the house-walls are green with *Prasiola crispa*; various mosses also grow upon the houses, especially *Bryum argenteum*[1].

Heather moors are extensively developed in Iceland both in the lowlands and valleys, on mountain-sides and on hills to a height of about 400 metres; they are not recorded from higher levels. On mountain-sides and on hill-slopes the heather moor is almost flat, on level land it is usually knolly; it is best developed upon old lava-streams and it often forms the ground vegetation of birch coppices. The dominant species are *Empetrum nigrum*, *Vaccinium uliginosum*, *V. myrtillus*, *Arctostaphylus uva ursi* and *Calluna vulgaris;* the last species is fairly common in many districts, but never occurs so abundantly as the others. Moreover, among the heather there is usually an abundance of *Dryas octopetala*, *Juniperus communis*, *Betula nana*, *Rubus saxatilis* and *Salix herbacea*. In heathy tracts at higher levels and also above these in scattered patches, are found *Loiseleuria procumbens*, *Cassiope hypnoides* and *Sibbaldia procumbens*. On the peninsulas on either side of Eyjafjördur patches of *Phyllodoce coerculea* — which is not recorded from more southerly habitats — are now and then found. There is a great variation in the distribution of the different character-plants in the heather moor; sometimes they all occur mixed with each other; sometimes each occurs separately in large or small patches, so that the different areas may be designated *Vaccinium* heaths, *Empetrum* heaths, *Calluna* heaths, *Arctostaphylus* heaths, etc. Between the heather, as ground vegetation, other plants occur in abundance, especially immigrants from the knolly grassland — from which the knolly heather-land often appears to have been derived — for instance, *Juncus trifidus*, *Elyna Bellardi*, *Luzula multiflora*, *L. spicata*, *Nardus stricta*, *Agrostis canina*, *A. alba* and several other Gramineæ, also *Salix lanata*, *S. glauca*, *S. phylicifolia*, *Silene acaulis*, *Thymus serpyllum*, *Bartschia alpina*, *Alchimilla alpina*, *Thalictrum*, *Galium*, *Hieracium*, and many others. In addition, there is very often a moss-carpet of *Grimmia hypnoides* beneath the heather.

Willow coppices. Although the various species of willows are widely distributed they rarely form coppices proper, and willow

[1] As regards the moss-vegetation on old house-walls see Helgi Jónsson's above-mentioned paper on the vegetation of South Iceland, 1905, p. 54.

coppices, as independent formations, have but a slight distribution in Iceland. As stated above, *Salix lanata* and *S. glauca* are distributed over extensive sandy areas, and occur there, together with some other plants, as dominants; in other places they occur on dry, flat, clayey tracts, as scattered shrubs of low growth (20—60 cm.) with an undergrowth of heather, *Elyna Bellardi*, various species of grasses, etc. It is chiefly *Salix phylicifolia* which forms coppices

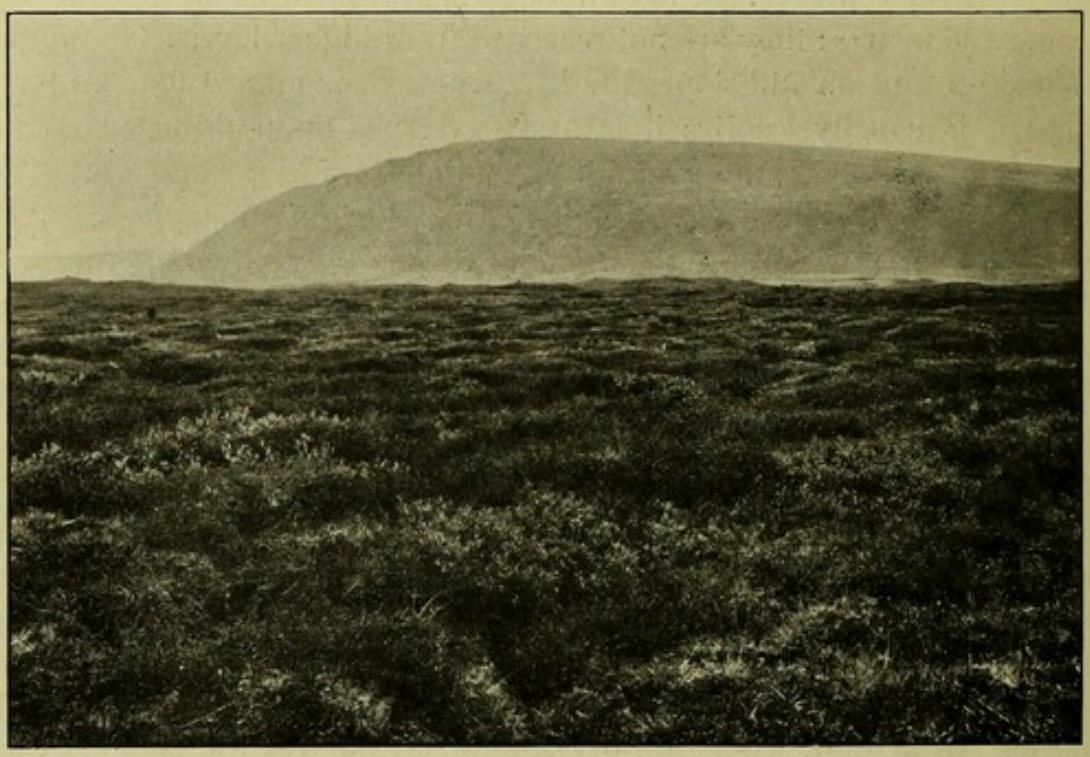

Fig. 35. Knolly moor of *Betula nana* intermixed with *Salix lanata* and *Salix phylicifolia* Ground vegetation: *Empetrum, Arctostaphylus uva ursi, Anthoxanthum odoratum* and *Polygonum viviparum.* (Phot. A. Hesselbo.)

(e. g. near Skaftafell, Fnjóskadalur, Hrafnkelsdalur, Kaldalón and Mývatn) in association with *Salix lanata* and *Betula odorata* and with a rich ground-vegetation of highly diverse plants common on "herb-flats." Now and then *Salix phylicifolia* forms the undergrowth of birch coppices, as for instance, in Bæjarstadaskogur near Øræfi; the willows here have an average height of 2 metres; the highest individuals are 3 metres in height, but the stems are only 18—24 cm. in circumference. *Salix phylicifolia* (often together with *Salix lanata*, which may attain a height of 1—1½ metres) is often found interspersed in birch coppices, in many places in different districts. In several places near Myvatn *Salix phylicifolia* forms coppices, among other places in Sluttnes, where a stem which I measured in 1882,

had a circumference of 21 cm. and a length of 5 metres, but it could not stand erect.

Birch coppices. An account has already been given of the distribution of birch coppices in Iceland, and in a subsequent part

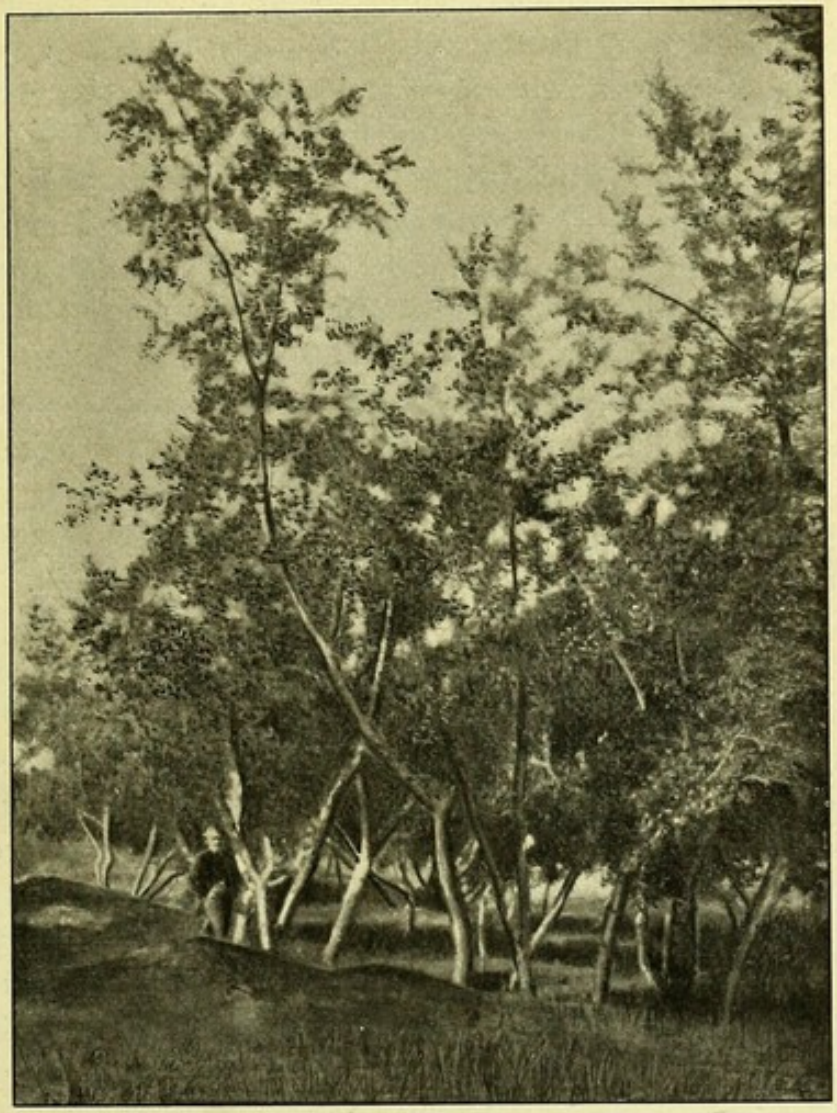

Fig. 36. Hallormstadaskógur; 1894 (see text).
(Phot. Th. Thoroddsen.)

of this work there will no doubt be an exhaustive description of tree-distribution in Iceland, so here only a few very brief notes on the subject will be given. The greater part of the birch coppices in Iceland consists of stunted shrubs having, as a rule, a height of 1—3 metres only, sometimes even lower; a fact which is undoubtedly due to the destructive habits of sheep. Well-grown birches — the remains of woods which have formerly been far more extensive — occur, however, in a few localities. Of such woods the following

are the most important: Hallormstadaskógur near Lagarfljót in East Iceland, Bæjarstadaskógur below Jökulfell in Øræfi in South Iceland, and Thórdarstadaskógur and Hálsskógur in Fnjóskadal in North Iceland. In Hallormstadaskógur some erect birch trees have a height of 8—9 metres and a circumference of 70—80 cm., and many others have a height of 5—7 metres. In Thórdarstadaskógur the highest tree is $8^1/_2$ metres high, with a circumference of 32 cm.; several of the trees are 6—7 metres high, and the average height of the whole wood is 3—4 metres. Hálsskógur is somewhat lower; some of the trees are, however, 6—7 metres high, and several 4—5 metres[1]. Bæjarstadaskógur is somewhat lower, but the trees are well-grown and erect, and stunted birches are absent; the average height of the birch trees is 4—5 metres and may often be as much as 6 metres[2]. In a ravine near Skaftafell I measured in 1894 a birch tree which was 7 metres high and a mountain ash which had a height of $9^1/_2$ metres. This tree occurs sometimes dispersed in birch coppices, and sometimes separately in ravines and on mountain slopes; it has often been allowed to stand on account of some superstition. In some places in North and South Iceland the mountain ash (*Sorbus aucuparia*) has been planted around farmsteads and by houses in towns. It attains a height of 7—10 metres, but in birch coppices it is generally only 4—5 metres, or even less. In birch coppices are also found *Betula nana*, *Salix phylicifolia*, *S. lanata* and *S. glauca* and *Juniperus communis*. The soil in coppice-woods consists often of "moar" — knolly clay which rests sometimes on gravel and sometimes upon rock. Coppices often occur also on a stony bottom, as in ravines, between rocky boulders, and often upon mountain slopes — occasionally they are found on boggy soil. The wood-floor is very often occupied by heather moor; and birch coppices of lower growth often even pass into heather moor; in the latter case the same species are found in the woods as are found on ordinary heather moors, and they form similar associations[3].

[1] S. Sigurdsson: Skógarnir i Fnjóskadal (Andvari, XXV, 1900, pp. 144 – 175).

[2] H. Jónsson, 1905, pp. 46—50. Th. Thoroddsen in Geografisk Tidsskrift, XIII, 1895, pp. 16—17.

[3] During latter years many papers have been written on the woods of Iceland. One of the most important is that by C. V. Prytz: Skovdyrkning paa Island in Tidsskrift for Skovvæsen, vol. XVII, 1905, pp. 20—89; it also contains interesting notes on the Icelandic soil. Moreover, works dealing with the woods of Iceland are enumerated in Lysing Islands, vol. 2, on pp. 443—445.

Sometimes the trees grow in grassland, and sometimes on "herb-flats;" occasionally the wood-floor consists of mosses. In grassland the commonest species are *Agrostis vulgaris*, *Aira flexuosa* and *Anthoxanthum odoratum* and other more scattered Gramineæ. Where the herb-flat formation is dominant many different species occur, especially *Spiræa ulmaria*, *Angelica silvestris*, *Rubus saxatilis*, *Leontodon autumnalis*, *Geranium silvaticum*, *Bartschia alpina*, *Myosotis arvensis*, *Alchimilla vulgaris*, *Fragaria vesca*, and others. *Trientalis europæa* grows here and there in woods in East Iceland only. Where mosses are dominant on the wood-floor the vegetation consists chiefly of *Hylocomium* (H. Jónsson, 1900, p. 76). On the whole, in coppices, scattered individuals of the numerous species from the different formations in the neighbourhood may be found.


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