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THE GRIMSNES LAVAS SW-ICELAND

BY

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WITH 5 PLATES
AND 7 FIGURES IN THE TEXT

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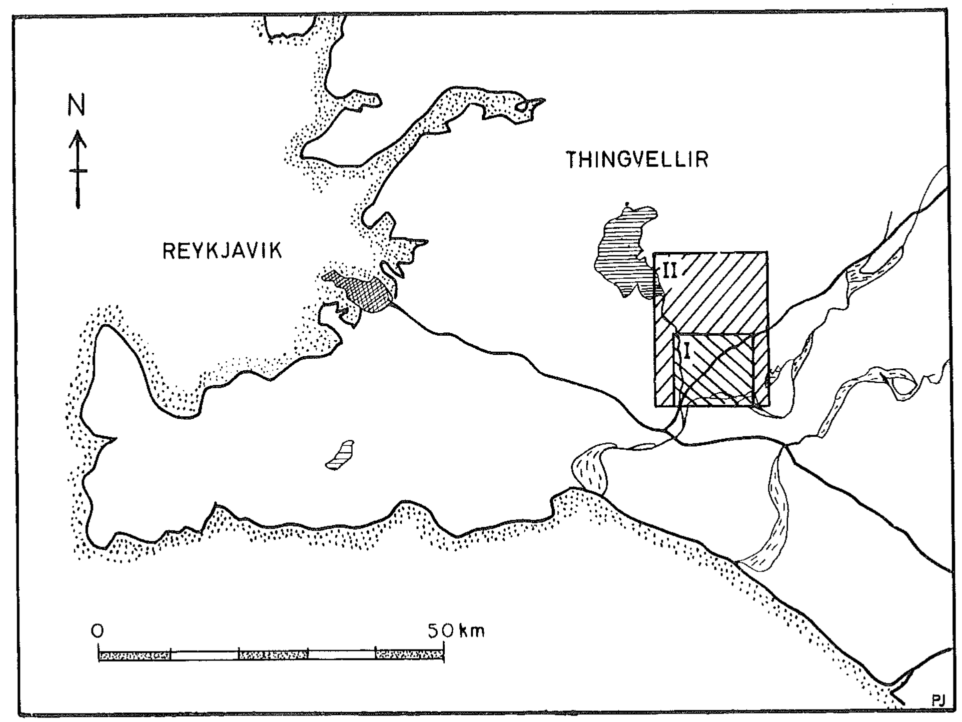

Fig. 1. Sketch map of SW-Iceland showing the location of the two maps. I: Geological map (Plate V) II: Tectonic map (Fig. 7).

ABSTRACT

A postglacial volcanic area in Grímsnes, SW-Iceland, is described and a geological map is presented in the scale 1 : 50.000. The older formations are dealt with briefly. In Grímsnes the volcanism had an unusual areal distribution for Iceland. The lavas, covering an area of 54 sq. km, can be traced back to ten craters and crater rows. The eruptions were nearly contemporaneous. By study of the position of tephralayers from the Grímsnes eruptions in soil profiles their age can be estimated as 5000—6000 years. The lavas are made up of uniform olivine-basalt, there is no sign of differentiation. A chemical analysis of one of the lavaflows is presented; it shows the same composition as the Skjaldbreidur lavas north of Grímsnes. Xenoliths of granular olivine-gabbro and vitrified acid rock are common in some of the craters and are discussed briefly. The mineralogy of the gabbro is very similar to that of the lavas; and an endogenic magmatic origin is not excluded. A noteworthy feature of the gabbro is an olivine with highly developed cleavage. The high silica content and the mineralogy of the acid xenoliths suggest a liparite or granophyre-intrusion at depth.

INTRODUCTION

Location and topography.

Grímsnes is situated in SW-Iceland (Fig. 1), in the neovolcanic zone which runs SW-NE through Iceland. This zone, which contains nearly all the active volcanoes, divides in South Iceland into two branches, the western one of which continues out through the Reykjanes peninsula. Grímsnes is situated on the eastern margin of this branch. Geomorphologically the area belongs to the South Icelandic lowland.

The mapped area is a postglacial volcanic area in the western part of the Grímsnes district, bounded south and west by the two big rivers Hvítá and Sog. The terrain rises gently from the Sog, which runs at a height of 14—18 m, and the Hvítá (14—25 m)above sea level, and reaches its highest point at Seydishólar (214 m). The palagonite mountain Búrfell (536 m) and the interglacial shieldvolcano Lyngdalsheidi (404 m) rise north of the lavafield (cf. Fig 7). The main part of the lavafield is covered by brush of birch and willow.

The volcanic area in Grímsnes has not been studied in detail before, although Kjartansson (1943) has given a description of the whole region in his book Árnesinga saga.

The Geological map is based on the topographical maps (1 : 50.000) of the Geodetic Institute, Copenhagen.

Acknowledgements.

I am indebted to my teacher, professor A. Noe-Nygaard, Director of the Mineralogical and Geological Institute of Copenhagen, for his instructive advice and discussions during the work, for excellent working facilities in the Institute, and for suggesting a chemical analysis of one of the lavas, which was kindly carried out by Me Mouritzen, cand. polyt.

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THE OLDER FORMATIONS

Palagonite breccias and basalts.

The oldest rocks in the area are palagonite breccias and basalts of Quarternary age. They are exposed at Hvítá south of the lavafield in low ridges orientated NNE-SSW, and more prominently in the mountain Búrfell to the north (see Geological map, Pl. V). The material is predominantly palagonite breccia locally intercalated with pillow lava and cut by small dykes. Along Höskuldslækur there are several outcrops of dark, fine-grained basalt, which is probably intrusive.

These rocks belong to the Palagonite Formation of Iceland. Most authors agree on the subglacial origin of this formation, the main part of it being Quarternary (Noe-Nygaard 1940, Kjartansson 1943, Áskelsson et. al. 1960).

The mountain Búrfell (Pl. Ia) is an example of a subglacial volcano. It is a 4 km long ridge trending N-S mainly made up of palagonite breccia. On the top of the mountain is a deep but narrow depression, evidently the rest of the crater. The mountain is cut by a tectonic fracture trending N 20°E, through the crater (Fig. 7). South of Búrfell small palagonite ridges extend SSW. It is probable that Búrfell was formed during a fissure eruption and was elongated to SSW, and that the present form of the mountain is mainly the result of glacial erosion.

Bombs of palagonite tuff are found both in the Tjarnarhólar and Selhóll I craters, suggesting that the palagonitic rocks extend under the lavas.

G. Kjartansson has made a subdivision of the Palagonite Formation. On the Geological Map of Iceland (1960, 1962), Búrfell is classified as belonging to the Palagonite Formation in *sensu stricto* (Quarternary), while all the other outcrops of palagonite breccia in the area are classified as belonging to the Old Gray Basalts (Quarternary and/or Tertiary). In his book, Árnesinga saga (1943), however, this author has classified Búrfell with the Old Gray Basalts.

The geology of the area surrounding the lavafield was not studied in detail, and I have not been able to see any clear difference between the palagonite breccia in for example the outcrops at Hvítá and Búrfell. They are therefore marked with the same signature on the map, and the age is supposed to be Quarternary.

Young Gray Basalts.

In the gorge at the farm Hædarendi, palagonite breccia and palagonitized conglomerate is covered by a light-gray basalt with a thickness of about 5 m. The basalt is striated on the surface, indicating that it is interglacial or interstadial. Many thin beds of the same gray basalt are seen farther west along the banks of the rivulet on the west side of Selhóll II lava. It is rather coarse-grained, light-gray olivine basalt with some variation in the olivine content. This basalt can be traced back to Lyngdalsheidi, a flat shieldvolcano (404 m), lying with its crater some 9 km farther north (Fig. 7).

Basalts of this type are common within the neovolcanic zone in Iceland, and seem generally to originate from shieldvolcanoes. These interglacial gray basalts have commonly been called dolerites in geological papers about Iceland. (The term was introduced by E. Robert: Mineralogie et Geologie I, in P. Gaimard, *Voyage en Islande* etc. Paris 1840). As the term dolerite is used exclusively about basaltic dykes and sills in geological literature elsewhere, it is misleading to retain this term because of its genetic implications. The term Young Gray Basalts is used here, following Kjartansson (in Áskelsson et al. 1960).

The rock is very similar in all exposures of the gray basalt in Grímsnes, and most probably it all derives from Lyngdalsheidi. The Young Gray Basalts have originally covered the main part of western Grímsnes, but are now found as erosion remnants in the hills of the area. No other volcano producing this type of basalt is known in the neighbourhood. The hills south of the farm Ásgardur are entirely made up of gray basalt, at Búrfellslækur it is up to 19 m in thickness. Smalaskáli, a hillock at the edge of the Tjarnarhólar lava near lake Álftavatn, probably belongs to the Young Gray Basalts. The rock contains glomerophyres of olivine up to 1 cm across in addition to the olivines in the groundmass.

In the maar Kerid of the Tjarnarhólar crater row, 7—8 m of the gray basalt are exposed under the lava- and scorialayers in the eastern craterwall (Fig. 4). Outcrops of gray basalt are found east of Borgarhólar and near the Foss farm, and the Young Gray Basalts therefore extend farther east and south than shown on the Geological Map of Kjartansson (1962).

Glacial deposits and striae.

Traces of the Pleistocene glaciation are distinct in Grímsnes. Along the NE-beach of lake Álftavatn a 1—3 m thick layer of moraine is exposed. This is a very hard moraine containing single boulders of basalt up to ½ m across. There is some black basaltic glass in the groundmass. The same moraine layer is exposed farther north along the river Sog. On the opposite side of Álftavatn it is distinctly striated with a SE direction. At the river Búrfellslækur a short distance east of the road the moraine layer rests on palagonite breccia and pillowlava. Moraine is found at various other places, for example north of Hædarendi, where it is very loose and seems to be much younger than the moraine along the river. The same applies to the moraine found along the river Höskuldslækur near the Mýrarkot farm. Gravel and sand deposits at the farms Búrfell and Hædarendi are probably of glaciofluvial origin.

It is possible that the moraine in the Sog-valley represents an older glaciation and was hardened before the last glaciation or advance of the ice. It is striated, and in the same direction as the basalts along the Sog. The other moraine deposits in Grímsnes are presumably ground moraines from the last glaciation.

The direction of the ice can be seen by numerous striae. These are most distinct on the basalts, and the striae shown on the geological map are all taken on basalt. In general the ice had a southerly direction of movement. In the eastern part of the area the direction was S-SSW, following the main topography. In the western half however, the glacier flowed to the SSE. The glacial striae probably only show the last movements of the ice in the region. As the ice became thinner it was forced to a more south easterly direction by the mountains Grafningsfjöll and Ingólfsfjall west of Grímsnes. Kjartansson (1943) has found striae with SW-SSW directions at 500 m height on Mt. Ingólfsfjall, presumably made by the ice when it was at its greatest thickness.

Lateglacial marine sediments.

The moraine along the rivers Sog and Búrfellslækur is overlain by hard layers of sand and silt about 4—6 m thick. These sediments are deposits of the lateglacial transgression, marks of which are found in all parts of Iceland. Very distinct gravel terraces have been formed along Ingólfsfjall and in Grafningur (west of the mapped area). These terraces are about 60 m above sea level according to the Geodetic Institute map. The marine sediments along the Sog, which are made up of alternating beds of sand and silt, are about 18—25 m above sea level. The same kind of sediments are found along the shores of Höskuldslækur between the farms Mýrarkot and Foss. At this locality these layers are about 40—50 m above sea level.

At Sog and Búrfellslækur the marine layers contain subfossil bivalves and gastropods. These have also been reported at Höskuldslækur (J. Hallgrímsson 1840, ed. 1933), but I have not succeeded in finding anything there. At Búrfellslækur, the layers are clearly disturbed by the ice, and the molluscs are found as fragments. The layers are up to ½ m in thickness here.

The following species were found at Sog and Búrfellslækur.

Yoldia hyperborea	1 ex.*
Cyprina islandica	very common
Macoma calcaria	very common
Saxicava arctica	common
Mya truncata	very common
Pecten islandicus	2 ex.
Boreotrophon clathratus	2 ex.
Balanus sp.	very common
Vertebra of a bony fish	1 ex.

Nos. 2—5 of the list were found as complete specimens. Most of the molluscs have thick shells, and as a whole the fauna suggests cold conditions. All the species are at present found in the seas around Iceland, except *Yoldia hyberborea* and *Pecten islandicus*, which are not found along the south coast (Óskarsson 1962, 1964). *Yoldia hyperborea* has not been found in these lateglacial deposits before with certainty, although Bárðarson (1921, 1923) mentions three occurences in Borgarfjördur and Breidafjördur as possibilities.

Recently C^{14}-datings have been published on sea-shells from two localities, Spóastaðir and Hellisholtalækur in S-Iceland. (Kjartansson et al. 1964). The dates were approximately 10000 and 9700 years respectively. At Spóastadir and Hellisholtalækur, which are 55—60 m and 70—75 m above sea level, all the species from Sog-Búrfellslækur have been found with the exception of *Yoldia hyberborea.* In addition many other species were found, and some of them as warmth-loving as *Mytilus, Zirphaea* and *Littorina.* In spite of this, it is thought probable that the

* *This specimen, a fragment only, was determinated by prof. Alfred Rosenkrantz at the University of Copenhagen, for which I am grateful.*

Sog-Búrfellslækur fossils are of an age similar to the fossils at Spóastadir and Hellisholtalækur, that is about 10000 years old.

The localities at Sog-Búrfellslækur were investigated and described by E. Ólafsson and B. Pálsson (1772) on their travels as early as 1756. Jónas Hallgrímsson travelled through Grímsnes in 1840 and found sea-shells both at Sog-Búrfellslækur and Höskuldslækur. Th. Thoroddsen visited the locality in 1883 (Ferdabók I, 1958, p. 216—217) and found: *Cyprina islandica, Pecten islandicus, Tellina sabulosa, Mya truncata,* and *Balanus Hameri.*

Some of the molluscs contain small needles of a white mineral growing out from the sides. Some are partly filled with these needles, others contain only a few

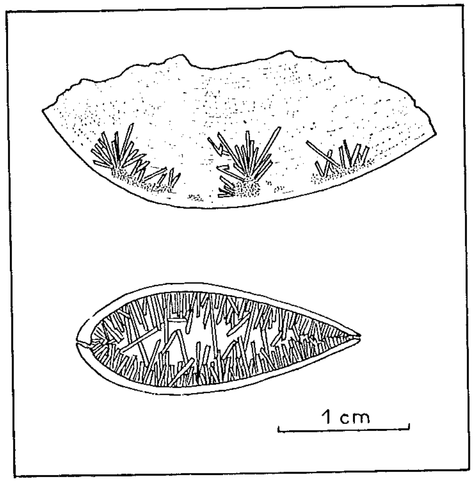

Fig 2. Macoma calcaria partly filled with needles of calcite.

needles radiating from small clusters of sand (Fig. 2). Refraction measurements and a X-ray powder photograph showed clearly that this was calcite. Thoroddsen, however, (1904), has described the mineral as aragonite, evidently deluded by its habit as it is unusual to find calcite in this form.

THE GRÍMSNES LAVAS

The Grímsnes lavas cover an area of about 54 sq. km. The lavas can be divided into at least ten individual flows, each derived from a crater or a crater row. The individual flows are named here after the craters. All the lavas are typical block-lavas; the surface is very rugged, consisting of loose blocks and plates. It has been rather difficult to distinguish the lavaflows from each other because of their uniform petrography and the birch and willow cover. Some of the contacts between the individual flows are therefore uncertain.

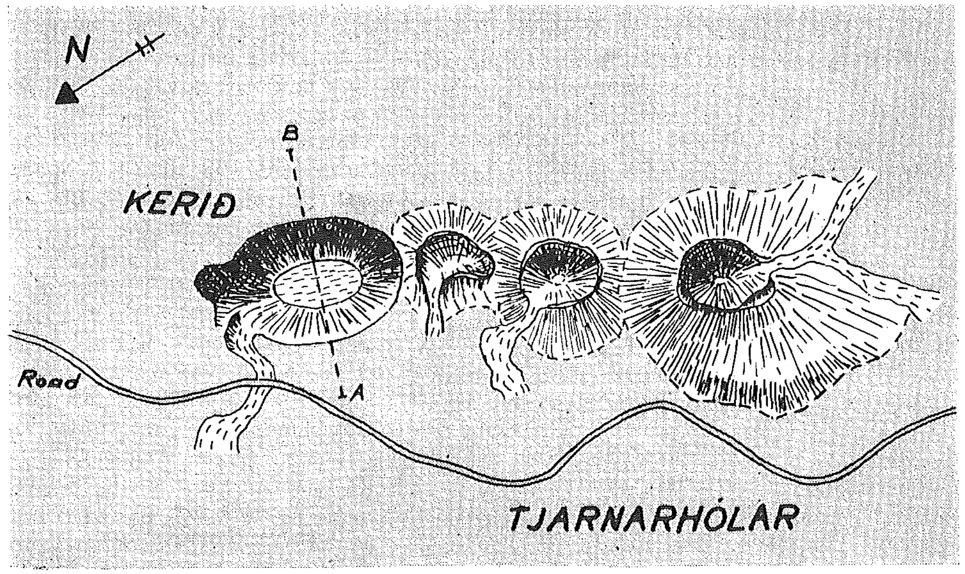

Fig. 3. Sketch of the crater row Tjarnarhólar. The length of the fissure is about 800 m.

The individual volcanic centers.

Tjarnarhólar.

The Tjarnarhólar (hólar: hillocks) crater row is made up of four craters lying on a 800 m long fissure (Fig. 3), trending N 30° E, approximately. The three southernmost craters are made up of scoriae and schweiss-schlacken and are crescent-shaped. They can be classified as spatter cones (or cinder cones). The craters are not pronounced, the highest one (126 m above sea level) rises 50 m above the surrounding country. The northermost crater, called Kerid (Fig. 4), is a typical explosive crater, maar, formed by one or few explosions. The crater is elliptical, about 270 by 170 m. A small lake lies in the crater with an average depth of 10 m. (G. Gígja pers. comm.). Kerid has an approximate total depth of 55 m. Bedrock is visible in the southeastern craterwall, it is light-gray basalt of the Young Gray Basalt Formation. The upper part of the craterwall consists of alternating beds of lava and scoria with a thickness of 25 m. Between the Tjarnarhólar lava and the interglacial basalt is a thin layer of soil mixed with scoria.

The lava from Tjarnarhólar has mainly flowed west and south down to the rivers. It is partly covered by four other lavas but the original size can be assumed to be about 11—12 sq. km.

Clear lavatracks, the channel in which the lava flowed when the lava nearest to the crater was solidified, are developed in most of the Grímsnes lavas. They can

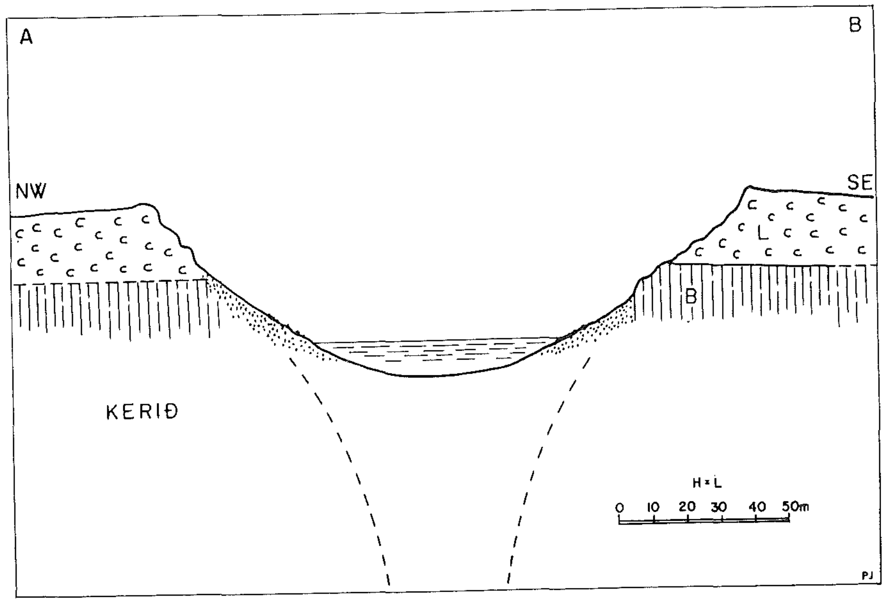

Fig. 4. Profile through the maar Kerid from NW to SE (cf. Fig. 3). L: Tjarnarhólar lava. B: Young Gray Basalts.

often be followed several kilometers in each flow. One of the clearest lava-tracks comes from the maar Kerid.

In the beginning of the eruption, lava has obviously flowed from Kerid, making up much of the northern and western part of Tjarnarhólar lava. Probably the whole fissure erupted at the same time, and a scoria cone formed where Kerid is now situated. At the end of the eruption in Tjarnarhólar there was an explosive phase which formed Kerid. There is no sign of any ashlayer in Grímsnes from this explosion.

On the rim of the crater altered pieces of gray basalt and palagonite-tuff can be found. Vitrified acid xenoliths are also found in the scoria quarry in the southernmost crater. These will be described together with xenoliths from other craters in a later chapter (p. 18).

Tjarnarhólar lava is made up of fine-grained, gray-blue basalt, sometimes porphyritic with small phenocrysts of feldspar and olivine.

Seydishólar.

The twin hillocks of Seydishólar are the largest craters in the volcanic area, rising to a height of 214 m above sea level. (Pl. Ib). They are actually two volcanic centres, the southernmost also being called Kerhóll. The northern crater, Seydishólar proper, has a relative height of about 90 m, and consists almost completely

of well stratified scoriae. The mound is slightly elongated from NE-SW, and this is most probably a fissure with the same direction as Tjarnarhólar, N 30°E. It seems to be in continuation with the Tjarnarhólar fissure. Most of the scoriae were formed at the end of the eruption and covered the fissure itself.

The volume of the scoriae in Seydishólar proper is about 30 mill. cu. m. measured with a planimeter, assuming the scoria cone to be 100 m thick. Scoriae are excellent for road ballast. Most of the craters in Grímsnes have therefore been quarried to this purpose. In Seydishólar the scoriae are of exceptionally good quality. They are very porous and homogenous, and have been used to make insulating bricks.

In the quarry in the south-end of Seydishólar a good section of the scoria layers can be seen. The scoria layers are of various colours, bluish and red scoriae are most common. Another colouring can be observed cutting across the scoria layers in the eastern side of the quarry (as it was in 1964). The scoriae are oxidized and have a deep-red colour. This colouring seems to be caused by volcanic gases after the deposition of the scoriae. In the quarry in Seydishólar, numerous xenoliths of gabbro and vitrified acid rock are found.

Kerhóll is a well formed crater with a height of 50 m above the surroundings. The craterwalls are made of alternating layers of lava and schweiss-schlacken. The crater can be described as something between spatter cone and lava cone. Most of Seydishólar lava was actually derived from Kerhóll, but as Seydishólar proper and Kerhóll erupted nearly simultaneously and their lavas can hardly be distinguished, the flows are marked with the same signature on the map. Seydishólar lava covers an area of 23 sq. km. At the road near the farm Mýrarkot the lava is seen resting on a thin layer of carbonized heather or moss.

The eruption in Seydishólar seems to have started with some explosive activity. Along the bank of Hædarendalækur (the uppermost part of Búrfellslækur) north of Seydishólar, a thick layer of pumiceous scoriae can be followed. It is bluish-black basaltic pumice with grain-size under 3 cm in diameter. The layer thins rapidly away from Seydishólar (cf. Fig. 6, soilprof. 3 and 2). This pumice layer is also found west of Kerlingarhóll lava (soilprof. 4) and on the heath up to 3 km NE of Seydishólar. The volume of this pumice layer is not less than 1 mill. cu. m. Seydishólar lava can be distinguished from the other lavaflows as it is more finegrained and only contains phenocrysts of olivine.

Kálfshólar.

Kálfshólar, the crater row west of Seydishólar, is made up of two relatively big craters (Pl. IIa). Farther SW there are also some irregular mounds of scoria, so presumably the fissure originally had a length of about 800 m, with a N 45°E direction. The lava has flowed to the west down to Sog and rests here on the late-glacial marine sediments. The contact is not visible. Kálfshólar lava covers an area of about 8,0 sq. km.

West of the farm Midengi there is a row of hillocks made up of schweiss- schlacken and scoriae, and a similar row of hillocks is seen in the lava along Búrfellslækur. These scoria mounds are probably pseudocraters. It is not unlikely that the scoria hillocks along Búrfellslækur formed when Kálfshólar lava flowed over the old course of Búrfellslækur.

Kálfshólar lava rests on Tjarnarhólar lava and presumably Seydishólar lava. The rock is very similar to that of Tjarnarhólar lava and it is macroscopically impossible to distinguish between these two lavas.

No xenoliths have been found in Kálfshólar.

Selhóll II, Kerlingarhóll, Borgarhólar. and Kolgrafarhóll.

The two northernmost volcanic centers, Selhóll II and Kerlingarhóll, are crater rows of a moderate length, both about 400 m. The N 60° E direction of the Selhóll II crater row is more easterly than the others, while the Kerlingarhóll crater row has the same direction as the Kálfshólar craters with which it is in direct continuation. The craters are of spatter cone row type as Tjarnarhólar and Kálfshólar.

Borgarhólar, lying isolated from the main lavafield, and Kolgrafarhóll are small single spatter cones, which have produced only little lava. Borgarhólar lava covers an area of only 0,4 sq. km and is the smallest lavaflow in the area.

Selhóll I, Raudhólar, and Álftarhóll.

These three single craters are situated in the southwest corner of the lavafield. Selhóll I and Raudhólar are spatter cones comparable in size to Borgarhólar and Kolgrafarhóll. The relative height of Selhóll I is about 15—16 m, the crater is crescent shaped with the opening to the SW, the diameter at the base (NW-SE) is 140 m. There are irregular prolongations to the SW. The Álftarhóll crater is considerably bigger. No distinct crater is visible at first, the lava rising gradually up to relatively small scoria walls. There is an irregular depression up to 250 m in diameter within the crater. On the north side, where scoriae have been removed for road ballast, a 19 m deep section of scoriae are laid bare. The lava has partly covered the crater.

Little lava flowed from Selhóll I and Raudhólar, whereas the lava from Álftarhóll covers an area of about 6.2 sq. km. In all three craters vitrified acid xenoliths are common, particularly in Álftarhóll and Selhóll, while in Selhóll I there are many inclusions of palagonite breccia and basalt with amygdales.

The origin of Selhóll I, Raudhólar, and Álftarhóll.

It has not been thought previously that all the scoria mounds in Grímsnes were real craters. Kjartansson (1943, 1960, 1962) refers to seven volcanic centres (if Seydishólar and Kerhóll are considered one center), but does not discuss the origin of the rest of the craters. Similarly, Tr. Einarsson (1949) considers it improbable that all the small mounds are real craters, but thinks they are more easily understood as pseudocraters.

The scoria mounds in question here are Selhóll I, Raudhólar, Álftarhóll and a cluster of scoria mounds called Borgarhóll in the lava south of Kolgrafarhóll. There can be no doubt at all as to the origin of the other craters and crater rows. Various details revealed by a closer study strongly suggest that Selhóll I, Raudhólar, and Álftarhóll are real craters, but the origin of the scoria mounds south of Kolgrafarhóll is more questionable; it is therefore suggested that there are 10 volcanic centres in all.

This view is supported by the following observations:

Firstly, the shape and size of Selhóll I, Raudhólar and Álftarhóll, and the topography in general support the idea that these are real craters and not pseudocraters. The volume and shape of Selhóll I and Raudhólar is very similar to that of Borgarhólar and Kolgrafarhóll, which are undoubtedly real craters. Álftarhóll is much bigger than the other craters and seems partly to be buried in lava. The craters, although irregular in form, are single, whereas pseudocraters are usually grouped in clusters in lavaflows where the conditions for their formation are favourable over a large area, (e. g. the pseudocraters at Mývatn, Álftaver, Landbrot, etc.). The scoria mounds in the Kálfshólar lava, which presumably are pseudocraters, are found in a linear row, and are much smaller than Selhóll I, Raudhólar and Álftarhóll. Pseudocraters are usually very regular in form in contrast to the craters described here. The lavas around Selhóll I, Raudhólar, and Álftarhóll dip outward from the craters, and a great part of the Álftarhóll lava is more than 10 m higher than the surroundings.

Secondly, distinct lava tracks can be followed from both Raudhólar and Álftarhóll for some 500 and 1200 m respectively. There is therefore no doubt that these craters have poured out a considerable amount of lava, that is as much as marked on the map with the signature of Raudhólar lava (0.9 sq. km) and Álftarhóll lava (6.2 sq. km). It is difficult to imagine how this could happen during the formation of a pseudocrater. If Selhóll I and Álftarhóll were pseudocraters formed in the Tjarnarhólar or Kolgrafarhóll lavas, that is, if Selhóll I lava and Álftarhóll lava were parts of these lavas, one would expect to find lava tracks where these lavas flow around the lava-free Finnheidi (NE of Selhóll I), as the connection on each side is rather narrow. This is not the case, however.

Thirdly, various types of xenoliths have been found in Selhóll I, Raudhólar, and Álftarhóll, vitrified acid xenoliths of the same type as found in Seydishólar and Tjarnarhólar are especially numerous. It is assumed that these xenoliths originate from a considerable depth (cf. p. 18). The xenoliths seem to occur predominantly in the scoriae as they have not been found in the lavas. Inclusions of palagonite breccia and basalt with amygdales are also common. In Selhóll I, I have found three bombs containing soil and sand. Bombs of this kind have been found in both real craters and pseudocraters. Bombs of dense lava up to ½ m across are found in the Raudhólar crater.

Finally, the petrography of the Raudhólar and Álftarhóll lavas seems to be slightly different from the adjacent lavas, although this is not a very reliable feature. The petrography of the Grímsnes lavas is rather uniform.

According to Tr. Einarsson (1949) the amount of vesicularity may be used to distinguish between primary and secondary mounds of scoriae. He compared scoriae from Seydishólar with that from some of the smaller mounds in the south-western part of the lavafield (not specified), and found that the scoriae from Seydishólar were light and spongy in contrast to the more dense scoriae in the other craters. Scoriae from Raudhólar near Reykjavík, — which are generally considered to be pseudocraters, — were found to be of the dense type.

I have not been able to see any overall differences between the scoriae from the various craters in Grímsnes, if those from Seydishólar are excluded. The scoriae from Borgarhólar, Tjarnarhólar, Raudhólar, Selhóll I and Álftarhóll for example seem to be of similar type, however, it should be emphasized that the scoriae are very variable in each crater as regards density and porosity, and it is therefore not easy to take a representative sample from each locality. Seydishólar is an exception, the scoriae are light and spongy and surprisingly homogenous throughout.

The origin of the scoriae mounds in the lava south of Kolgrafarhóll is much more questionable. They have been marked as pseudocraters on the map as there is little to suggest that they are real craters. On the contrary they form a cluster of small mounds which do not appear to have emitted any lava. No xenoliths have been found in them.

Petrography.

The lavas.

Only a preliminary petrographic study has been made on the rocks from Grímsnes, which show little difference in the petrography of the separate lava-flows. The rock is a fine-grained, gray-blue olivine-basalt, occasionally containing small phenocrysts of plagioclase and olivine. Both grain-size and abundance of the phenocrysts can vary to some extent, even in a single flow. This makes it very difficult to distinguish between the lavas macroscopically.

The texture is ophitic-quasiophitic to porphyritic (Pl. IVa). The rock is generally holocrystalline, glass was only found in small amounts, except in the scoriae, which are mainly made up of glass with scattered crystals of plagioclase, pyroxene and olivine. The scoriae are found in many colours, with red, bluish, and brownish scoriae as the most common. Other colours are also met with together in the same crater. Not much is known about the origin of this colouring, the red is most probably due to oxidation of ferrooxide.

A few determinations of the three essential minerals, plagioclase, pyroxene, and olivine have been made.

The plagioclase is usually found as lath-shaped polysynthetic twins ranging in size from 0.05 to 0.2 mm in the groundmass and as phenocrysts generally ranging between 0.3—0.5 mm. Measurements of extinction angles between albite-carlsbad twins in the zone (010) in plagioclase from the Tjarnarhólar lava, showed a composition near 60—65% An. A determination of the refractive index of plagioclase-phenocryst from the Borgarhólar lava gave $n\beta$: 1,5702 $\pm$ 0,0005, corresponding to 74% $\pm$ 1,0% An using the glass method(Micheelsen 1957). Zoning in the plagioclase was observed in a few cases.

The pyroxene was often found in ophitic intergrowth with the plagioclase, the size ranging from 0,2 to 0,5 mm. Four determinations of the optical angle in pyroxenes in the Tjarnarhólar lava measured with the universal stage gave the values: $2V\gamma$ 47°, 51°, 55°, 56°. A phenocryst from the Kálfshólar lava, near the crater, measuring 6 x 5 mm was the only pyroxene-phenocryst found in the lavas. $2V\gamma$ of the phenocryst was determined to be 54°, and the extinction angle $c \wedge \gamma$ was found to be 42°. The pyroxene in both lavas is diopsidic augite.

The olivine is occasionally found as phenocrysts, mainly in the Seydishólar lava. In the groundmass the olivine reaches a size of 0,1 x 0,2 mm and is in most cases automorphic, whereas the phenocrysts are often found as skeletal crystals, up to 1 mm across. One olivine-phenocryst from the Seydishólar lava (proper) was determined by X-ray powder diffraction to have a composition of Fa 25% $\pm$ 4%, using the data by Yoder and Sahama (1957). In a few cases the olivine was partly altered to an iddingsitic mineral. Small grains of black ore are abundant in the groundmass.

Five modal analyses of the Grímsnes lavas were carried out. Two of the Tjarnarhólar lava and one each of the Raudhólar, Kálfshólar and Borgarhólar lavas. In each slide 1000—1600 points were counted. The modes are presented in fig. 9, which shows the proportions of plagioclase, pyroxene, and olivine of the lavas in relation to the gabbro xenoliths. As the lavas are very finegrained and identification of the minerals therefore difficult, the modes must be regarded as provisional. The shaded area is believed to represent the lavas in general.

A preliminary microscopical examination of the Grímsnes lavas does not reveal any sign of differentiation. There seems, however, to be some difference between the individual lavaflows as regards texture and amount of phenocrysts, which developed as the eruptions went on. The size and number of the phenocrysts increase gradually in the younger lavas. This agrees with the age relations between the lavas as far as seen from the topography, and the soil profile taken at Hólakotslækur. A much more detalied study of the lavas is required before anything can be said with certainty about their development.

T. Tryggvason (1943) found an increase in the amount of phenocrysts in the last flows from Skjaldbreid, although there were no clear signs of differentiation.

A chemical analysis of Tjarnarhólar lava, carried out by M. Mouritzen is presented in Table I.

The sample was taken 250 m west of the southernmost Tjarnarhólar crater. The molecular norms are calculated, using T. W. Barth's method (Barth 1962, p. 65—70), and the Niggli-values in the usual manner. The modal analysis of the sample does not show good agreement with the norm.

This analysis of the Tjarnarhólar lava may be regarded as representative of the Grímsnes lavas as there is hardly any noteworthy change in the chemical composition within the lavas. It shows practically the same composition as the lavas of the shield volcano Skjaldbreidur and the Tindfjallaheidi fissure, 15—35 km north of Grímsnes. The Tjarnarhólar analysis falls within the group of the six analyses of the Skjaldbreidur area presented by T. Tryggvason (1943). According to a recent C^{14}-dating the lavas of Skjaldbreidur and the Tindfjallaheidi fissure are about 9000—10000 years old (Kjartansson et al. 1964). The lavas of the Skjaldbreidur area and the Grímsnes lavas must be assumed to be comagmatic in spite of the time interval.

TABLE I.

Weight %		Cat. prop.		Cat. %	Molec. norm		Niggli-values	
SiO_2	47,39	60	7898	44,2	Or	1,9	qz	—17,7
TiO_2	1,80	80	225	1,2	Ab	17,9	si	100,3
Al_2O_3	15,08	51	2957	16,5	An	31,5	fm	48,4
Fe_2O_3	1,53	80	191	1,1		Σsal 51,3	al	18,8
FeO	10,30	72	1435	8,1	En	12,1	c	28,3
MnO	0,18	71	25	0,1	Fs	6,4	alk	4,5
MgO	8,63	40	2158	12,1	Wo	11,8	ti	2,87
CaO	12,49	56	2230	12,5	Fo	9,0	k	0,09
Na_2O	1,99	31	642	3,6	Fa	4,8	mg	0,57
K_2O	0,32	47	68	0,4	Mt	1,6	c/fm	0,59
P_2O_5	0,22	71	31	0,2	Il	2,5		
H_2O^+	0,11				Ap	0,5		
$H_2O^÷$	0,04					Σfem 48,7		
Sum	100,08		17860	100,0		100,0		

Anal: Me Mouritzen.

Although the material emitted is of the same chemical composition there is difference in the character of the eruptions in the Skjaldbreidur area and Grímsnes. The eruptions in the former area were entirely effusive, while the Grímsnes volcanism displayed more explosive activity (Kerid, Seydishólar).

The xenoliths.

Gabbro. Xenoliths of gabbro were only found in Seydishólar, the biggest crater in Grímsnes. They are easily found in the scoria quarry and seem to occur mainly in the lowest scoria layers as loose blocks about the size of a fist or smaller. There are numerous small inclusions of this gabbro in a little lavaflow coming from the north side of Seydishólar, although it was not found in other parts of Seydishólar lava. The xenoliths are usually angular and always have sharp boundaries against the host rock. Reference to gabbro xenoliths in Seydishólar was made by T. Tryggvason in a footnote in Thorarinsson (1953).

The rock is a medium-grained gabbro of granular appearance, it is rather porous and crumbles easily. It is made up of plagioclase, clinopyroxene, and olivine with black ore as an accessory mineral. The composition of the rock is variable. The proportions of the three principal minerals in ten gabbro xenoliths are shown in Fig. 5. In each slide 1000—3000 counts were made. The modes of five gabbro xenoliths from different localities in Iceland (J. Jónson 1963) are also plotted on the diagram. All the xenoliths examined fall in the general range of olivine gabbro. Individual blocks may approach anorthosite, pyroxenite, and troctolite in composition.

The rock is quite fresh and the minerals show no sign of alteration with the exception of the olivine in some of the specimens.

The texture is generally xenomorphic-granular.

The plagioclase grains are xenomorphic to hyp-automorphic, with an average size of about 0,8 x 0,3 mm. Polysynthetic twins are common. A refractive index measurement on a powder preparation using the glass method showed: nβ: 1,577 ± 0,001 corresponding to An: 86 ± 2%. Zoning was not observed.

The pyroxene occurs mainly as xenomorphic grains 1—2 mm in diameter and is only poikilitic in habit in a few examples. Five determinations on the universal stage gave: 2Vγ 48°, 52°, 53°, 53°, 55°, respectively. The (010) extinction, cAγ was 43° (the average of six measurements from a powder preparation). The pyroxene is diopsidic augite.

The olivine is quite fresh in most specimens and is similar in size to the pyroxene. These two minerals were often difficult to distinguish from each other. Two grains of olivine were determined by X-ray powder diffraction, they gave Fa 25 ± V 4% in both cases.

A very unusual looking olivine was found in some of the gabbro xenoliths from Seydishólar (Pl. IVb). It appears as red-brown, 1—4 mm grains. In thin section it showed a distinct cleavage pattern as well as the usual irregular cracks characteristic of olivine. It thus has a striking resemblance to pyroxene. X-ray diffraction analysis, however, showed quite clearly that the mineral was olivine with a composition of Fa 25 ± 4%, identical with the fresh olivine. Determinations of the optical angle on twelve grains gave 2Vγ 80°—92° with an average of 85°, corresponding to 23% Fa.

By plotting the poles of the various cleavage planes in 12 grains against the optical directions on a stereogram, five cleavage directions were detected. The most common cleavages were on the (100), (010) and (001) planes, (101) and (121) (?) were more unusual. These are all common crystal faces in olivine. There were usually 3—4 cleavage directions in each grain.

All the olivines showing this intense cleavage were altered to some degree. The grains were coloured strongly red-brown. Under high magnification this could be seen to be due to red-brown microscopical "threads", undulating through the grain. These "threads" have a diameter of 4—5μ, and where they are especially abundant the mineral becomes red-brown in colour. This alteration product is pleocroic from dark- to light red-brown and green-blue to light-brown. It is possibly „iddingsite".

Well developed cleavage is rare in olivines. Cleavage after (010) is most common, and (100) is occasionally found. Hawkes (1946) has described an olivine in dunite from Dunsmuir, California, with perfect cleavage on the (010) and (100) crystal planes. Cleavage parallel to (001) and (110) was also observed.

There is no sign of the olivine being affected by mechanical stress. It seems clear that the cleavage occurred in connection with the alteration of the mineral as the cleavage is only developed in the altered olivines. The red-brown secondary mineral is introduced along at least 5 crystallographic directions in the olivine.

The altered olivine is only found in xenoliths collected from red or reddish scoriae, that is lumps of molten lava, which have been subjected to intense oxidation, during cooling. This suggests that the intense cleavage and the alteration of the olivine developed at the same time as the oxidation of the scoriae.

The olivine is sometimes interstitial in character and can be found surrounding both plagioclase and pyroxene.

Ore is only found in small amounts as tiny black grains enclosed in the pyroxene and the olivine. It never exceeds 0,1% in volume.

Gabbro xenoliths have been found at various localities in Iceland, and have been studied by Tryggvason (1957) and Jónsson (1963). The results of a careful study by Tryggvason on a gabbro bomb from Grænavatn agrees with that found in the Seydishólar xenoliths. Jónsson mentions 18 different localities for gabbro xenoliths in Iceland in late Tertiary and younger volcanic rocks. These were all practically of the same composition. Jónsson suggests that the gabbro xenoliths were probably derived from a zone in the earth's crust above the peridotite layer. The xenoliths have a wide geographical distribution in Iceland and have, according to J. Jónsson, been found in various rock types. It can be noted, however, that they have not been found in rocks with any great range of chemical compositions.

Pálmason (1963) has mentioned the possibility that the gabbro xenoliths are derived from a gabbroic (or basaltic) layer, found at depths of 1,2 to 4,5 km under Northern Iceland. This layer is considered to be associated with the Faroes-Iceland-Greenland ridge.

There is, however, no indication that the gabbro xenoliths are connected to the Wyville-Tompson ridge. No xenoliths of gabbro have been found in the Faroes so far (Noe-Nygaard 1962), and none are reported from the tertiary basalts of East and West Greenland (Noe-Nygaard 1942, Krokström 1942).

Gabbro xenoliths of similar type as those found in Iceland have previously been recorded from several localities elsewhere. On Hawaii inclusions of gabbro and ultrabasic rocks are abundant. Olivine gabbro with granitoid texture was found grading into ultrabasic rock (MacDonald 1949). These xenoliths are thought to be derivied from a zone in the crust somewhat higher than the olivine-rich nodules (Ross et al. 1964). Boulders of olivine gabbro and anorthositic gabbro, showing resemblance to the rock described, here were among the rocks dredged from the Mid-Atlantic ridge SW of the Azores (Shand 1949).

The xenoliths from Seydishólar show a wide range in composition in contrast to those examined by Jónsson (Fig. 5). This suggests that the source is a layered body of gabbro. One of the xenoliths showed crystal sorting (Pl. IIIa). This sample has the same distribution of minerals as the diagram in Fig. 5. The plagioclase: pyroxene ratio varies while the amount of olivine is relatively constant. The mineralogical and textural similarity seems to indicate that the Seydishólar xenoliths have an origin similar to other xenoliths in Iceland in spite of their wide range in composition. The modal analyses of the five gabbroes from Jónsson (1963) fall among those from Seydishólar.

As regards the Seydishólar xenoliths, however, nothing was found speaking in favour of an exogenic magmatic origin of the gabbro. The mineralogy and the composition of the gabbro and the host rock is very similar. The olivine and the pyroxene are practically of the same composition in both rocks. The plagioclase

shows a higher An-content in the gabbro, but this may equally well be expected, supposing an endogenic as an exogenic origin. The range in the composition of the gabbro is considerable. The average composition, however, of the ten xenoliths in fig. 9 is plagioclase 55%, pyroxene 36% and olivine 9%, and that is within the shaded area of the Grímsnes lavas. The most noteworthy difference between the

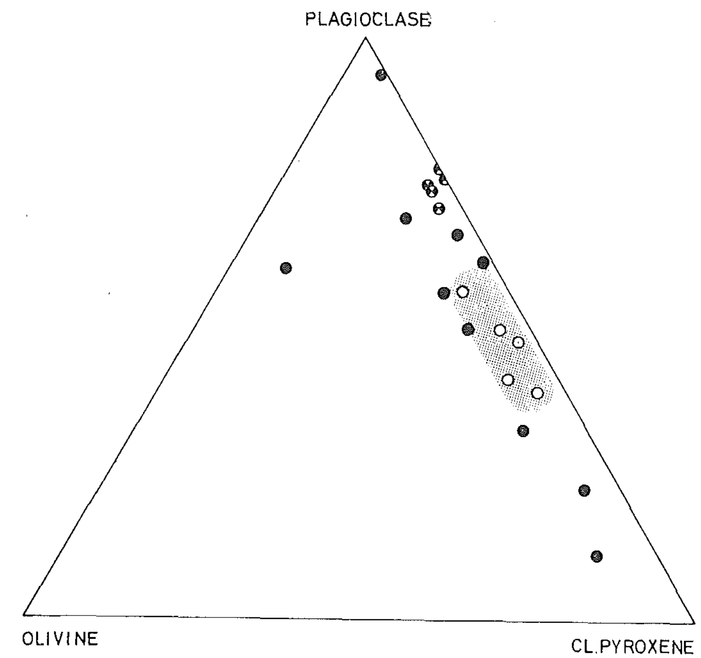

Fig. 5. Diagram showing the proportions (vol. %) of the three principal minerals in the Grímsnes lavas (shaded area), the gabbro xenoliths from Seydishólar (black dots) and five gabbro xenoliths quoted from Jónsson (1963) (particoloured).

two rocks is in the amount of ore, which is not included in the diagram. Only a minimal amount of ore (<0,1%) was found in the xenoliths, whereas five analyses of the lavas showed a range from 6,0—10,7% in volume. None of the minerals of the gabbro showed sign of deformation.

No definite conclusion can be arrived at from the preliminary examination of the xenoliths presented here. An endogenic magmatic origin of the gabbro is not ruled out, however. Further comparative studies on the xenoliths and the host rock are being made and will be presented later.

Vitrified acid xenoliths. Glassy inclusions up to 10 cm across were found in the scoriae layers of five of the craters: Seydishólar, Tjarnarhólar, Raudhólar, Selhóll I, and Álftarhóll.

The xenoliths are a pumiceous, fragile, white rock, varying from very porous or frothlike in Seydishólar and Tjarnarhólar to a more dense porcellanic material in Álftarhóll and Selhóll I. Some of the pieces have sharp edges, and where the contact between the siliceous inclusions and the enclosing scoria is seen, it is very sharp and shows no sign of reaction. The vitrified xenoliths are quite common in the Grímsnes craters and they exceed the gabbro xenoliths in quantity.

The xenoliths are mainly made up of clear liparitic glass with ngl: 1,490—1,499, containing scattered crystals of quartz and altered feldspar. The quartz is up to 1,2 mm in diameter and is often found as aggregates of shattered grains. It generally has a sharp contact with the glass. The feldspars are altered, but it has been possible to distinguish both plagioclase and potash feldspar. Small grains of black ore are found, and the glass has in places a hematitic pigment. The glass normally shows a glass-bubble or glass-shard texture except in areas where the rock is completely remelted. In one xenolith from Seydishólar granophyric texture could be distinguished. In some of the xenoliths from Álftarhóll and Selhóll I the rock appears to have split up along certain planes when expanding.

The xenoliths are obviously fragments of an acid rock melted and vitrified to a high degree. In order to get some idea of the composition of the original rock, the silica content of a xenolith from Álftarhóll was determined. This showed an amount of 74,78% SiO_2. This is identical with the average silica content of five chemical analysis of liparites from Vatnajökull, presented by Noe-Nygaard (1952). In an analysis of granophyre from Hafnarfjall, West-Iceland (unpubl., anal. J. Jakobsson, Univ. Research Inst. Reykjavík) the silica content was determined to be 74,47%.

In Selhóll I two small pieces of unaltered white rock were found. The largest (Pl. IIIa) was 3 x 2 x 2 cm in size. This rock consists solely of quartz and feldspar approximately in the ratio 1:4. The feldspar is plagioclase with refractive index nγ: 1,555 $\pm$ 0,005, indicating an An-content around 40%. No glass could be found. The grain size is 0,1—0,2 mm, while the texture is allotriomorphic.

It is unlikely that this quartz-andesine aggregate represents the source of the vitrified xenoliths. Apart from the mineralogical differences, no widespread volcanic rock of this composition is known (Johannsen 1939—45).

T. Tryggvason (pers. inform.) reports that veinfillings of quartz, feldspar, and ore with a similar texture as the liparite xenoliths from Selhóll I are found in connection with the liparite intrusion near Thyrill, Hvalfjördur.

Acid xenoliths are widespread in Iceland. Tryggvason (1965) has described acid xenoliths from Hekla. No absolute proof of the origin of these was found. Acid glassy xenoliths have been found recently on Snæfellsnes. (G. Sigvaldason pers. inform.). Xenoliths of similar type are abundant both in Askja and Surtsey, the new volcanic island.

Milton (1944) gives a description of white bombs from the eruption of Paricutin. These show a striking similarity to the xenoliths described here, and the description by Milton could be adapted here to cover most of the material from Grímsnes. The material was identified as liparitic, possibly originally a liparitic breccia. White pumice, consisting of glass with scattered crystals of quartz and

feldspar, was ejected in the eruption of Nilahue, Chile (Müller & Veyl 1957). The pumice was believed to indicate a granitic source close to surface.

Considering the origin of the vitrified acid xenoliths from the Grímsnes craters, it is unlikely that they are differentiation products of the magma. The Grímsnes and the Skjaldbreidur lavas show no sign of differentiation in spite of great amount of emitted material. No indication of an acid layer in the crust of Iceland has been found yet according to Båth (1960) and Pálmason (1963). The acid xenoliths therefore probably represent intrusions of liparitic composition at depth. Granites are unknown in Iceland, whereas liparitic intrusions are common and granophyres are known from several localities in West and East Iceland.

The age of the lavas.

The two farms Midengi and Klausturhólar (formerly Hallkelshólar) lie on the lavas. According to the Book of Settlement (Landnámabók), these farms were built in the 10th century. This proves that the lavas were already covered with vegetation a thousand years ago and must therefore be considerably older.

It is possible to estimate the age of the lavas by studying soil profiles. Four soil profiles from Grímsnes are shown in Fig. 6. Profile 1 is taken at Selhóll I (Finnheidi), profile 2 and 3 along the banks of Hædarendalækur (the uppermost part of Búrfellslækur) and profile 4 at Hólakotslækur, a brook running at the east side of Kerlingarhóll lava. All profiles contain tephralayers from the Grímsnes craters.

Near the top of profiles 2 and 3 there is a thin black ashlayer, most probably from the Katla eruption in 1918. The lower black ashlayer in profiles 1 and 2 could be the black Katla ashlayer from about 1500 found by Thorarinsson (1961) as far west as Reykjavík. A two cm thick dark-brown tephralayer is conspicuous at a depth of about 0,5 m in all the profiles. The origin of this layer is uncertain, but the likeliest source is Hekla. The thickness of the layer is surprising as Grímsnes is far from the great tephra-producing volcanoes. The brown layer is younger than the tephralayer H 3 (about 2800 years old) and the age can be estimated to about 2000 years or somewhat younger. In two soil profiles from Lambhagi and Skallakot west of Hekla, Thorarinsson (1954) shows three brown tephralayers younger than H 3, and older than the colonization layer VII. It is probable that the brown tephralayer in Grímsnes is identical with one of those.

The white tephralayer H 3 from Hekla is found in profiles 1 and 2. It is about 2800 years old (Thorarinsson 1954).

A thin white ashlayer is shown under the pumice layer from Seydishólar in profile 2. This could be the Hekla layer H 5 (Thorarinsson pers. inform.); if this is H 5 it is one of the westernmost points found so far. The H 5 is about 6600 years old.

By comparing the position of the scoriae and pumicelayers from Selhóll I, Seydishólar and Kerlingarhóll to the layer H 3, it is clear that they are considerably older than 2800 years. Profiles 2 and 3 rest on gravel and profile 4 on "móhella" (hardened eolian soil). It is assumed that each of the profiles 2 and 4 represent a total of approximately ten thousand years, and if the thin white ashlayer in pro-

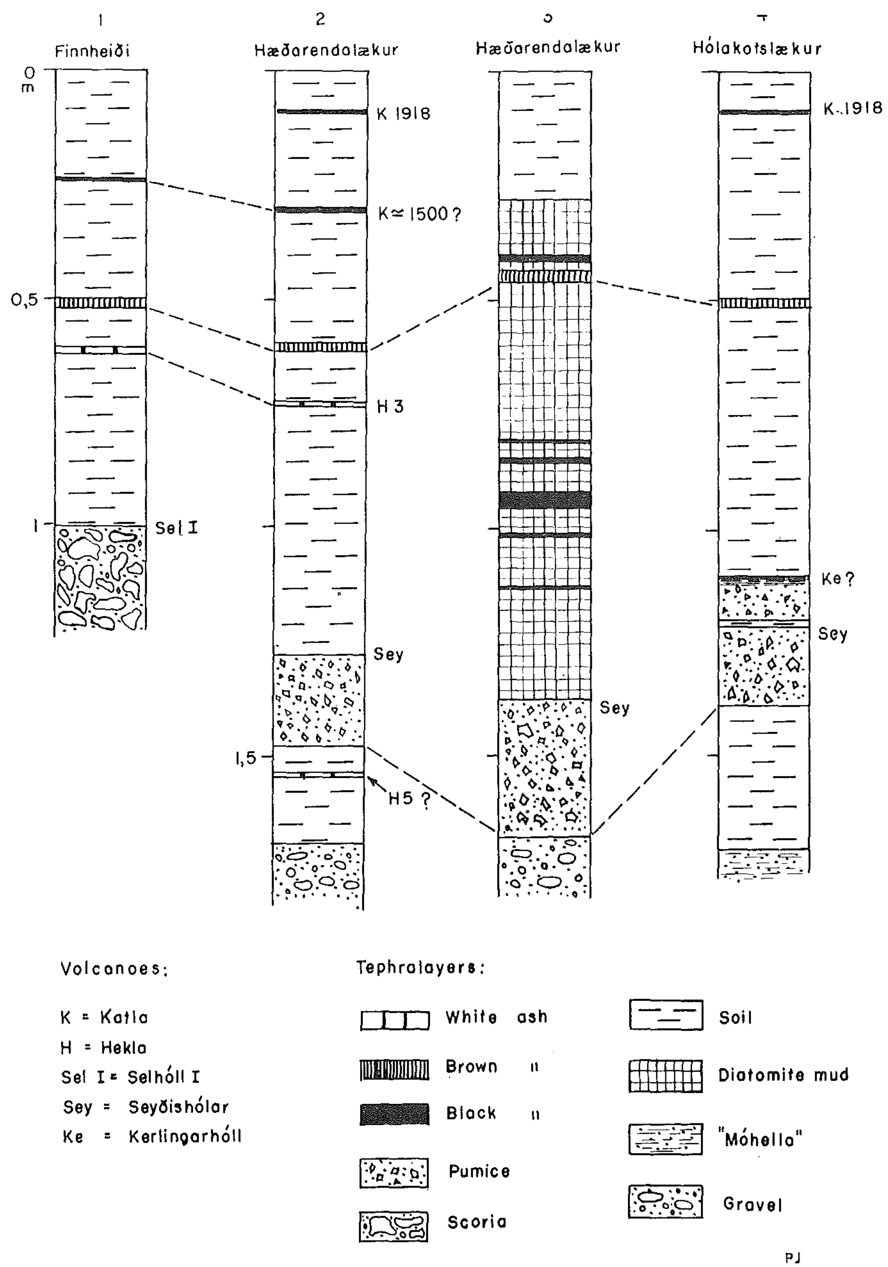

Fig. 6. Four soil profiles from Grímsnes (cf. Plate V).

file 2 is correctly identified as H 5, the age of the scoriae- and pumicelayers from the three craters mentioned above can be estimated to be 5000—6000 years, and they are all of similar age. The lower pumice layer in profile 4 is assumed to be from Seydishólar and the upper one from Kerlingarhóll crater. There is a 0,5—1,0 cm thick layer of soil between them. These two layers have only been seen in one profile and must be interpreted with some care; however, there is no sign that the layers are secondary. Both layers consist of bluish-black pumice, the upper layer, which is of smaller grain-size, is covered with a thin black ashlayer. This has not been observed in the Seydishólar pumice layer elsewhere, and as both layers cannot be from Seydishólar, the upper layer is in all likelihood from the Kerlingarhóll craters. There appears therefore to be a little time interval between the eruption of Seydishólar and Kerlingarhóll.

A thin layer of carbonized moss or heather is found under the Seydishólar lava (or Kerhóll lava), and it should therefore be possible to get the exact age of the flow by the C^{14}-dating method.

Profile 3 is taken a short distance north of Seydishólar and shows a diatomite layer formed in a lake dammed up by Seydishólar and Selhóll II lavas; the diatomite mud has begun to form directly after the deposition of the pumice layer. It can be seen that the diatomite mud was under formation for more than 3000 years, as the brown tephralayer near the top of the diatomite layer is about 2000 years old. There are several black horizons in the diatomite mud, probably tephralayers, being particularly distinct in the white diatomite.

Remarks on the volcanism.

The volcanism in Grímsnes had an areal distribution not commonly reported from Iceland. There were eruptions from 10 volcanic vents within a short period of time. The craters lie in a zone, 12 km in length and up to 4 km in breadth, stretching from SW to NE, which is the characteristic orientation of volcanic and tectonic fissures in S-Iceland.

Crater groups are not uncommon in Iceland and were formerly thought to indicate eruptions over a large area. Thorarinsson (1951), however, has shown that all crater groups in Iceland are of secondary origin with the possible exception of a group of explosive craters in the Veidivötn district described by Nielsen (1933). This consists of 17 explosive craters in an area of 1 sq. km. It is therefore necessary to emphasize the linear character of the volcanism in the Grímsnes district in contrast to the irregular pseudocrater groups.

At least five fissure eruptions occurred in the Grímsnes area, however Kálfshólar-Kerlingarhóll and Tjarnarhólar-Seydishólar respectively should probably be regarded as parts of the same fissure lines. The Álftarhóll crater is elongated to SW, so probably the eruption was linear in the beginning. The orientation of the crater rows varies slightly, but when viewed as a whole is identical with that of the zone.

In Fig. 7 the orientation of the Grímsnes craters is shown in relation to tectonic features in Búrfell and Lyngdalsheidi. The tectonic direction is the same, broad-

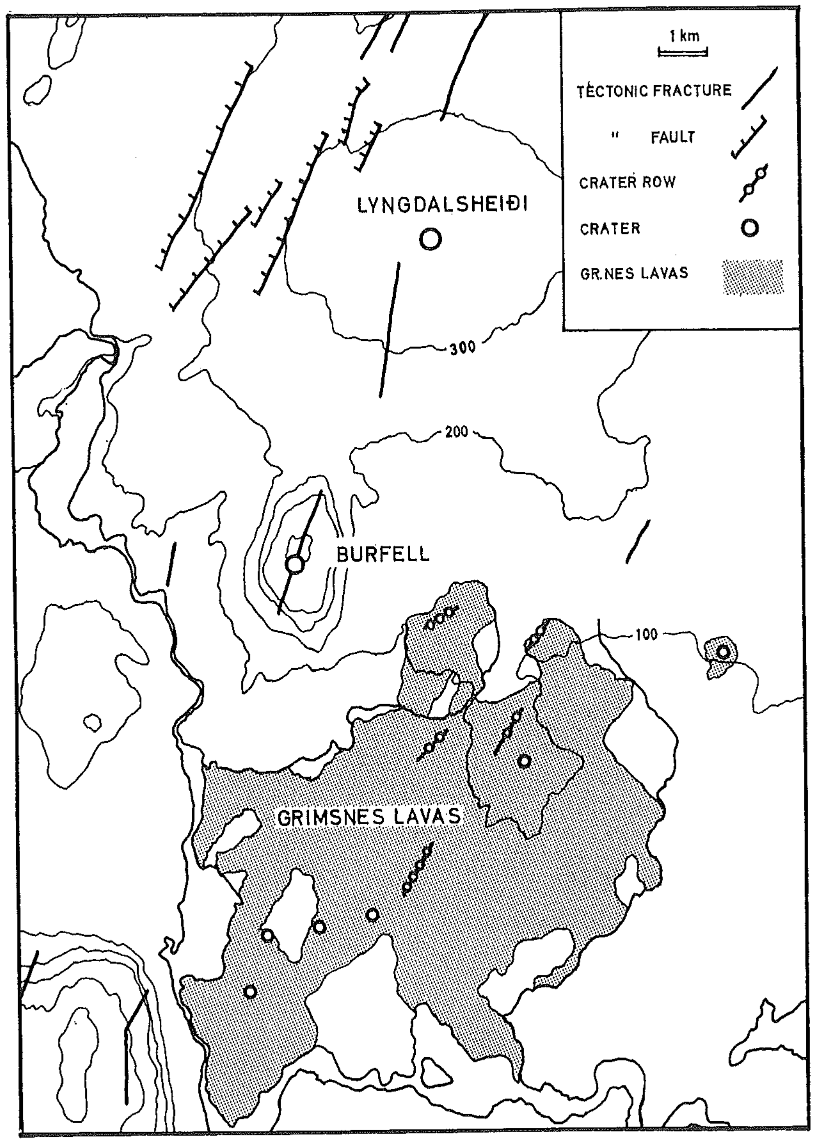

Fig. 7. The tectonic setting of the postglacial volcanic area in Grímsnes and the region north of it.

ly speaking, although the pleistocene Búrfell and Lyngdalsheidi show a more southerly direction of fractures and faults. The faults in the NW-part of Lyngdalsheidi are at the margin of the Thingvellir graben. The length of the fissures varies from 500 to 800 m. Eruptive fissures of this length are frequent in Iceland. The central eruptive craters do not differ from single craters in the crater rows, they have the same shape and a similar size. The craters are made up of scoria and schweiss-schlacken and occasionally of a lava layer (Kerhóll). The Grímsnes craters are classified as spatter cones and spatter cone rows, while Kerid alone is maar. (cf. the classification of Thorarinsson in: Kjartansson et al. 1960).

It is possible to calculate the volume of the Grímsnes lavas, as the thickness is known from several localities. Drilling was made for water at the Midengi farm, the lava showed to be 18 m thick. The thickness of the lava- and scorialayers at Kerid is about 25 m. Assuming an average thickness as 18—20 m, the total volume of the lavas is approximately 1 cu. km.

The volcanic events in the Grímsnes district started with the formation of Tjarnarhólar and Seydishólar, which are the two volcanic centres displaying the highest explosive activity. The pumice layer which can be traced back to Seydishólar and the light, spongy scoriae of Seydishólar proper show the relatively high gas content of the magma at the beginning. The volcanic activity then continued with the eruption of other craters and crater rows which were largely effusive.

It is interesting to compare the volcanism in the Grímsnes district to the volcanic eruptions near Mývatn, the "Mývatn-fires", in 1724—1729 (Thoroddsen 1925 p. 226—229). The eruptions in the Grímsnes district may have developed in a similar way.

The eruptions started with vigorous explosive activity in 1724 which resulted in the formation of the maar Víti (diam. 350 m). In 1725 fissures opened farther west at Leirhnúkur and Bjarnarflag producing lava. In 1727 and 1728 the Leirhnúkur and Bjarnarflag fissures had a renewed activity and in addition a fissure opened at Hrossadalur and Dalfjall also producing lava. The production of lava ceased in 1729, but according to one source there was some explosive activity in the Leirhnúkur-fissure as late as 1746.

The Leirhnúkur-fissure which has a length of 10 km, gradually grew during the eruptions. Hrossadalur and Bjarnarflag which are much shorter, lie on the same fissure line as the Leirhnúkur fissure. The Dalfjall fissure is parallel to the others. The total output of lava in the "Mývatn-fires" is approximately 1 cu. km, i. e. the same as in Grímsnes.

The Askja-eruption of 1961 (Thorarinsson and Sigvaldason 1962) is of the same magnitude as the eruptions in Tjarnarhólar and Kálfshólar. The Askja fissure is 700 m long and the lavaflow covers an area of 11 sq. km, the total volume being 0,1 cu. km. These are about the same figures as for Tjarnarhólar lava and Kálfshólar lava.

Rittmann (1960) has introduced the explosivity index E, the ratio between tephra and total material ejected. In lava volcanoes E is lower than 10. The amount of tephra in Grímsnes is estimated to be 0,07 cu. km (Seydishólar alone is 0,03 cu. km), and the explosivity index is then:

$$E = \frac{0,07}{1} 100 = 7$$

According to this classification the Grímsnes volcanism is effusive.

However, as Thorarinsson (1954) has noticed, it is necessary to use comparable specifications regarding the volume of the tephra, when eruptions are classified. "In order to obtain comparable sizes, the volume of tephra and lava should be reduced to a corresponding volume of compact lava of the same chemical composition, i. e. it is necessary to measure not only the thickness of the tephra layer but also its volume-weight, or its absolute weight per unit area".

Four hot wells are found in the mapped area. The temperature does not exceed 50° C. The hydrothermal activity does not appear to have any direct connection to the volcanism in the Grímsnes area. Numerous low-temperature alkaline hot wells (springs) are found all over the country but are mainly found outside the neovolcanic areas (Barth 1950).

HYDROLOGY

The Grímsnes lavas are typical blocklavas. The surface is very uneven and consists mainly of loose blocks. This means that all precipitation drains directly through the lavas and emerges out as springs at the edges of the lavas. These may be observed particularly at two places, at Nautavakir south of Snæfoksstadir farm, and at Álftavatn, where the springs are called Vadlækir. A considerable amount of water with a constant temperature the year round streams out with the result that Hvítá and Sog never freeze near these springs.

A drilling was made for water at the Midengi farm on the Kálfshólar lava. Water was found just below the lava at a depth of 18 m. The height of the farm is about 65—70 m above sea level according to the Geodetic Institute map. The height of the ground-water is thus near 50 m above sea level. This is about the same as the height of the small lake in Kerid. So presumably the lake in Kerid simply shows the height of the ground-water; it is a hydrographic window.

According to G. Gígja's measurements in 1943 (pers. comm.), the depth of the lake varied between 7—14 m during the summer, thus showing the variations of the height of the ground water-table.

The formation of the Grímsnes lavas has not changed the course of the two rivers Sog and Hvítá to any extent. The outcrops of late glacial sediments under the Kálfshólar lava and the lava-free north-coast of Álftavatn shows that the Sog has the same course as before the eruptions at least so far as Álftavatn. In the southernmost part of Álftavatn there is a deep, narrow fissure in the bottom of the lake, which seems to extend farther south in the bottom of the Sog. When seen from a boat, the fissure can be estimated as several meters deep below the normal bottom of the lake; which is at a depth of about 5 m here. This cannot be a tectonic fissure because of its irregular course. P. Hannesson has written a note about this fissure in one of his diaries. (*Frá óbyggðum*, 1958, p. 319, transl.): "A distinct fissure can be seen on the bottom of the lake, probably eroded by the older Sog before the Grímsneslava was formed". The fissure (or the gorge) is probably the result of erosion by the Sog, but hardly under the present conditions. The Sog has not a great erosional force today, its water-content is constant the year round and the amount of transported material is very little. The height difference along the Álftarhóll lava is only one meter according to the Geodetic Map.

The gorge was most probably eroded before the Thjórsá lava was formed (about 8000 years ago). This lava adjoins the Grímsnes lavas in south (see Pl. V). According to Kjartansson (1943, p. 202), the Thjórsá lava was probably formed at a lower sea-level than today as it extends forward into the sea near the coast between Thjórsá and Ölfusá .The dating of submerged peat from Seltjörn at Reykjavík shows that about 9000 years ago the sea-level was at least 2 m below the present one. (Thorarinsson 1956). Álftavatn has a height of 15 m above sea level and if the depth of the gorge is estimated as 4—5 m, the bottom of the gorge is then 8—10 m below the surface of Álftavatn or only 5—7 m above sea level at a distance of 18 km from the present coast. To account for this gorge a considerably lower sea level more than 8000 years ago must be presumed.

The diatomite layer found along the bank of Hædarendalækur (soil profile 3) was obviously formed in a lake when Hædarendalækur was dammed up by the Seydishólar and Selhóll II lavas. The maximal thickness of the layer is 1,10 m but, generally it is much thinner.

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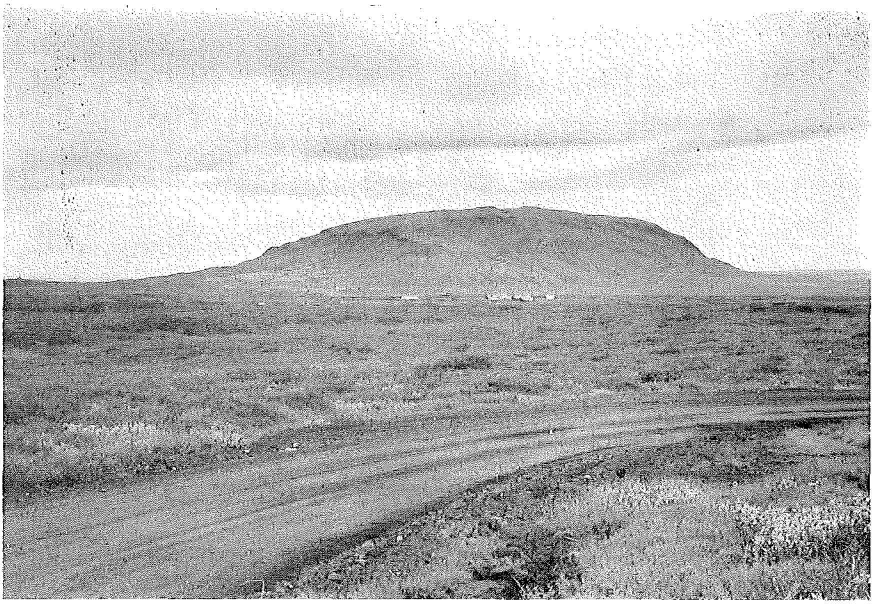
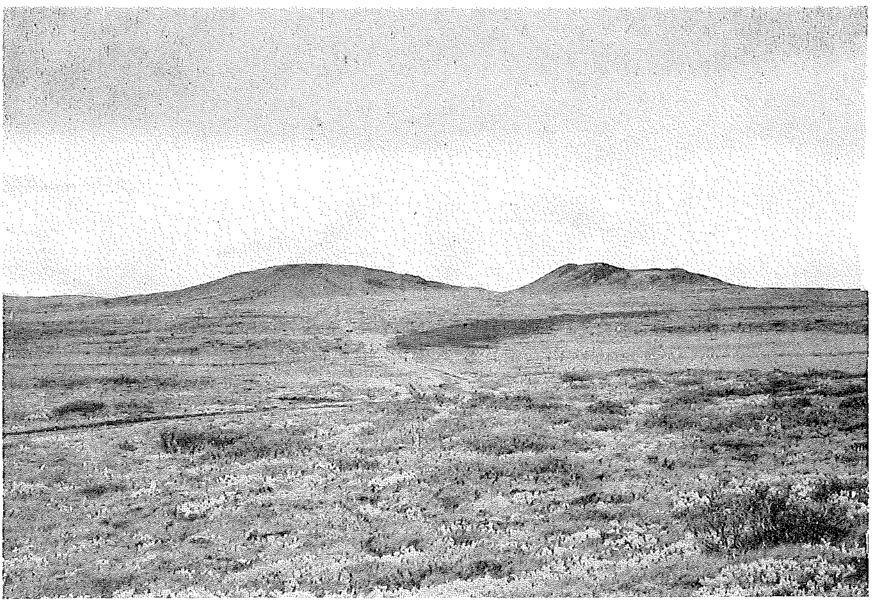
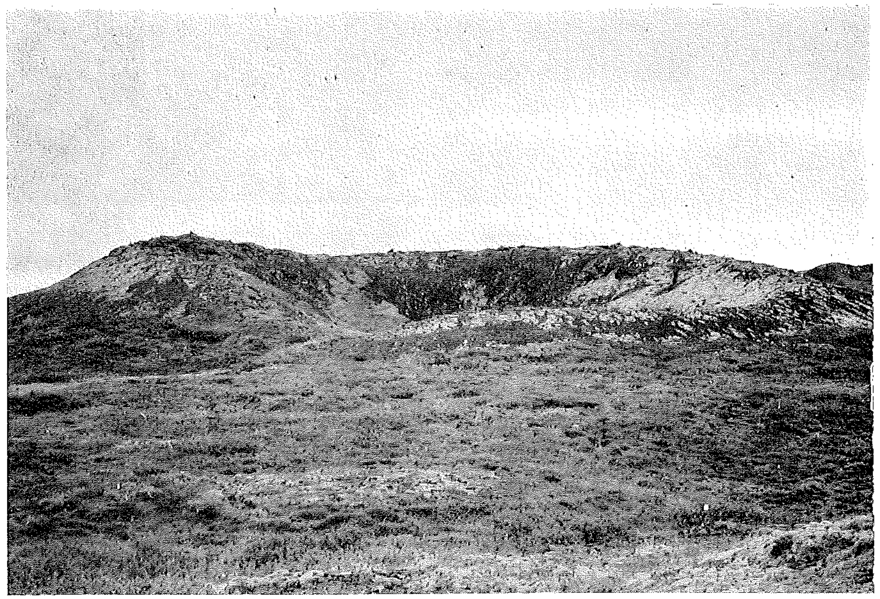


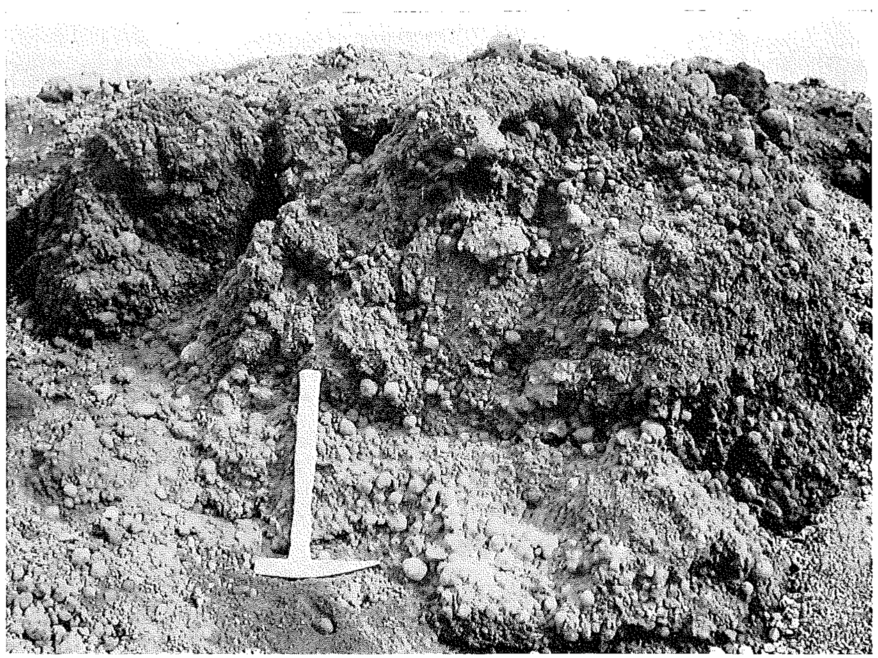
Pl. Ia. A view from Tjarnarhólar across the lavafield towards the mountain Búrfell (536 m).



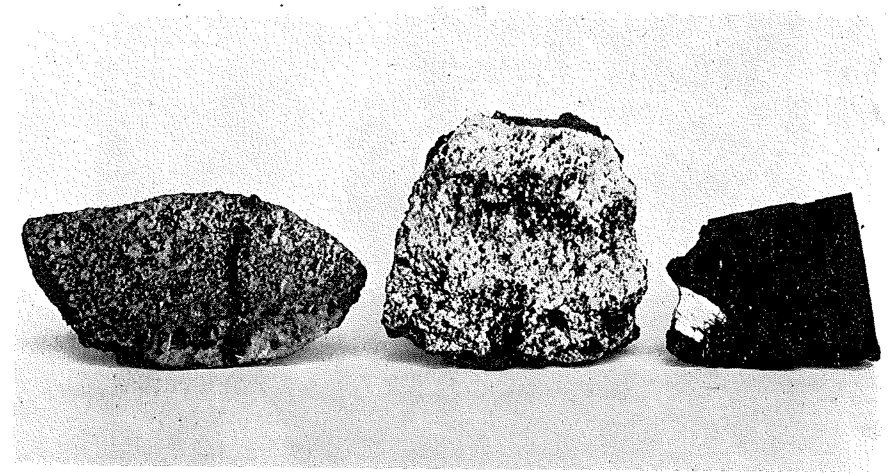
Pl. Ib. Seydishólar seen from SW. To the right Kerhóll.



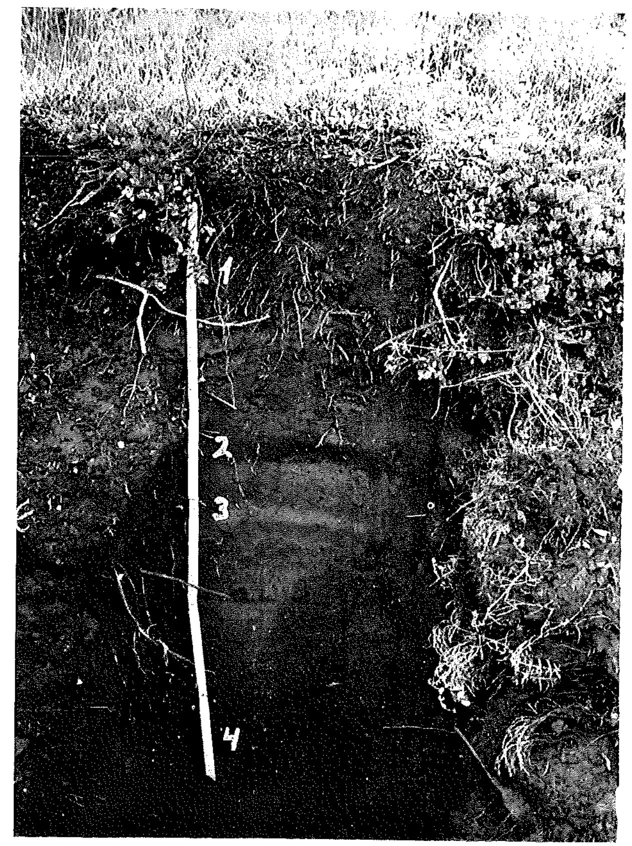
Pl. IIa. The southernmost Kálfshólar crater. The diameter of the crater is about 110 m.



Pl IIb. Scoriae containing small volcanic bombs in Selhóll I.

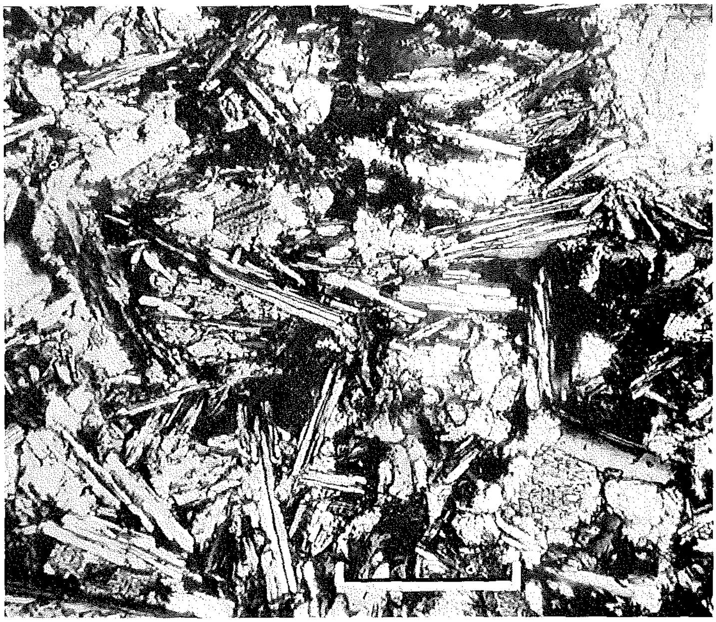


Pl. IIIa. Three types of xenoliths from Grímsnes. At left, gabbro xenolith from Seydishólar showing crystal sorting, then vitrified acid xenolith from Seydishólar and at right quarts-plagioclase aggregate in scoria from Selhóll I.



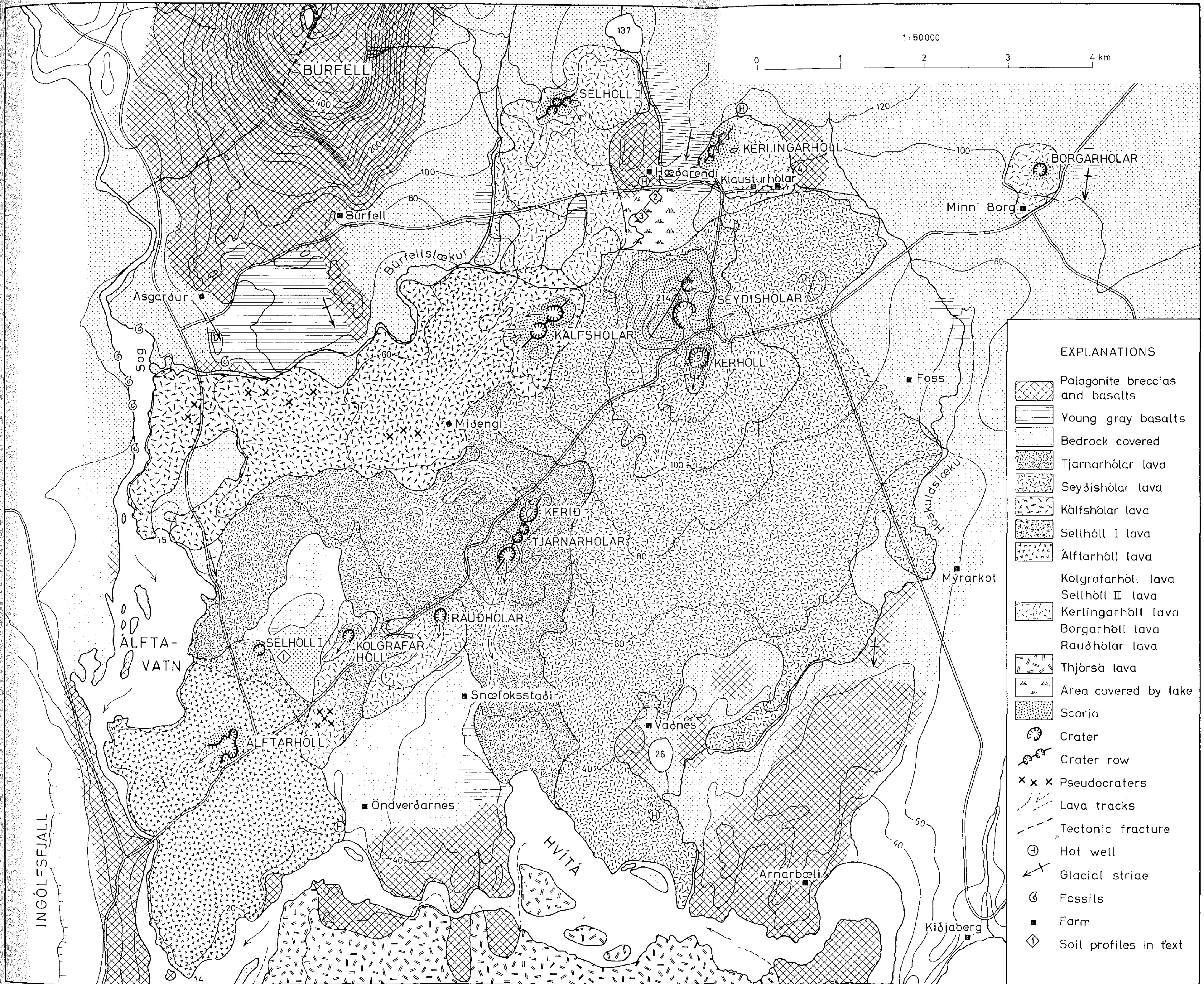
Pl. IIIb. Soil profile 1 (Finnheidi) in fig. 6. From above, black ash layer, K $\cong$ 1500? (1), the brown ashlayer (2), the white Hekla layer H 3 (3), and scoria from Selhóll I (4). The foot rule is 1 m.

PLATE IV.



Pl. IVa. Tjarnarhólar lava. Ophitic to quasiophitic texture. The scale is 0,2 mm. Crossed nicols.

Pl. IVb. Gabbro xenolith. Olivine with highly developed cleavage. The scale is 0,2 mm. Crossed nicols.



Pl. V.
The postglacial volcanic area in Grimsnes.