Landsbókasafn Íslands
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Eftirfarandi grein var sótt af Tímarit.is þann 9. desember 2022 klukkan 19:41

Titill
On the age of the terminal moraines of Brúarjökull and Hálsajökull

Höfundur
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Tímarit
Jökull
14. árgangur 1964
1. tölublað
Bls. 67-75

Vefslóð
https://timarit.is/gegnir/000571538

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SIGURDUR THORARINSSON:

On the Age of the Terminal Moraines of Brúarjökull and Hálsajökull

A Tephrochronological Study

THE TERMINAL MORAINES OF BRÚARJÖKULL

In 1962 I was invited by two professors of the University of Iceland, Kristinn Stefánsson and Snorri Hallgrímsson, to join them on a trip to Kringilsárrani north of Brúarjökull in late August that year. They were going to this area in order to study supposed disease in the reindeer stock living wild there as the area is protected by the two large glacier rivers Kringilsá and Jökulsá á Brú. I gratefully accepted this invitation, as it gave me an opportunity to fill a gap in my tephrochronological knowledge of the postglacial soils in the interior of Iceland. I was also eager to have a look at the „Vorfeld" of Brúarjökull in this area, well known in the glacial-geological literature, especially through the investigations of Hannesson (1953), who visited Kringilsárrani in 1933, Woldstedt (1939), who was there in 1936, and Todtmann (1955, 1957, 1960), who spent the summer of 1955 in this very interesting area.

The most striking topographical features of Kringilsárrani are high terminal moraines (max. relative height 18 m) covered by relatively luxuriant vegetation. These moraines are typical thrust moraines, showing complex folding and overthrusting. E. Kjerulf, who wrote a contemporary report on the 1890-advance (cf. Jökull 1962, pp. 47–48) calls such moraines *jökulýtur,* which is an excellent term. The local name for the vegetation-covered thrust moraines is *hraukur,* plur. *hraukar.* They stretch not only over Kringilsárrani, but continue, mainly as block moraines, towards W to Kverkárnes and towards E to Maríutungur. No doubt they are mainly formed by the catastrophic advance of Brúarjökull in 1890 (op. cit.), but in some places their distal part may have been formed by the catastrophic advance in 1810, and pushed a little farther northwards by the 1890-advance. This seems to be the case in Kringilsárrani, according to contemporary descriptions of the 1890-advance. East of Jökulsá there are some "hraukar", such as Útigönguhaus south

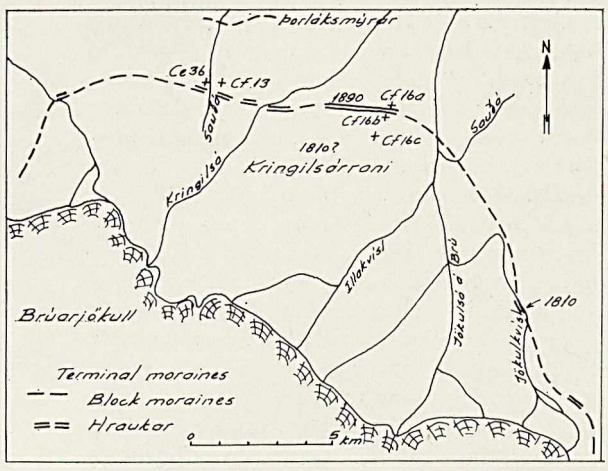


Fig. 1. Sketch map showing the situation of profiles discussed in the text in relation to the terminal moraines of 1890 and 1810. Schematized with some alterations by the author from the maps Fig. 2, Todtmann 1957 and Fig. 5, Todtmann 1960.



Fig. 2. The 1890-moraine short W of Kringilsá. The scar to the left goes down to the ice core, showing that the ice-free moraine cover is only about 1.5 m thick in this place.
Photo: S. Thorarinsson, Sept. 5, 1962.

of Jökulkvísl, which existed before the 1890-advance, and in all probability they date back to the 1810-advance, which thus has brought the ice margin a little farther than the 1890-advance in that area.

Todtmann describes a large terminal moraine in Kringilsárrani about 1.5 km south of the "hraukar", and regards this moraine to be the 1810-moraine, which had been overridden by the ice during the 1890-advance. (Todtmann 1955, p. 261). This may be true, although it does not quite agree with Kjerulf's report of the 1890-advance. Todtmann mentions that the Askja tephra of 1875 is found in the foldings of the uppermost layers of these moraines. According to my investigations in 1962 the southern limit of the 1875-tephra sector is definitely north of the "hraukar" (cf. the isopach map, fig. iv in Thorarinsson 1963). However, wind drifted 1875-tephra may be found south of the "hraukar", because, at 13 cm depth and some cm upwards the soil in section Cf 16a (fig. 6) is lighter in colour than the underlying soil, and there is no doubt that the light colour is caused by wind drifted dust from the 1875 tephra layer. I am, however, a little doubtful as to the possibility of recognizing it as far south as the "1810" moraine. I would think it more likely that the tephra mentioned by Todtmann as the 1875 one is the Öræfajökull tephra of 1362.

SOIL SECTIONS JUST NORTH OF HRAUKAR

Sept. 4th, 1962, I measured a soil section about 10 m north of Hraukar on the E part



Fig. 3. Position of section Cf 16a (indicated by an arrow to the farthest left) north of Hraukar on Kringilsárrani. View towards E.
Photo: S. Thorarinsson, Sept. 4, 1962.



Fig. 4. The same area as on fig. 3 (cf. the arrow) but viewed towards W. Relative height of the "hraukar" to the left is 18 m. During the first summers after the 1890-advance meltwater from the ice margin has eroded a lateral bed through the loessial soil cover down to the ground moraine.
Photo: S. Thorarinsson, Sept. 4, 1962.

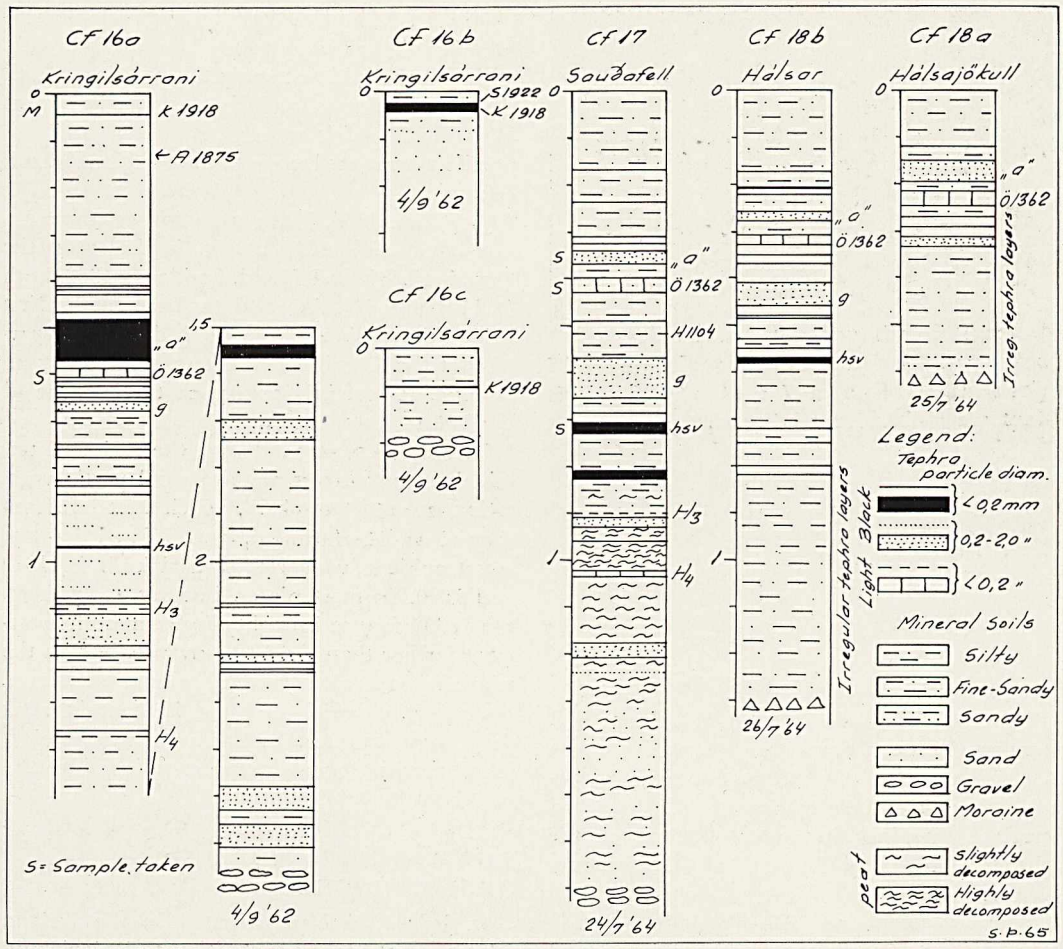


Fig. 5. Soil sections from the Kringilsárrani and Snæfell areas. For location see fig. 1.

of Kringilsárrani, just before the sloping towards the Jökulsá valley begins. This section is shown as Cf 16a on fig. 5 and on the photo fig. 6. In this section we recognize 3 rhyolitic tephra layers. The uppermost and thickest one is from the great Öræfajökull eruption in 1362. Its average thickness in the Kringilsárrani area is between 2 and 2.5 cm, or about half a cm thicker than shown on the isopach map in my monograph of this eruption (Thorarinsson 1958, fig 27), but on the whole my thickness measurements of this layer on Brúaröræfi, as well as in the Snæfell area in 1964, fit tolerably well into the picture of the distribution of the 1362-tephra given on that map.

The other two rhyolitic layers are the Hekla layers designated as H_3 and H_4. According to radiocarbon datings their age is 2800 and 4000 years respectively. (Kjartansson, Thorarinsson, Einarsson 1964, pp. 115–120). The layer of loess-soil from H_4 down to the sub-soil contains many undisturbed black tephra layers, and its thickness below H_4 is about the same as above that layer. There is therefore no doubt that here undisturbed building up of soil has taken place since the withdrawal of the Würm ice from this area. Thus it is definitely proved by tephrochronology that the 1890-advance brought Brúarjökull to its maximum extension on Kringilsárrani since the withdrawal of the Würm ice.

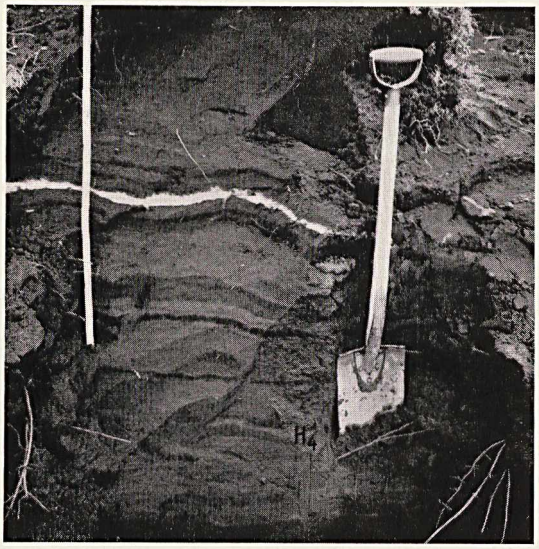


Fig. 6. Section Cf 16a on Kringilsárrani. Visible length of ruler 95 cm.
Photo: S. Thorarinsson, Sept. 4, 1962.

THE THORLÁKSMÝRAR STAGE

Todtmann has described old-looking end moraines between Saudá and Kringilsá about 2.5 km north of the 1890-moraines. She regards these moraines as corresponding to old terminal moraines in front of some of the southern outlets of Vatnajökull—Öræfajökull, such as Stóralda in front of Svínafellsjökull (Todtmann 1960, pp. 47—49). The Stóralda moraine is regarded both by Todtmann and myself as early Subboreal. Having proved definitely that the "hraukar" on Kringilsárrani mark the maximum extension of Brúarjökull in that area since the recession of the Würm ice I found it unlikely that any subboreal advance could have brought the margin of the glacier between Kringilsá and Saudá as far north as to the Thorláksmýrar moraines. In order to get some tephrochronological evidence pro or contra Todtmann's opinion I walked over the ridge south of Saudafellsalda Sept. 5th, 1962, and dug a hole in a grass-covered loessial soil-spot short east of Saudá, about 300 m north of the 1890 moraines (Cf 13 on fig. 1). I found Ö 1362 at 70 cm depth and loessial soil below to more than 1.4 m depth. Although I could not study the profile beneath Ö 1362 in detail, and did not notice layers H_3 and H_4, I felt rather certain that this soil profile represented more than 3000 years of soil formation.

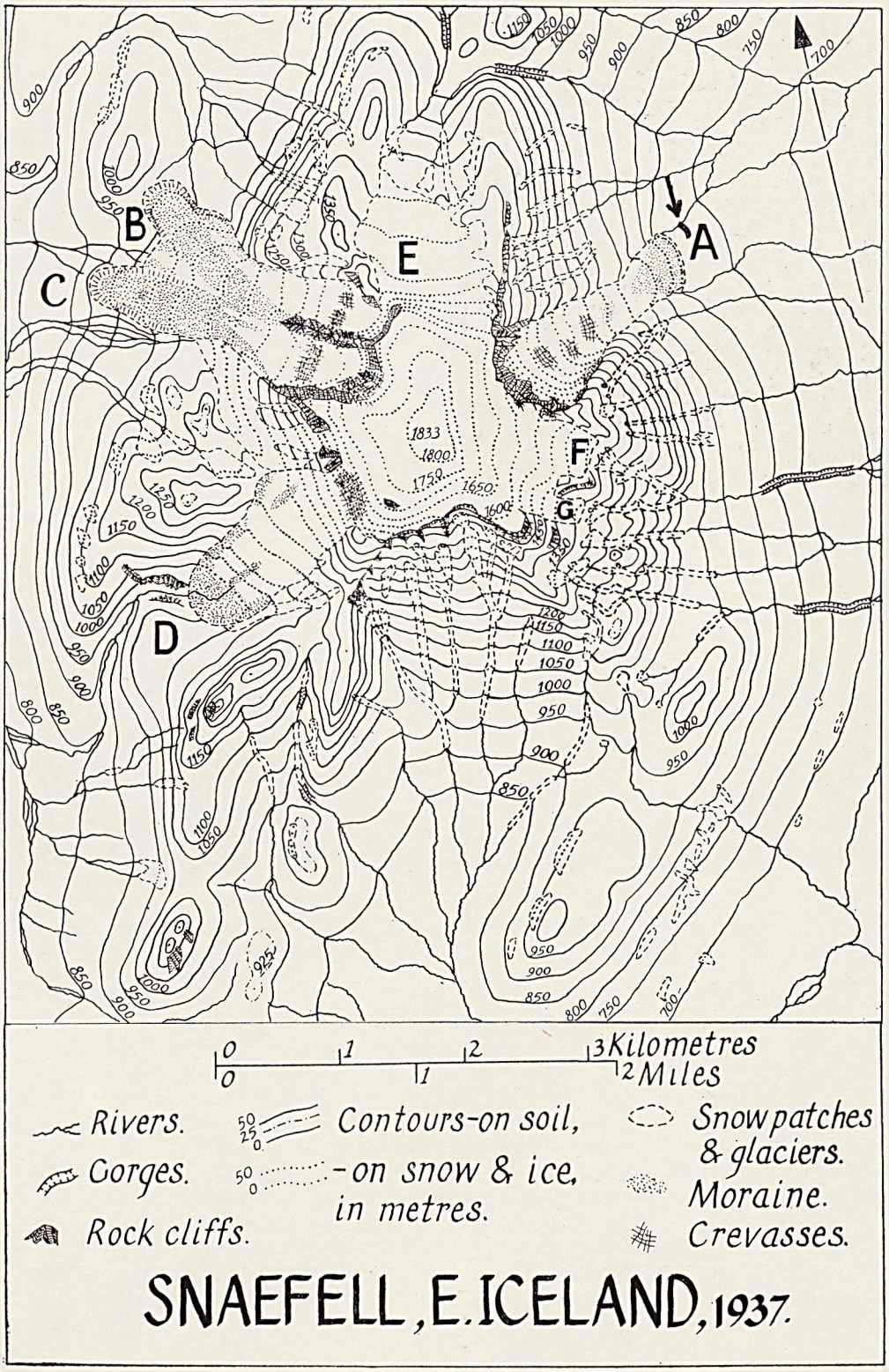
July 21st, 1964, I dug a section on the western bank of Saudá, 130 m in front of the "hraukar". There I found, besides Ö 1362, both H 1104 and H_4. As H_4 dates back to the first half of the Subboreal Time it is definitely proved that the Thorláksmýrar stage cannot be sub atlantic. It certainly goes back to the time of the Würm ice recession.

Summing up we find that the series of terminal, mainly thrust moraines and partly vegetation covered "hraukar", which stretches from Kverká to Maríutungur, was formed by two catastrophic advances of Brúarjökull, in 1810 and 1890. In most places, but not everywhere, the 1890 advance brought the ice margin somewhat farther than the 1810 advance, but on the whole there seems to have been small difference between the position of the ice margin after those two advances. By these advances Brúarjökull reaches its maximum extension since the withdrawal of the Würm ice.

THE TERMINAL MORAINES OF HÁLSAJÖKULL

In July 1964 I participated in the Iceland Glaciological Society expedition to Brúarjökull. Towards the end of this expedition we spent a few days, July 24th—27th, in the surroundings of the extinct cone volcano Snæfell, the highest mountain in Iceland outside Vatnajökull, 1833 m. The morphology of Snæfell and the state of its glaciers has been described by J. N. Jennings (1952), who surveyed this mountain in 1937 when participating in an expedition led by W. V. Lewis. On the mountain there are four true glaciers (fig. 7), three of which are on the W side, one on the ENE side. All these glaciers are without a name, but the glacier on the ENE side (Cf. fig. 8) I have given the name Hálsajökull. From Jennings (op cit., p.

Fig. 7. J. N. Jennings' map of Snæfell. The glaciers are designated by block letters. A is Hálsajökull. Added to the map by the author is the old terminal moraine in front of Hálsajökull to which the short arrow points.



SNAEFELL, E. ICELAND, 1937.



Fig. 8. Aerial view of the ENE face of Snæfell. Arrow 1 shows the front of the recent terminal moraine of Hálsajökull, arrow 2 points to the old moraine. Photo: S. Thorarinsson, Sept. 9, 1964.

133) I quote the following description of this glacier:

"The north-east glacier (A) heads in a deep cirque, whose walls rise nearly 200 m above the névé field. The walls of volcanic tuff and breccias are very steep and intricately sculptured; no ice appeared to reach this glacier from the summit in 1937, even by avalanche. The glacier drops with two unpronounced steps to end just above the surrounding plateau at 800 m, the last half a kilometre is an area of irregular piles of moraine, very slightly vegetated but with slip faces, indicative of melting ice cores. Although the pattern of moraines suggests the lines of former transverse crevasses, there were no indications of present movement (op cit., p. 133)."

My visit to this glacier on July 25th, 1964, was too short to allow any measurments in order to compare the thickness and extension of the glacier with that of 1937. If one may rely on the 1937-map as being tolerably correct, the snout has retreated a lot, and the lower part of the glacier got considerably thinner since 1937. A broad belt of terminal moraines rises above the snout, which is covered by ablation moraine. These terminal moraines look very fresh and are still very slightly vegetated



Fig. 9. The area in front of Hálsajökull. To the right the big block in front of the recent terminal moraine (cf. Fig 10); to the left a piece of that block is resting on the old terminal moraine.
Photo: S. Thorarinsson, July 25, 1964.

even in their distal parts. Immediately in front of them is a large block, dark in colour (figs. 9—10), which appears to be composed of some pitchstone breccia (I did not take a close look at it). It has obviously fallen down somewhere from the nearby vertical walls of the névé area of Hálsajökull, and smaller parts of it are found farther down the slope (fig. 9).

About 160 m in front of the recent terminal moraine there is a terminal moraine (cf. figs. 8 and 9) of similar type, but obviously much older. It has a steep distal front, about 4 m high. This moraine is vegetation-covered, and in a small depression just inside the distal front I measured the soil section shown as Cf 18a on fig. 5, together with a section dug about 3 km farther south (Cf 18b), and another (Cf 17) dug at our camping place 10 km N of Snæfell and 1 km NW of Saudafell. In the last mentioned section we can identify most of the layers identified in section Cf 16a in Kringilsárrani. In the sections E of Snæfell, however, I found only one rhyolitic layer, viz. Ö 1362. Comparing Cf 18a with Cf 17 and Cf 18b, which represent the entire postglacial soil-formation in this area, we are led to the conclusion that Cf 18a represents in all probability a considerably shorter period. On the other hand it is obvious that the old terminal moraine in front of Hálsajökull is more than 1000 years older than Ö 1362. In my opinion there is little doubt that this old terminal moraine dates back to he beginning of the Subatlantic Time.

Thus the climatic deterioration, which brought a sudden end to the relatively warm subboreal climate, brought this steep glacier to a position a little more advanced than it reached during the "Little Ice Age" 1550—1890, whereas the flat lobe-shaped Brúarjökull reached its maximum postglacial extension during the 1810 and 1890 advances. This is in very good agreement with the conclusion I have formerly reached regarding the southern outlets of Vatnajökull—Öræfajökull (Thorarinsson 1956), viz. that the rising of the firn line during the Postglacial Warm Period had a greater effect of the big outlets of Vatnajökull proper, with their relatively flat intake areas, than it had on the steep alpine Öræfajökull outlets, which consequently had more advanced starting position when the climatic deterioration began. I have formerly proved by tephrochronology that the Hagafell glaciers of Langjökull,



Fig. 10. View from the old terminal moraine of Hálsajökull towards the recent one. The big, dark block shown on fig. 9 is visible in front of the moraine to the right on the photograph.
Photo: S. Thorarinsson, July 25, 1964.

which also have a flat intake area, reached their maximum extension quite recently (Thorarinsson 1949).

In many peat bogs, especially in Northern Iceland, the transition from subboreal to subatlantic conditions is very marked, indicating a sudden and great change in the climate, which seems to have become both colder and more humid. For a period of unknown length the subatlantic climate must have been a little more favourable for glacier growth, viz. a little more severe, than the climate of the "Little Ice Age". This period was long enough to bring highly alpine glaciers in Iceland from their minimum to their maximum extension in Postglacial Time, but not long enough to bring outlet glaciers with a flat intake area to a similar position.

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Vatnajökull hlaupinn. Frásögn Þorvarðar læknis Kjerúlfs 1890. Jökull, 12. ár: 47–48.

ÁGRIP

Í ofanritaðri grein er fjallað um öskulagarannsóknir á Brúaröræfum og kringum Snæfell í því skyni að ákvarða aldur þeirra jökulgarða, er sýna mesta útbreiðslu Brúarjökuls og Hálsajökuls austan í Snæfelli síðan ísa leysti af landinu í lok síðasta jökulskeiðs.

Frá Kverkárnesi austur í Marlutungur teygja

sig jökulýtur (sbr. 1. mynd), sem sums staðar, einkum á Kringilsárrana, mynda háa hryggi, svo gróðursæla, sem tún væri. (3. og 4. mynd). Þessar grasi grónu jökulýtur nefnast Hraukar. Víðast eru þessir hraukar frá hlaupi Brúarjökuls 1890, en finna má eldri hrauka, frá hlaupi jökulsins 1810. Einn slíkur er Útigönguhaus við Jökulkvísl (sbr. 1. mynd). Virðist Brúarjökull heildarlega séð hafa náð nokkuð svipaðri útbreiðslu í báðum þessum hlaupum.

Haustið 1962 dvaldist ég nokkra daga á Kringilsárrana í fylgd með prófessorunum Kristni Stefánssyni og Snorra Hallgrímssyni, sem voru þar að athuga sjúkleika í hreindýrum. Þá gróf ég gryfju rétt framan við Hrauka (3.—6. mynd). Þar var að finna meðal öskulaga Öræfajökulsösku frá 1362, Hekluöskuna H_3, sem er 2800 ára, og H_4, sem er 4000 ára. Þetta jarðvegssnið og önnur, sem mæld voru vestan Kringilsár og Sauðár, sanna, að aldrei síðan ísaldarjökla leysti hefur Brúarjökull náð jafnmikilli útbreiðslu og eftir hlaupin 1810 og 1890.

Í júlí 1964 tók ég þátt í leiðangri Jöklarannsóknafélagsins til Brúarjökuls og Snæfells. Þá gafst mér tækifæri til að athuga öskulög á Snæfellssvæðinu. Austan í Snæfelli er skálarjökull, brattur, sem hér er nefndur Hálsajökull (7. og 8. mynd). Framan við hann eru þveröldur, lítt grónar, og framan í þeim svartur klettur, sem hrunið hefur úr Snæfelli. Um 150 m neðar er þverálda, eldri miklu. Samanburður á sniði, sem grafið var gegnum jarðvegslög hennar (Cf 18a á 5. mynd), og öðrum sniðum á Snæfellssvæðinu (Cf 17 og Cf 18b) sannar, að þveralda þessi er meir en helmingi eldri en Öræfajökulsaskan frá 1362, en að öllum líkindum miklu yngri en svo, að hún geti verið frá ísaldarlokum. Er líklegast, að þveraldan hafi myndazt á kuldaskeiði því, sem hófst um 600 f. Kr. og sjá má merki um í flestum mómýrum landsins. Á þessu kuldaskeiði virðast einnig nokkrir af skriðjöklum Öræfajökuls, svo sem Kvíárjökull og Svínafellsjökull, hafa náð mestri útbreiðslu sinni síðan í ísaldarlok, en breiðjöklar þeir, er ganga suður úr Vatnajökli, svo sem Breiðamerkurjökull og Skeiðárjökull, hafa, eins og Brúarjökull, náð mestri útbreiðslu síðustu aldirnar. Eðlilegust skýring á þessu er sú, að á póstglasíala hlýviðrisskeiðinu hafi þessir flötu jöklar rýrnað hlutfallslega miklu meir en bröttu jöklarnir á Snæfelli og Öræfajökli og að kuldaskeiðið í byrjun járnaldar hafi ekki verið nógu langt til þess að þeir þá næðu sinni mestu útbreiðslu, en hins vegar nægilega langt til þess að bröttu jöklarnir næðu henni. Hefur því einhver hluti þessa kuldaskeiðs skapað jöklum betri vaxtarskilyrði (verið kaldari eða rakari eða hvort tveggja) heldur en kuldaskeið síðustu alda, en aftur hefur tekið að hlýna áður en stóru, flötu jöklarnir höfðu náð mestu útbreiðslu sinni.