Geomorphology 207 (2014) 213–220

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

The drumlin field and the geomorphology of the Múlajökull surge-type glacier, central Iceland

Sverrir Aðalsteinn Jónsson [a,*], Anders Schomacker [b], Ívar Örn Benediktsson [c], Ólafur Ingólfsson [a,d], Mark D. Johnson [e]

[a] Institute of Earth Sciences, University of Iceland, Sturlugata 7, Askja, IS-101 Reykjavík, Iceland
[b] Department of Geology, Norwegian University of Science and Technology, Sem Sælands Veg 1, N-7491 Trondheim, Norway
[c] Department of Geology, Lund University, Sölvegatan 12, S-223 62 Lund, Sweden
[d] University Centre in Svalbard (UNIS), P.O. Box 156, N-9171 Longyearbyen, Norway
[e] Department of Earth Sciences, University of Gothenburg, Box 460, S-405 30 Göteborg, Sweden

ARTICLE INFO

Article history:
Received 23 May 2013
Received in revised form 6 November 2013
Accepted 11 November 2013
Available online 20 November 2013

Keywords:
Múlajökull
Iceland
Glacial geomorphology
Surge-type glacier
Drumlin

ABSTRACT

Here we present a new geomorphological map of the active drumlin field and the forefield of Múlajökull, a surge-type outlet glacier, Iceland. The map is based on aerial photographs taken in 1995 and LiDAR data recorded in 2008. Mapping was done using ArcGIS 10 software on orthorectified imagery, LiDAR data and digital elevation models. The mapped landforms were initially identified on the aerial imagery and LiDAR and then ground-checked in the field. We mapped subglacial, supraglacial, ice-marginal, periglacial, and glaciofluvial landforms. The geomorphology of the Múlajökull forefield is similar to that of the forefields of other surge-type glaciers in Iceland: with a highly streamlined forefield, crevasse-fill ridges, and series of glaciotectonic end moraines. However, the large number (i.e., 110) of drumlins forming the drumlin field is unique for modern Icelandic surge-type glaciers and, as yet, unique for contemporary glaciers in general. Also apparent is that the drumlins are wider and shorter in the distal part of the drumlin field and narrower and longer in the proximal part. Hence, the mapping reveals a development of the drumlins toward a more streamlined shape of the proximal landforms that have experienced more surges. The drumlins in the drumlin field are active, i.e., they form during the modern surges of Múlajökull.

1. Introduction

Conceptual models have been made for various types of glacial landsystems based on studies of Icelandic glaciers; the glaciated valley landsystem (Spedding and Evans, 2002), the active temperate glacier landsystem (Evans and Twigg, 2002), the plateau icefield landsystem (Evans et al. 2006), and the surging glacier landsystem (Evans and Rea, 1999, 2003). The active temperate glacier landsystem is considered to be a suitable modern analogue for reconstructing the margins of Pleistocene glaciers and ice sheets (Evans et al. 1999; Evans and Twigg, 2002). The surging glaciers are considered to be suitable modern analogues to terrestrial palaeo-ice streams (Evans and Rea, 1999, 2003; Evans et al. 1999; Kjær et al. 2006, 2008).

Some glacial landforms have been considered as diagnostic of surges. These include, in particular, crevasse-fill ridges and concertina eskers; but other landforms, such as long flutes, glaciotectonic end moraines, and hummocky moraines have also been strongly linked to glacier surges (Knudsen, 1995; Evans and Rea, 1999, 2003; Schomacker and Kjær, 2007; Benediktsson et al. 2008, 2010; Evans et al. 2010; Schomacker et al. in press). Drumlins have also been described in association with surging glaciers, although they are not considered as particularly typical of surging (Hart, 1995; Kjær et al. 2008; Waller et al. 2008; Johnson et al. 2010; Schomacker et al. in press). Johnson et al. (2010) described an active drumlin field at the margin of Múlajökull, a surge-type outlet glacier in central Iceland. This drumlin field is the only known active drumlin field in the world, making the Múlajökull glacier and its forefield a unique site. The purpose of this study is to map the geomorphology of the Múlajökull forefield (Fig. 1A) in order to enhance the current understanding of the surging-glacier landsystem and the development of active drumlin fields. For this purpose, we present a geomorphological map of the forefield of Múlajökull (Fig. 2).

2. Setting

Múlajökull is a surge-type piedmont glacier of the Hofsjökull ice cap, which rests on the largest central volcano in Iceland (Sigurðsson and Williams, 2008; Björnsson, 2009). Múlajökull is about 7 km wide in the accumulation zone and drains a part of the ice-filled caldera of the volcano (Björnsson, 2009). The glacier drains through a 2-km narrow valley between Mt. Hjartafell to the west and Mt. Kerfjall to the east (Fig. 1C). As the glacier leaves the valley, it spills onto the relatively

* Corresponding author. Tel.: +354 863 9674.
E-mail address: saj7@hi.is (S.A. Jónsson).

0169-555X/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.geomorph.2013.11.007

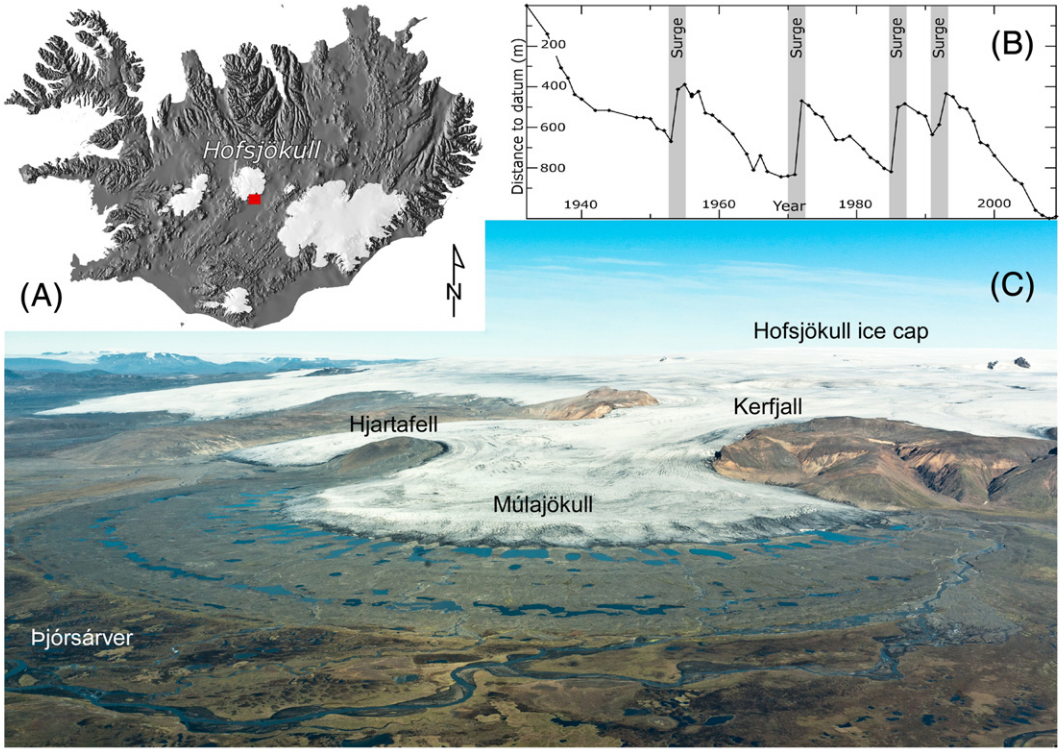

Fig. 1. (A) Location of Múlajökull (red square) at the southern margin of the Hofsjökull ice cap; map based on a hillshade terrain model of Iceland. (B) Variations of the glacier snout during past decades, modified from Johnson et al. (2010). (C) Overview photo of the Hofsjökull ice cap, Mt. Hjartafell, Mt. Kerfjall, and the Múlajökull piedmont lobe. The vegetated wetlands of Þjórsárver can be seen in the foreground.

flat forefield forming a 4-km-wide piedmont lobe. The largest river in the forefield is the glacial river Arnarfellskvísl that emerges from the ice front close to Mt. Kerfjall. Apart from Arnarfellskvísl, numerous small streams drain the ice front and run toward the outwash plains in the northeast and southwest corners of the map.

The glacier terminates with a 6.5-km-long ice margin at around 620 masl. The ice margin lies about 2 km inside the outermost Little Ice Age (LIA) end moraine, and the glacier has a history of four surges since 1924 (Fig. 1B; Johnson et al. 2010). In addition, a minor surge occurred in 2008 but produced, however, a significant push moraine. The glacier has retreated about 700 m since the last major surge in 1992 revealing over 50 drumlins, which are argued by Johnson et al. (2010) to have been formed and shaped progressively during the previous surges of the glacier.

3. Methods

The mapping of the forefield was done using panchromatic aerial photographs taken in 1995 by Landmælingar Íslands. Mapping took place on derived orthophotographs with 1-m pixel size. A digital elevation model (DEM) with 3-m ground sample distance produced with stereophotogrammetry was also used in the mapping. Ground-control points were identified and measured in the field with a differential GPS. All data were handled in the UTM/WGS84 reference system, and elevations are in metres above sea level.

An airborne 0.5-m LiDAR DEM covering the glacier and about 600 m into the forefield was visualized as a terrain shade-relief model and used for mapping the recently deglaciated part of the forefield. The LiDAR data were recorded in 2008 by the Icelandic Meteorological Office and the Institute of Earth Sciences of the University of Iceland (Jóhannesson et al. 2013).

Landforms were mapped on the orthophotograph distal to the 1995 glacier margin and on the LiDAR data, where they were available, in the area deglaciated after 1995. The geomorphic map was constructed using ESRI ArcGIS 10 and ESRI ArcScene 10.

A three-dimensional assessment was made by draping the orthophotograph over the 3-m DEM and using a hillshade model of the 0.5-m LiDAR DEM. These were viewed in ArcScene while mapping in ArcGIS, aiding in identification and in mapping of landforms. Landforms were mapped either as polygons or lines in a scale of 1:400 or lower. The resulting map is designed to be viewed digitally or printed in A0 format (Fig. 2). The map has been checked in the field, and all drumlins were identified in the field before being mapped. The length, height, and width of all the drumlins that are outside the LiDAR data were measured in the field with a TopCon total station.

4. Mapped landforms

The glacial landforms and sediments occurring in the forefield of Múlajökull can be divided into five main assemblages: (i) subglacial, (ii) supraglacial, (iii) ice-marginal, (iv) periglacial, and (v) glaciofluvial. A description of the landforms and their sediments follows below.

4.1. Subglacial landforms

4.1.1. Till plain

The forefield is predominantly covered with till; and based on Johnson et al. (2010) and observations of flutes, drumlins, and crevasse-fills on the surface and bullet-shaped clasts, deformation, and fissility in the sediments, it is interpreted as a subglacial till plain (Fig. 3A–B). The till plain is covered with a clast pavement of subrounded to rounded pebbles, cobbles, and some boulders; and it is dissected by lakes and meltwater streams. The till plain mapped in Fig. 2 also includes some patches of lake and outwash plains too small to map. It covers the majority of the area between the LIA end moraine and the glacier.

4.1.2. Drumlins

The most striking features characterising the geomorphology of the Múlajökull forefield are the drumlins and the drumlin field (Figs. 3C, 4A). We mapped 110 drumlins in front of Múlajökull with

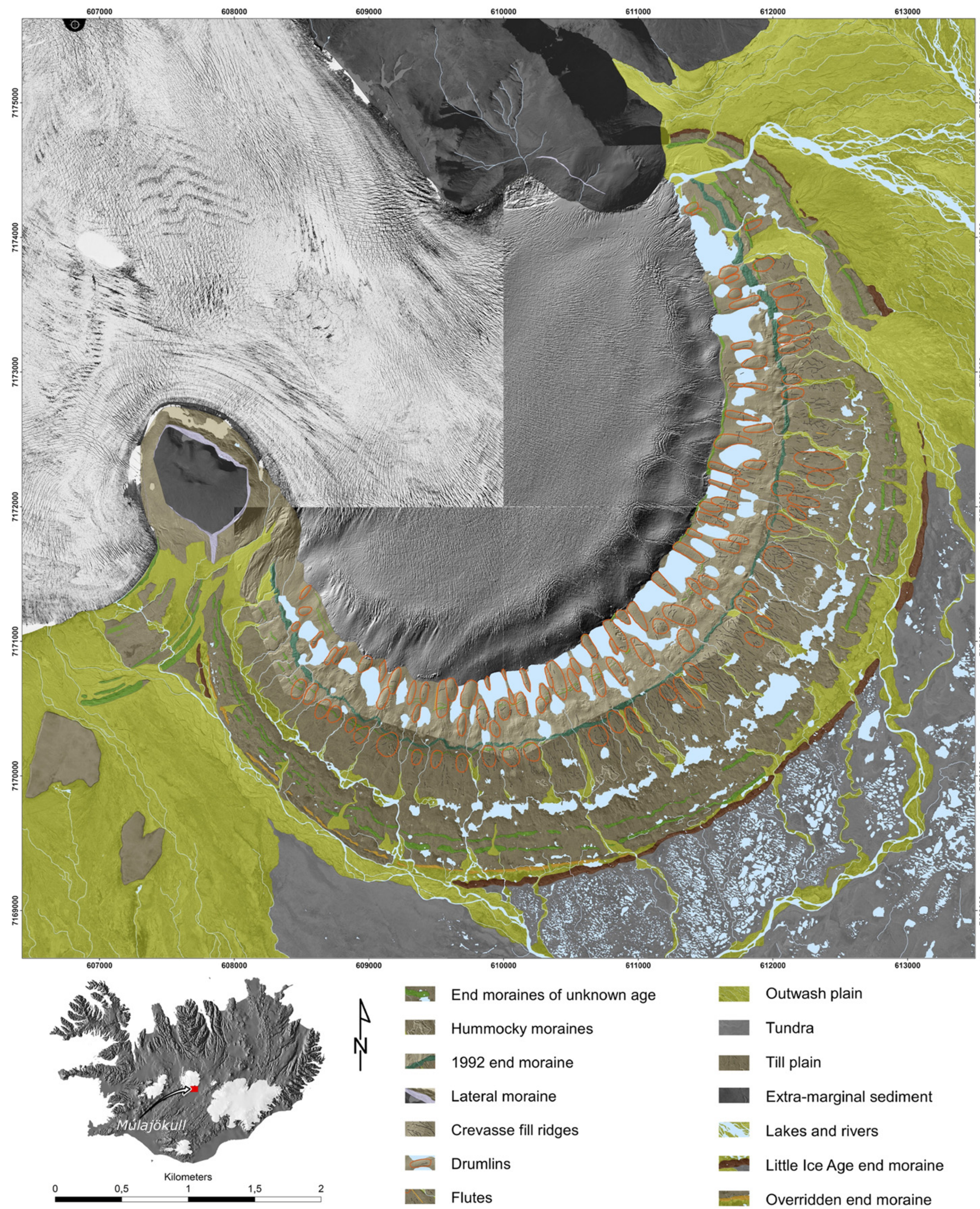

Fig. 2. Geomorphological map of the Múlajökull forefield. For a full resolution version of the map, see online supplementary data at 10.1016/j.geomorph.2013.11.007. The map shown here is downsized and modified slightly, but the full-resolution map is designed for printing on A0 paper size. The map is based on aerial photographs recorded in 1995 and LiDAR data from 2008. Map projection and datum: UTM 27N, WGS 84. Scale 1:9000.

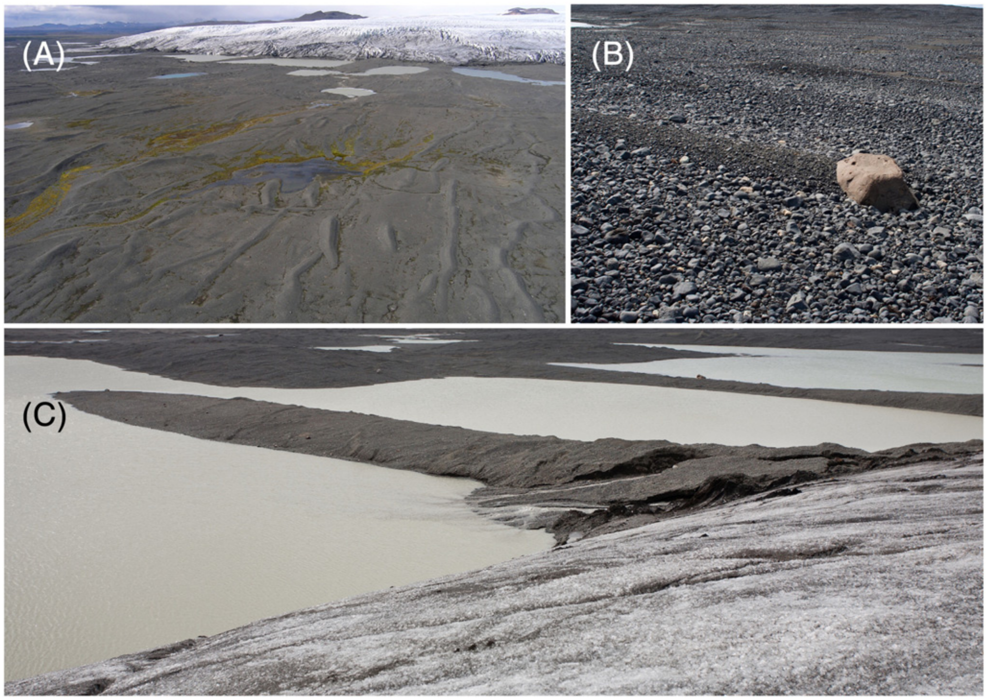

Fig. 3. (A) An overview of the till plain with a number of crevasse-fill ridges in the foreground. The crevasse-fill ridges are predominantly oriented subparallel to the ice flow direction. Because of low preservation potential the ridges appear slightly disintegrated. Photo location: 612158; 7171726 UTM. (B) Flute in front of Múlajökull. The boulder at the head of the flute is about 0.5 m in diameter. Photo location: 609510; 7170671 UTM. (C) A spindle-shaped drumlin exposed at the retreating ice front, the surrounding lake enhances the outlines. The drumlin is about 200 m long. Photo location: 610155; 7170758 UTM.

an average spacing of 94 m and on average areal density of around 10 drumlins/km^2 on the till plain. Drumlin orientation varies by nearly 180° as they occur in a splayed fan distribution in the forefield, so that the stoss end of drumlins in the northeastern part of the forefield points toward NE whilst the stoss end points toward SW in the southwestern part (Fig. 2). The drumlins range from 70 to 380 m in length, 20 to 180 m in width, and 2 to 10 m in height (Fig. 4B) and tend to be asymmetric in the sense that they are higher and wider upglacier and taper downglacier. Close to the glacier front, lakes occupy depressions between the drumlins and accentuate the

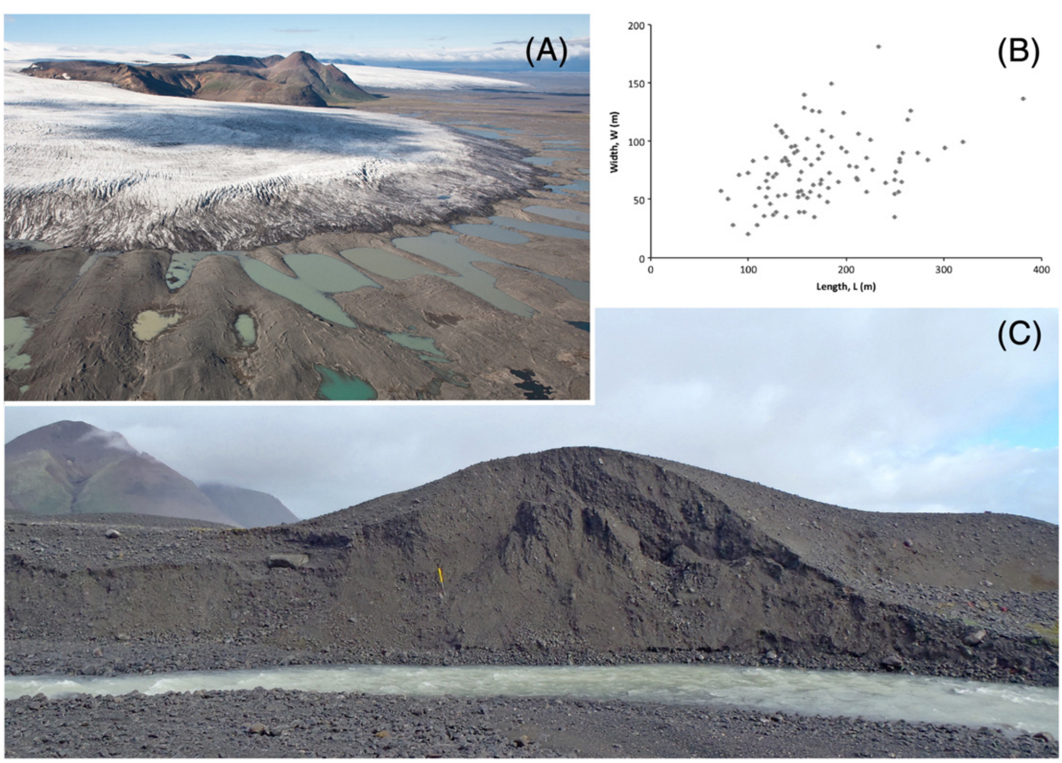

Fig. 4. (A) An overview from south to north over Múlajökull and a part of the drumlin field. Drumlins and crevasse-fill ridges can be seen on the till plain. Photo location: 609807 7170271 UTM. (B) Length and width of the drumlins in this study. Drumlins that are not fully exposed in front of the glacier were not measured. (C) A river cut through a large crevasse-fill ridge, spade for scale. In this photo it appears clearly that the crevasse-fill ridge is made up of till. Photo location: 612220; 7172556 UTM.

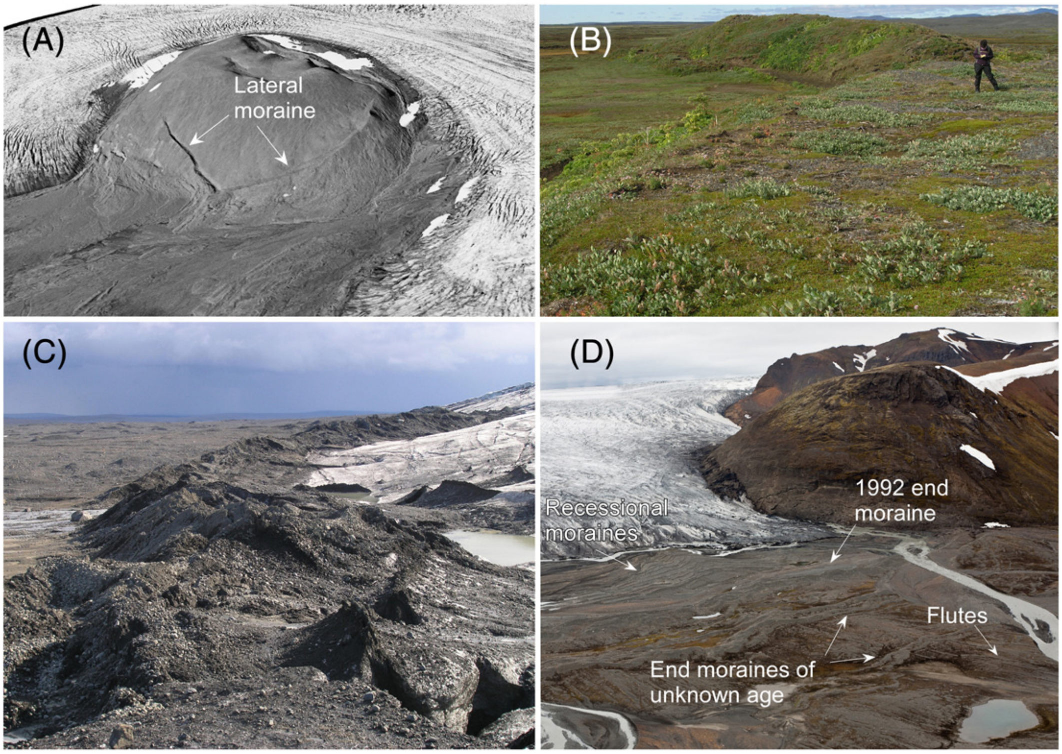

Fig. 5. (A) Lateral moraines on Hjartafell. Múlajökull is to the right and Nauthagajökull to the left. (B) The Little Ice Age end moraine, Arnarfellsmúlar. The glacier was flowing from right to left. Photo location: 612467; 7170413 UTM. (C) The 2008 end moraine, photo taken in 2010. The moraine is about 5–10 m high and 10–20 m wide. Photo location: 611540; 7172391 UTM. (D) The northernmost part of the forefield with Mt. Kerfjall in the background. Recessional moraines can be seen close to the glacier as well as the 1992 end moraine, two end moraines of unknown age, and flutes. Photo location: 611735; 7174117 UTM.

drumlin morphology. The drumlins are draped by flutes, crevasse-fill ridges, and small push moraines. Previous investigations suggest that the drumlins are made of several till layers, each of which is associated with a surge advance. The till units, which are often separated by lenses of sorted sediments, tend to have strong clast fabrics parallel to ice flow and usually contain massive, brecciated, or fissile

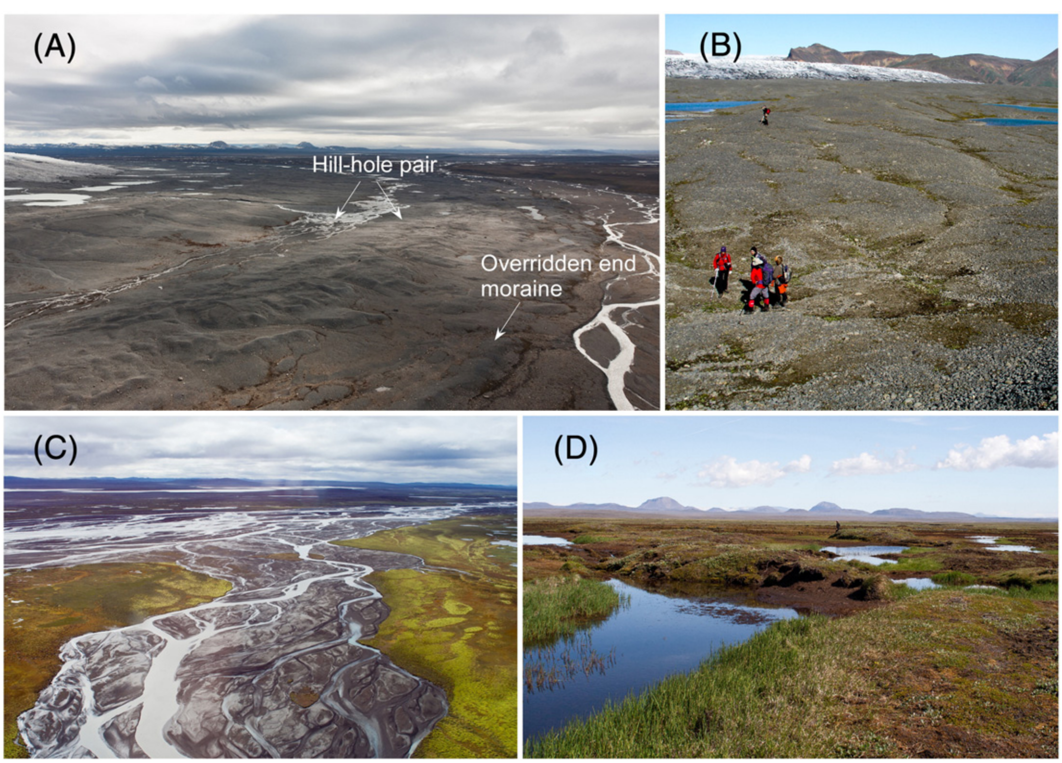

Fig. 6. (A) An overview of the southern part of the forefield, showing hill–hole pair and an overridden end moraine. Photo location: 608127; 7170331 UTM. (B) Hummocky moraine. Photo location: 611983; 7170896 UTM. (C) The braided outwash plains of Arnarfellskvísl where it merges with the Þjórsá glacier river. Photo location: 612601; 7174524 UTM. (D) Thermokarst lakes and palsas in Þjórsárver distal to the LIA end moraine. Photo location: 611298; 7169444 UTM.

horizons and hydrofractures (Johnson et al. 2010). All geological sections in the drumlins that were visited during this study have confirmed that they consist of several till units.

4.1.3. Flutes

Flutes are narrow, elongated, straight, and usually ice-flow parallel ridges, generally consisting of till. Only six flutes are mapped in this study, and some of these have an initiating boulder at their head. The flutes mapped range from 40 to 290 m in length and are between 0.25 and 0.5 m high (Fig. 3B). More flutes were observed in the field (Fig. 5D), but these could not be mapped because of their small size or low resolution on the LiDAR image or aerial photographs.

4.1.4. Crevasse-fill ridges

Crevasse-fill ridges are 1–2 m wide, 1–2 m high, and up to a few hundred metres long. They lie on top of the drumlins and the till plain and are an order of magnitude narrower and more irregular in orientation. We mapped 963 crevasse-fill ridges in the forefield of Múlajökull with an average areal density of around 90 crevasse-fill ridges per km^2. Most of them occur immediately distal to the 1992 surge moraine and show preferred orientation in the ice flow direction (Fig. 3A). Our observations show that these crevasse-fill ridges are composed of till (Fig. 4C), which is in agreement with crevasse-fill ridges that have been described at Brúarjökull (Evans et al. 1999; Kjær et al. 2008) and Eyjabakkajökull (Sharp, 1985; Schomacker et al. in press).

4.2. Ice-marginal landforms

4.2.1. End moraines

Eight end moraines occur in front of Múlajökull. The outermost end moraine is the LIA terminal moraine, which is known locally and historically as *Arnarfellsmúlar* (Fig. 5B). The Arnarfellsmúlar moraine is commonly 30–60 m wide, 5–10 m high, and made of glaciotectonized loess–peat–tephra soils, making its morphometrics and internal architecture largely similar to end moraines described from Brúarjökull and Eyjabakkajökull (Benediktsson et al. 2008, 2010; Benediktsson, 2012). The moraine is to a large degree vegetated, and it marks the boundary between the boggy tundra of Þjórsárver (Fig. 1C) and the sparsely vegetated forefield of Múlajökull. About 500 m from the present ice margin is a conspicuous end moraine resulting from a surge in 1992 (Fig. 5D). This end moraine is 20–30 m wide, 1–3 m high, and traceable continuously across the forefield. A small advance during the 2008 surge left a significant, partially ice-cored, end moraine of 20–30 m in width and 3–6 m in height (Fig. 5C). Five other sets of end moraines of unknown age occur between the Arnarfellsmúlar and 1992 end moraines (Fig. 5D). In many parts of the forefield, a series of small end moraines occurs between the 1992 and the 2008 end moraines. These small moraines are most prominent in the northern part of the forefield, where they are up to 1.5 m high and 7 m wide. We have observed similar ridges form each year during our fieldwork in the years 2009 to 2013 in that particular part of the forefield. Elsewhere in the forefield, these ridges are 1–2 m wide and <1 m high. The spacing between the ridges ranges from 10 to 20 m and the number of ridges between the 1992 and 2008 moraines varies between 8 and 15. We interpret these ridges as annual, winter-advance moraines (Fig. 5D). The variation in moraine-ridge spacing results from variations in summer retreat rates (Krüger, 1995), and the various numbers of ridges between places are probably caused by the fact that a ridge may not be formed or preserved every year.

4.2.2. Overridden end moraine

On the map, one overridden end moraine is shown. This moraine can be seen proximal to the LIA terminal moraine in the southern part of the study area (Fig. 6A). The moraine is about 1–2 m high, and it has smoother surface topography than the other end moraines. Additionally, the moraine disappears under the LIA terminal moraine farther to the east, indicating that it is older than the LIA terminal moraine. The surface topography and the cross-cutting relationship with the LIA moraine lead us to interpret it as overridden.

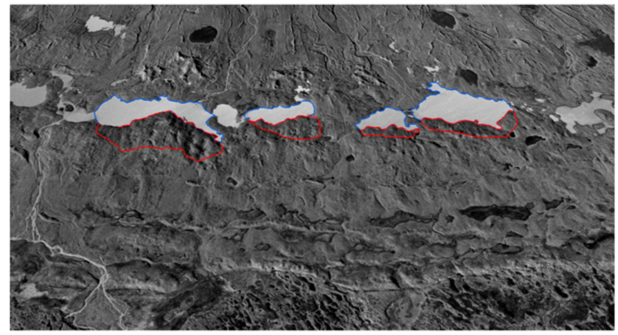

Fig. 7. Possible hill–hole pairs, hills in red and holes in blue. The image is an orthophotograph from 1995 draped over a 3 m DEM. Ice–flow was towards the viewer. Photo location: 611252; 7169868 UTM.

4.2.3. Lateral moraines

Mt. Hjartafell is rimmed by lateral moraines from Múlajökull and from its neighbouring outlet glacier, Nauthagajökull (Fig. 5A). The lateral moraines are about 40 m wide, 10 m high, and consist of coarse diamict and boulders. They connect with the LIA terminal moraines at the foot of Mt. Hjartafell and were most likely formed during the maximum LIA extent of Múlajökull.

4.3. Supraglacial landforms

4.3.1. Hummocky moraine

The term hummocky moraine is used as a descriptive term for irregular ice-cored morainic topography with high variation in relief (Benn and Evans, 2010) as well as for fully de-iced dead-ice moraines (Krüger and Kjær, 2000; Kjær and Krüger, 2001; Johnson and Clayton, 2003; Schomacker, 2008). There are eight distinct patches of hummocky moraines in the forefield of Múlajökull about 1 km from the ice front (Fig. 6B). Even though these hummocky moraines have not been excavated, at least some of them likely are still ice-cored. Active backslumping and extension cracking observed in the field strongly indicate ongoing melting of buried dead-ice. Signs of dead-ice were observed in many other places in the forefield but were too limited in extent to be included on the map. We should note that the retreat of the ice margin since 2008 has revealed significant ice-cored hummocky moraine on the proximal slope of the 2008 end moraine. Because the map shows the ice margin as in 2008, this hummocky moraine is not included.

4.4. Periglacial landforms

4.4.1. Tundra

Widespread palsas can be found in the Þjórsárver peat bogs distal to the Arnarfellsmúlar terminal moraine (Fig. 6D). Observations in the summer of 2010 showed discontinuous permafrost below the peat bogs outside of the LIA terminal moraine. Numerous small thermokarst lakes and ponds occur together with the palsas.

4.5. Glaciofluvial landforms

4.5.1. Outwash plain

Braided fluvial plains and outwash fans are mapped collectively as outwash plains and cover about one-third of the mapped area (Fig. 6C). Most of the outwash occurs in front of the neighbouring outlet glacier, Nauthagajökull, where its meltwater stream has migrated laterally over the forefield and in the northern part of the map where Arnarfellskvísl emerges from Múlajökull. During fieldwork in 2010, Arnarfellskvísl started migrating to the south; and in 2011 part of the river was flowing proximal to the LIA terminal moraines for about 1.5 km, causing severe erosion on their proximal side.

5. Discussion and conclusions

The main focus of this study was to map the geomorphology in the forefield of Múlajökull outlet glacier to better understand the Múlajökull glacial landsystem and its emerging drumlin field.

The geomorphology of the Múlajökull forefield agrees well with previous models of surging glacier landsystems (Evans and Rea, 1999, 2003; Schomacker et al. in press). Evans and Rea (1999, 2003) and Schomacker et al. (in press) identified three zones in the forefields of the Brúarjökull and Eyjabakkajökull surging glaciers, although both recognise that some mixing of the zones can take place where multiple surges have occurred. Zone A, the outermost zone, is characterised by hill–hole pairs and thrust moraines of presurge sediments. This corresponds to the outermost glaciotectonic end moraine (Arnarfellsmúlar) at Múlajökull. We were not able to identify examples of hill–hole pairs in the Mulajökull forefield clear enough to include as a map unit in Fig. 2. However, places can be found where lake basins and adjacent morainic hills line up in such a way that a thrusting genesis for the excavation of the lake basin and formation of the hills downice seems plausible (Figs. 6A and 7). Weakly developed or patchy hummocky moraine draped on the ice-proximal side of the push moraines can be considered as part of zone A because of its association with the push moraines, following Schomacker et al. (in press), or as an independent zone (zone B) according to Evans and Rea (1999, 2003). This agrees in part with the forefield of Múlajökull except for the patchy hummocky moraines, which are not situated on the ice-proximal side of the glaciotectonic moraine but proximal to the depression of the hill–hole pair (Fig. 7). The lack of hummocky moraines on the ice-proximal side of the outer glaciotectonic moraine could be the result of erosion as outwash almost always appears immediately on the ice-proximal side of the moraine. Zone C of Evans and Rea (1999, 2003) and Schomacker et al. (in press) is characterised by flutes, crevasse-fill ridges, and concertina eskers. At Múlajökull, crevasse-fill ridges are abundant; and minor flutes are common, although only a few large flutes could be mapped. Concertina eskers are, on the other hand, completely absent from the Múlajökull forefield. To our knowledge, these landforms have only been identified in front of four surge-type glaciers in Iceland, Svalbard, and Novaya Zemlya (Knudsen, 1995; Hansen, 2003; Grant et al. 2009; Schomacker et al. in press). No concertina eskers were described at Sátujökull, a surge-type outlet glacier on the north margin of Hofsjökull (Evans et al. 2010). At Múlajökull, the inner zone is instead dominated by the drumlins of the drumlin field.

We conclude that the geomorphology of the Múlajökull forefield and the zonation of sediments and landforms correspond largely to the surging-glacier landsystem models of Evans and Rea (1999, 2003) and Schomacker et al. (in press), as well as to the geomorphology of other surge-type glaciers in Iceland (e.g., Kjær et al. 2008; Evans, 2011). The major difference between the forefield of Múlajökull and those of other surge-type glaciers is the active drumlin field, which is unique for modern surge-type glaciers and, as yet, unique for contemporary glaciers in general.

The lack of drumlin fields at other contemporary surge-type glaciers and thus their absence from the surging-glacier landsystem models could very well be because the drumlin fields have not yet been exposed. Drumlins are usually formed some distance behind the glacier front and, generally, modern glaciers have not retreated far enough from their LIA end moraines to expose the potential drumlins and drumlin fields formed during the peak of the LIA. More modern drumlin fields might therefore become exposed in the coming years.

The drumlins farther away from the ice front appear wider, shorter, and with lower relief than those closer to the glacier. Therefore, we hypothesize that drumlins, which have only experienced a few surges, are shorter and wider with low relief; whilst those that have been attributed to more surges are longer and narrower with higher relief. This hypothesis, however, needs to be tested with further studies.

Acknowledgements

The Múlajökull project was funded by the Icelandic Centre for Research (RANNÍS), the University of Iceland Research fund, the Energy Research Fund of Landsvirkjun, and the Carlsberg Foundation. Geoff Gadd is thanked for the photograph in Fig. 4C and Skafti Brynjólfsson, Jón Björn Ólafsson, and Márus Hjörtur Jónsson are thanked for their assistance in the field. The manuscript benefited from constructive comments from Kent M. Syversson and one anonymous reviewer.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.geomorph.2013.11.007.

References

Benediktsson, Í.Ö., 2012. Polyphase structural evolution of a fine-grained, fold-dominated end moraine, Brúarjökull surge-type glacier, Iceland. Jökull 62, 167–184.

Benediktsson, Í.Ö., Möller, P., Ingólfsson, Ó., van der Meer, J.J.M., Kjær, K.H., Krüger, J., 2008. Instantaneous end moraine and sediment wedge formation during the 1890 glacier surge of Brúarjökull, Iceland. Quat. Sci. Rev. 27, 209–234.

Benediktsson, Í.Ö., Schomacker, A., Lokrantz, H., Ingólfsson, Ó., 2010. The 1890 surge end moraine at Eyjabakkajökull, Iceland: re-assessment of a classic glaciotectonic locality. Quat. Sci. Rev. 29, 484–506.

Benn, D.I., Evans, D.J.A., 2010. Glaciers and Glaciation, 2nd edition. Hodder Education, London, England (802 pp.).

Björnsson, H., 2009. Jöklar á Íslandi. Opna, Reykjavík (479 pp. in Icelandic with English summary).

Evans, D.J.A., 2011. Glacial landsystems of Sátujökull, Iceland: modern analogue for glacial landsystem overprinting by mountain ice caps. Geomorphology 129, 225–237.

Evans, D.J.A., Rea, B.R., 1999. Geomorphology and sedimentology of surging glaciers: a land-systems approach. Ann. Glaciol. 28, 75–82.

Evans, D.J.A., Rea, B.R., 2003. Surging glacier landsystem. In: Evans, D.J.A. (Ed.), Glacial Landsystems. Arnold, London, England, pp. 259–288.

Evans, D.J.A., Twigg, D.R., 2002. The active temperate glacial landsystem: a model based on Breiðamerkurjökull and Fjallsjökull, Iceland. Quat. Sci. Rev. 21, 2143–2177.

Evans, D.J.A., Lemmen, D.S., Rea, B.R., 1999. Glacial landsystems of the southwest Laurentide ice sheet: modern Icelandic analogues. J. Quat. Sci. 14, 673–691.

Evans, D.J.A., Twigg, D.R., Shand, M., 2006. Surface geology and geomorphology of the Þórisjökull plateau icefield, west-central Iceland. J. Maps 2006, 17–29.

Evans, D.J.A., Twigg, D.R., Orton, C., 2010. Satujökull glacial landsystem, Iceland. J. Maps 2010, 639–650.

Grant, K.L., Stokes, C.R., Evans, I.S., 2009. Identification and characteristics of surge-type glaciers on Novaya Zemlya, Russian Arctic. J. Glaciol. 55, 960–972.

Hansen, S., 2003. From surge-type to non-surge-type glacier behavior: midre Lovénbreen, Svalbard. Ann. Glaciol. 36, 97–102.

Hart, J.K., 1995. Recent drumlins, flutes and lineations at Vestari-Hagafellsjökull, Iceland. J. Glaciol. 41, 596–606.

Jóhannesson, T., Björnsson, H., Magnússon, E., Guðmundsson, S., Pálsson, F., Sigurðsson, O., Thorsteinsson, Th., Berthier, E., 2013. Ice-volume changes, bias-estimation of mass-balance measurements and changes in subglacial lakes derived by LiDAR mapping of the surface of Icelandic glaciers. Ann. Glaciol. 63, 63–74.

Johnson, M.D., Clayton, L., 2003. Supraglacial landsystems in lowland terrain. In: Evans, D.J.A. (Ed.), Glacial Landsystems. Arnold, London, pp. 228–258.

Johnson, M.D., Schomacker, A., Benediktsson, Í.Ö., Geiger, A.J., Ferguson, A., Ingólfsson, Ó., 2010. Active drumlin field revealed at the margin of Múlajökull, Iceland: a surge-type glacier. Geology 38, 943–946.

Kjær, K.H., Krüger, J., 2001. The final phase of dead-ice moraine development: processes and sediment architecture, Kötlujökull, Iceland. Sedimentology 48, 935–952.

Kjær, K.H., Larsen, E., van der Meer, J., Ingólfsson, Ó., Krüger, J., Benediktsson, Í.Ö., Knudsen, C.G., Schomacker, A., 2006. Subglacial decoupling at the sediment/bedrock interface: a new mechanism for rapid flowing ice. Quat. Sci. Rev. 25, 2704–2712.

Kjær, K.H., Korsgaard, N.J., Schomacker, A., 2008. Impact of multiple glacier surges — a geomorphological map from Brúarjökull, east Iceland. J. Maps 2008, 5–20.

Knudsen, Ó., 1995. Concertina eskers, Brúarjökull, Iceland: an indicator of surge-type glacier behaviour. Quat. Sci. Rev. 14, 487–493.

Krüger, J., 1995. Origin, chronology and climatological significance of annual moraine-ridges at Mýrdalsjökull, Iceland. The Holocene 5 (4), 420–427.

Krüger, J., Kjær, K.H., 2000. De-icing progression of ice-cored moraines in a humid, subpolar climate, Kötlujökull, Iceland. The Holocene 10, 737–747.

Schomacker, A., 2008. What controls dead-ice melting under different climate conditions? A discussion. Earth Sci. Rev. 90, 103–113.

Schomacker, A., Kjær, K.H., 2007. Origin and de-icing of multiple generations of ice-cored moraines at Brúarjökull, Iceland. Boreas 36, 411–425.

Schomacker, A., Benediktsson, Í.Ö., Ingólfsson, Ó., 2014. The Eyjabakkajökull glacial landsystem, Iceland: geomorphic impact of multiple surges. Geomorphology. http://dx.doi.org/10.1016/j.geomorph.2013.07.005 (in press).

Sharp, M., 1985. "Crevasse-fill" ridges — a landform type characteristic of surging glaciers? Geogr. Ann. 67, 213–220.

Sigurðsson, O., Williams Jr., R.S., 2008. Geographic names of Iceland's glaciers: historic and modern. U.S. Geological Survey Professional Paper 1746, Reston, Virginia (225 pp.).

Spedding, N., Evans, D.J.A., 2002. Sediments and landforms at Kvíárjökull, southeast Iceland: a reappraisal of the glaciated valley landsystem. Sediment. Geol. 149, 21–42.

Waller, R.I., Van Dijk, T.A.G.P., Knudsen, Ó., 2008. Subglacial bedforms and conditions associated with the 1991 surge of Skeiðarárjökull, Iceland. Boreas 37, 179–194.