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

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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

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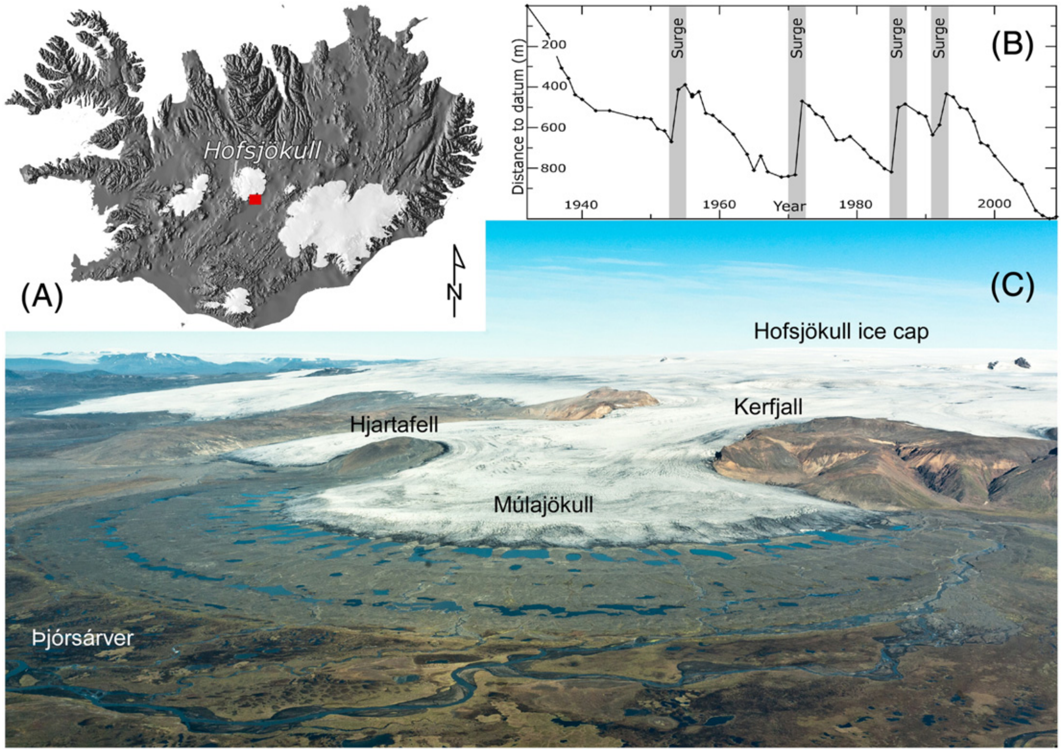

Fig. 1. (A) Location of Múlajökull (red square) at the southern margin of the Hofsjökull ice cap; map based on a hillshade terrain model of Iceland. (B) Variations of the glacier snout during past decades, modified from Johnson et al. (2010). (C) Overview photo of the Hofsjökull ice cap, Mt. Hjartafell, 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