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The Eyjabakkajökull glacial landsystem, Iceland: Geomorphic impact of multiple surges

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ABSTRACT

A new glacial geomorphological map of the Eyjabakkajökull forefield in Iceland is presented. The map covers c. 60 km^2 and is based on high-resolution aerial photographs recorded in August 2008 as well as field checking. Landforms are manually registered in a geographical information system (ArcGIS) based on inspection of orthorectified imagery and digital elevation models of the area. We mapped subglacially streamlined landforms such as flutes and drumlins on the till plain, supraglacial landforms such as ice-cored moraine, pitted outwash, and concertina eskers, and ice-marginal landforms such as the large, multi-crested 1890 surge end moraine and smaller single-crested end moraines. The glaciofluvial landforms are represented by outwash plains, minor outwash fans, and sinuous eskers. Extramarginal sediments were also registered and consist mainly of old sediments in wetlands or locally weathered bedrock. Eyjabakkajökull has behaved as a surge-type glacier for 2200 years; hence, the mapped landforms originate from multiple surges. Landforms such as large glaciotectonic end moraines, hummocky moraine, long flutes, crevasse-fill ridges, and concertina eskers are characteristic for surge-type glaciers. The surging glacier landsystem of Eyjabakkajökull serves as a modern analog to the landsystems of terrestrial paleo-ice streams.

1. Introduction

Eyjabakkajökull is an attractive locality for studies of surge-type glaciers and has been regarded as a modern analog to terrestrial paleo-ice streams (e.g. Sharp, 1985a,b; Croot, 1987, 1988; Evans and Rea, 1999; Benediktsson et al., 2010). Studies of sediment cores from Lake Lögurinn, which receives meltwater from Eyjabakkajökull, have shown that the surge-type behavior of Eyjabakkajökull reaches back to 2200 cal. years BP, and that surges were most frequent during the Little Ice Age (Striberger et al., 2011). This indicates that the glacial geomorphology of the forefield results from multiple surges. Although the glacier flow is confined to a valley, the margin spreads out in a low-relief forefield with thick sediments, making it a relevant analog to paleo-ice streams and fast-flowing paleo-ice sheet lobes.

General overviews of the glacial geomorphology of the Eyjabakkajökull forefield have been provided by Todtmann (1960) and Evans and Rea (1999), and Kaldal and Víkingsson (2000) mapped the surface deposits of Eyjabakkar, i.e. the valley distal to the 1890 end moraine. Evans and Rea (1999) proposed a land-system model for surging glacier margins, based on their observations from Eyjabakkajökull and the neighboring glacier, Brúarjökull. Their model suggests that the surging glacier landsystem consists of an outer zone of proglacially thrusted sediments and end moraines, a middle zone of hummocky moraine on the proximal side of the end moraines, and an inner zone of flutes, crevasse-squeeze ridges and concertina eskers. Geomorphological maps from other surge-type glaciers in Iceland generally support this model although concertina eskers and prominent drumlins have only been described at Brúarjökull, Eyjabakkajökull, and Múlajökull (Schomacker et al., 2006; Evans et al., 2007; Kjær et al., 2008; Evans et al., 2009, 2010; Johnson et al., 2010).

Other studies from Eyjabakkajökull have focused on individual landforms or landform assemblages, e.g. the prominent surge end moraine from 1890 (Croot, 1987, 1988; Benediktsson et al., 2010), the numerous crevasse-fill ridges that dominate the proximal part of the forefield (Sharp, 1985a,b), the relationships between tills, flutes and crevasse-fill ridges (Ferguson et al., 2009), or the concertina eskers (Ólafsdóttir, 2011). A detailed geomorphological overview of the Eyjabakkajökull forefield enhances the understanding of these individual landforms and the link between them and other landforms and sediments deposited during the same surges. In addition, such overview provides valuable information for the development of the forefield during future surges. The aim of this paper is to present a high-resolution geomorphological map and describe the sediments and landforms in the forefield of

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Eyjabakkajökull, as well as erecting a conceptual model for the surging glacier landsystem.

2. Setting

Eyjabakkajökull is a 10 km long and 4 km wide surge-type outlet glacier that drains the NE part of the Vatnajökull ice cap in Iceland (Fig. 1). The glacier consists of three distinct outlets, separated by medial moraines in the ablation zone, that drain the main ice cap from 1200 to 1500 to approximately 700 m a.s.l. Historically documented surges occurred in 1890, 1931, 1938, and 1972–73 (Thoroddsen, 1914; Thorarinsson, 1938, 1943; Todtmann, 1953, 1960; Williams, 1976; Björnsson et al., 2003). Possibly, a minor surge also took place in the eastern part of Eyjabakkajökull around 1990 (Kaldal and Víkingsson, 2000). Based on sedimentary varves in Lake Lögurinn, which receives meltwater from Eyjabakkajökull, Striberger et al. (2011) demonstrated that the glacier began surging about 2200 cal. years BP and that a uniform 34- to 38-year surge periodicity prevailed from ca. 1700 years BP until the Little Ice Age when surges occurred every 21–23 years. Currently, the glacier has a low-relief snout that is rapidly retreating.

Various glacial landforms characterize the Eyjabakkajökull forefield, such as conspicuous end moraines, ice-cored and hummocky moraines, eskers, concertina eskers, flutes, drumlins, crevasse-squeeze ridges, meltwater channels and outwash plains (Figs. 1, 2; Todtmann, 1953; Sharp, 1985a,b; Croot, 1987, 1988; Evans and Rea, 1999; Evans et al., 1999; Evans and Rea, 2003; Kaldal and Víkingsson, 2000; Benediktsson et al., 2010). Outside the 1890 terminal end moraines, frost-crack polygons occur together with circular ponds, which are interpreted as collapsed palsas, an indicator of deteriorating permafrost (Todtmann, 1955, 1960; Friedman et al., 1971; Benediktsson et al., 2010). From November 1997 to October 2008, the mean annual air temperature on the Eyjabakkar outwash plain approximately 10 km north of the glacier margin was 0.1 °C. Thus, the present climate is too warm to support substantial permafrost. However, discontinuous permafrost likely existed in the Eyjabakkajökull forefield during the Little Ice Age when temperatures in Iceland were generally 1.5–2.5 °C lower (Bergthórsson, 1969; Guðmundsson, 1997; Flowers et al., 2008).

3. Methods and data

3.1. Data

The map is based on aerial photographs recorded in August 2008 using a digital aerial camera (Vexcel UltraCAM-D) with 90 megapixel resolution. The imagery was recorded in RGB mode and covers an area of 60 km^2. Mapping took place on derived orthophotographs with 0.2 m pixel size and a digital elevation model (DEM) with 3 m ground sample distance produced with stereophotogrammetry. The terrain shaded relief model at the base of the map is derived from

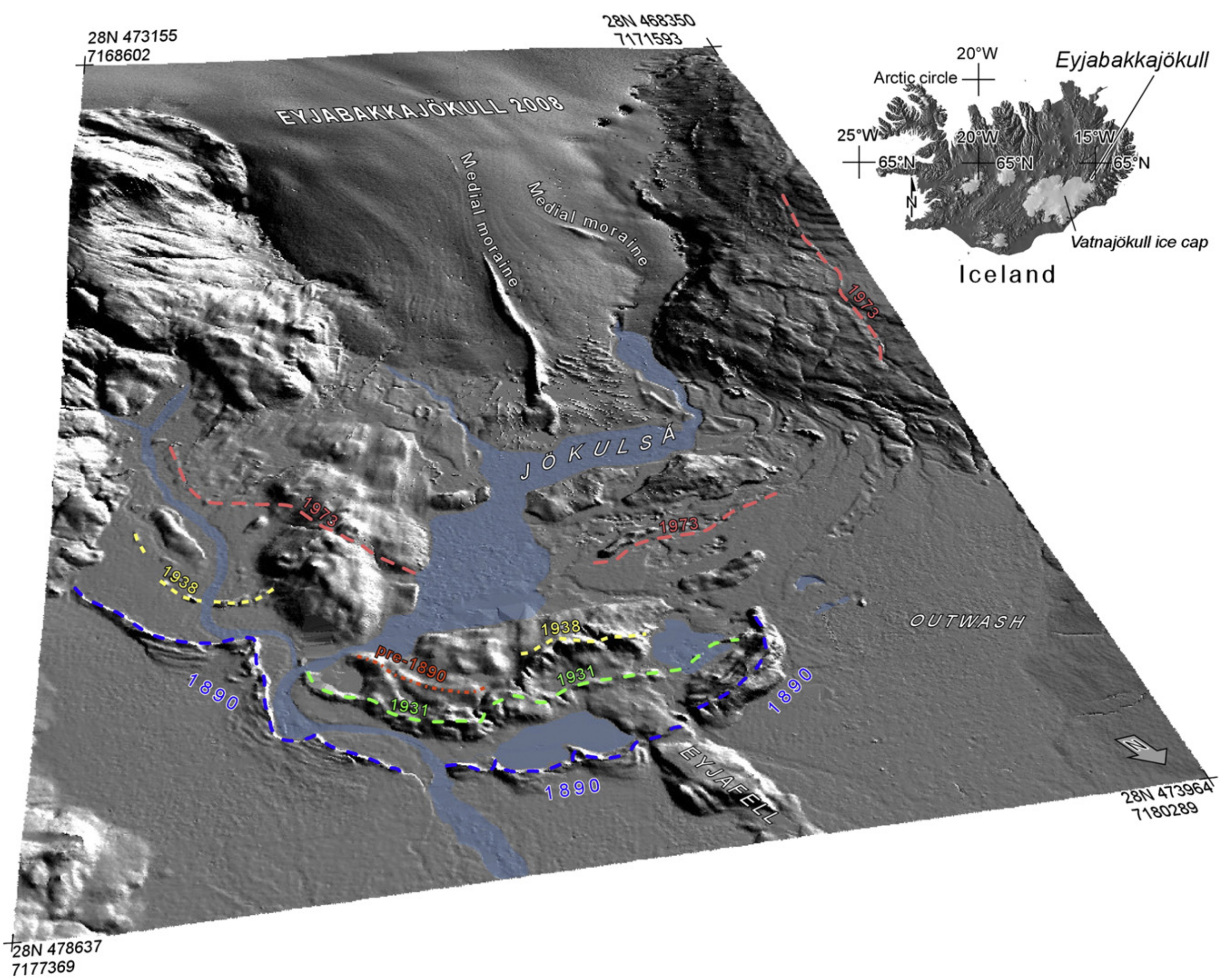

Fig. 1. The forefield of the surge-type glacier Eyjabakkajökull, eastern Iceland. The landscape is visualized as a terrain shaded relief model viewed towards the SSW. The end moraines from the surges in 1890, 1931, 1938, and 1973 are indicated as are major rivers and lakes. The area is approximately 5 km across. Coordinates are in UTM/WGS84 and shown in meters.