Geomorphology 213 (2014) 292–304

Contents lists available at ScienceDirect

Geomorphology

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

Geomorphology and the Little Ice Age extent of the Drangajökull ice cap, NW Iceland, with focus on its three surge-type outlets

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ARTICLE INFO

Article history:
Received 19 September 2013
Received in revised form 15 January 2014
Accepted 23 January 2014
Available online 19 February 2014

Keywords:
Drangajökull
Iceland
Glacial geomorphology
Surging glacier
Landform
Little Ice Age

ABSTRACT

Detailed geomorphological maps from the forefields of three surging outlets of the Drangajökull ice cap, northwest Iceland, are presented. The maps are based on field studies in 2011–2013, high resolution orthorectified aerial photographs recorded in 2005–2006, and airborne LiDAR data from 2011. The maps cover an area of about 40–60 km^2 each. Furthermore, we present an overview map that covers the area surrounding the Drangajökull ice cap. Landforms and sediments were manually registered in a geographic information system (ESRI ArcGIS 10). We mapped glacial landforms such as flutes, ice-sculpted bedrock, hummocky moraine, kame terraces, and moraines. Fluvial landforms include outwash plains/sandur, pitted sandur, and eskers. In addition raised beaches were mapped. The Little Ice Age (LIA) maximum extent of Drangajökull and its outlet glaciers are fingerprinted by surficial till deposits and freshly glacially scoured bedrock. Sediments distal to the LIA deposits were recorded and consist mainly of late Weichselian and early Holocene sediments and locally weathered bedrock. Periglacial activity is demonstrated by patterned ground, mainly occurring on the 500–700 m high plateaux, and three rock glaciers. At least 3–4 surge events are described from each of the outlet glaciers, occurring over the last three centuries. In contrast to most other surge-type outlets from Icelandic ice caps, the Drangajökull outlets are confined within valleys, which affect the forefield geomorphology. Glaciofluvial landforms, moraines, and a thin sheet of till with numerous boulders are characteristic for the forefields of the Drangajökull outlets.

1. Introduction

The three main outlets of the Drangajökull ice cap (Reykjarfjarðarjökull, Leirufjarðarjökull and Kaldalónsjökull) are all surge-type glaciers (Þórarinsson, 1969; Björnsson et al., 2003; Sigurðsson, 2005; Sigurðsson and Williams, 2008). Eythorsson (1935) and Þórarinsson (1943) summarized the historical information regarding the fluctuations of the glacier margins, as chronicled by local farmers and previous explorers in the area. Leirufjarðarjökull and Kaldalónsjökull surged around A.D. 1700 and 1740. All three glaciers surged in the mid-nineteenth century and again in the 1940s. Finally, Leirufjarðarjökull and Kaldalónsjökull surged during the period 1995 to 2000 and Reykjarfjarðarjökull between 2002 and 2006 (Sigurðsson, 1998; Sigurðsson and Jóhannesson, 1998; Sigurðsson, 2003; Þrastarson, 2006). Björnsson et al. (2003) described the nature of surging glaciers in Iceland, concluding that the advance of the surging terminus usually lasts a few months. However, during the last two surges of the Drangajökull outlets, the advance of the terminus lasted about five years (Sigurðsson, 1998; Sigurðsson and Jóhannesson, 1998; Sigurðsson, 2003). Such long lasting advances of other surging glacier termini in Iceland have only been reported from Búrfellsjökull, a small surging cirque glacier in Tröllaskagi, north Iceland (Brynjólfsson et al., 2012). This makes the surge activity of Drangajökull unique, compared to the surge-type outlets of the other ice caps in Iceland. The duration of the Drangajökull surges resemble the surging of glaciers of Svalbard where the active phase typically lasts 3–10 years (Dowdeswell and Hamilton, 1991; Jiskoot et al., 1998; Murray et al., 2003).

Glacier surging is a cyclic flow instability generally thought to be triggered within the glacier system rather than by external climate forcing (i.e., Benn and Evans, 2010). However, notably, Striberger et al. (2011) suggested that a mass-balance control on surge frequencies was found on Eyjabakkajökull, a northeastern outlet of Vatnajökull ice cap, Iceland. During the active phase of surge, ice is transferred from the reservoir area to the snout of the glacier. Ice flow velocity of the active phase can be up to a thousand times faster than the quiescent phase, whereas the quiescent phase is characterised by snout stagnation and ice build-up in the reservoir area (Meier and Post, 1969; Raymond, 1987; Sharp, 1988; Harrison and Post, 2003; Benn and Evans, 2010). Landform-sediment assemblages on the foreland of such glaciers have been used to define a surging glacier land system model (Evans and

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http://dx.doi.org/10.1016/j.geomorph.2014.01.019
0169-555X/

Rea, 1999, 2003). The forefield of the nontopographically confined surging glaciers, Brúarjökull, an outlet of northern Vatnajökull, was one of the main study areas for the land system model (Evans and Rea, 1999, 2003; Kjær et al., 2008). Such an approach can be used to recognise the imprint of former surging on the landscape (Evans and Rea, 2003; Benn and Evans, 2010). However, sometimes this land system model has to be modified as each surging glacier is unique. A recent study of small surging cirque glaciers in Tröllaskagi, northern Iceland, shows that a modified version of the surging glacier land system model best described the fingerprints of surging cirque glaciers (Brynjólfsson et al., 2012), and Schomacker et al. (2014) described a modified surging glacier landsystem model for Eyjabakkajökull, eastern Iceland.

Geomorphological maps exist from the Drangajökull region (Eythorsson, 1935; Þórarinsson, 1943; John and Sugden, 1962; Groove, 1988; Principato, 2008). However, no detailed geomorphological maps exist of the forefield of the Drangajökull surging outlets, except the map of Kaldalón outlet by John and Sugden (1962). The aim of this paper is to present detailed geomorphological maps and describe the sediments and landforms that occur in the forefield of the three surging outlets of the Drangajökull ice cap. This is in order to better interpret the scarcely known surge dynamics before the observed surges in the 1930s and to identify characteristic landforms and sediments formed by the surges. Furthermore, based on the geomorphological mapping and historical information, we aim to reconstruct the Little Ice Age (LIA) maximum extent of the ice cap.

2. Regional setting

The Drangajökull ice cap reaches 915 m above sea level (asl) and is located on the eastern highland plateau of the Vestfirðir peninsula in northwest Iceland (Fig. 1). This dome shaped, fifth largest ice cap in Iceland, rests on Neogene flood basalts interbedded with thin sedimentary layers (Einarsson, 1991; Kristjánsson and Jóhannesson, 1994). The equilibrium line altitude (ELA) at 550–600 m asl is about half the altitude of ELA on the other ice caps in Iceland, reflecting low summer temperature, short melting season, and high precipitation over the eastern Vestfirðir peninsula (Eythorsson, 1935; Crochet et al., 2007; Björnsson and Pálsson, 2008). This unique glacial condition, in terms of Iceland, is considered to be amplified by the proximity of Greenland and the cold polar East Greenland Current (EGC) (Bergþórsson, 1969; Björnsson, 1979; Ingólfsson et al., 1997; Eiríksson et al., 2000). Short distance to the open ocean to the west, north, and east of the eastern Vestfirðir peninsula favours the access of moist air to the glacier (Eythorsson, 1935). The EGC converges with relatively warm Atlantic water of the Irminger Current off the Vestfirðir peninsula (Stefánsson, 1969; Eiríksson et al., 2000). Enhanced advection of either of the currents strongly affects sea ice extent north of Iceland and regional changes in temperature (Bergþórsson, 1969; Stötter et al., 1999; Hanna et al., 2004; Geirsdóttir et al., 2009).

The present climate of Iceland is classified as cool, temperate maritime (Einarsson, 1976). Regional climate conditions at Drangajökull are characterised by steep precipitation and temperature gradients from the northeast to the southwest. The mean summer temperature (June–September) is 6–7 °C on the northeast coast of the ice cap and 8–9 °C on the west coast of the ice cap (Eythorsson, 1935; Hanna et al., 2004; http://www.vedur.is/Medaltalstoflur-txt/Manadargildi.html accessed 15 August 2013). The precipitation gradient reflects prevailing wind direction in the area from the northeast (Einarsson, 1976), with about 1100 mm annual average precipitation close to sea level on the northeast coast and about 580 mm on the west coast on the lee side of the Drangajökull ice cap (Crochet et al., 2007; http://www.vedur.is/Medaltalstoflur-txt/Arsgildi.html accessed 15 August 2013).

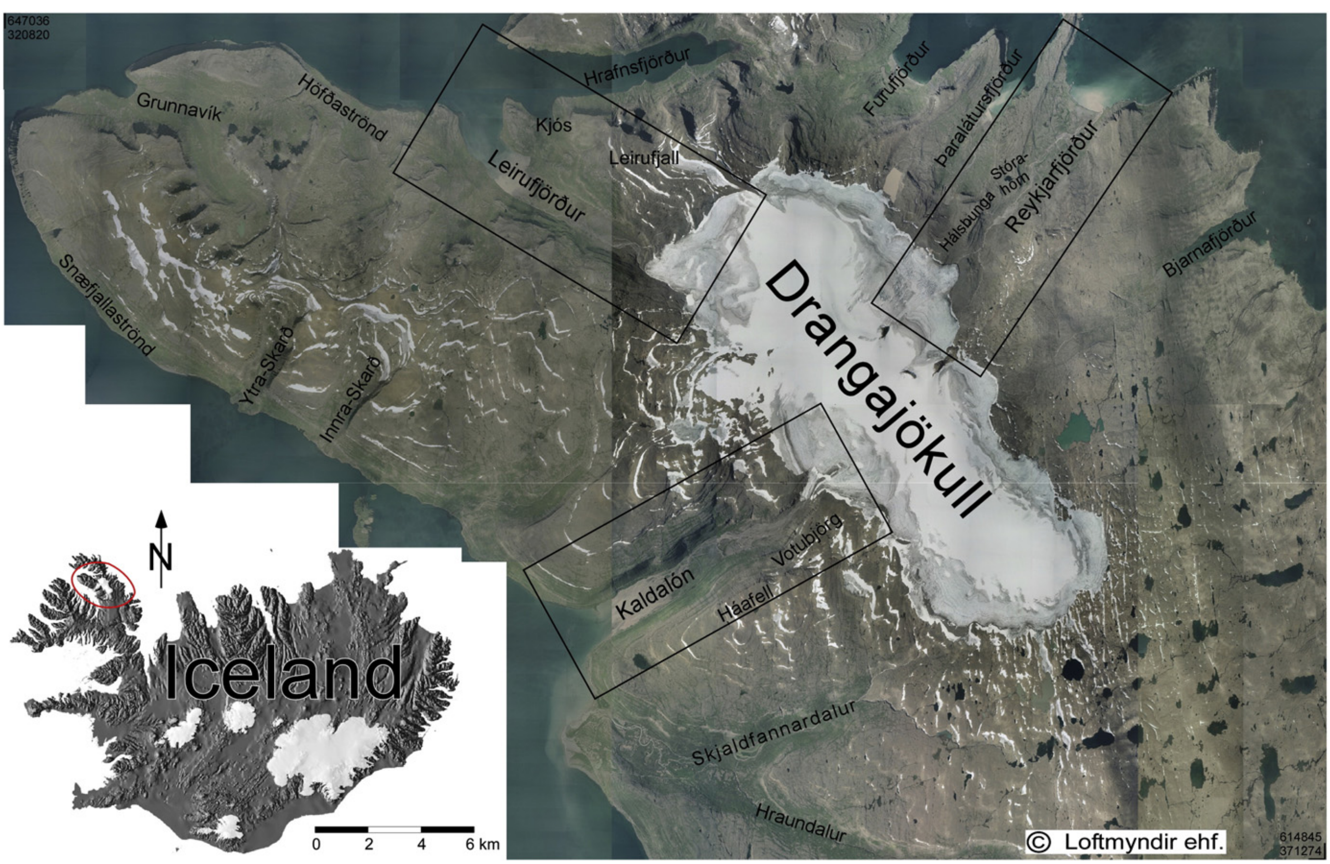

Fig. 1. The Drangajökull ice cap, located on the eastern Vestfirðir peninsula, north-western Iceland. The main geographical names are presented on aerial orthophotos from 2005 to 2006 taken by Loftmyndir ehf.