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Submarine glacial landforms and sedimentary environments in Vaigattbogen, northeastern Spitsbergen

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A B S T R A C T

Vaigattbogen is located in northern Svalbard. The area is currently affected by several tidewater glaciers. This study uses multibeam-, sub-bottom acoustic data, and four sediment cores to reconstruct the Late Weichselian and Holocene glacial history in Vaigattbogen. During the last glacial, ice flowed northwards through Vaigattbogen and fed into the Hinlopen Strait Ice Stream. Streamlined bedforms indicate relatively fast ice flow and their increasing elongation ratios towards the north suggest increasing flow velocities. De Geer moraines in the shallower parts of Vaigattbogen imply that multiple halts and/or re-advances interrupted the ice retreat in these areas. A sediment core suggests that the north basin deglaciated prior to 9.1 cal. ka BP. In the south basin, two large moraine ridges and networks of crevasse-squeeze ridges suggest that at least two surge-type advances occurred during the Holocene. The Hinlopenbreen glacier surged in the early 1970s and deposited the inner (R.2) of the two large moraine ridges. Radiocarbon ages from a sediment core recovered from the crest of the outer (R.1) ridge yield a basal age of 2.6 cal. ka BP. However, the core did not sample subglacial diamict and the age of the ridge could be anything between 2.6 cal. ka BP and early Holocene. The R.1 ridge formed prior to the Little Ice Age (LIA), implying that more than one tidewater glacier has experienced a pre-LIA surge on the east coast of Spitsbergen, suggesting that surging during the Holocene was a regional phenomenon. The R.1 ridge is double-crested with small crevasse-squeeze ridges between the crests suggesting that more than one surge-type advance occurred during the Holocene reaching approximately the same location. Data from eastern Svalbard indicate differences in surge-landform assemblages suggesting that different mechanisms could have governed surge-cycles throughout the Holocene.

1. Introduction

Polar ice sheets and ice caps lose the majority of their mass by calving at their marine margins, i.e. ice shelves and tidewater glaciers. Rapid climatic and oceanographic change at the marine margins can lead to draw-down of inland ice, changes in ice dynamics, increased mass loss and subsequent sea-level rise (Joughin et al., 2014). It is thus imperative to understand how future global climate change will affect these dynamic components of the ice sheets and ice caps (IPCC, 2014). Geological imprint of paleo ice sheets and past glaciers can provide clues regarding the links between past and future ice dynamics and their climatic and oceanographic controls.

In recent years, several studies have been published based on multibeam-bathymetric data from the fjords in eastern Spitsbergen and Nordaustlandet, providing new knowledge on glacier dynamics in eastern Svalbard during and after the Last Glacial Maximum (LGM) (Ottesen et al., 2007; Fransner et al., 2017; Noormets et al., 2016a; Noormets et al., 2016b; Flink et al., 2017a; Streuff et al., 2017). It has, for example, been suggested that a surge-type advance took place in Mohnbukta in eastern Spitsbergen during early Holocene, and that similar early Holocene advances could have occurred in other Svalbard fjords or bays, thus indicating a more dynamic early Holocene than previously presumed (Flink et al., 2017b). High-resolution data from the fjords in eastern and northern Svalbard are however still few compared to western Svalbard (Vieli et al., 2002; Hald et al., 2004; Ottesen and Dowdeswell, 2006; Ottesen et al., 2008; Blaszczyk et al., 2009; Kristensen et al., 2009; Forwick and Vorren, 2009; Forwick et al., 2010; Baeten et al., 2010; Kempf et al., 2013; Flink et al., 2015; Streuff et al., 2015; Sobota et al., 2016).

In this study, we map and analyze submarine glacial landforms in Vaigattbogen in order to reconstruct the past glacier dynamics of the bay. The study aims to provide a broader context for understanding the surge history of Svalbard glaciers and the role of climatic events in regional glacier dynamics, such as the deglaciation and the Little Ice Age (LIA) and to compare this with recently published data from other Svalbard fjords and bays. An important question to be answered is: was

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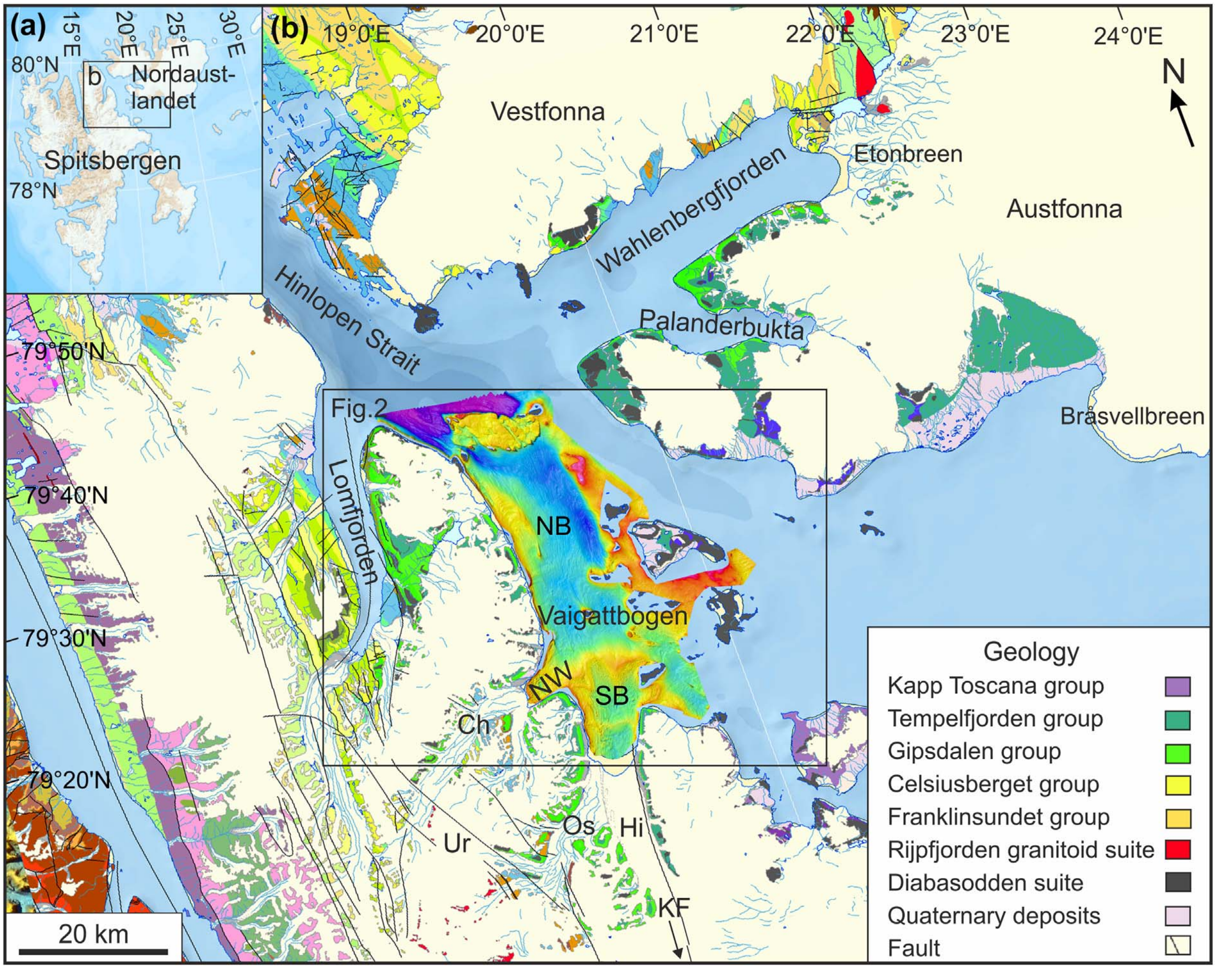

Fig. 1. (a) The location of Svalbard. Area within black box is shown in (b). (b) Bedrock map of northeastern Svalbard. Black box outlines the area shown in Fig. 2. Abbreviations indicate the locations of: Hi-Hinlopenbreen, Os-Oslobreen, Ch-Chydeniusbreeen, Ur-Ursafonna, NB-north basin, SB-south basin and NW-northwest basin. KF-arrows the direction towards Kongsfonna. Maps were derived from Svalbardkartet, Norwegian Polar Institute (NPI).

the pre-LIA surge in Mohnbukta, on the east coast of Spitsbergen (Flink et al., 2017b) a unique event or do we see evidence for similar advances in other parts of Svalbard?

2. Regional setting

Vaigattbogen is a bay located between northeastern Spitsbergen and Nordaustlandet (Fig. 1a, b). It is connected to the southern part of the Hinlopen Strait, which separates Spitsbergen from Nordaustlandet and leads into the Hinlopen Through on the northern Svalbard shelf. Submarine landforms indicate that both the Hinlopen Strait and Trough were occupied by a northward flowing ice stream during the last glacial (Batchelor et al., 2011). Inner Vaigattbogen is a two-branched bay with a larger south basin and a smaller NW basin, which are constrained by submarine ridges, R.1 and R.3, respectively. The ridges create sills between the south and NW basins and the deeper north basin (Fig. 2a). The maximum depths of the south and NW basins are 146 m and 116 m, respectively. Vaigattbogen is surrounded by several small islands, comprising of resistant dolerite intrusions from the Diabasodden suite (Fig. 1b) (Dallmann et al., 2002). Dolerites are also present along the mountainsides and coastlines of northeastern Spitsbergen. The dominant bedrock type consists of soft Mesozoic sedimentary rocks, such as shales, sand- and siltstones from the Tempelfjorden and Gipsdalen Groups (Fig. 1b). Carbonates from the Akademikerbreen and Polarisen Groups are present further inland (Dallmann et al., 2002). Quaternary unconsolidated glacial, glacifluvial and marine deposits drape the shorelines.

Three glaciers, Hinlopen-, Oslo- and Hønerbreen, terminate into the south basin with a joint tidewater cliff (Fig. 3a). Hinlopenbreen, which drains ice towards the east coast from the Kongsfonna ice cap is the largest of these. The glacier is 68.5 km long at its centerline and covers an area of approximately 1250 km^2 (Hagen et al., 1993). Oslobreen is the second largest glacier draining into the south basin (Fig. 2). The glacier is located west of Hinlopenbreen and has a drainage area to the southwest (Fig. 1b). Hønerbreen is a small glacier, wedged in between Oslobreen and the west coast of the south basin (Fig. 3a). Several small glaciers, such as Veite-, Loder- and Vellebreen terminate with tidewater cliffs into the south basin (Fig. 3a). Two tidewater glaciers, Polaris- and Chydeniusbreen flow into the NW basin. Polarisbreen drains the Ursafonna ice cap and flows northwards into Vaigattbogen (Fig. 1b). Chydeniusbreen has a large drainage area, extending towards the southwest and is fed by several tributary glaciers during its course northwards. Two tidewater glaciers, Kosterbreen and Sven Ludvigbreen, terminate into the north basin (Figs. 2a and 3a).

3. Glaciological background

The earliest maps of Vaigattbogen were produced in 1901 (Vassiliev, 1907; De Geer, 1923). Both maps show a straight glacier front situated at approximately the same location (Fig. 4). After 1901, the glacier experienced general retreat. In 1956 the front was located far back in the bay, only 2 km from its present position (Fig. 4). Hinlopenbreen surged in the early 1970s. The surge initiated in 1969 and lasted for at least three years (Lefauconnier and Hagen, 1991). The