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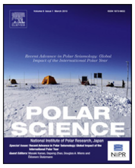

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Seismic explosion sources on an ice cap — Technical considerations

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Abstract

Controlled source seismic investigation of crustal structure below ice covers is an emerging technique. We have recently conducted an explosive refraction/wide-angle reflection seismic experiment on the ice cap in east-central Greenland. The data-quality is high for all shot points and a full crustal model can be modelled. A crucial challenge for applying the technique is to control the sources. Here, we present data that describe the efficiency of explosive sources in the ice cover. Analysis of the data shows, that the ice cap traps a significant amount of energy, which is observed as a strong ice wave. The ice cap leads to low transmission of energy into the crust such that charges need be larger than in conventional onshore experiments to obtain reliable seismic signals. The strong reflection coefficient at the base of the ice generates strong multiples which may mask for secondary phases. This effect may be crucial for acquisition of reflection seismic profiles on ice caps. Our experience shows that it is essential to use optimum depth for the charges and to seal the boreholes carefully.

Keywords: Active sources; Seismology; Greenland; Seismics on ice

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1. Introduction

The recent global geo-community interest in the polar regions brings new challenges to the logistics and scientific setup of experiments in these unfriendly environments. The presence of ice caps and extreme weather conditions require reassessment of the approaches and techniques to be used for geophysical data acquisitions.

In this paper we share our experience of conducting a successful controlled source seismic experiment on top of the ice sheet in east-central Greenland from the viewpoint of technical issues of planning and conducting a controlled source seismic acquisition campaign, together with the challenges experienced in post-experiment data processing. Our analysis suggests that proper pre-planning of the experiment is crucial for the success of the experiment, in addition to the large logistic challenges of operating on the ice cap. We hope our observations are helpful to the future seismic experiments, and that they may assist in reducing a number of unpleasant surprises that may be met when working on the ice caps.

Although we do not address the crustal structure *per se*, we find it important to provide some geological/tectonic information on objectives of the project. The conjugate Atlantic passive margins of western Norway and eastern Greenland are characterized by the presence of coast-parallel mountain ranges with peak

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elevations of more than 3.5 km close to Scoresbysund in eastern Greenland and above 2000 m in Norway. These mountains are located far from the nearest plate boundary, which is the spreading ridge in the North Atlantic Ocean. There is substantial evidence that they have been uplifted during the latest 65 My (Japsen and Chalmers, 2000; Anell et al., 2009), although some authors believe that the topography already came into existence during the Caledonian Orogeny at around 440 Ma (Nielsen et al., 2002). The issue of recent uplift in Norway is heavily discussed, because there is no sedimentary cover in onshore Norway, which prevents determination of a maximum age of the uplift. However, the offshore shelf and their sedimentary basins provide evidence for significant vertical displacement up to present time, including km-scale subsidence of the shelf and basins therein during the last 1–2 My (Faleide et al., 2002, 2008; Anell et al., 2010).

Understanding the causes of these pronounced and fast changes in topography requires knowledge of the crustal and mantle structure. A series of seismic experiments have recently been carried out, many as part of the TopoEurope programme (Cloetingh et al., 2007, 2009). In southern Norway and western Sweden the MAGNUS experiment operated about 60 seismometers for a period of 2 years (Weidle et al., 2010; Maupin et al., 2013). A main result from this experiment is that the upper mantle velocities change abruptly from the topographically low Baltic Shield in Sweden into the high topography of Norway (Medhus et al., 2012). This change is accompanied by a change from shield type crust to a crust lacking a high-velocity lower crust (Stratford et al., 2009; Stratford and Thybo, 2011; Frassetto and Thybo, 2013; Loidl et al., 2014), which is similar to much of the crustal structure on the continental shelf (Kvarven et al., 2014).

There is very little information available on the crustal structure in Greenland (Artemieva et al., 2006; Artemieva and Thybo, 2008) where the topographic change is better documented than in Scandinavia due to the presence of sedimentary and volcanic rocks at high altitude. The presence of Jurassic rocks (Dam and Surlyk, 1998) at almost 1000 m altitude in interior Greenland shows that the topography cannot be caused by the Caledonian orogeny alone. Further, volcanic rocks of the North Atlantic Igneous province, related to the break-up of the North Atlantic at the beginning of the Tertiary (Brooks, 2011) are now found at altitudes up to 3700 m.

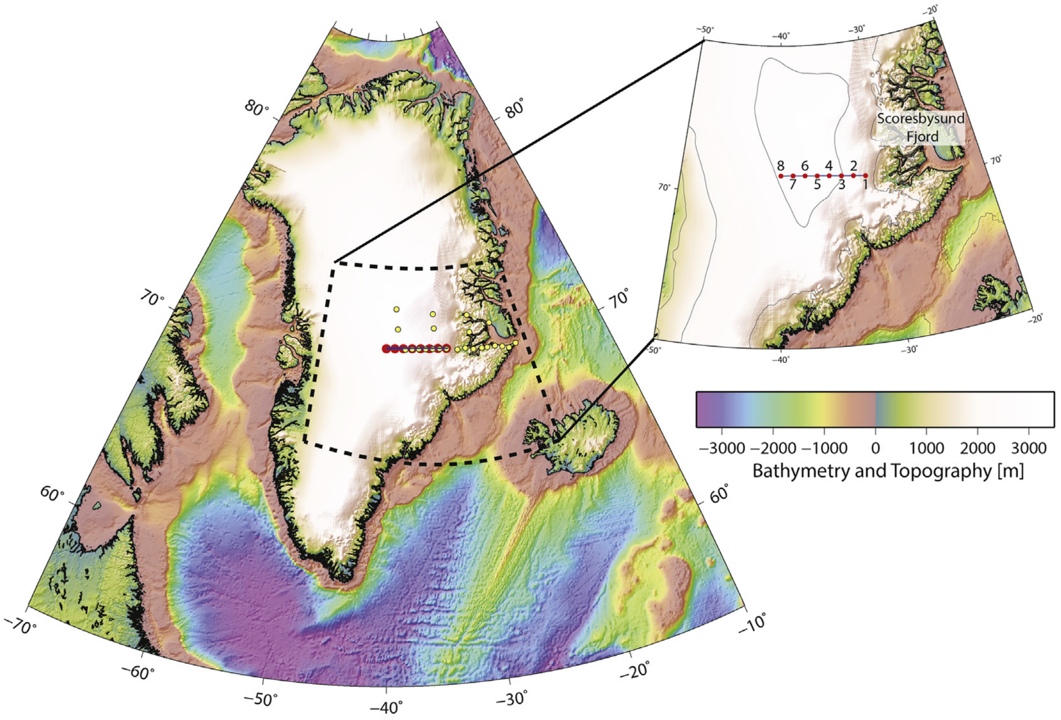

Fig. 1. Topographic map of Greenland and the bathymetry of the surrounding ocean. The dashed box shows the extent of the zoomed plot of the working area. The solid line shows the location of the refraction profile TopoGreenland-2011. The red circles mark the locations of the eight shot points along the profile. Small yellow circles mark the locations of the long-term deployed broad-band seismic stations. Numbering of the shots is from East to West (shown on the insert map).