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Electrical conductivity structure of north-west Fennoscandia from three-dimensional inversion of magnetotelluric data

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ABSTRACT

New magnetotelluric (MT) data in north-west Fennoscandia were acquired within the framework of the project "Magnetotellurics in the Scandes" (MaSca). The project focuses on the investigation of the crustal and upper mantle lithospheric structure in the transition zone from stable Precambrian cratonic interior to passive continental margin beneath the Caledonian orogen and the Scandinavian Mountains in western Fennoscandia. An array of 59 simultaneous long period and 220 broad-band MT sites were occupied in the summers of 2011 to 2013.

The 3-D inversion of the MaSca data was obtained using the ModEM 3-D code. The full impedance and tipper data were used for the inversion. The rocks of Archaean and Proterozoic basement towards east and the Caledonian nappes towards west are modelled as resistive structures. In the central and southern parts, the whole crust is resistive and reflects the Trans-Scandinavian Igneous Belt granitoids. The middle to lower crust of the Svecofennian province is conductive. An uppermost crustal conductor is revealed in the Skellefteå Ore District. The south end of the Kittilä Greenstone Belt is seen in the models as a strong upper to middle crustal conductor. In the Caledonides, the highly conductive alum shales are observed along the Caledonian Thrust Front. A map of the crustal conductance for the north-west Fennoscandian Shield is presented.

1. Introduction

The "Magnetotellurics in the Scandes" (MaSca) project targets at development and application of the magnetotelluric (MT) method to study the Earth's structure in north-west Fennoscandia. The MaSca array covers an area from E13 to E23 and N64 to N69. The area of investigation consists of the Archaean Domain, northern Svecofennian volcanic belt and the Scandinavian Caledonides. The array crosses two important boundaries: the Archaean–Proterozoic boundary and the Caledonian Thrust Front (Fig. 1).

Prior to this project, there were no MT data acquired in western Fennoscandia, except for two recent MT profiles in southern Norway (Cherevatova et al., 2014) and across the central Scandinavian Mountains (Korja et al., 2008) (Fig. 1c). These studies have revealed highly conductive alum shales between the resistive Proterozoic basement and the overlying Caledonian nappes. Airborne electromagnetic data from Finland indicate the alum shales formations extend to the north (Korja et al., 2002). Hence, it is likely that the Caledonides are underlain by the alum shales everywhere. A number of MT surveys have been conducted in the rest of Fennoscandia (Agustsson, 1986; Hjelt et al., 2006; Korja, 2007; Korja et al., 1989, 2008; Lahti et al., 2005; Rasmussen, 1988; Rasmussen et al., 1987) and its margins (Brasse et al., 2006; Jones, 1983; Smirnov and Pedersen, 2009). The Baltic Electromagnetic Array Research (BEAR) project was an international experiment for deep electromagnetic sounding. Earlier studies together with the BEAR data allowed for compiling a map of integrated conductance of the Fennoscandian Shield (Korja et al., 2002). The map revealed large variations in conductance ranging from a few Siemens to tens of thousands of Siemens. The crust is generally resistive with a few highly conducting belts: Skellefteå and Kittilä conductors (with the total conductance of more than 1000 *S*) (Fig. 1). The MaSca array crosses only parts of these conductors and further extension of the array is planned to the north-east and south.

Unfortunately, north-west Fennoscandia is not well studied by seismic methods. Therefore, a comparison of the electric and velocity models is not currently possible. In Sweden, the European Geotraverse and related experiments provide information on the central part of the Fennoscandian Shield (Guggisberg et al., 1991; Lund and Heikkinen, 1987). The results show a thick crust below the low topography of the

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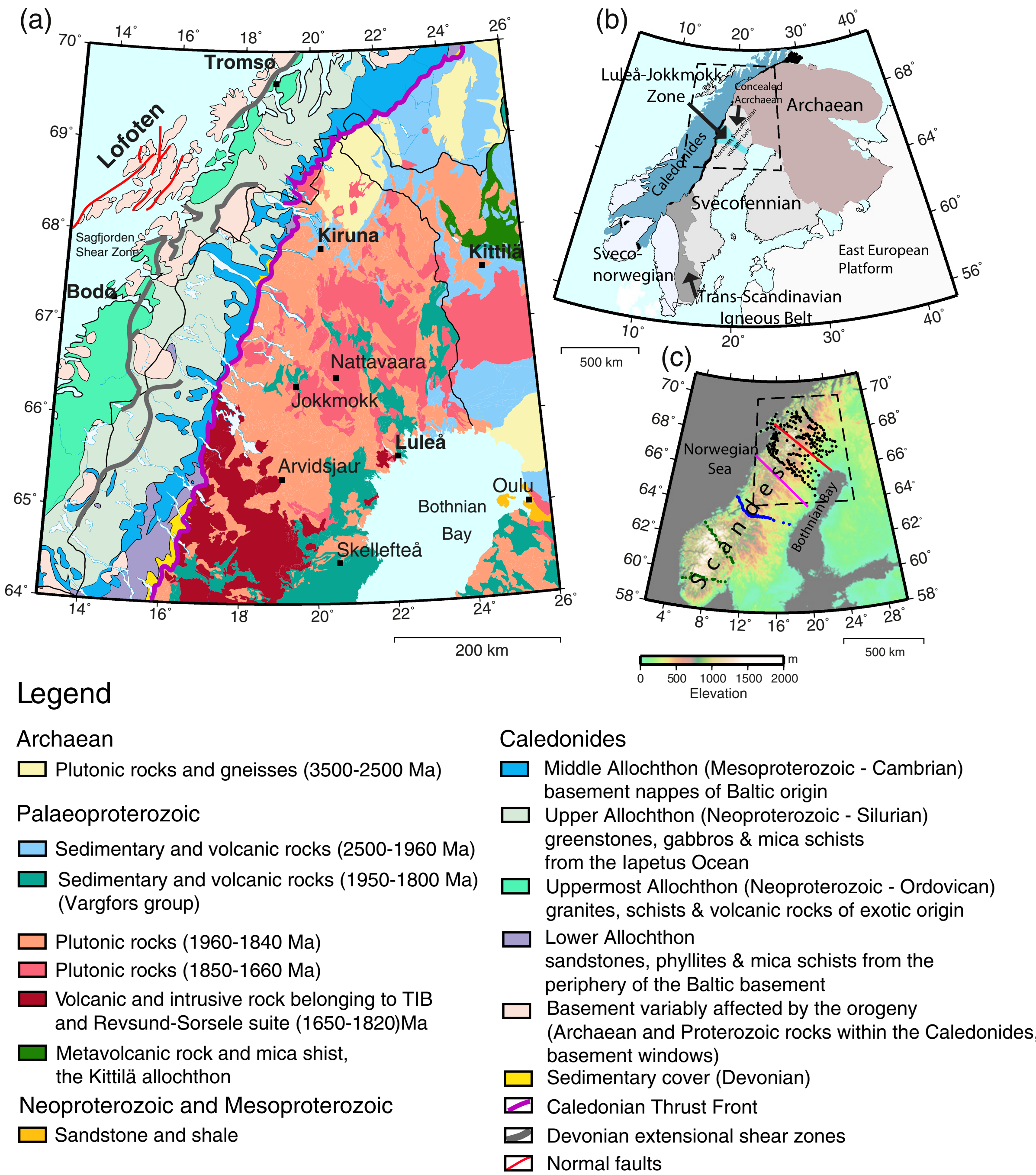

Fig. 1. Main geological units of the Caledonian orogen and the Precambrian basement in the north-west Fennoscandia. (a) Simplified geology map. The map is compiled and simplified after (Gorbatschev and Bogdanova, 1993; Ramberg et al., 2008) and (Ebbing et al., 2012). (b) Main tectonic domains in Fennoscandia (modified from (Koistinen and et al, 2001)). (c) Elevation map: black circles — MaSca array, blue — Jämtland–Trøndelag MT profile (Korja et al., 2008), green — ToSca MT profiles (Cherevatova et al., 2014), red line — seismic SCANLIPS experiment (Ebbing et al., 2012), magenta line — the Blue Road seismic profile (Lund, 1979).

central Fennoscandian Shield, which is not in agreement with the observed gravity signal (Ebbing et al., 2012). The Blue Road profile across the northern Scandinavian Mountains (Lund, 1979) is located some 100 km to the south from MaSca array (Fig. 1c). Lund (1979) stated that there is evidence for a shear (S) wave low-velocity zone of a few tens of kilometres in the uppermost mantle. Therefore, an extension of the MaSca measurements is planned along the Blue Road seismic profile. In addition, results from the SCANLIPS-2 seismic profile in northern Norway (Fig. 1c) will be available in the coming years and facilitate modelling of the processes that shaped the topography of the Scandinavian Mountains (Ebbing et al., 2012).

In this paper we present the first 3-D MT model of the crust beneath the Archaean and Svecofennian Domains and the Caledonides. The MT method is sensitive to resistivity contrasts, therefore the model is very informative in mapping resistive basement features and conducting mineral phases. The possible causes of enhanced electrical conductivity in the middle and lower crust are saline fluids, graphite or carbon grain-boundary films and partial melts. (Korja et al., 2008) described, that partial melts are unlikely to be present in the Fennoscandian middle and lower crust. Despite the advantages of 3-D inversion (see later in Section 2) we always undertake prior 2-D inversion. The detailed description of the strike and dimensionality analysis of the MaSca data,