DEEP STRUCTURE OF THE KARELIAN PART OF THE FENNOSKANDIAN SHIELD (SEISMOLOGICAL AND GEOELECTRICAL RESEARCH)

M. V. Cherevatova

Institute of Physics, St. Petersburg University, St. Petersburg, 198504, Russia,

e-mail: Maria.Cherevatova@gmail.com

Abstract. In the paper we give a review and analysis of the geologic, deep seismologic and geoelectric research at the eastern (Russian) part of the Fennoskandian Shield for the past 10 years. Due to the absence of a sedimentary cover, the Fennoskandian Shield represents a natural proving ground for geophysical research. We have analyzed results of the deep lithosphere studies to define which areas demand more careful data consideration, using newly developed approaches. Geoelectrical methods revealed the presence of two conducting layers: the first one is the crust layer, at the depth of 10-15 km, and the other is the under-crust one, at the depth of 40-160km, which is observed almost throughout at the eastern part of the Fennoskandian Shield. Nowadays, the nature of the crust conducting layer usually connects with astenosphere. Furthermore, the seismic research has been examined too, aimed at investigating the deep structure of the Fennoskandian (Baltic) Shield construction. Joint interpretation of the seismic and geoelectric data reveals that their results do not contradict to each other, and supplement more likely.

Based on the observed results in geologic and geophysics we are planning to reanalyze magnetotelluric data using 2D approach, to invert some invariants of impedance tensor data using REBOCC by Siripunvaraporn&Egbert and also 3D inversion based on SVD method (St.Petersburg State University).

The eastern part of the Fennoskandian Shield, which incorporates the Murmansk Oblast and Karelia, has been studied both geologically and geophysically. Due to the fact that there is no sedimentary cover, it can be used as natural proving grounds to update old concepts, to develop new models in order to fill the gaps in our deep structure knowledge of the continental crust and old-crust forming processes. The structure of the earth crust and upper mantle was found to be highly heterogeneous both vertically and laterally.

The greatest contribution to the understanding of the lithosphere is made by geophysical studies. Seismic methods, such as deep seismic sounding (DSS), increase our knowledge of the composition of deep lithospheric horizons, and heterogeneities like faults, intrusions, and low velocity layers. In the past few years the Fennoskandian Shield has been studied using the common deep point (CDP) method to obtain images of seismic heterogeneities that seem to be in better agreement with geological observations. The Magnetotelluric and Magnetovariational methods in geoelectric allow penetrating to the deepest horizons of the crust and the upper mantle. We managed to get the electro conductivity distribution in the large intervals of the periods \((10^3 – 10^7 \text{sec})\). Joint interpretation of the seismic and geoelectric data reveals that their results do not contradict to each other, and supplement more likely.

The Fennoskandian Shield is an outcrop of Pre-Cambrian basement in a northwest part of East-European platform. It is consisted of Archaean and low Proterozoic rocks (gneisses, crystal slates, etc.) and it covers almost all territory of Scandinavia, Karelia, Kola Peninsula. This region is precisely divided into three geological structural areas. The northern part is Kola Peninsula. The central part of considered territory is the large site of the earth crust which is named Karelian Craton unchanged rather steadily during all Pre-Cambrian histories. From the northeast it is adjoined with Belomorian Folded belt, and from the southwest there is an extensive Svekofennian folded area.

Karelian Craton has a two-storeyed structure (fig.1) [13]. The low structural floor is granite-greenstone basement. It consists of gneisses tonalities, granite diorites and diorites. The greenstone belts are pressed in them in the form of narrow and lengthy lines (width less then 10 km and extensions more then 200 km). The greenstone belts are formed by the sedimentary-volcanic rocks of the late Achaean. The top structural floor consists of sedimentary-volcanic rocks of the early Proterozoic, which lies at the rocks with the structural variance. Along the western coast of the White Sea stretches a narrow 50-150 km zone of the amphibolites, different gneisses and migmatites – Belomorian Folded belt. It differs sharply from the rest of the Fennoskandian Shield and represents the most ancient collision structure in Europe. Belomorian Folded
Belt is formed by Achaean sedimentary-volcanic rocks, undergoing the repeated folding, metamorphism and migmatism at the large depths. The extensive Fennoskandian folded area occupies a small part of the Russian territory. But the greatest advantage of this fact is that this is a region of a joining with Karelian Craton. The Ladoga zone of the Svekofennian Folded area is formed of the early Proterozoic rocks, the Achaean Granit gneisses were saved in the contact zone with Karelian Craton.

---

**fig. 1 Geological sketch map of the Karelian region**

The deep structure of the Russian part of the Fennoskandian Shield has been studied by the seismic and seismologic methods using the special and industrial explosions, registration of the distance and near earthquakes, vibroseismic sources and pneumosignals. This territory has been studied by 32 regional profiles with total extension 10500km and still the most studied by the seismologic methods. Since 1995 the most important project aimed to the deep structure studying of the crust and upper mantle using the common deep point modification method (CDPM) has been realized in the East – European platform [11]. We have decided to consider only to seismic profiles, 1-EU transect and 4B profile. The 4B profile crossed the considerable part of the Karelian Craton and its boundary with Belomorian area. The 1-EU transect traversed all over territory of the Karelia from the north-west to the south-east [1]. We did not consider the technique and peculiar properties of the experiments. Here are the main research results at these profiles:

- Geological interpretation of the data received as a result of seismological researches along 1-EU transect and profile 4B, crossing Karelian granite-greenstone complex, Belomorian belt, a number of Paleoproterozoic sedimentary-volcanic belts and Svecofennian accretion orogeny structure, testify that the early Pre-Cambrian crust is characterized by inclined structural stratification.
- Formation of inclined-lying structural ensembles occurred both in Paleozoic, and in Neoarchaean.
- Paleoproterozoic East-Karelian sedimentary-volcanic belt is formed by a system of monoclinal dipping tectonic plates.
- Detailed figure of structural lines in the low crust testifies to the tectonic nature of Moho border which, apparently, represents a powerful zone of tectonic current and moving of large plates of the crust, accompanied immersion of separate fragments of the low crust to the mantle.
- Accommodation slightly-inclined borders on a day surface are defined by a level of an erosive section and cannot be accepted as the borders any “tectonic blocks” in traditional understanding.

Nowadays, the most of the geological objects of this region are covered by the deep geoelectrical research. The deep sounding has been carried out by the magnetotelluric and magnetovariational methods, in general [6]. Throughout 20 years the staff of SPbGU continues the magnetotelluric research in the limited interval of periods in the eastern part of the Fennoskandian Shield, for the purpose of studying the construction of crust and upper mantle of this region. The research points are situated along the profiles Teriberka-Kovdor-Suoyarvy, Suoyarvi-Vyborg (LADOGA), SVEKA. The eastern part of the Shield consists of the fifty blocks (third order), separated by the faults, which has the different geological structure. One picks out the four mega blocks – Kola, Belomorian (southern and northern), Karelian (western, central and eastern) and Svekofennian [7].

The profile Teriberka – Kovdor – Suoyarvy – Vyborg was studied using the MT and AMT methods. Even point of this profile was characterized by the four components of the impedance tensor. It gives the complete information about the geoelectrical structure but extraction of this information is very difficult problem, especially if to take into account the blocked structure of the region [10]. The LADOGA and SVEKA profiles has a compact net of the observations, in practice it allows getting the electro conductivity distribution up to the 300 – 400 km [8]. Furthermore, the soundings in the external interval of periods have been realized in the profile SVEKA. It is crosses the western and central Karelian and southern Belomorian megablocks just as junction zone between the Karelian and Belomorian megablocks. The great interest to the LADOGA profile is connected with the fact that this profile crosses Ladoga – Bothnic zone (LBZ) of the faults, which is situated in the Karelian and Svekofennian megablocks zone of a joint. The area of the LBZ there is the largest anomaly of the electro conductivity in the north-west of the East – European platform. This anomaly was revealed by the MVS and tested by the MTS. The MTS allows studying the structure of the upper mantle. But there are some problems, caused the large depth. Than more depth there is worse data over the 3D environment influence. Thanks to the international experiment BEAR the opportunity to reach the great depth is realized. Now we able to use both module and phase of the impedance. In contrast to the amplitude curves the phases curves do not shift over the 3D and 2D effects and can be used for getting of the conductivity distribution at the great depths [9].

- Geoelectrical interpretation of the data received as a result of research along profile Teriberka - Kovdor – Suoyarvi crossing Kola, Belomorian and Karelian megablocks, revealed the presence of two conducting zones, at the depth 10-15 km where specific resistance reaches a minimum from 70 up to 2000 Ohm m, and 40-160 km, with specific resistance from 40 up to 400 Ohm m.
- The data received during international project SVEKALAPKO, along structure SVEKA-2 crossing a zone of a joint Karelian and Belomorian megablocks, have specified the presence of extensive area of the faults separating the West-Karelian block from Central-Karelian. Tectonic activity has led to
the extensive area occurrence of the lowered resistance up to depth more 50 km in the field of a joint Central-Karelian and Belomorian megablocks.

- Magnetotelluric sounding along structure Suoyarvi - Vyborg (LADOGA), crossing East-Karelian and Svekofennian megablocks, allow revealing distinctions of this geoblocks: on the Karelian block increase electro conductivity at the depth 40-160 km, connected with astenosphere. On Svekofennian geoblock resistance goes down smoothly and conducting layers distinctly are not allocated, that allows speaking, that on this block astenosphere distinctly does not come to light.

- Geoelectrical research by method MTS in the top mantle have allowed construction of two types sections of the top mantle. The first type resistance distribution of the crust is widely spread on the Kola geoblock and north Belomorian geoblock. Distribution of resistance to the Central-Karelian block in the further has formed a basis for introduction of concept "normal" resistance distribution in the mantle. The basic geoelectrical characteristics of the received "normal" section is the following: resistance within the limits of 10 km grows, reaching maximal size in hundred thousands of Ohm·m on 4-8 km, then it decreases up to a minimum on depth 15 km, equal 1500-2000 Ohm·m (the width of a minimum does not exceed 15 km), further resistance slightly increases, and the second reduction of resistance begins with depths 70-100 km (on these depths resistance reaches 400-500 Ohm·m), from depth 100 km there is qualitatively new, fast growth of total conductivity of the section.

- Owing to international experiment BEAR one more opportunity of research resistance distribution on the low depths has been realized, using not only “longitudinal” values of impedance, but also a phase of impedance. Interpretation of phase curves has shown presence of a small minimum on a curve in an interval of depths 200-350 km on a background of the general decrease of resistance from depth 100 km. Longitudinal conductivity of a layer on depths 200-350 km which can be connected with existence of area of the lowered resistance, makes nearby 3000-4000 Sm, and average resistance on these depths does not exceed 10-30 Ohm·m.

As it has been said above, joint interpretation of the seismic and geoelectric data reveals that their results do not contradict to each other, and supplement more likely. We have tried to compare results both of them and have received the following:

- The seismic data along the transect 1-EU points out a presence of a tectonic plate in northern and central parts in the low crust of profile. It is possible to compare confidently to the crust plate which is formed by the rocks of the West-Karelian granite-greenstone complex. The given statement will be coordinated with results of geoelectric research along Teriberka-Kovdor-Suoyarvi-Vyborg profile, where it is found out a conductive layer at the depth 40 – 60 km in the north and 90 – 160 in the center of the profile. Longitudinal conductivity reaches several hundreds Sm. Such correlation between depth deposition and longitudinal conductivity is typically for S – effect.

- The great interest is represented with zones of a joint such megablocks as Karelian and Belomorian. Seismic data along the profile 4B allows allocating an inclined plate which separates Belomorian province from Karelian Craton. It includes a series structurally - homogeneous domains. Data of SVEKA profile also find out more than 50 km zone of a joint of the plates, showing the different periods of tectonic activity which has led to occurrence of extensive area of the lowered resistance up to depth more than 50 km. Most likely anomaly carries 3D character besides it is not shown in any way in cross-section polarization of a field that speaks about more complex, scaly structure when the conductive body is broken by non - conductive objects into small objects.

- Seismic profile the Zelenaya Roshcha – Kurkieki – Lahdenpohja – Sortavala crosses key structure of southern slope of the Baltic Shield - the Ladoga anomaly. The seismology data specifies a presence of Priozersk and Ruskealsk junction which is falling towards to each other under corners 60 – 40 degree. It is having the obvious tendency to a joint in the top mantle at the depths 100 - 120 km. According to the geoelectric research the North-Ladoga block is shown in the form of the inclined prism shifted to the north with the increased conductivity. Except for that the geoelectric and seismic data along Northern part of Ladoga Lake unequivocally enough allocate geoblocks of the third orders and interblocks junctions.
Despite of the many research at the Fennockandian Shield as geological as geophysical, there is lots of questions which is not answered yet. This brief review allows understand which regions and questions require more careful attention. The question of astenosphere under the Fennoskandian Shield is still opened. There are too many unexplored opportunities for an explanation of the received distribution of resistance in mantle at the depth of 200-350 km. An area of a joint of two plates, Svekofennian and Karelian where is the complex zone of increased electro conductivity, provokes interest. As well as zone of a joint Karelian and Belomorian megablocks represents the big interest from the point of view of studying tectonic development of the Baltic Shield. The structure of this area causes many discussions to this day. Results of seismonological research allow defining more precisely geometrical position of layers and inclusions, and the geoelectric data give distribution of conductivity. For the preliminary analysis the area of joint Belomorian and Karelian megablocks has been chosen. With using of BEAR and the St.Petersburg State University data have been constructed pseudo sections of a phase and the module of effective impedance, and also skew.

References