BEAR

Baltic Electromagnetic Array Research

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and the BEAR Working Group

Background and aims

At the time, this Newsletter is being prepared, some 15 researchers from eight countries are in the field to run the BEAR project, a part of EUROPROBE's SVEKALAPKO project, realising an ultra-deep electromagnetic (EM) sounding. The experiment, which uses a shield wide magnetotelluric (MT) and magnetometer array, is designed to determine the electrical conductivity of the upper mantle beneath the ancient Fennoscandian (Baltic) Shield (FS).

The absence of the sedimentary cover makes the FS an extremely favourable place to probe upper mantle electrical properties because well-conducting sediments screen and distort deep EM images to such an extent that resolution becomes very poor. The existing knowledge on the upper crustal conductivity allows avoiding the influence of conductive regions within traditional deep sounding schemes. At the same time, the use of extensive BEAR array observations combined with 3D interpretation tools gives new possibilities to treat severe crustal heterogeneities as secondary field sources providing additional signal from deep structures.

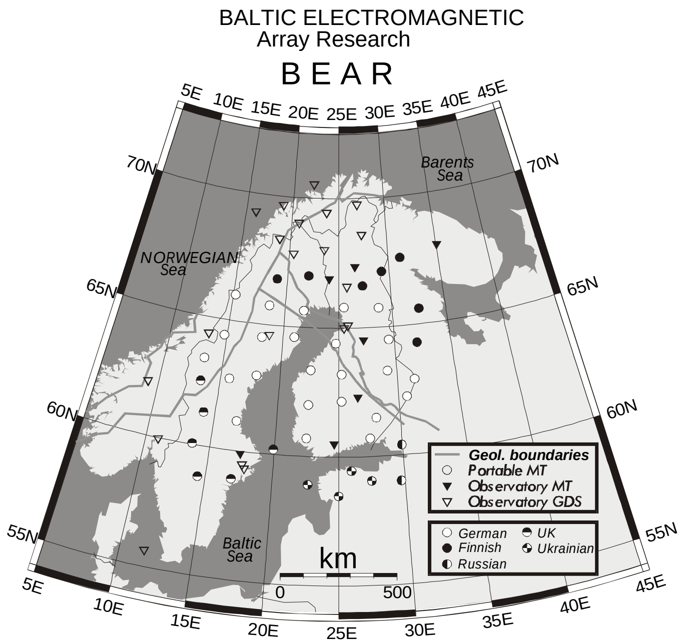
In order to deal with the fundamental questions of the lithosphere-asthenosphere boundary the project is aimed at answering questions as

- What are the lateral and vertical variations in the electrical conductivity of the lithosphere?
- Is the lower lithosphere electrically isotropic or anisotropic?
- How deep does the anisotropic region extend, and are there any lateral variations in anisotropy?
- Is there an electrically well conducting asthenospheric layer beneath the Fennoscandian Shield and what is its geometry and conductance (depth integrated conductivity)? How shallow is it in peripheral regions and how thick in the centre?
- What is the conductivity of the upper mantle beneath the asthenosphere?

The results from BEAR research will provide important information on the nature of the mantle lithosphere and complement the seismic lithosphere-asthenosphere models obtained through SVEKALAPKO deep seismic (e.g. tomography) research (see following paper). BEAR will provide independent models of the geometry and properties of the lithosphere-asthenosphere system. Together with SVEKALAPKO thermal studies it will constrain the thermal state of the lithosphere and give information on the physical state of the sub-asthenospheric mantle beneath the stable craton. In this way it will contribute to our understanding on the formation and dynamics of the continental lithosphere in (plate) tectonic processes.

Methods

The BEAR experiment is unique in the sense that, for the first time, a large array of MT stations will be used which enables modelling of the data taking into account the non-planar nature of the source field at the long periods (1000 - 200000 s) required to reach a depth of 500 km. The simultaneous operation of the array, consisting of 50 portable MT instruments and 20 permanent magnetic stations (BEAR array; Fig 1), will allow for a more complete physical description of the systems of electric currents in the ionosphere and in the solid Earth. Therefore, it enables more realistic modelling of the electrical properties of the upper mantle. This knowledge will be largely unbi-



ased by source field effects in contrast to previous attempts in Fennoscandia and elsewhere in the world.

From a practical point of view, the project is divided into two major parts: The BEAR.DAT, scheduled for June-July 1998, acquires a 1.5 months long magnetic and electric time series simultaneously from the 50 magnetotelluric sites. In addition, simultaneous magnetic data from 20 magnetic observatories and permanent magnetic stations (primarily from the IMAGE magnetometer network) can be added to the BEAR time series database to be used by various BEAR research groups in the BEAR.PMI stage (BEAR Processing, Modelling and Interpretation).

The main objective of BEAR.PMI is to apply the best existing techniques and develop new methods for data interpretation, taking into account the influence of the non-uniform auroral source of the electromagnetic field variations and the influence of crustal conductors. Particular objectives are:

- To process and analyse data obtained from 1.5 month long simultaneous recordings on the array of 50 magnetotelluric and 20 magnetometer sites covering an area of 1000 km by 1400 km.
- To detect ionospheric currents and to estimate and reduce their distorting source effects in the electromagnetic data of the BEAR array.
- To create a crustal conductivity model of the BEAR array area by generalising a priori models and inverting the BEAR data in the short-period range of 10 to 1000 s, and to use this model to reduce the distorting effects of crustal conductivity heterogeneities in deep conductivity models.
- To construct conductivity models for the deep lithosphere, asthenosphere and upper mantle beneath the asthenosphere using high resolution 1D, 2D and 3D inversion schemes in a long-period range of 1000-200000 s and to study the resolution limits of these models.
- To compare and integrate final geoelectric models with other geophysical and geological models and integrate them in a geodynamic reconstruction of the FS in order to determine the thickness and age of the lithosphere, the disposition of major lithospheric structures, and the evolution of its current dynamics.

The objectives of the processing and data analysis phase (P) is to create a BEAR times series database from the array observations and to create reliable estimates of EM data (transfer functions). Methods include standard and new ones designed by the BEAR research teams. The key development is planned in the following fields: advanced robust and multi-station estimation of transfer functions, detailed “Solar-quite” (Sq) current system analysis, temporal monitoring of transfer functions and source structure, separation of EM fields into external and internal parts, advanced Fourier analysis on irregular (in time and space) grids.

The objectives of the modelling and inversion phase (M) is to create a sequence of geoelectric models from reference 1D sections to local 2D and 3D structures, and finally to a volume-3D conductivity image of the area based on existing a priori information and inversion solutions for BEAR data. Methods include non-uniform source 1D inversion solutions, numerical 2D and 3D modelling techniques, recently developed advanced 3D finite difference modelling tools, EM scale analogy installation, time domain thin sheet simulations, forward complex image methods and new non-linear robust optimisation schemes for MT inversion within continuous and block conductivity structures.

The objectives of the interpretation and integration phase (I) are to compile the crustal and upper mantle models of electrical conductivity and to provide verification and correlation of these models with other geophysical and petrophysical models through data and model correlation. Data interpretation will allow the determination of the nature of conductivity (fluids, graphite, partial melt) within normal sections and anomalous structures, the establishment of physical relationships (e.g. conductivity vs. temperature). The integration will help to distinguish between different models considered to describe the deep tectonic FS evolution.

Schedule

Data acquisition including simultaneous long period magnetotelluric soundings at 50 sites took place between 15 June - 25 July 1998. Creation of the BEAR time series database, including BEAR magnetotelluric data and magnetic data from observatories and other permanent magnetic stations and distribution of the data to participating teams is scheduled for August - October 1998. Processing & data analysis, modelling & inversion and integration and interpretation is scheduled for 1999-2001.

Participating institutes

The BEAR Working Group consists of research teams from the following countries: Finland (University of Oulu, Finnish Meteorological Institute and Geological Survey of Finland), Sweden (University of Uppsala and Geological Survey of Sweden), Germany (University of Goettingen, GeoForschungsZentrum-Potsdam, Free University of Berlin and University of Frankfurt), Russia (Geological Institute of the Kola Science Centre, St. Petersburg University, St. Petersburg branch of the Institute of Terrestrial Magnetism, United Institute of the Physics of the Earth in Troitsk and P.P. Shirshov Institute of Oceanology in Moscow), Ukraine (National Academy of Sciences of Ukraine in Kiev and Lviv Centre of the Institute of Space Research), United Kingdom (University of Edinburgh) and Estonia (University of Tartu).