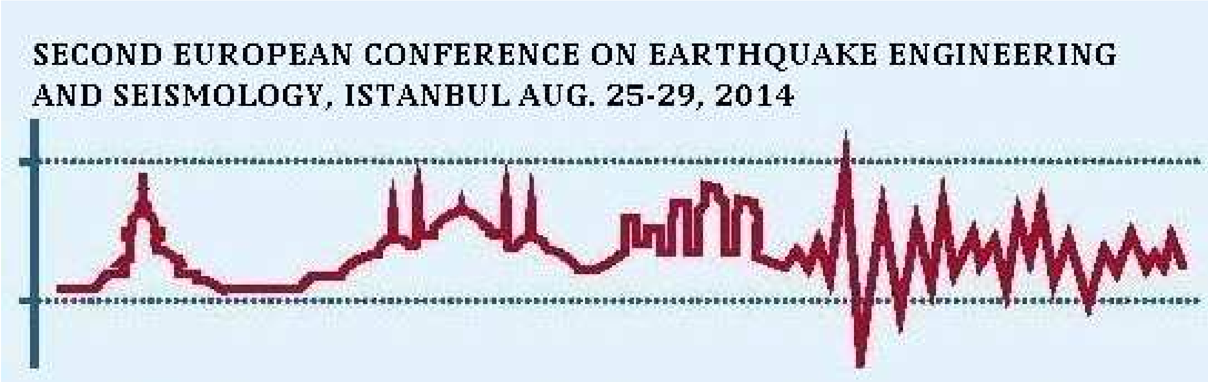

THE SEISMIC CONFIGURATOR SOFTWARE FOR SEISMIC LOCATION MODELLING AND ITS APPLICATION TO DEVELOPMENT OF 3D VELOCITY MODEL OF KHIBINY AND LOVOZERO MOUNTAIN MASSIFS, NORTH RUSSIA

Vladimir ASMING[1] and Yuri VINOGRADOV[2]

Khibiny and Lovozero alkaline mountain massifs are situated in the centre of Kola Peninsula, North-West Russia (Fig.1). They are two parts of a single intrusion having similar ages and nearly the same rock types. The exploitation of Khibiny massif is carried out by “Apatit” joint-stock company. Currently a set of underground mines and quarries excavate about 27 million ton of apatite ore per year. Large underground and open-pit blasts which summary explosive yields can amount to several hundred ton are carried out here almost every week. Typically a large explosion here is followed by hundreds of rock bursts but the process relaxes during first several days. But rock bursts or man-made earthquakes do exist which are not connected directly with the explosions.

Within the Lovozero massif rare metal deposits are mined by two underground mines: Umbozero (1984-2004) and Karnasurt (since 1951). But no large explosions were conducted there. Since 1992 Kola Branch of Geophysical Survey of RAS (KB GS RAS) routinely recorded some tens of seismic events from Lovozero massif per year. But bad source-station geometry makes it impossible to locate the events exactly and associate with the mining areas. The rock-tectonic burst on August 17, 1999 with M=4 was one of the strongest events of this kind.

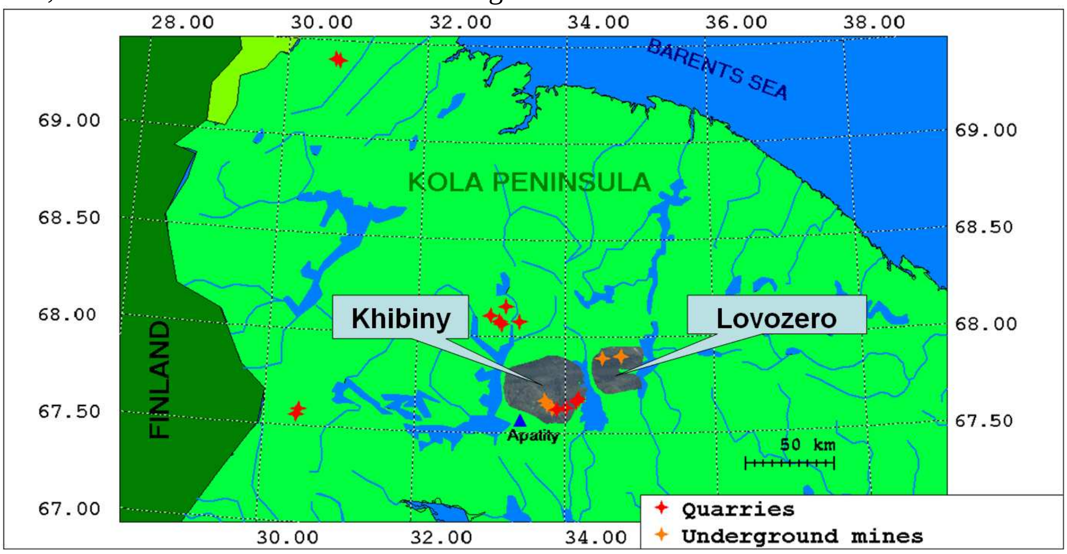

Figure 1. Map showing location of the Khibiny and Lovozero mountain massifs and mines in Kola peninsula.

KB GS RAS carries out seismic monitoring by digital stations since 1992. Since 1984 a seismic network of "Apatit" joint-stock company is in operation. It surrounds mining areas of Kirovsk and

[1] PhD, Kola Branch of Geophysical Survey of RAS, Russia, Apatity, asmingve@mail.ru
[2] PhD, Kola Branch of Geophysical Survey of RAS, Russia, Apatity, uavin@mail.ru

Rasvumchorr mines in the Khibiny Massif and enables to locate seismic events inside the areas with accuracy of dozen meters (Fig.2). In 2010 the KB GS RAS and "Apatit" networks were united i.e. joint data processing and event location system was developed.

The system can detect and locate seismic events everywhere in the two massifs but accuracy of the location is good only for Kirovsk and Rasvumchorr areas. The location error can amount to one kilometer for more distant Khibiny mines and several kilometers for Lovozero massif.

The location uncertainty is caused by lack of seismic stations around the massifs as well as that the massifs are objects of very complicated 3D structures so usage of 1D velocity model for seismic location leads to errors.

Our study, performed in 2013, was aimed at the development of software that allows to locate seismic events in 3D medium and to estimate the location errors caused by the inaccuracy of used velocity model and geometric configuration of seismic stations. This software has been created and called “The Seismic Configurator (SC)”. It also enables to estimate apparent velocities and compute source specific station corrections (SSSCs).

At the end of 2013 a temporary network of stations was installed in Khibiny and near the massif. Several industrial explosions have been recorded (Fig.2). The information obtained was not enough to make a full seismic tomography but enabled us to fit reliable 3D model based on known geological structure of the massifs. The fitting was done by the SC software.

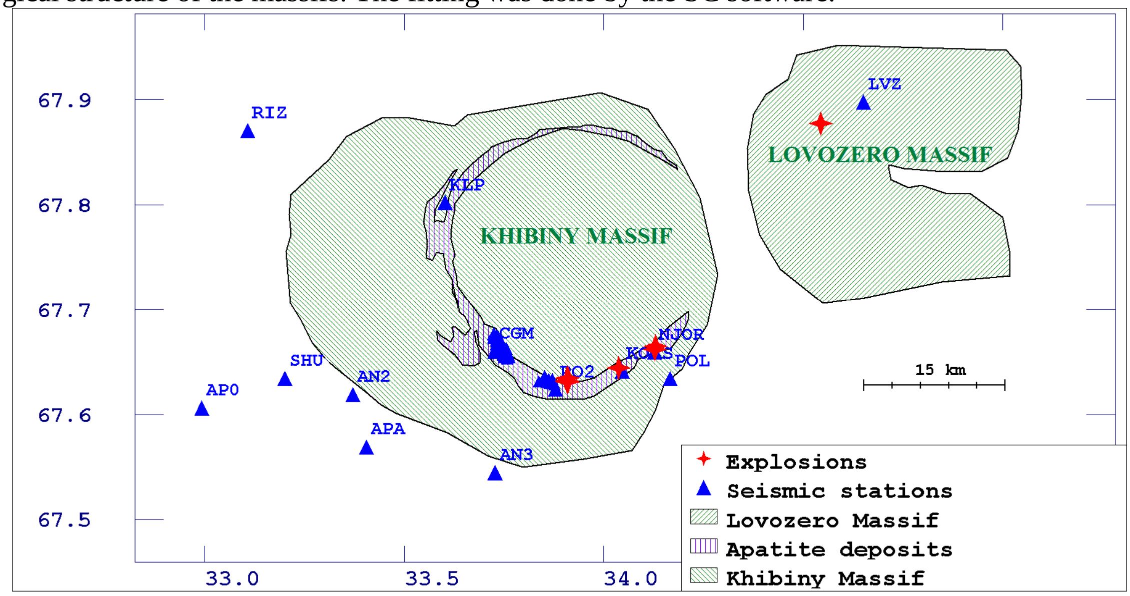

Figure 2. Map showing seismic network and calibration explosions used for the 3D model fitting.

The Seicmic Configurator enables to specify 3D velocity model of a seismic medium: horizontally-layered medium with inserted bodies of arbitrary shapes with different seismic velocities which can be equal to zero (voids). For modeling velocity model influence on location error it is possible to specify two different velocity models: forward one (as if 'true' one) and backward one (the model is used for location). For a given point the program can compute arrivals using the forward model and make its location using the backward one. The difference between the source point and the location result can give an idea about location errors caused by uncertainties in velocity models.

Also the program enables to locate events by known onsets, estimate location errors and trace rays through 3D medium obtaining SSSCs.

The principle of the program's work is as follows: a medium is replaced by a random graph containing a large number of vertices and edges. Travel of a seismic wave between two points in the medium is simulated by the shortest path between these two points projected into the graph. The well-known quick wave algorithm for finding shortest paths in a graph is used.

Location is made by inversion method. Let we have arrivals of a wave to N seismic stations T_i. If TT_i is a travel time from the source to i-th station then for all stations T_i-TT_i must be the same and equal to origin time. For our graph we can say that for a vertice which is the closest to the location result the values TT_i-T_i must be about the same, i.e., their dispersion must be minimal. Thus, for event location the wave algorithm is applied N times, for each station. Every station is taken as a source point and inverted arrival time $-T_i$ is taken as a start time. Dispersions of arrival times are computed in each graph vertice. The point with minimal dispersion is taken as the location result.

The program enables to set up a point and trace rays from it to all seismic stations included into modeling. For each station an apparent velocity is computed. This mode is convenient for fitting travel time models (Fig.3). For explosions registered by the temporal network we computed experimental apparent velocities and compared them with the velocities obtained by the program for several 3D models.

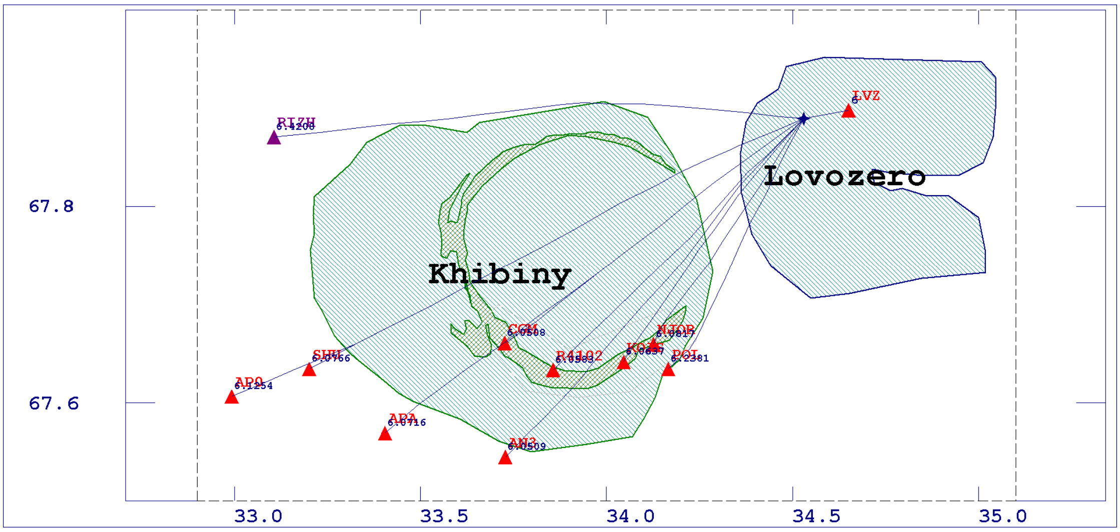

Figure 3. Map illustrating the fitting process. For a given point (blue star) rays were traced to all stations and apparent velocities were computed for comparison with experimental ones.

As a result a simple reasonable 3D model was worked out containing of 3 kinds of medium with different velocities: surrounded medium (V_p=6.5), medium of the massifs (V_p=6.0) and apatite deposites (V_p=5.7). This model appeared to be in a good agreement with the data obtained.