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6.5 Threshold Monitoring of the Mines in the Kola Region

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Introduction

We have evaluated the utility of a regional threshold monitoring scheme for the mining areas on the Kola Peninsula, Russia. Fig. 6.5.1 shows the location of the major mines in this area, together with the location of the two seismic arrays ARC and APA. Both the primary IMS array ARC and the non-IMS station APA record high-SNR observations of all important regional phases at a range up to at least 500 km, which is the maximum distance range being considered in this case study. Furthermore, for the more distant recordings, these phases are well-separated in time.

Fig. 6.5.1. Map of the Kola Peninsula with the main mining areas. Also shown are the locations of the ARCES and Apatity arrays.

We have access to ground truth information, and explosion and rockburst observations for mines of the Kola peninsula. Such information is regularly collected from the mine operators by Kola Regional Seismological Center (KRSC), and will serve as a reference set for our studies. The mining areas comprise Khibiny, Olenegorsk, Kovdor and Zapolyarnyi.

In particular, the mines of the Khibiny Massif provide a natural laboratory for examining and contrasting the signals generated by different types of mining explosions and rockbursts. Of the five mines in the Massif, three have both underground operations and surface pits. Shots underground range in size from very small (~2 tons) with only a few delays and durations on the order of a few hundred milliseconds, to very large (400 tons) with many delays and durations approaching a half second (Ringdal et al., 1996). Shots above ground range from 0.5 tons to 400 tons with a wide range of delays and durations. Induced seismicity is frequent and triggered rockbursts accompany a significant fraction of the underground explosions (Kremenetskaya and Trjapitsin, 1995).

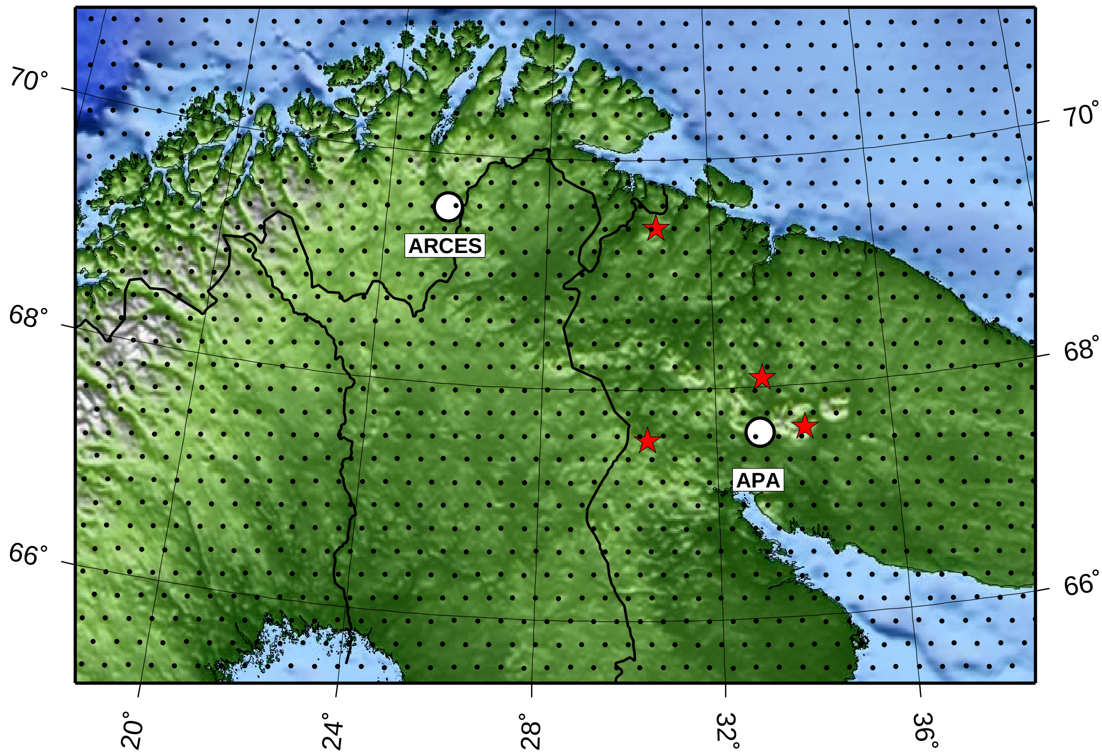

Fig. 6.5.2. Grid points used for regional threshold monitoring of the Kola Peninsula. The grid spacing is 0.2 degrees.

The grid system used for this study is shown in Fig. 6.5.2, and is based on a dense grid spacing of 0.2 degrees. In computing the threshold traces, magnitudes based on the attenuation of Pg and Lg amplitudes were used for grid point to station distances within 2 degrees, while magnitudes for distances above 2 degrees are based on Pn and Sn attenuation (see Table 6.5.1). This is in accordance with the distances at which these phases are observable in the actual region. The frequency band used in the study was 3-6 Hz for all phases, except for Lg for which we used 2-4 Hz. Software to extract peak and mean threshold magnitudes for each grid point within a given time segment was used to analyze the TM results.

Table 6.5.1. Parameters used for Regional Threshold Monitoring of the Kola mining areas

Travel time model	'barey' - Schweitzer and Kennett, 2002
Attenuation model	Hicks et al., 2002
Grid Spacing	0.2 degrees
Pg distance range	0 - 2 degrees
Pn distance range	2 - 20 degrees
Lg distance range	0 - 2 degrees
Sn distance range	2 - 20 degrees
Pg frequency band	3 - 6 Hz
Pn frequency band	3 - 6 Hz
Lg frequency band	2 - 4 Hz
Sn frequency band	3 - 6 Hz

Processing example 1

Fig. 6.5.3 shows mean threshold magnitudes for each grid point for a 1-hour time segment starting at 2002-102:06.30. Even if this time interval is not without seismic events, this figure is representative of the combined TM capabilities of ARC and APA during typical noise conditions. In this and other similar plots, the individual TM grid points have been resampled onto a continuous grid using a minimum curvature surface fitting algorithm. As seen from the figure, the monitoring capability is between 0.5 and 1.0 m_b units for the mining sites (marked as black squares).

Fig. 6.5.4 shows the threshold time traces for a two hour interval surrounding the interval described previously. We have plotted the threshold trace of the grid point closest to the actual mine for each of the four major mining sites. There is one large mining explosion (mine 5 of the Khibiny group) during this time interval, and this explosion causes a peak for each beam. Otherwise, the typical background threshold is between 0.5 and 1.0 m_b units, consistent with Fig. 6.5.3.

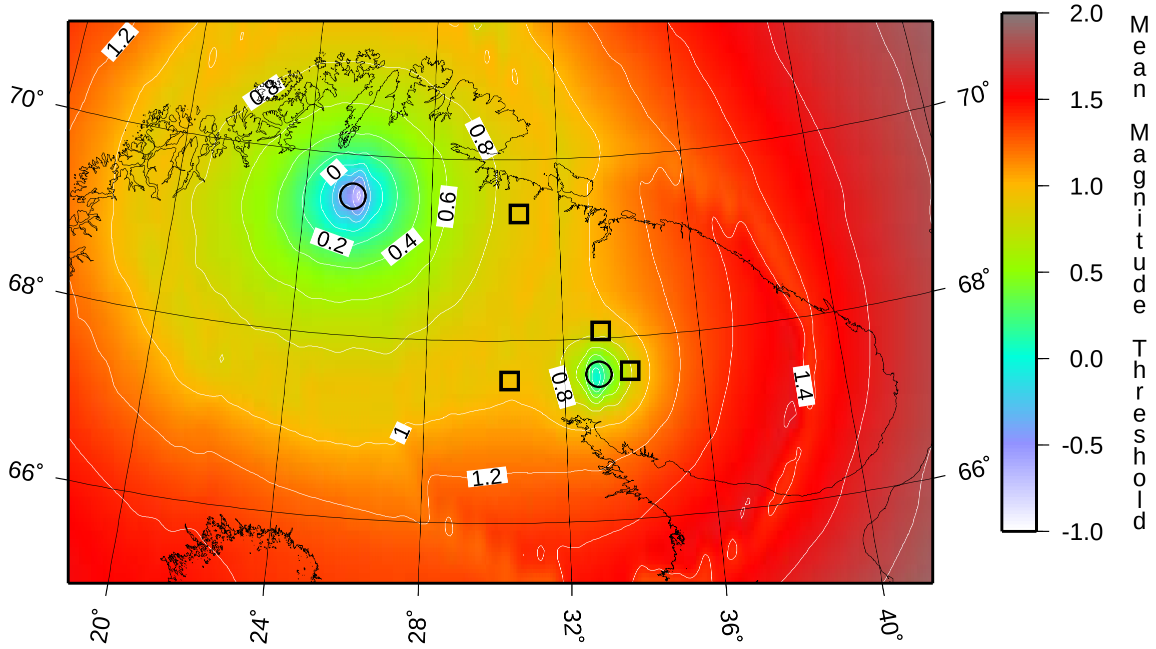

Fig. 6.5.3. Mean network magnitude thresholds for a 1-hour time interval starting 2002-102:06.30, using the ARCES and Apatity arrays (black circles). The locations of the mining areas Khibiny, Olenegorsk, Kovdor and Zapoljarny (see Fig. 6.5.1) are shown by black squares.

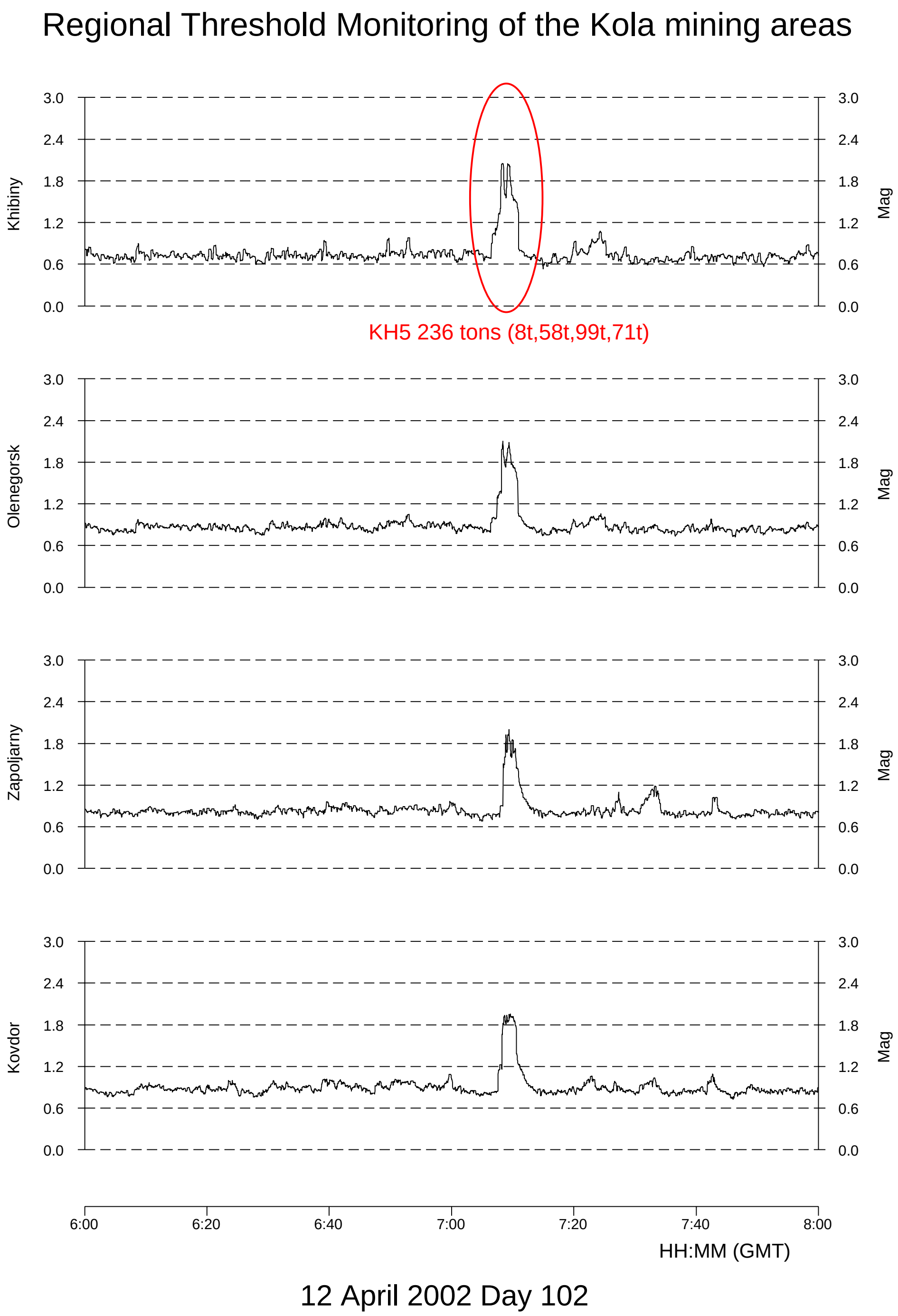

Fig. 6.5.4. Network magnitude thresholds for the grid points closest to the four mining areas shown in Fig. 6.5.1, for the 2-hour time interval starting 2002-102:06.00. The threshold peak corresponds to an explosion in the open mine Koashva (KH5) located in the Khibiny area. The total yield of the ripple-fired explosion was reported to 236 tons, and consisted of 4 smaller explosions with yields of 8, 58, 99 and 71 tons, respectively.

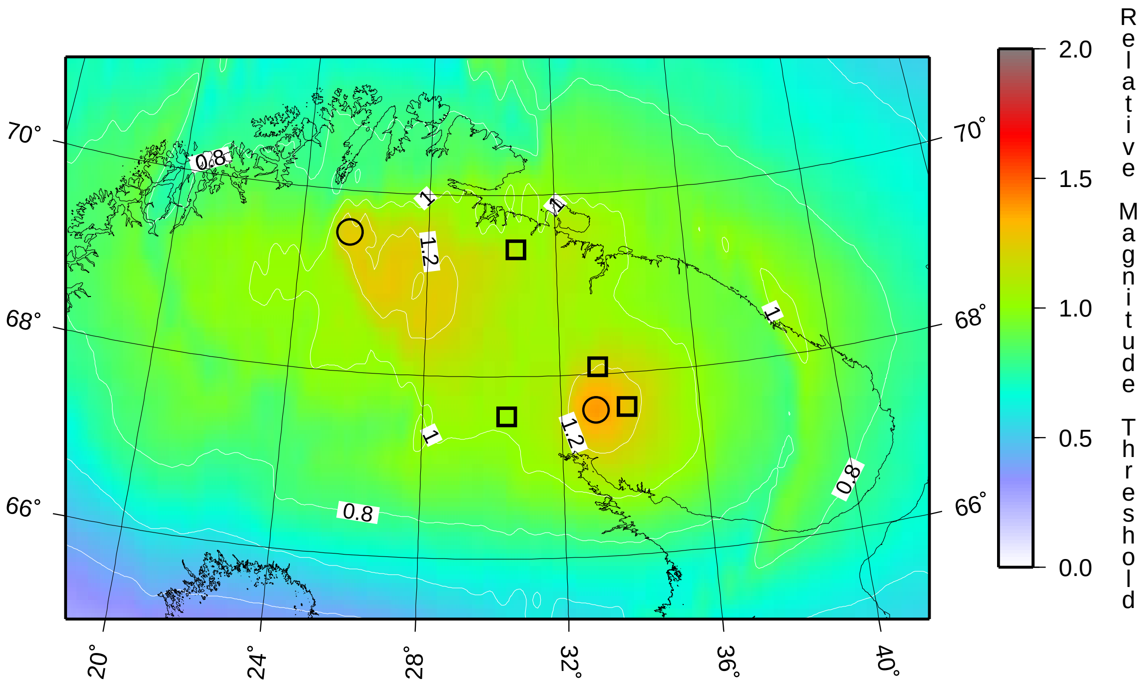

Fig. 6.5.5. Peak network magnitude thresholds with mean subtracted for the same 1-hour time interval as shown in Fig. 6.5.3.

Fig. 6.5.5 shows the peak network magnitude thresholds with mean subtracted for the same 1-hour time interval as shown in Fig. 6.5.**3**. This essentially shows the height of the highest peak above the background level within the time interval for each grid point. Note that the event in the Khibiny mine KH5 (see Fig. 6.5.4) creates a significant threshold peak in almost the entire region.

Processing example 2

Figs. 6.5.6- 6.5.8 show a second example of threshold plots, similar to the plots shown in Figs. 6.5.3-6.5.5. In this second case, the time interval processed is a two-hour interval starting at 2002-102:10.00, i.e. some hours later during the same day. The mean magnitude thresholds (Fig. 6.5.6) are almost identical to the mean thresholds for the first interval (Fig. 6.5.3), which shows that the background noise level is stable. The individual time traces for each of the four mining sites (Fig. 6.5.7) show quite significant activity during these two hours, with confirmed mining explosions both at Khibiny, Olenegorsk and Zapolyarnyi. As expected, there is a corresponding threshold increase on all the traces for each mine explosion, but in each case the increase in threshold level is greatest for the actual site of the explosion. There is also an unknown event (perhaps a small earthquake) that is located outside of the mining areas. The peak network threshold magnitudes with mean subtracted (Fig. 6.5.8) are quite similar to those in Fig. 6.5.5.

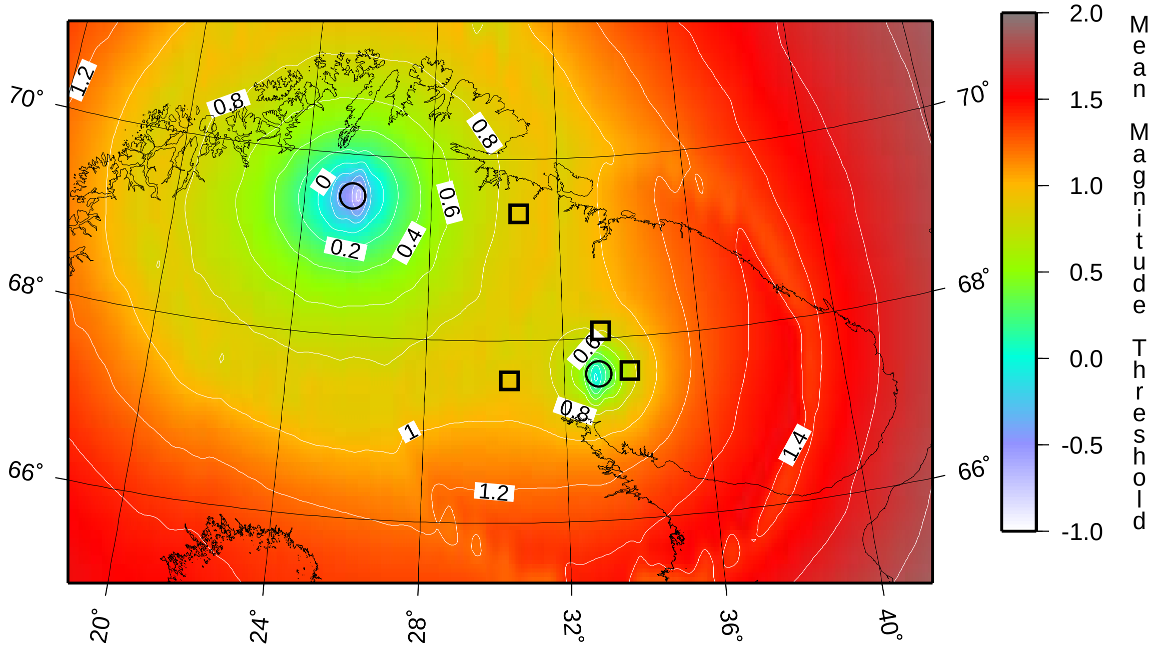

Fig. 6.5.6. Mean network magnitude thresholds for a 2-hour time interval starting 2002-102:10:00.

Processing a 24 hour interval

Fig. 6.5.9 shows network magnitude thresholds for the grid points closest to the four mining areas Khibiny, Olenegorsk, Zapoljarny and Kovdor for the entire day 12 April 2002. This is the same day from which the two previous time segments were extracted. During this day 10 events are found which are located in three of these mining areas, of which 6 are confirmed by KRSC. The corresponding mines and threshold peaks are indicated by red arrows.

Conclusions

Using data from the ARCES and Apatity arrays, we have implemented a regional threshold monitoring scheme for northern Fennoscandia, including the Kola Peninsula. For the most active mining areas in this region (Khibiny, Olenegorsk, Zapoljarny and Kovdor), the magnitude thresholds during "normal" noise conditions vary between 0.7 and 1.0 magnitude units. During the studied time interval (12 April 2002), 10 out of 18 peaks exceeding threshold magnitude 1.2 at any of the mining areas were caused by events in the actual mining areas. However, the spatial resolution of the threshold magnitudes when using the ARCES and Apatity arrays is quite low, such that the mining events also created significant threshold peaks for the other mining areas.

This implies that for a regional threshold monitoring scheme for the Kola Peninsula it will be sufficient to deploy a set of targets for the most active mining areas. When a threshold peak is found at any of these targets, the peaks have to be associated to seismic events by correlating the threshold plots to seismic detection lists or bulletins.

T. Kværna

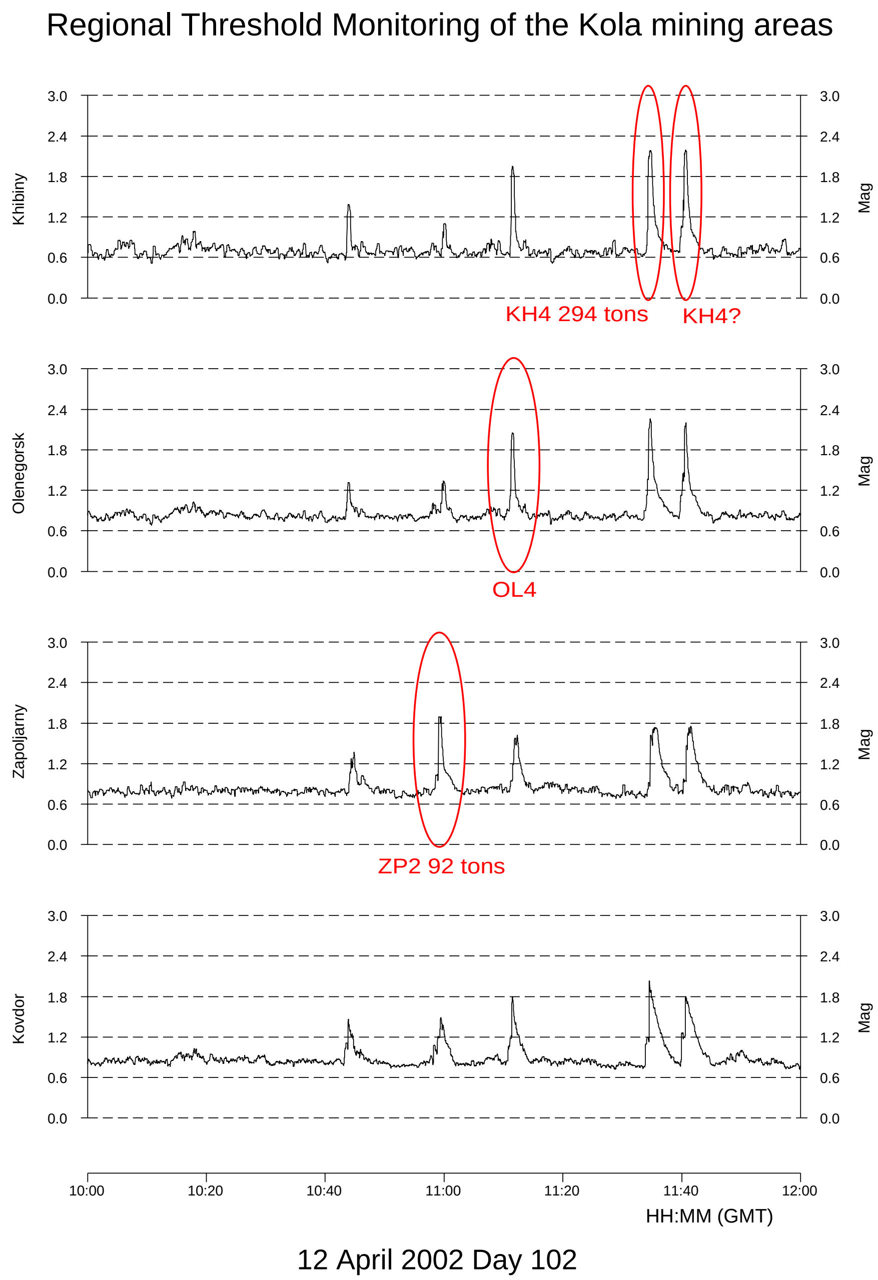

Fig. 6.5.7. Network magnitude thresholds for the grid points closest to the four mining areas shown in Fig. 6.5.1, for the 2-hour time interval starting 2002-102:10.00. Five significant threshold peaks are seen during this time interval, of which three are mining explosions reported by the KRSC. The last peak at 11:40 is believed to be an additional explosion at the Central Khibiny mine KH4. The first peak at 10:44 is caused by an event located approximately 70 km south-west of the Apatity array.

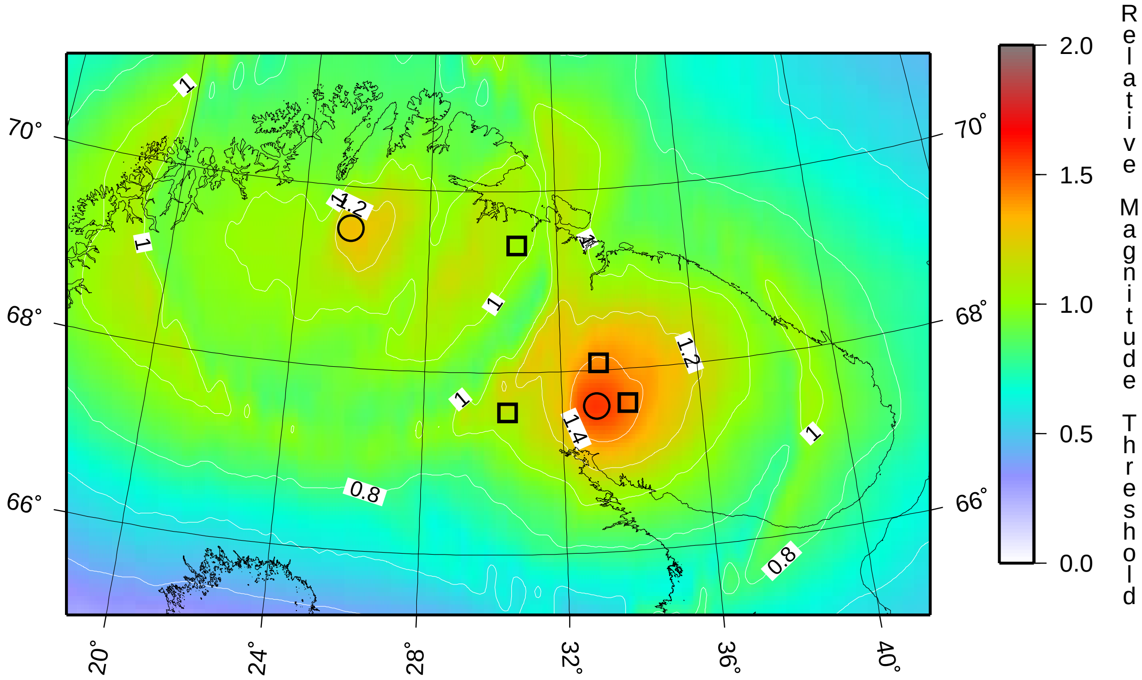

Fig. 6.5.8. Peak network magnitude thresholds with mean subtracted for the same 2-hour time interval as shown in Fig. 6.5.6. This essentially shows the height of the highest peak above the background level within the time interval for each grid point. The five events occurring in the region during this time interval create significant threshold peaks in the entire region.

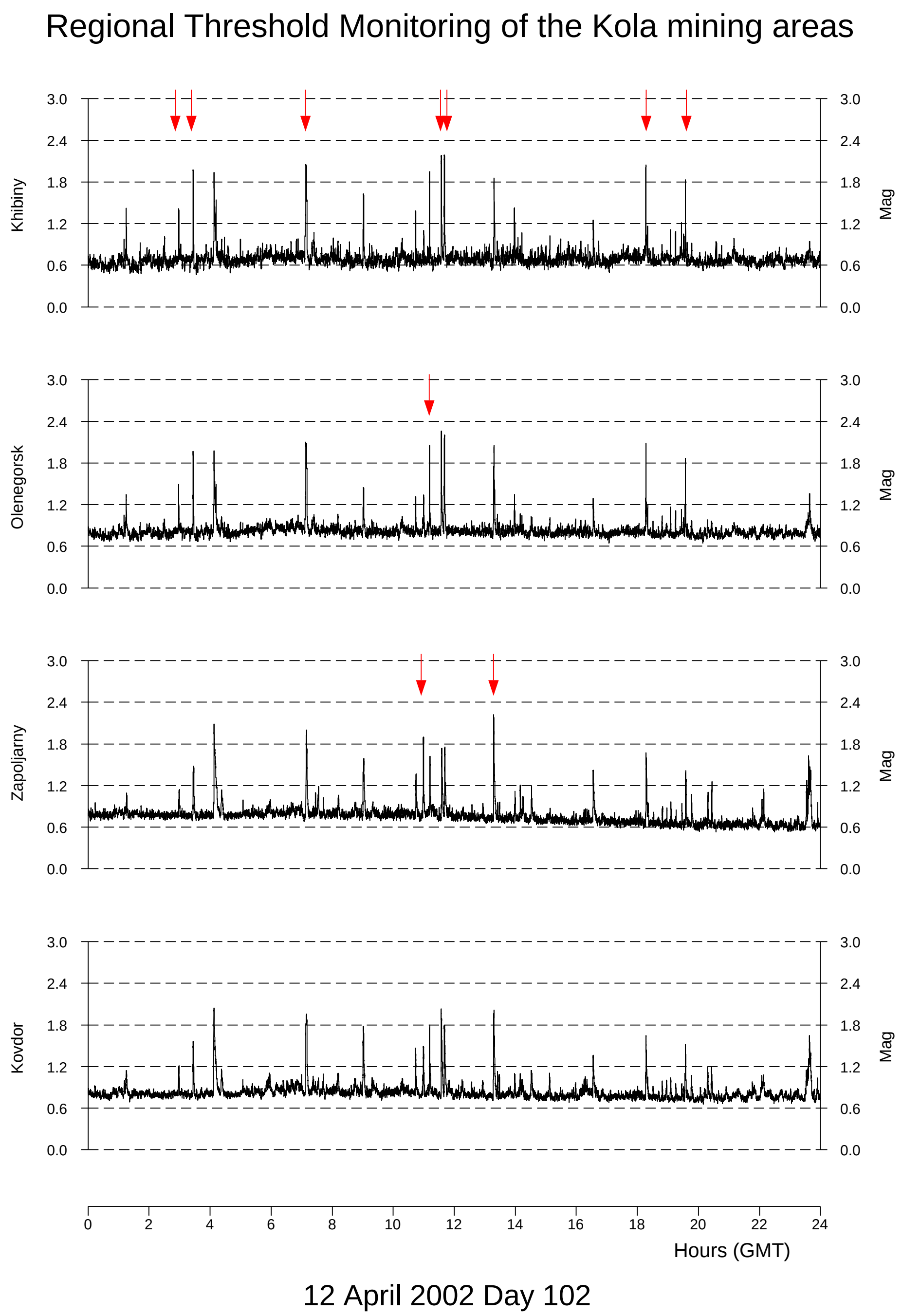

Fig. 6.5.9. Network magnitude thresholds for the grid points closest to the four mining areas Khibiny, Olenegorsk, Zapoljarny and Kovdor for 12 April 2002. During this day 10 events are found which are located in three of these mining areas, of which 6 are confirmed by KRSC. The corresponding mines and threshold peaks are indicated by red arrows.

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