Testing different discrimination methods between micro earthquakes and quarry blasts – a case study in Hungary

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1. Introduction: Due to the development of seismological network, increasing number of events have been detected in the last years in Hungary. However about 50% of these shocks were quarry blasts. Therefore decontamination of catalogue for revealing the reliable natural seismicity has become an important task. We have studied the events occurring in the surroundings of Mecsek Hills. The goal of our research was to find the best method to separate earthquakes and quarry blasts, and revising the classification of catalogues.

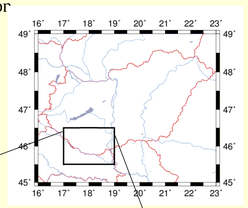
We have analyzed the waveforms of three stations: KOVH, MORH and PKSM for EQs and EXs occurred in the years between 2015 and 2016. There are 4 major quarries in the investigated area, and their explosions were detected regularly.

In the first step we have studied the diurnal and weekly distributions of the events. Because of different focal mechanisms the waveforms and amplitudes of arriving phases of earthquakes and quarry blasts are different, we studied different methods.

Discriminations using different methods:

- Amplitude ratios of different phases (did not give good results).
- The waveform similarities have been analyzed using cross-correlation matrix and dendrograms. The earthquakes and the blasts of different quarries have been arranged into different clusters.
- We have computed spectra and because the blasts were carried out by delay-fired technology we computed binary spectrograms too. We also have studied the scalloping and steepness of spectra.

FIRST STEP: Initial catalogue: the discrimination was made only by 'first sight' (Fig. 1).
We received the lists of explosions from the considered mining districts:
EQ/EX: 71/75
1. **Bükkösd** I; II quarries
2. **Komló** quarry
3. **Nagyharsány** quarry



EQ / EX
49% / 51%

Seismicity map of the investigated area between the years 2015 and 2016

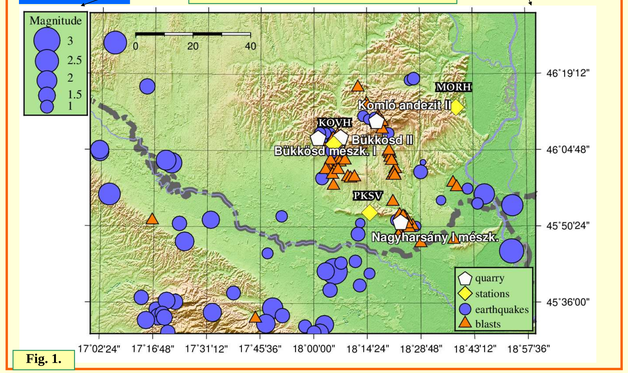


Fig. 1.

2. Waveform similarity: The waveforms of 75 earthquakes and 71 explosions were analyzed for all three channels of stations. The elements of clusters were very similar on the three channels (cross correlation matrix: Fig.2.). One event was connected to a cluster only if at least two channels of the same station contained it. The waveform belonging to a cluster/quarry was stabile for over more than 19 months. Waveforms of EXs (cxy>0.55) Fig.3.: KOMLÓ; Fig.4.: BÜKKÖSD; Fig.5.: NAGYH.

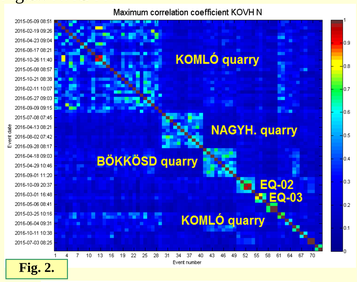


Fig. 2.

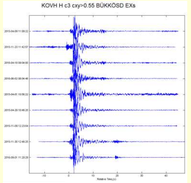


Fig. 4.

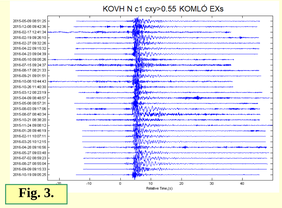


Fig. 3.

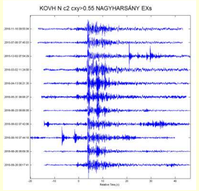


Fig. 5.

SECOND STEP: The waveform analysis arranged the events into different clusters, and revealed more misclassifications (Fig.6.).

EQ / EX
40% / 60%

Number of seismic events (KOVH): 146
Number of seismograms appropriate for corr. analysis: 130
Number of similar events: 52 (40%)

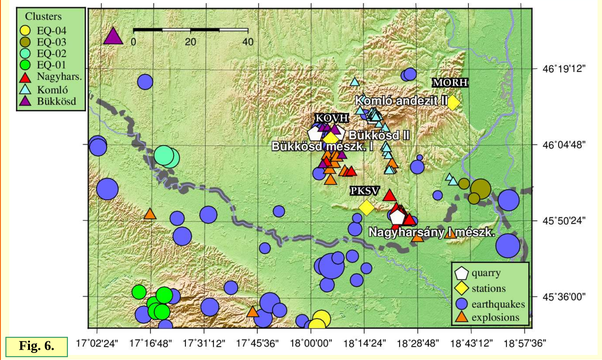


Fig. 6.

3. Spectral analysis: The power spectra of blasts and earthquakes have shown fundamental differences. The earthquakes were richer at high frequencies and the steepness of power spectra proved smaller compared to the spectra of blasts. The delay-fired technology modulates the spectra of blasts (Gitterman et al. 1983). The blasts were carried out by the same delay-fired technology (delay time was 0.25 ms and 0.5 ms), so we have expected increased performance at about 2-4 Hz (f_{max} = 1/delay time; Fig.5-6.).

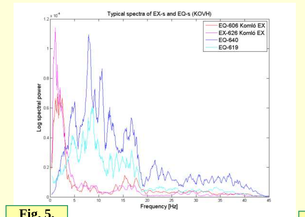


Fig. 5.

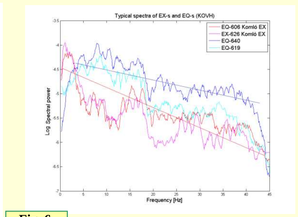


Fig. 6.

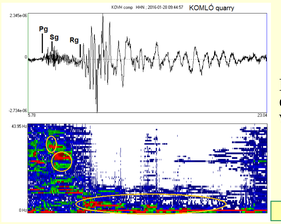


Fig. 7.

Because of shallow focal depths, in most of the case the appearance of explosions had surface wave: Rg (Fig. 7.)

The binary spectra is a useful visualization method to recognize the delay-fired explosions, because it emphasizes the long-duration modulations of spectra. This is made from original spectra by application of filters that replace spectral information with a binary code, that simply reflects local spectral highs and lows. The modulations of ripple-fired technique were present in most of the recordings of the blasts, but their strength and spacing was highly variable (Fig. 8-9.).

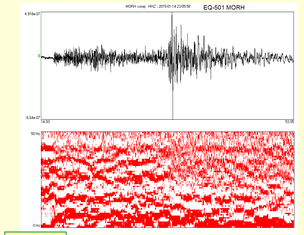


Fig. 8.

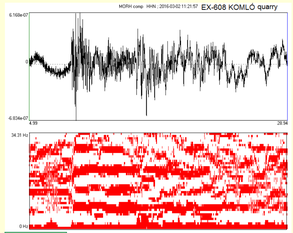


Fig. 9.

The diurnal distributions before and after the waveform and spectral analysis (Fig. 10-11.)

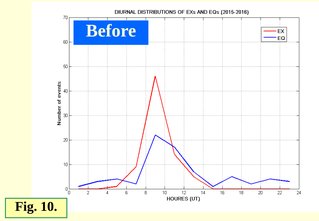


Fig. 10.

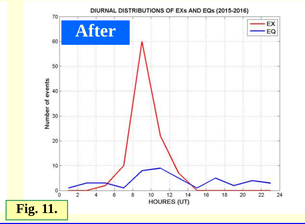


Fig. 11.

THIRD STEP: The revised catalog data; using the spectral properties together with the waveform correlations results.

EQ / EX
29% / 71%

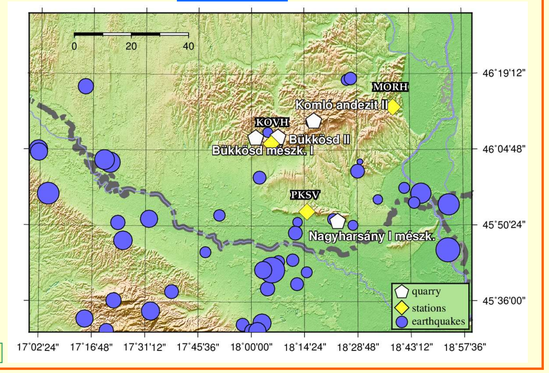


Fig. 3.

Conclusions:

1. The most of explosions were performed at workdays and between 8-12 hours.
2. The magnitude of 64% of registered seismic events were $M_L \leq 1.0$.
3. The P wave arrival showed more compression input in the case of EXs than EQs.
4. The waveform correlation resulted 55% of EXs separated into different cluster(s). The clusters of earthquakes and explosions weren't mixed with each other (in the case of the correlation coefficient cxy>0.55).
5. 26 EQs were proven to be connected to one of the quarries, so we deteriorated the catalogue with misclassified events.
6. Creating waveform database for each quarries, and continuously adding the seismograms of new blasts, a high portion of the explosions might be filtered out. More stations, better results!
7. The discrimination capability of MORH, KOVH and PKSV were different.

Acknowledgemet:
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