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Discrimination of microearthquakes and quarry blasts based on the observations of the PSZI infrasound array and seismic station PSZ in Piszkés-tető, Hungary

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AZ NKFI ALAPBÓL MEGVALÓSULÓ PROGRAM
NEMZETI KUTATÁSI, FEJLESZTÉSI ÉS INNOVÁCIÓ HIVATAL
AZ INNOVÁCIÓ LENDÜLETE

1. Motivation

Contamination of earthquake catalogues with anthropogenic events largely complicates seismotectonic interpretation. It is especially true for relatively low seismicity areas, such as Hungary. In the present study we analyze the characteristics of local earthquakes and blasts around PSZ seismological station. An infrasound array PSZI was deployed in this region in 1 June 2017. Most of the quarry blasts were registered on the infrasound array PSZI. If the infrasound signal that accompanies a quarry blast can be observed at the infrasound array, it provides further evidence that the event was indeed man-made.

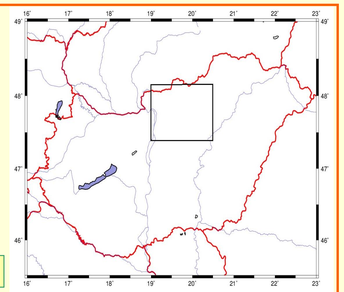
The problem was particularly challenging because the size of the seismic events was usually low and the number of stations detecting them was limited. Therefore discrimination based on hypocentral parameters could not be used because of the large location errors. In the investigated area there are at least 8 different quarries. The blasts were carried out with ripple fired technique. Mine explosions tend to be set off during daytime hours day (6-12 h). The natural seismic activity is significantly increased in 2013. M_L=4.8 earthquake shocked the region of Heves, and an M_L=4.2 occurred at Érsekvadkert and Iliny in 2013 (Gráczer et al. 2012-2018; Tóth et al. 2012-2019. The mainshocks were followed by many aftershocks. Different waveform-based discrimination parameters were tested.

The goal is to find the best single station discrimination methods and parameters!

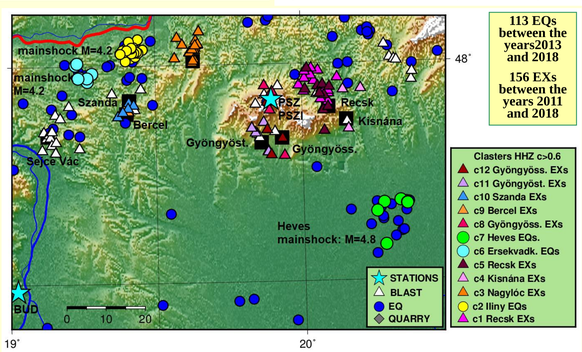
- The waveform similarities have been analyzed using cross-correlation matrix.
- Amplitude ratios of different phases.
- We have computed spectra and studied the spectral ratios and the steepness of spectra.
- Infrasound detections

The discrimination was made by 'first sight' and in several case we received lists of date of explosions from the mining districts

Quarries: 11-64 km from PSZ
- Gyöngyössolymos 10.4 km
- Gyöngyöstarján 11.1 km
- Recsk 16.3 km
- Kisnána 22.5 km
- Nagylóc 24.1 km
- Szanda 40.1 km
- Becel 40.5 km
- Sejce Vác 65 km



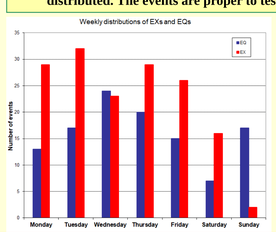
Seismicity map of the investigated area with the results of waveform correlation analysis

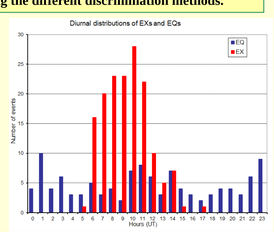


113 EQs between the years2013 and 2018

156 EXs between the years 2011 and 2018

The diurnal and weekly discriminations of earthquakes in the investigated area are evenly distributed. The events are proper to testing the different discrimination methods.



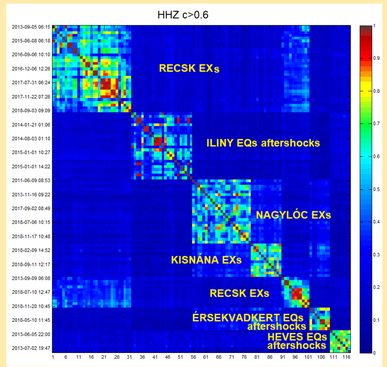


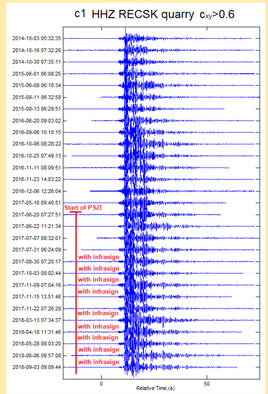
2. Waveform similarity

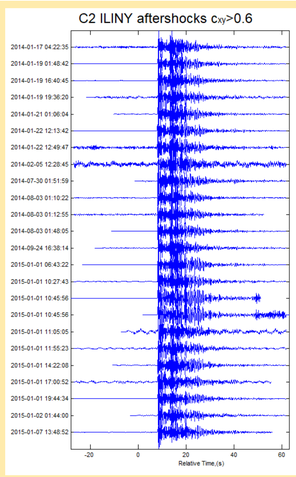
Waveform similarities have been studied by cross-correlation methods. We used the GISMO Matlab toolbox for the analysis (Reyes and West, 2011) and analyzed 80 sec long seismograms filtered between 1-5 Hz. The critical correlation coefficient was chosen to be 0.6. The waveforms of 113 earthquakes and 156 explosions were analyzed for HHZ channel of PSZ stations. The elements of clusters were very similar on the three channels (cross correlation matrix). Above the correlation coefficient 0.6 the seismograms were handled as 'similar' and it was found that 60% of the events were similar to any other. Waveforms of aftershocks were very similar that originated from hypocenters very close to each other.

Conclusions:

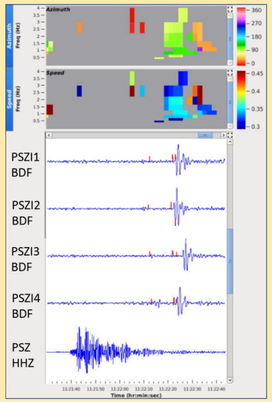
The explosions of different quarries formed different cluster(s). The clusters of earthquakes and explosions were never mixed with each other. The waveform belonging to a cluster/quarry was stabile for over more than 4 years. Within the clusters the included events had different magnitudes; the size of seismic events did not affect the similarity. In the case of clusters consisted of explosions of Bercel and Gyöngyössolymos, appeared two seismic events that previously regarded as earthquakes. These events managed to connect to these quarries, so deteriorated the catalogue with misclassified explosions.







The infrasound detection of quarry blast of RECSK (Bondar et al. 2019)



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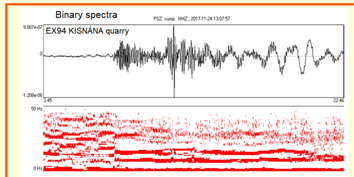
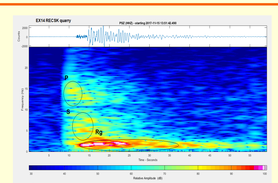
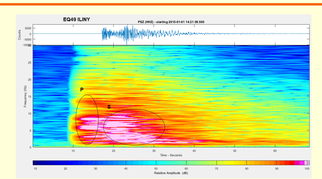
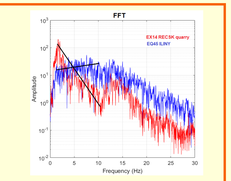




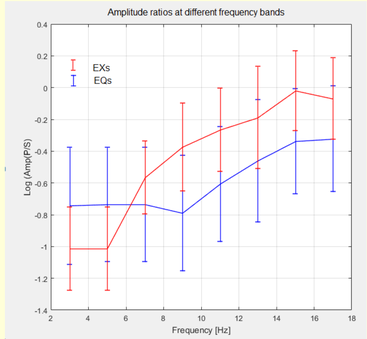




3. The main features of earthquakes and explosions: The power spectra of blasts and earthquakes have shown fundamental differences. The earthquakes were richer at high frequencies and the steepness of power spectra proved smaller compared to the spectra of blasts. The delay-fired technology modulates the spectra of blasts (Gitterman et al. 1983). The blasts were carried out by the same delay-fired technology (delay time was about 0.25 ms). Because of shallow focal depths, in most of cases the appearance of explosions had surface wave: Rg. Computation of binary spectrograms is also a useful visualization method to recognize the ripple-fired explosions, because emphasizes the long-duration modulations of spectra.

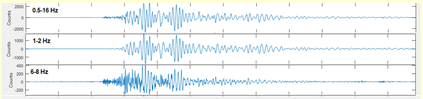
4. Amplitude ratios at different frequency bands:

We investigated the effectiveness of P/S amplitude ratios using filtered waveforms at different range of frequency bands (O'Rourke et al. 2016). Each seismogram was processed by removing the mean and trend, tapering, and filtering with a two-pole, two-pass Butterworth band-pass filter. We tested passbands in 2 Hz intervals from 2 to 16 Hz (2–4, 4–6, …, 14 –16 Hz) to determine which range provided the best differentiation between source types. We calculated amplitudes by taking the root mean square (rms) of the P and S windows, as well as P and S prephase noise levels. P amplitudes were measured using only the vertical (Z) and radial (R), because no energy should exist on the transverse (T) component, and S amplitudes were measured on all three components (Z, R, T). We measured the rms amplitude one ach component and took the square root of the sum of the squares for each component. In this way, we ensured that we measured the full amplitude fo each arrival, regardless of incidence angle or polarization of the seismic wave. Our results show that the P/S method fails at our local distances <60 km. About ~40 local EQs and ~ 40 EXs were analyzed.



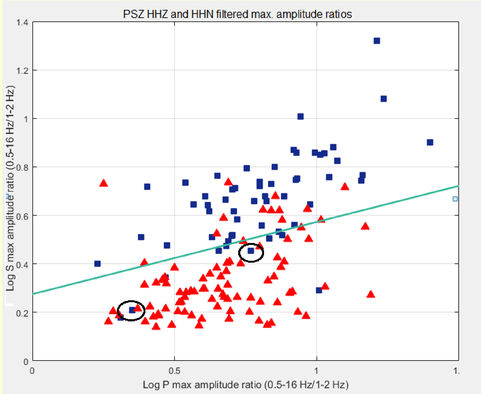
5. Lg and P maximum amplitude ratios at different frequency bands:

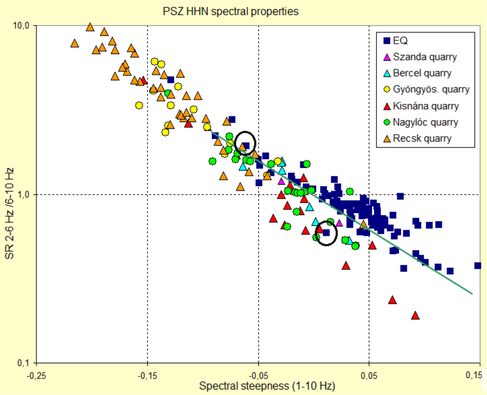
We measured the logarithms of S coda (HHN) and P coda (HHZ) maximum amplitudes at different frequency bands: 1–2Hz, 0.5-16 Hz and 6–8 Hz, and we calculated the logarithm of different amplitude ratios (Vargas et al. 2017) and determined the linear discrimination line between the two classes EQs and EXs.



We tested different spectral parameters:

1. The steepness of power spectra is calculated between 1-10 Hz.
2. The Spectral Ratio (SR) is calculated using the ratio of integrated spectral amplitudes of the selected lower and higher frequency bands. The SR between 2- 6 Hz and 6-10 Hz will indicate the spectral modulation of ripple-fired technique.





Conclusions and future plans:

1. We tested various event discrimination methods in the vicinity of the Piszkés-tető station, co-located with an infrasound array. Quarries in this region regularly report their activities, therefore these explosions are considered ground truth and can form a training set for testing local discrimination methodologies. Beyond 60 km distance the SNR from both explosion and earthquakes becomes too low to produce meaningful results.
2. Waveform correlation separates earthquakes and explosions into different clusters. We were able to identify two explosions that were classified as earthquakes.
3. Creating a set of master events for individual quarries will allow us to run correlation detectors on past waveforms and identify explosions that were misclassified as earthquakes in the Hungarian National Bulletins.
4. The P/S amplitude ratios do not separate well events in any of the frequency bands in these close distances as they produce siginficant overlaps among earthquakes and explosions
5. Spectral ratios and max amplitude ratios provide more promising results and they can be used in combination with other measurements, such as waveform correlation and infrasound data, to develop a multiparameter local event discrimination methodology.