Source discrimination between Mining blasts and Earthquakes in Tianshan orogenic belt , NW China

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1. Introduction

In recent years, a large number of quarry blasts have been detonated in Tianshan Mountains of China. It is necessary to discriminate those non-earthquake records from the earthquake catalogs in order to determine the real seismicity of the region. In this study, we investigated spectral ratios and amplitude ratios as discriminants for regional seismic-event identification using explosions (blasts) and earthquakes recorded at Xinjiang Seismic Network (XJSN) of China. We used a data set (26,581) that includes 1071 earthquakes and 2881 non-earthquakes as training data recorded by the XJSN between years of 2009 and 2016, with both types of events in a comparable local magnitude range (1.5 to 2.9). The non-earthquake and earthquake groups could be well separated in our study. Our results suggest that earthquakes occurring on land are related to small faults, while the blasts are concentrated in large quarries.

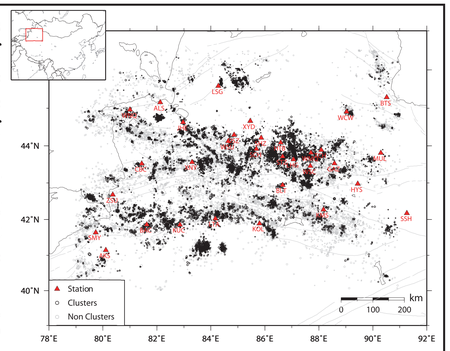

Figure 1. Seismic event distribution (black circles indicate clustered earthquakes; grey circles indicate non-clustered earthquakes), locations of seismic stations (red triangles) and mapped faults (dashed lines). (Inset) A regional map of China in which the red rectangle indicates the study area. Here we focused on those seismic events occurred between 2009 and 2016 with a local magnitude larger than 1.5.

2. Data and Methods

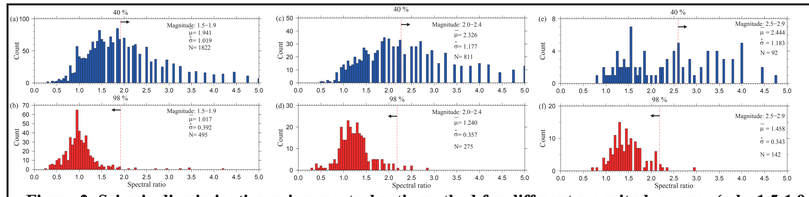

Figure 2. Seismic discrimination using spectral ratio method for different magnitude ranges (a-b: 1.5-1.9; c-d: 2.0-2.4; e-f; 2.5-2.9). The discrimination results for quarry blasts and natural earthquakes are shown in (a, c, e) and (b, d, f), respectively. Red dashed lines show the discrimination boundaries for both blasts and earthquakes.

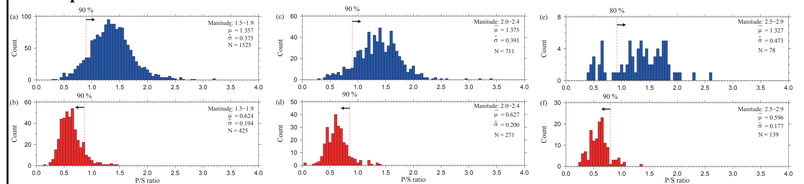

Figure 3. Seismic discrimination using amplitude ratio method for different magnitude ranges (a-b: 1.5-1.9; c-d: 2.0-2.4; e-f; 2.5-2.9). The discrimination results for quarry blasts and natural earthquakes are shown in (a, c, e) and (b, d, f), respectively. Red dashed lines show the discrimination boundaries for both blasts and earthquakes.

Training Events Selection:

Tectonic earthquakes are selected from aftershock sequences of 16 main shocks (ML>5.0), which include a total of 1071 aftershocks with a magnitude range of 1.5-2.9. Here we assume that blasts mainly occur in daytime and they are clustered in a local region. We selected 2881 clustered blasts with percentage of event daytime occurrence greater than 0.9.

Discrimination using Spectral Ratios:

Principally, blasts radiate more lower dominant frequency in seismogram than earthquakes. Therefore, it could be an approach to discriminate blasts from earthquakes based on spectral ratios of energy in different frequencies. We define the spectral ratios method as the integrated spectral energy ratios between higher frequency components and lower frequency components of particular seismic phases (e.g., Pg). Although spectral ratios method can classify some of these events, there is significant overlap (about 60% overlap) between the earthquake and non-earthquake populations (Figure 2).

Discrimination using Pg/Sg Amplitude Ratios:

The relative excitation of compressional and shear wave energy, represented in terms of P-to-S ratios, has been considered as a possible discriminant between explosions and earthquakes. In this study, Pg/Sg amplitude ratio is selected due to their large and reliable amplitudes. Our results suggest that blast and earthquake groups are well separated by amplitude ratios of Pg/Sg, with the separation increasing with frequency when averaged over three stations. The 8- to 15-Hz Pg/Sg ratio is proved to be the most precise and accurate discriminant, which works for more than 90% of the events.

3. Classification Results

By applying our classification criteria show in Section 2, our classification results suggest that 44% of the investigated seismic events in this study have the nature of explosion (blast), 55% have the nature of earthquake and the rest 1% cannot be determined their type. Actually, our results could be verified from the hourly/monthly occurrence distribution of classified quarry blasts and earthquakes. It shows that most of blasts occur in the daytime while earthquakes occur randomly. Obviously, the monthly occurrence distribution of quarry blasts correlated with seasonal variation. In addition, the spatial b value distribution of classified tectonic earthquake is more reasonable than those of unclassified original seismic events.

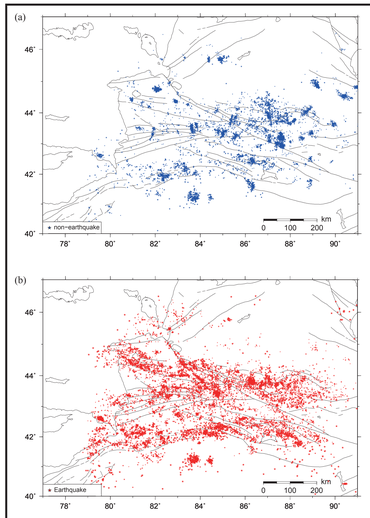

Figure 4. Classified quarry blasts (a) and natural earthquakes (b) after applying the discrimination criteria shown in Section 2.

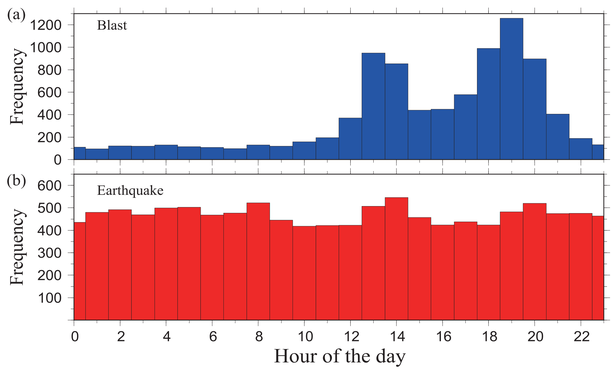

Figure 5. Histograms of number of events per hour for classified quarry blasts (a) and natural earthquakes (b). Here only ML < 3 seismic events are shown. Most of quarry blasts occurred in the daytime (11 am – 9 pm). Time Zone: UTC+8.

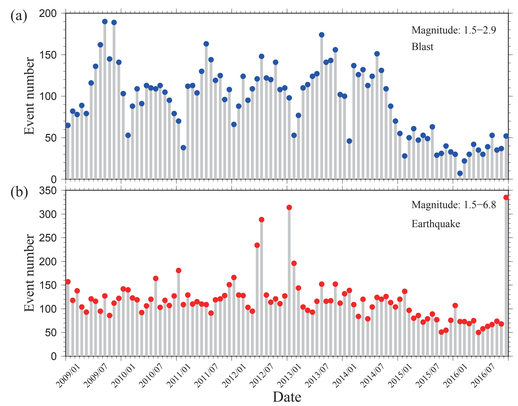

Figure 6. Time-frequency distributions for quarry blasts (a) and classified natural earthquakes (b). Here only ML <3 seismic events are shown.

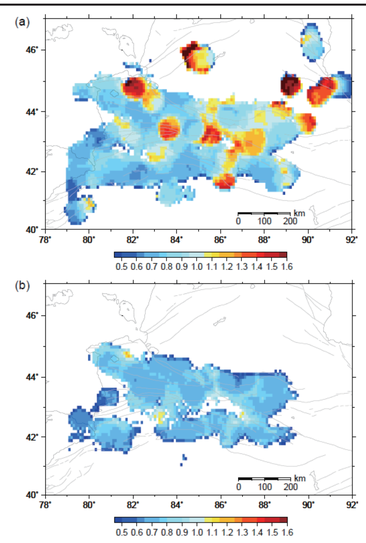

Figure 7. b value distribution in space for all unclassified seismic events (a) (Fig. 1) and classified natural earthquakes (b) (Fig 4b).

4. Conclusions

1. The non-earthquake and earthquake groups were well separated by amplitude ratios of Pg/Sg, with the separation increasing with frequency when averaged over three stations.

2. In contrast, the P spectral ratio performed considerably worse with a significant overlap (about 60% overlap) between the earthquake and explosion populations.

3. In the region of the study, 44% of the examined seismic events were determined to be non-earthquakes and 55% to be earthquakes, and the rest 1% cannot be determined their type.

4. The earthquakes occurring on land are related to small faults, while the blasts are concentrated in large quarries.

5. The b values of classified tectonic earthquakes are much closer to one than total unclassified seismic events.