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## Abstract

In this study, the P- and S-wave observed velocity and displacement source spectra from earthquakes and Quarry explosions with similar magnitudes were analyzed and compared. We have examined 1755 vertical component seismograms of 244 earthquakes and 239 Quarry explosions with magnitudes  $M_d=1.5-3.3$  between 2009 to 2015 recorded by the Egyptian National Seismic Network (ENSN) in northern Egypt at epicentral distances up to 200 km in order to develop a criteria for qualitative and quantitative discrimination between shallow earthquakes and quarry explosions based on differences in their spectral properties. The computed spectra were corrected for site, propagation path and instrumental effects for each recorded station. Based on omega-square fitting Brune's model, the source parameters of seismic moment ( $M_0$ ), corner frequency ( $f_c$ ) and moment magnitude ( $M_w$ ) were determined from corrected displacement spectra then the quantitative analysis is performed. Results of this study show that the quarry explosions spectra decrease more sharply at high frequencies than earthquakes of the same estimated magnitudes, leading to lower corner frequency estimates. Moreover, earthquake velocity spectra contain high-frequency content compared with the spectrum of the quarry explosions. A scaling relations were constructed between  $M_0(P,S)-f_c(P,S)$ ,  $f_c(P)-f_c(S)$  and  $f_c(P)/f_c(S)-M_w(P,S)$ ; it reflect an effective separation between earthquakes and explosions.

## Data Collection

- In this study, we examined 1755 vertical seismograms of 244 earthquakes and 239 explosions (quarry blasts) that occurred in Egypt with duration magnitudes ranging from  $M_d=1.5$  to 3.3 with epicentral distances up to 200 km in the period from 2009 to 2015 recorded by Egyptian National Seismological Network (ENSN) (Fig. 1). Only earthquakes shallower than 25 km were used. The data consist of the vertical components of broadband and short period stations of ENSN with sampling rate 100 sample/sec.
- We have tried to keep up a balance through the same magnitude ranges for studied earthquakes and explosions to achieve a reliable statistical discrimination analysis (Fig. 2).

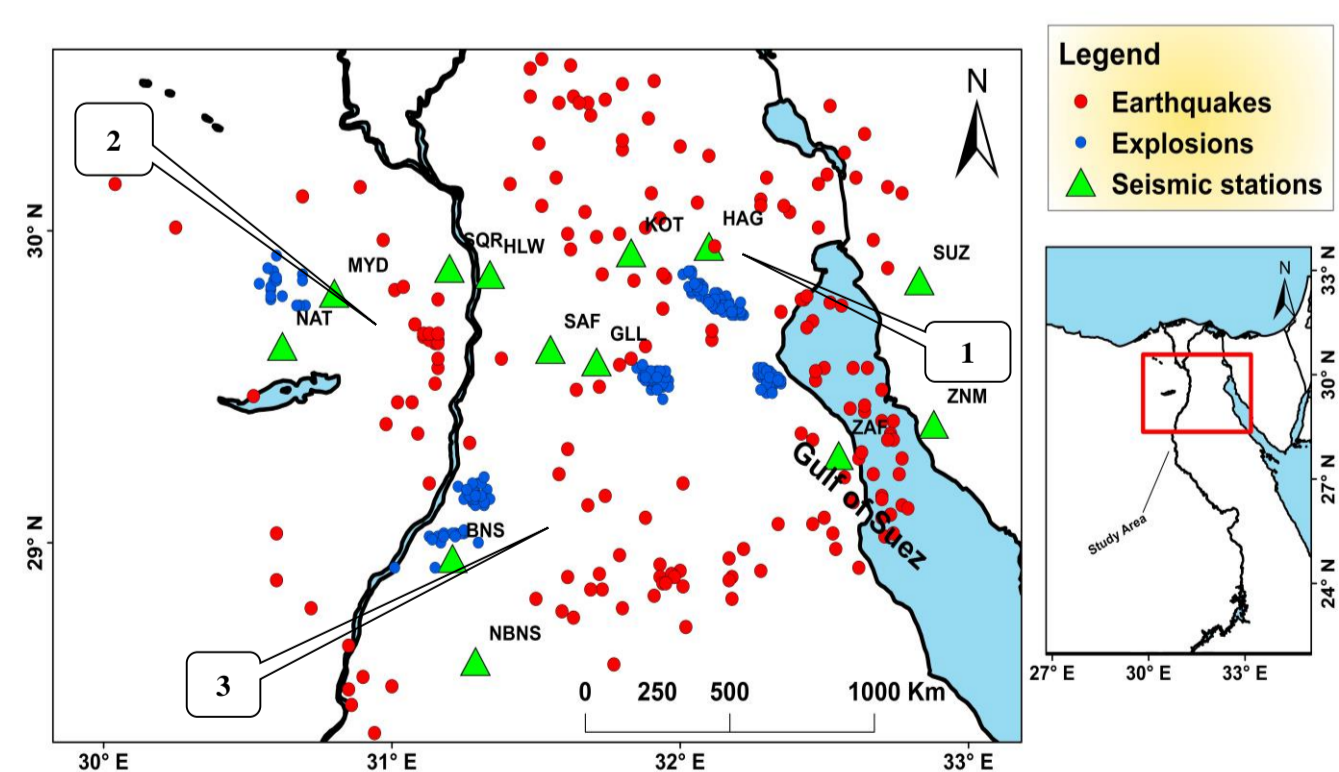


Figure 1. Location map of earthquakes, explosions and seismic stations used in this study.

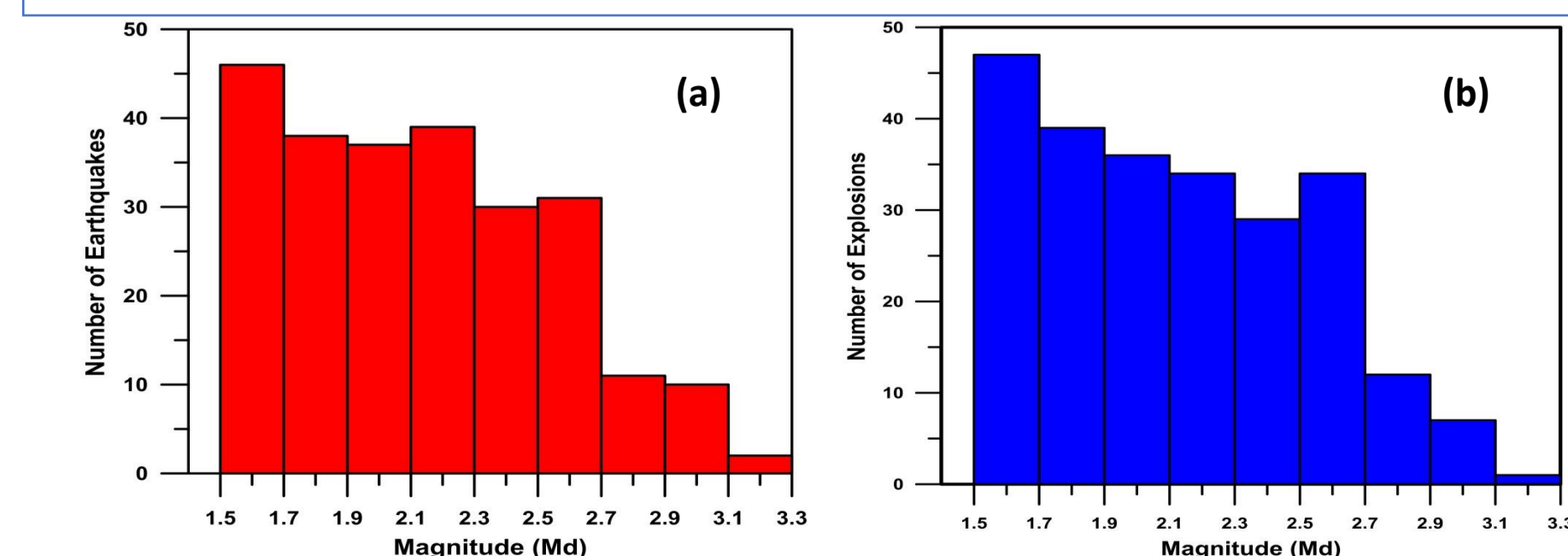


Figure 2. Histograms of duration magnitudes of (A) earthquakes and (B) explosions used in this study.

## Spectral Discrimination Technique

In fact, two spectral features were used in the present study:

### 1- Spectral Displacement Analysis:

- In this study, we analyzed and compared the P- and S-wave displacement spectra from vertical component seismograms between earthquakes and quarry explosions with similar magnitudes using EQK\_SRC\_PARA (Kumar et al., 2012) software in accordance with omega-square Brune's source model (1970).
- The calculated spectra is corrected for geometrical spreading using  $G(R,h) = 1/R$  by Havskov and Ottemöller, 2010 and attenuation using a frequency dependent P-wave and S-wave quality factors  $Q_p(f)=171.36^{0.79}$  and  $Q_s(f)=85.68^{0.79}$  attenuation correction relations by EL-Hadidy et al., 2006.

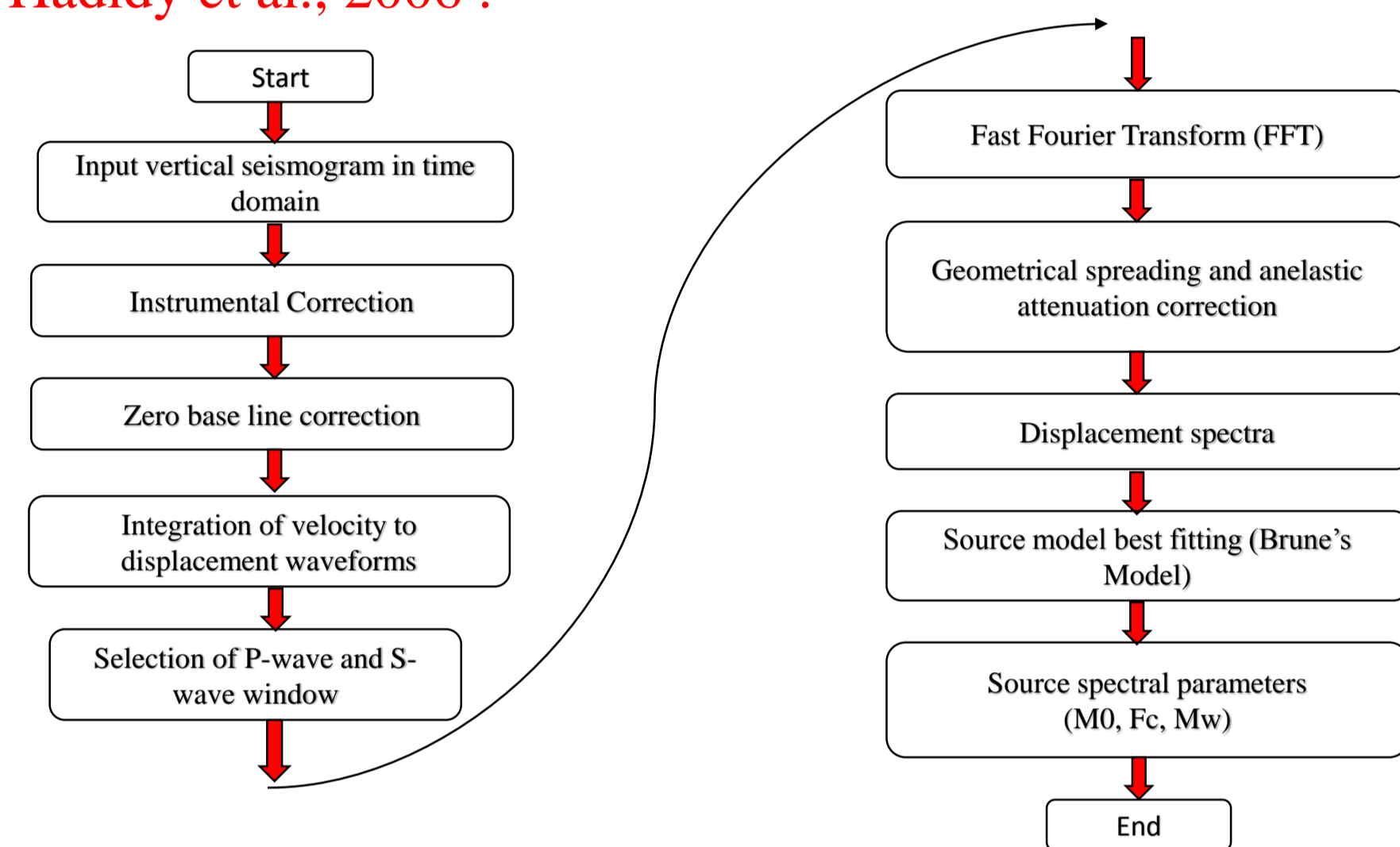


Figure 3. Flowchart of procedure adopted for estimation of spectral displacement and source parameters for studied earthquakes and explosions.

### 2- Spectral Velocity Analysis:

- we also analyzed and compared the amplitude velocity spectra of earthquakes and explosions together for complete vertical component seismograms to study the spectral properties and frequency content using Seismic Analysis Code (SAC).

## Spectral Discrimination Results

### 1- Spectral characteristics between earthquakes and quarry explosions based on spectral displacement analysis:

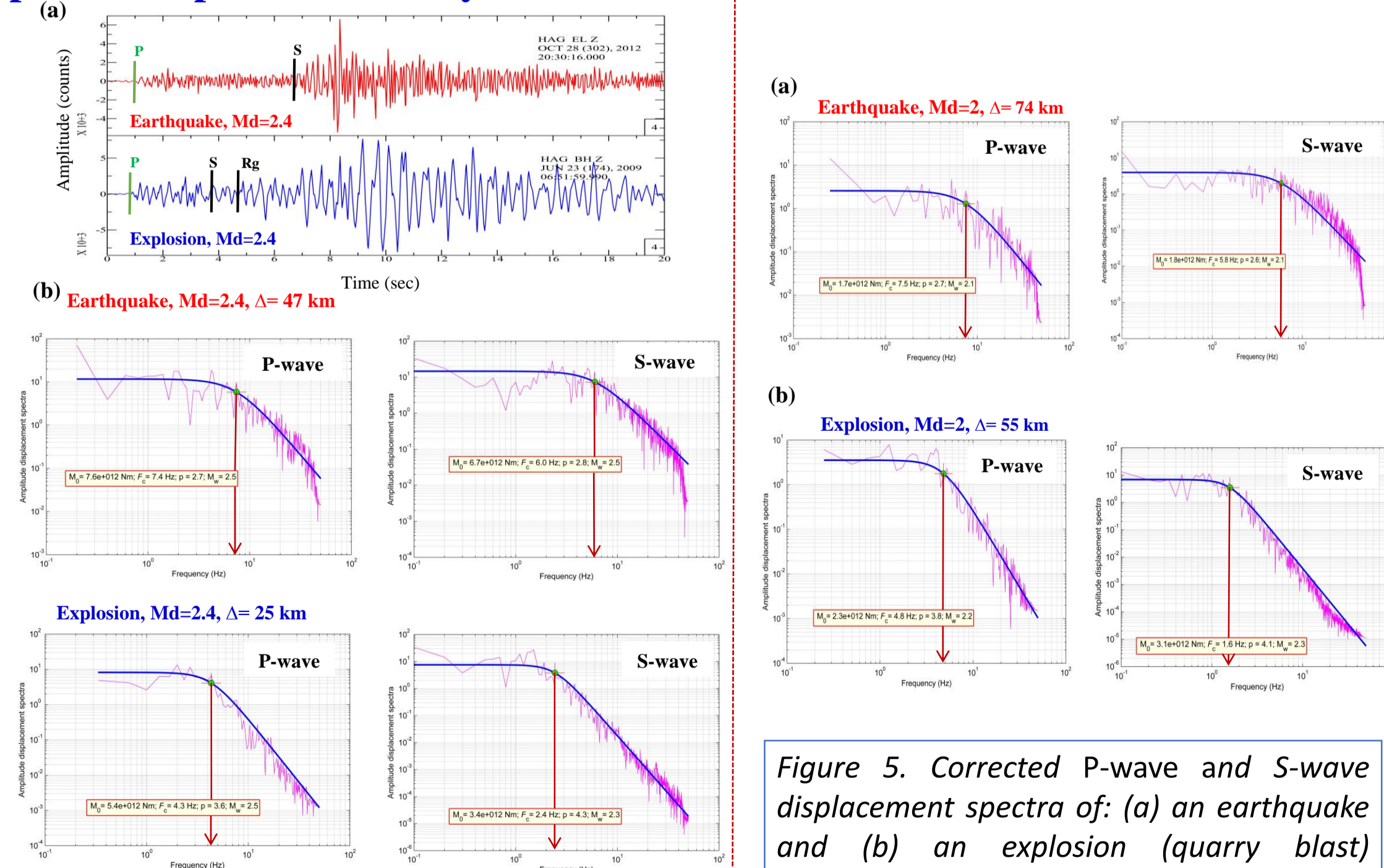


Figure 4. (a) Vertical component seismograms of an earthquake and of a quarry blast (explosion), recorded by HAG station (b) Their Corrected P-wave and S-wave displacement spectra. (See events position1 at figure 1).

Figure 5. Corrected P-wave and S-wave displacement spectra of: (a) an earthquake and (b) an explosion (quarry blast) calculated from vertical seismograms of GLL station. (See events position1 at figure 1).

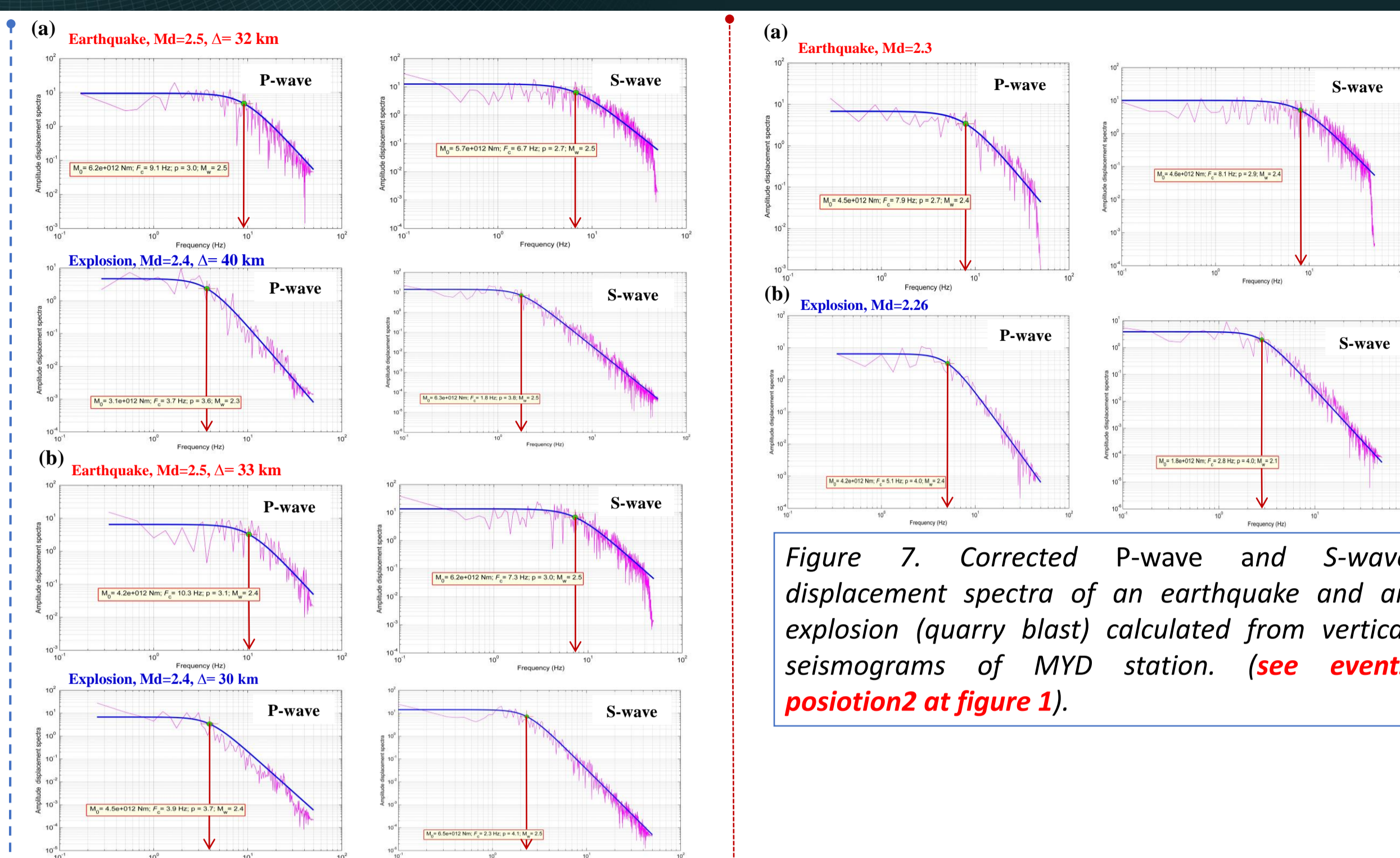


Figure 6. Corrected P-wave and S-wave displacement spectra of an earthquake and an explosion (quarry blast) calculated from vertical seismograms of: (a) GLL station and (b) SAF station. (see events position2 at figure 1).

Figure 7. Corrected P-wave and S-wave displacement spectra of an earthquake and an explosion (quarry blast) calculated from vertical seismograms of MYD station. (see events position2 at figure 1).

### 2- Spectral characteristics between earthquakes and quarry explosions based on spectral velocity analysis

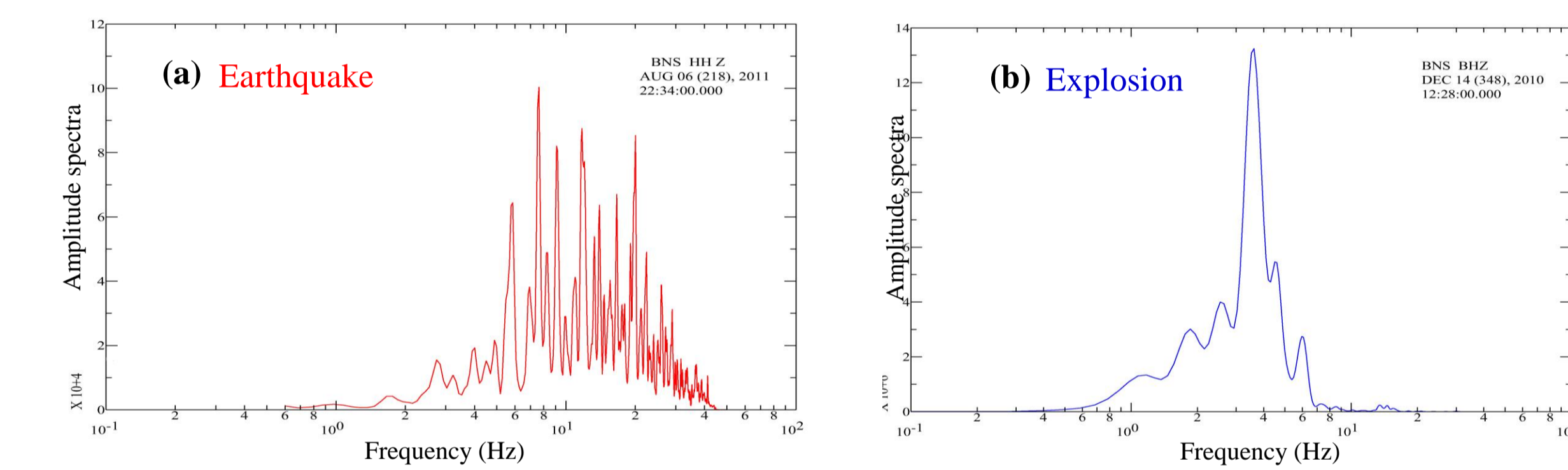


Figure 8. The Amplitude velocity spectra of an earthquake ( $M_d=2.1$ ) (a) and of a quarry explosion ( $M_d=2.0$ ) (b), calculated from vertical component seismograms of BNS seismic station.

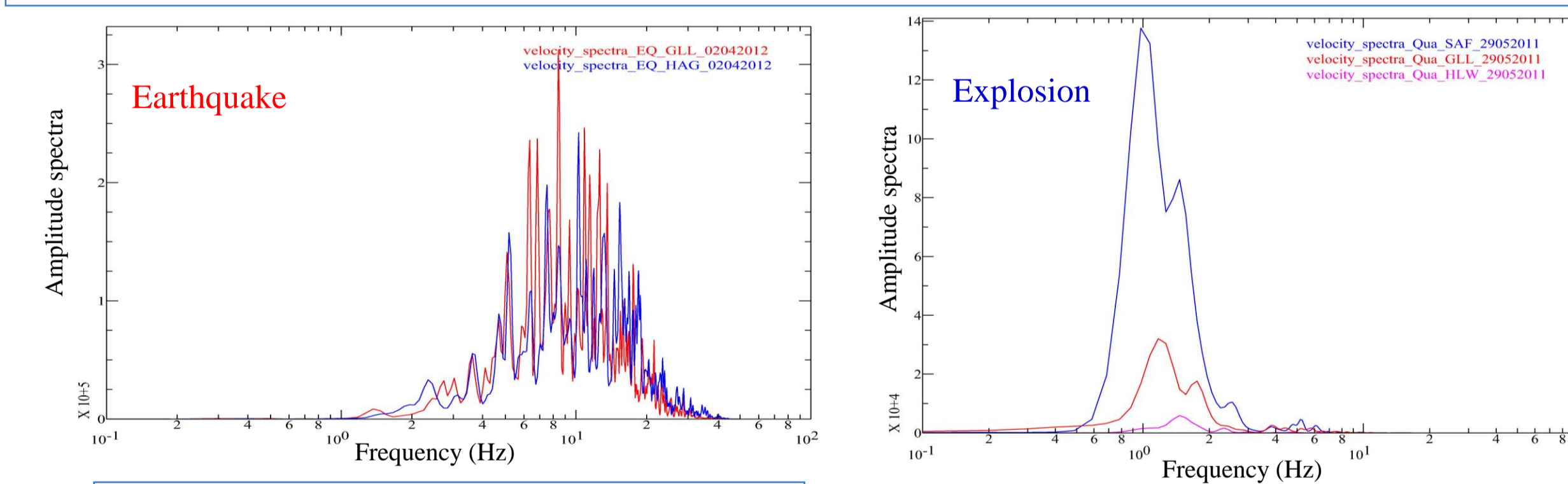


Figure 9. The Amplitude velocity spectra of an earthquake ( $M_d=2.25$ ), calculated from seismograms of GLL and HAG seismic stations.

Figure 10. The Amplitude velocity spectra of a quarry explosion ( $M_d=2.25$ ), calculated from seismograms of SAF, GLL and HLW seismic stations.

### 3- Comparison of source spectra parameters for studied earthquakes and explosions (quantitative discrimination analysis)

-Averaging the values  $M_0$ ,  $f_c$  and  $M_w$  using the equations of Archuleta et al. (1982) from available recorded stations for earthquakes and explosions were used for discrimination statistical and comparative analysis, separately for P- and S-waves.

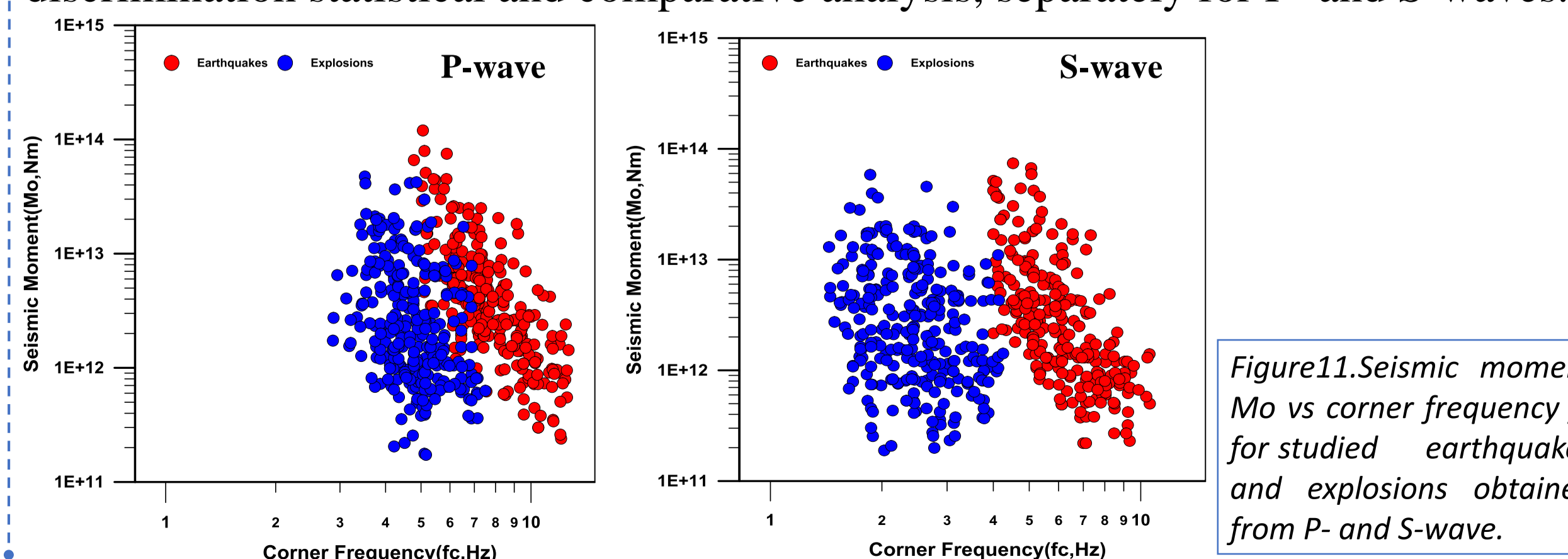


Figure 11. Seismic moment  $M_0$  vs corner frequency  $f_c$  for studied earthquakes and explosions obtained from P- and S-wave.

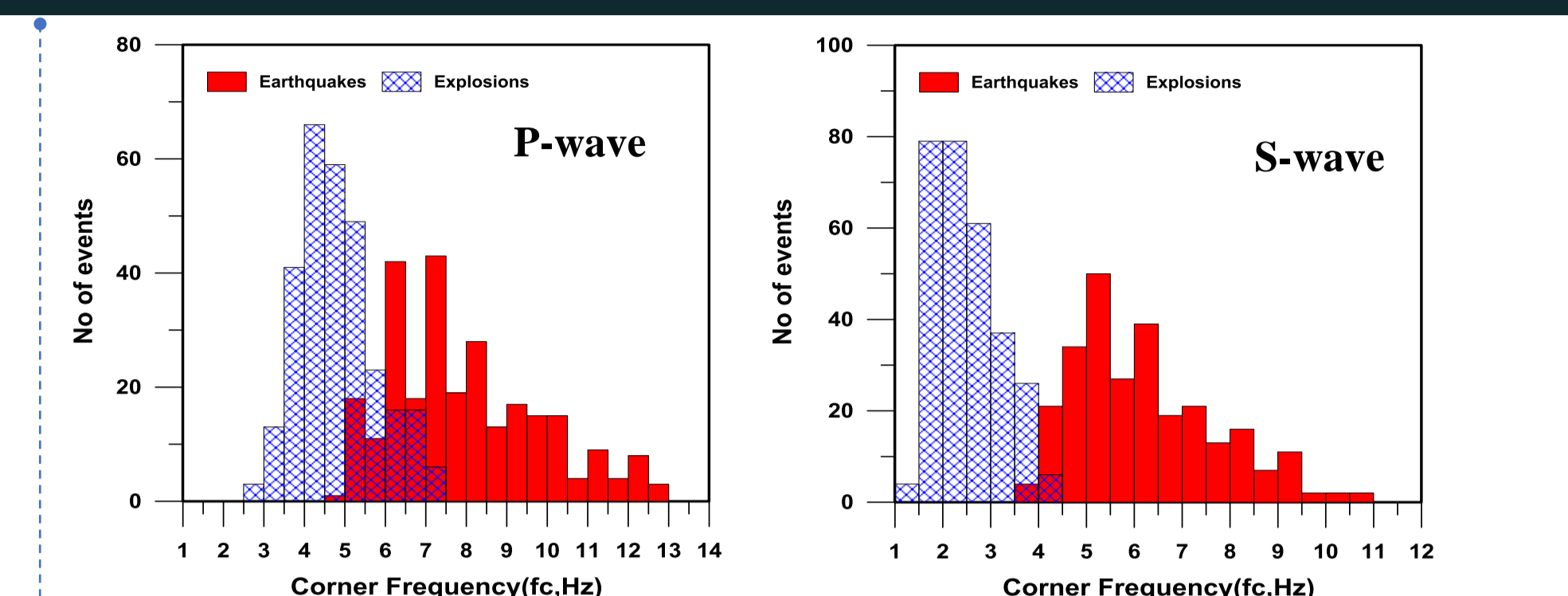


Figure 12. Histograms of the corner frequency for all studied earthquakes (red) and explosions (blue) obtained from P-wave and S-wave spectra.

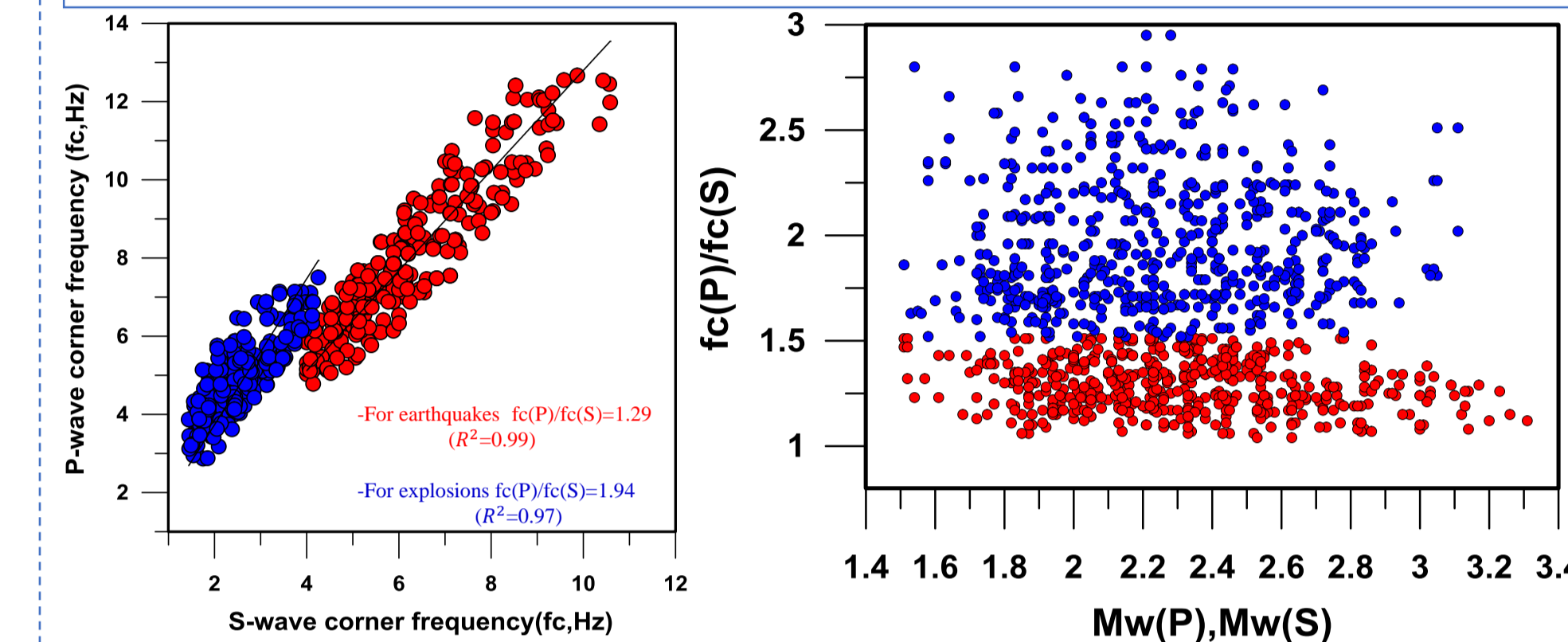


Figure 13.  $f_c(P)$  versus  $f_c(S)$  estimated from P- and S-wave analysis.

Figure 14. Ratio between  $f_c(P)$  and  $f_c(S)$  versus moment magnitude  $M_w(P,S)$ .

## Conclusions

In this study, The P-wave and S-wave displacement spectra between earthquakes and explosions with similar magnitudes were analyzed and compared. This study concluded that shallow earthquakes and explosions in Northern Egypt demonstrate significant differences in their spectral properties. The analysis shows that the displacement spectra of explosions show a lack of high frequency energy in P-wave and especially in S-wave (Fig.4-7). Therefore, the explosions show lower corner frequencies than those obtained from earthquakes of the same magnitude at the same station. Moreover, the explosions spectra also demonstrate the steeper "fall-offs" (decrease more sharply) at high frequencies, leading to lower corner frequency estimates. The lower corner frequency of explosions is related to strong attenuation near to the surface and ripple firing delays that affect the recording signals. So, the corner frequency from displacement spectra is the most important information about the seismic source type. In addition to, the velocity spectra of earthquakes revealed spectral characteristics in frequency content range higher than that of explosions and less than 50 Hz, while the explosions spectra has low frequency bands (less than 10-15 Hz) (Fig. 8-10). Moreover, The velocity spectra for explosions also show smoothed spectral shape; otherwise, the earthquakes is complex. The lower frequency content of explosions due to ripple firing delays that act as a bandpass filter, enhancing some frequencies and absorbing others. From corrected spectra, we computed the source parameters with small ranges of standard deviations to apply some quantitative scaling discrimination relations for separation between earthquakes and explosions. The result show that the seismic moments of earthquakes and explosions are in the same range and more separated for S-wave than P-wave (Fig. 11) and the estimated corner frequencies of explosions lower than earthquakes for both P- and S-wave (Fig.12-13). Our observation also show the ratio between  $f_c(P)$  and  $f_c(S)$  is larger for explosions than earthquakes. So, this result assumes an ability for discrimination (Fig.14). In conclusion,  $M_0(P,S)-f_c(P,S)$ ,  $f_c(P)-f_c(S)$  and  $f_c(P)/f_c(S)-M_w(P,S)$  relations reflect an effective separation between earthquakes and explosions.