



Seismic Signal Discrimination Between Natural Earthquakes and Mining Explosions Using Moroccan Seismic Network

Ibrahim Ouchen, Oussama Arab, Younes El Fellah, and Mimoun Harnafi

Abstract

Some regions of Morocco are characterized by relatively moderate active seismicity and mining. The seismic activity in Morocco is related to the African and Eurasian plate's convergence. In this work, we examined several diagnostic techniques to identify and distinguish between earthquakes as natural events and explosions as artificial events in the northern part of Morocco. The methods used are based on seismic spectral amplitude ratio, moment magnitudes (M_w), the time duration of signals, and focal mechanisms. The discrimination has been checked regarding monitoring of local seismicity and chemical explosion using the data recorded from more than 80 seismic stations in the framework of several projects; PICASSO, Topo Iberia, Morocco-Array, SIMA, RIFSIS for the period from 2010 to 2012. It comes out that using the distribution of Amplitude/Frequency methods between 0.1 and 25 Hz frequency band, the separation appears clearly for the earthquakes in the range 1–3 Hz and explosions in the range 9–12 Hz. Therefore, the moment magnitude of natural earthquakes is greater than that of artificial explosions. The detectability of the local earthquake and chemical explosion is estimated by the near station to the mine. The magnitude of explosions and earthquakes is between 2 and 4. Our approach is to apply these methods to better separate the populations of earthquakes and explosions to help calibrate local discriminants, especially in the phosphate areas where explosions rich database is available. This may shed light on the seismicity pattern of the region.

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Keywords

Discrimination · Earthquakes · Mining explosions · Method relative amplitude/frequency · Method M_w/M_L

1 Introduction

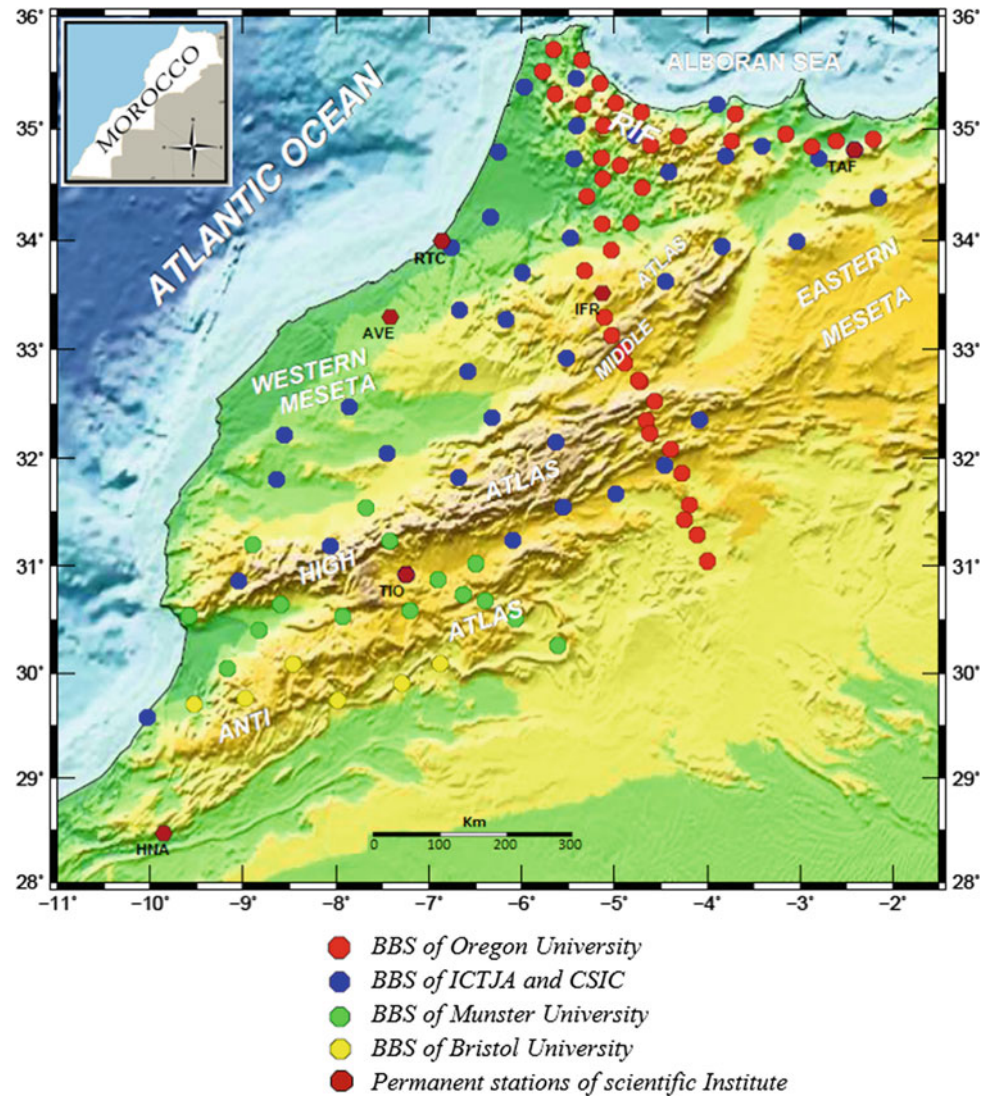
The discrimination between seismic events and explosions is one of the most studied sections in seismology. Moreover, with the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO), the research is increasing in order to obtain efficient and powerful packages to characterize the sources of seismic signals captured by the seismometers.

In order to improve the performance of our seismic data recorded on the stations of our network, some discrimination methods have been applied on the seismic signals recorded on Moroccan network, with the aim of developing more relevant and adapted methods to our data in the future. The objectives are the distinguish between artificial events and natural events and to allow the correction of trajectory effects on seismic wave propagation in the different geological parts of Morocco (Michard et al., 2008).

2 Materials and Methods

The data selected for this work was collected from the Picasso, Topo Iberia, and Morocco-Array networks (Fig. 1). The stations used are broadband seismographs (BBS) type with three components, equipped with seismometers Nanometrics Trillium 120P/Streckeisen STS-2/ and Guralp. Eighteen small events were selected for this study in the magnitude range between 2.0 and 4.3, of which seven are small natural earthquakes, and eight are explosions induced by the RIFSIS (Gil, et al., 2014) and SIMA (Ayarza et al., 2014) projects. All events were recorded between 2010 and 2012, located between latitude 30–36 and longitude from – 3 to – 9.

Fig. 1 Deployment of temporary and permanent seismic stations used in this study



A vast number of techniques have been used to discriminate between earthquakes and quarry explosions; in this work, we test some of these methods for the identification of chemical explosion signals from earthquakes. The main identification method previously used in discrimination is the duration of the signal, because for the majority of events, the duration is longer for earthquakes than for explosions (Li et al., 1995). The spectral analysis method is based on the distribution of the amplitude-frequency spectrogram in the time domain, and to study the spectral characteristics of signals and the frequency content of whole seismic waveforms (Plafcan et al., 1997). Finally, the moment magnitude M_W is the most accurate and modern quantification for measuring the size of an earthquake; however, magnitude scales have long been used for this purpose (Hanks & Kanamori, 1979). The following relation defines the moment magnitude M_W :

$$M_W = (\log_{10} M_0 / 1.5) - 6.07 \quad (1)$$

M_0 (N·m): is the seismic moment; it is a static parameter and is not related to the dynamic properties of the source.

In order to improve our study of discrimination, we calculate the ratio between the moment magnitude M_W and the local magnitude M_L using the maximum amplitudes on the Z channels (vertical) (Table 1). This method is based on a physical model of deformation of seismic events that allows the best calculation of the magnitude in both cases of large and small earthquakes.

3 Results and Discussion

Many papers have attempted to deal with the discrimination issue, including some similar to our study of small earthquakes and explosions (Allmann et al., 2008; Dahy &

Table 1 Moment magnitude and signal duration (SD) with corresponding M_L and M_c , for the studied earthquakes and explosions indicated by EV and SP/SR, respectively

Date	Events	H:M:S	Lat	Long	ELV (m)	Depth (m)	M_w	M_L	SD(s)	Mc
04/05/2010	SP1	16:00:03	33.67	- 5.20	381	60	2.2	1.6	23	0.6
06/05/2010	SP3	16:59:59	32.86	- 4.97	1525	30	2.0	1.3	34	1.0
07/05/2010	SP4	12:01:00	32.30	- 4.49	1380	30	2.3	1.6	35	1.0
07/05/2010	SP5	17:00:00	31.79	- 4.22	1030	30	2.3	1.6	24	0.6
08/05/2010	SP6	12:00:00	30.99	- 3.96	714	30	3.1	1.8	31	0.9
11/10/2011	SR2	17:01:00	35.10	- 5.30	496	30	2.6	1.7	40.5	1.2
12/10/2011	SR3	16:00:00	34.49	- 5.19	276	30	2.6	1.9	31.4	0.9
13/10/2011	SR4	14:00:00	34.74	- 3.87	1368	30	2.4	1.8	30.5	0.9
17/02/2012	SPY1	14:09:28	32.22	- 8.39	390	< 100	2.4	0.9	34	1.0
28/02/2012	SPY2	15:13:00	32.22	- 8.39	390	< 100	2.2	1.2	34	1.0
28/02/2012	SPB	15:04:00	32.32	- 7.86	560	< 100	2.4	1.0	34	1.0
21/01/2010	EV1	16:57:07	34.78	- 5.73	317	18,000	4.3	3.4	166	2.9
19/02/2010	EV2	04:13:09	33.43	- 4.14	2232	0	2.9	2.5	101	2.3
05/08/2010	EV3	18:54:14	32.17	- 5.84	2383	7000	4.3	4.2	212	3.3
01/03/2011	EV4	10:26:26	35.13	- 4.69	123	76,000	3.2	2.5	92.7	2.3
28/02/2012	EV5	06:26:30	32.32	- 6.96	360	400	2.8	2.5	112	2.4
02/06/2010	EV6	16:35:42	34.71	- 3.89	1157	3000	3.4	3.0	111	2.2
29/02/2012	EV7	04:11:52	32.19	- 4.84	1631	0	2.9	2.7	115	2.5

Hassib, 2009). This work indicates that one of the most effective methods for distinguishing artificial events from natural events is the use of relative amplitude and frequency.

Applying this ratio between the moment magnitude M_w and the local magnitude M_L discussed in Sect. 2, we can see that the distinction between them is very clear (Fig. 2a); the discrimination is easier when the moment magnitude M_w is > 2.8 . However, the local magnitude of the explosions is smaller than that of the earthquakes.

We deduce from Fig. 2b that the correlation between the duration and coda magnitude (Mc) works as an important factor in discriminating between earthquakes and explosions, the two populations appear separated and there is no confusion between them. The results of the spectral distribution in the different stations (Table 1), represented in Fig. 2c show the general view of the average of the spectrograms of mining explosions and earthquakes in station. This demonstrates the relationship between the relative amplitude and frequency detected in the Moroccan seismic network. As the graph reveals, discrimination in the frequency domain is observed between 9 and 12 Hz for earthquakes and between 1 and 3 Hz for explosions.

4 Conclusions

In this paper, we have applied some methods for discriminating between earthquakes and explosions in Morocco. We work then to quantify the performance of these methods as sufficient discriminants in the case of small earthquake magnitudes and artificial events. The dataset used in this study was collected from 2010 to 2012 with more than 80 seismic stations distributed over the Moroccan territory.

The relative amplitude-frequency ratio used for the totality of the signals recorded at the Moroccan network shows that explosions have a relatively high amplitude-frequency ratio compared to earthquakes. We conclude that the best frequency band filter to apply for earthquakes is 1–3 and 9–12 Hz for explosions. It should also be noted that to complete our study of discrimination, we need to explore the effect of other methods. It is clear from the results obtained in this work that an additional research is needed for regional explosions recorded via teleseism in our seismic network to provide valuable information regarding discrimination for future studies.

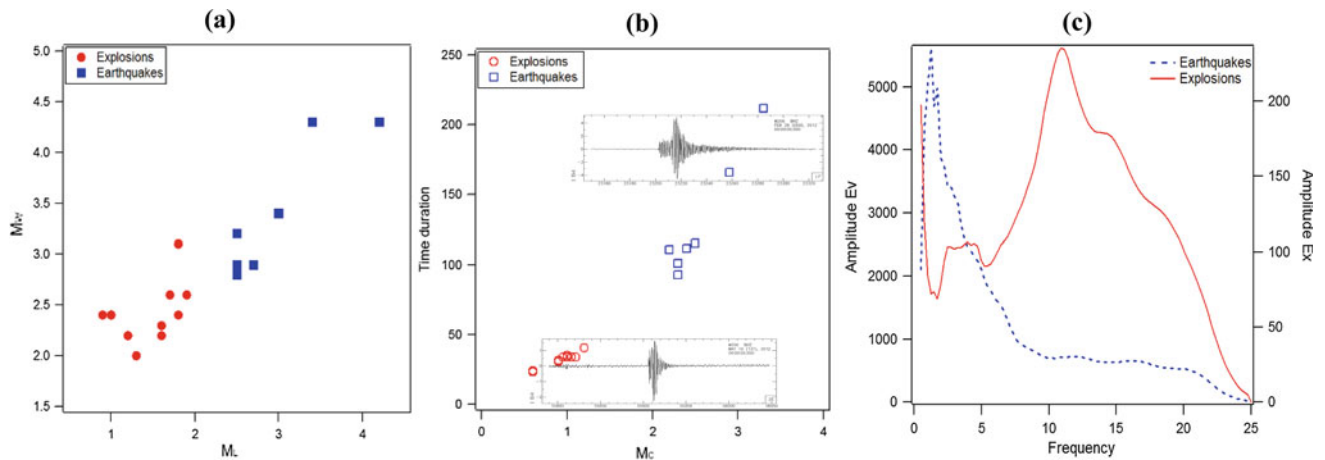


Fig. 2 a The M_w/M_l ratios for the studied events b Relationship between time duration (second) and coda magnitude c Amplitude-Frequency average spectra from all events studied in this work. Explosions are in Red and earthquakes are in Blue colour

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