Explosion source data analysis from a Jordanian quarry

Matthew J. Yedlin[1], Gary F. Margrave[2], and Yochai Ben Horin[3]

ABSTRACT

This seismic case study is a preliminary analysis of a unique seismic data set of 1805 quarry blasts detonated in a phosphate quarry of the Jordan Phosphate Mines Company (JPMC). Three component recordings of these blasts at the broadband station, HRFI, Israel, are analyzed to determine source similarity. Presented herein are the singular value decomposition and reconstruction of the z component of the recorded data. The noisy quality of the original records is evident in the reconstruction, as the L2 norm of the reconstruction error has the same log-linear dependency as the singular value spectrum.

INTRODUCTION

Verification of compliance with the Comprehensive Nuclear Test Ban Treaty depends critically on seismic techniques of magnitude estimation and source function analysis (Richards and Kim, 2009). Source function discrimination is a focal point of seismic verification, given that explosion sources are principally compressive in nature. However, further identification is necessary to distinguish between mining blasts, nuclear weapons tests and natural events. An example of an event is the Chelyabinsk meteorite blast of February 15, 2013.

The current research focuses on 1805 quarry blasts to determine if there is sparse representation of the recorded seismic data. Since we expect the strength of the shear arrivals to be weaker, this preliminary analysis focuses on the z component. The principal tool we will use for the similarity analysis of the 1805 blasts will be singular value decomposition(SVD) in order to highlight the similarities of the data recorded and their representation in terms of the eigenvectors. (Yedlin et al., 2015)

DATA COLLECTION AND PREPROCESSING

The station HRFI, latitude $30.04°$ N and longitude $35.04°$ E, recorded a three component sequence of 1805 quarry blasts, shot from by the Jordan Phosphate Mines Company, from March 2002 to January 2015. The geographic centroid of these blasts has an estimated location $29.9°$ N and longitude $36.3°$ E. The station HRFI, located in southern Israel, approximately 50 km north of Eilat,is part of the NDC Cooperating National Facility (CNF as defined by the CTBT) seismic network which is part of the Israeli Seismic Network (ISN) operated by the Geophysical Institute of Israel. Its location relative to the quarry is shown in Figure 1.

HRFI is home to a three component broadband STS-2 seismometer connected to Quanterra digitizer. The sampling rate at the station is 40Hz. All P arrival times, P_{times}, recorded

[1]Department of Electrical and Computer Engineering, University of British Columbia
[2]Geoscience, University of Calgary
[3]SOREQ Nuclear Research Center (SNRC), Yavneh, Israel

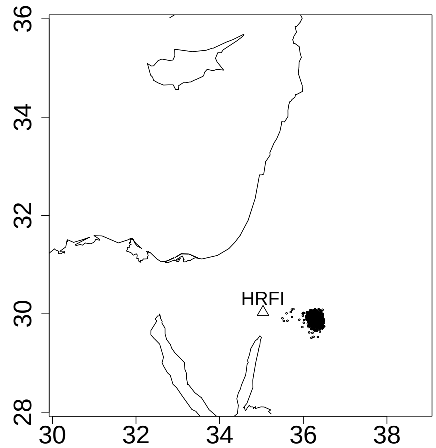

FIG. 1. Location of HRFI and JPMC quarry indicated by collection of points.

at the station HRFI, were used in the location of the events. Data segments, from the 1805 events, were chosen based on the distribution of maximum amplitudes shown in Figure 2. These data segments were retrieved starting from P_{times} - 30 seconds up to P_{times} +120 seconds, resulting in 6000 samples per event. In Figure 3, 1805 events are winnowed based on segments for which the maximum amplitude occurred between 29 and 35 seconds from the beginning of the data.

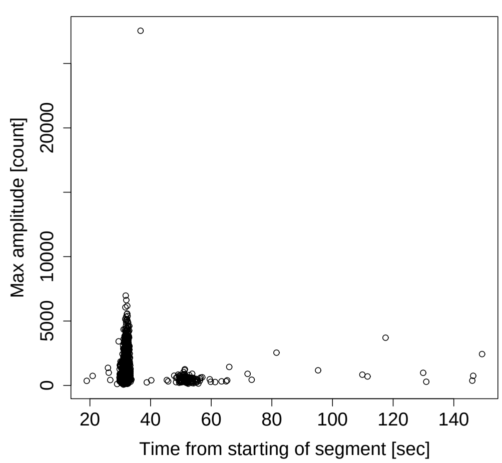

FIG. 2. Maximum amplitude times.

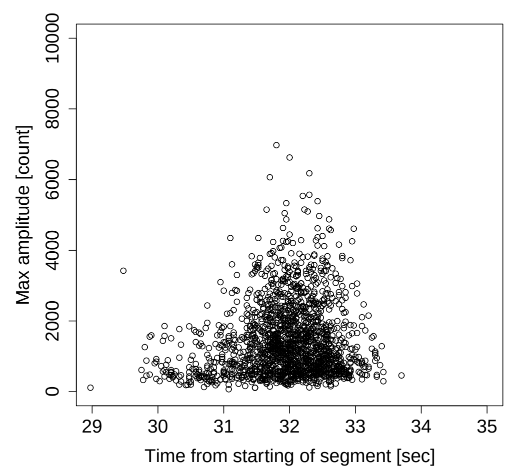

FIG. 3. Winnowed events.

The histogram in Figure 4 shows the location variation of all the blasts, with most of them occurring at epicentral distances ranging from 110 to 130 km.

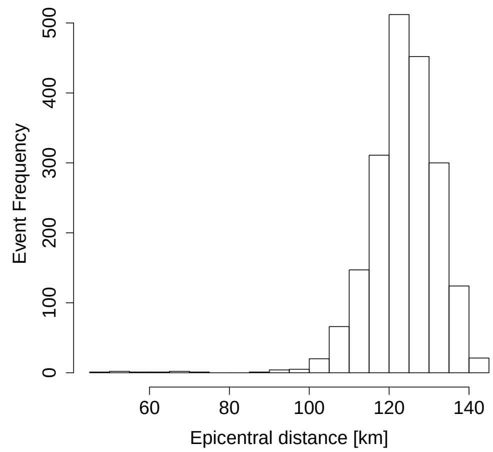

FIG. 4. Histogram of epicentral distance distribution.

SINGULAR VALUE DECOMPOSITION PROCESSING

The winnowed z component data, comprising 1654 events, were first detrended using the algorithm of Cleveland (Cleveland et al., 1990). An example of this process is shown in Figure 5. The low frequency jitter in a) has clearly been removed in b).

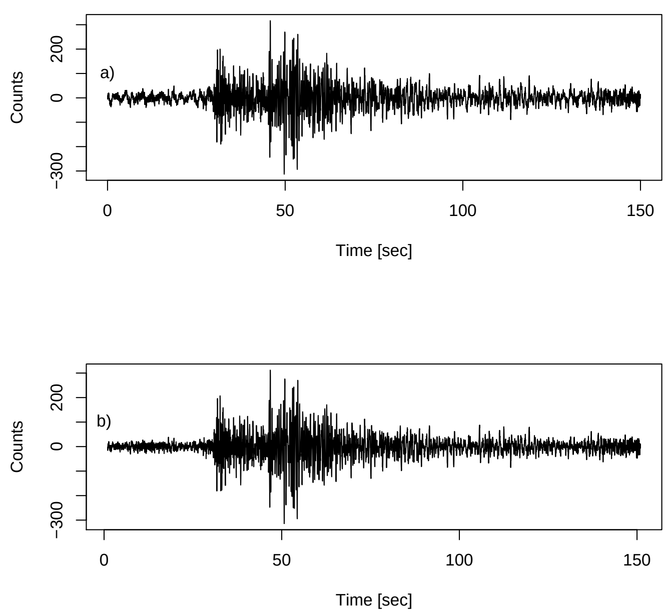

FIG. 5. Results of the detrend processing: a) Original trace. b) Detrended trace

The detrended data was then bandpass filtered from .1 to 12Hz using an eighth-order Butterworth filter and then sorted based on maximum value, resulting in Figure 6. In this blind experiment, in which we currently do not have mining data access to blast sizes, locations and times, in order to determine source similarity, we perform a singular value decomposition of the data and reconstruct it using only 10% of the singular values. The result of this reconstruction is shown in Figure 7. The results are promising, demonstrating that the noise has been significantly reduced, while all the main data features have been preserved. Notably, the S arrival is clearly delineated and the surface waves arriving after 80 seconds are much more evident.

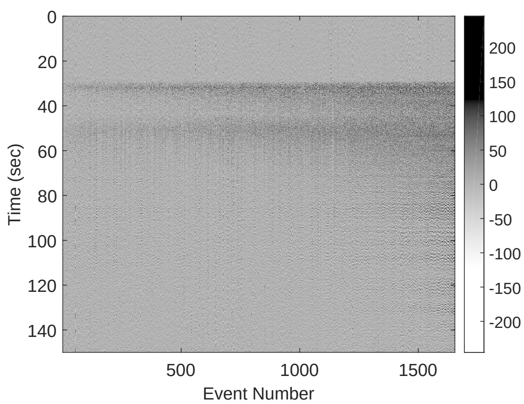

FIG. 6. Z component data

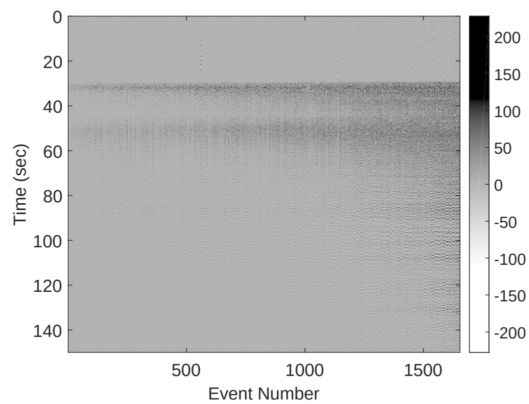

FIG. 7. SVD reconstruction (10%)

To quantify the foregoing, the singular value spectrum shown in Figure 8 illustrates the classical log-linear dependence, with the later singular value indices corresponding to noise. As a verification of this, we first reconstruct the data in Figure 6 using the first 20 singular values, the first 40 singular values and continue in this manner to include the entire singular value spectrum. For each of these reconstructions in the sequence, we compute the L2 norm of the error between the reconstruction and the original data. The results, shown in Figure 9, have the same log-linear dependence seen in Figure 8. The L2 norm has decreased by one order of magnitude using 10% of the singular values. and it is not surprising that the L2 norm curve has the identical log-linear dependence

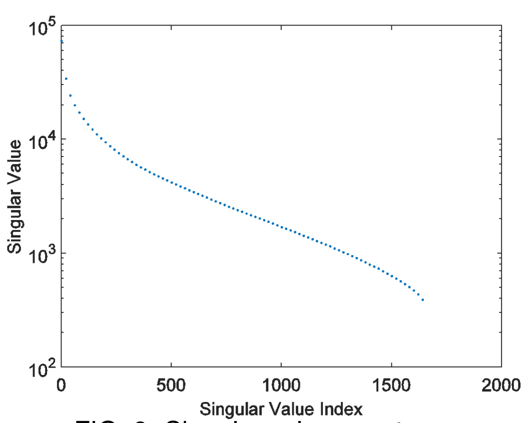

FIG. 8. Singular value spectrum

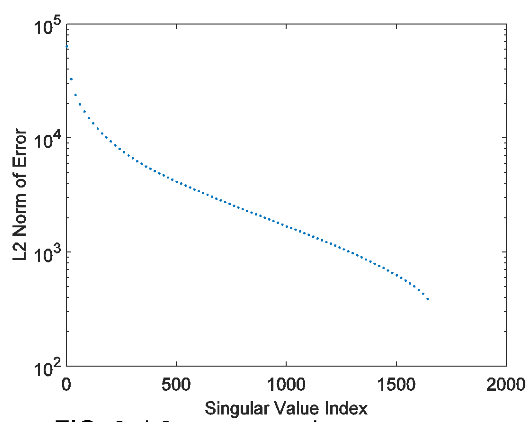

FIG. 9. L2 reconstruction error norm

CONCLUSIONS

The current study is a first attempt in classifying source similarity from an ensemble of quarry blasts. The singular value decomposition has been used to demonstrate that the data set can be represented by one tenth of the singular values and the corresponding eigenvectors. Essential features of the data were preserved in the reconstruction and the noise was significantly reduced. This data set is highly non-stationary in its frequency content and is thus a good candidate for detailed time-frequency analysis (Yedlin et al., 2014).

ACKNOWLEDGEMENT

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