Seismicity of the Strait of Gibraltar during 1991

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ABSTRACT: This study summarizes our present knowledge on the seismicity of the Strait of Gibraltar with a particular emphasis on data collected by a newly installed network. The area of study is confined to the rectangle extending 34-38° N and 4-8° W. Even though this area has not suffered from any large magnitude earthquake in this century, it has been historically known as a region which suffered a great deal from large magnitude events such as the 1755 Lisbon earthquake. The seismicity of this area for the period 1900-1989 shows that this region is characterized by three alignments of seismicity:
- a N-S trend of seismicity bet 35-37°N at 5°W,
- a NE-SW alignment of seismicity in southern Spain,
- and a NW-SE direction of seismicity in northern Morocco.

The Strait of Gibraltar is in itself very quiescent seismically. Furthermore, seismic risk studies have shown that the area north of 35°N is subject to high risks from earthquakes of magnitudes > 5.5.

In order to accomplish a more refined study of the seismicity of the area of the Strait of Gibraltar, two networks specifically designed for this purpose were installed in northern Morocco and in southern Spain in 1989. The Moroccan network consists of six short-period telemetered seismic stations, while the Spanish network consists of nine. The data are available in both digital and analog forms. In this study we invert travel-time P and S-wave data for the hypocentral locations of the events recorded in 1991. In our data processing, we include readings from stations of the national networks as well.

The analysis of the 1991 seismic data shows two major trends of seismicity: a NE-SW trend in southern Spain and a NW-SE trend in northern Morocco, the Strait of Gibraltar remaining very aseismic during this period. Those results are in good agreement with the previously reported ones for the period 1900-1989. Moreover, we find that the events recorded in southern Spain have magnitudes that vary between 1.0 and 3.5, while those in northern Morocco vary between 2.0 and 3.8. In general, the events occurring in northern Morocco have relatively stronger magnitudes, but are deeper. They occur at a depth around 30 km, while the events in southern Spain are very shallow with depths around 5 km.

While the new networks have substantially helped in reducing the error on hypocentral locations, the threshold of detected events in northern Morocco remains relatively high. It is therefore suggested to rearrange the configuration of the Moroccan network and to add a three-component digital seismic station. This would help decrease the thresholds of magnitudes to an estimated magnitude of 1, and would equally allow us to calculate the spectral response from both local and remote earthquakes.

1. INTRODUCTION

The purpose of this paper is to study the seismicity of the area of the Strait of Gibraltar using data collected at a newly installed network in this region. This work is part of a major feasibility study initiated by both the Moroccan and the Spanish governments for the establishment of a fixed link between Morocco and Spain.

The method used in this study consists of inverting travel-time P and S-wave data to invert for hypocentral locations of the recorded seismic events. The data used in this study cover the year of 1991 only, and consist, not only of events recorded by the Strait of Gibraltar networks, but also of readings from the national Moroccan and Spanish networks as well. The Spanish data are taken from monthly reports of the "Real Instituto y Observatorio de la Armada" of Spain and from the Earthquake Data Reports (EDR) published by the USGS.

In this paper, we briefly review the historical seismicity and seismic risk studies. The seismicity patterns for the 1991 events are analyzed as well as their depth distribution. Finally, the results of this short-term study are used to give suggestions to improve the quality of the data acquisition.

2. HISTORICAL SEISMICITY AND SEISMIC RISK.

The Strait of Gibraltar is situated in the centre of a
zone of N-S convergence between the African and Eurasian plates. This compression is partly accommodated by an E-W opening along normal faults in the Alboran sea, which enables some of the materials to be squeezed out of the area (Buform et al., 1991)[1]. Farther to the west of this area, a triple junction connects the Mid-Atlantic ridge to the Ibero-Maghrebian region by a play of transform faults (Mezzac a et al., 1991)[2].

Historically, the Strait of Gibraltar has been inactive seismically. Yet, this area suffered a great deal from large magnitude earthquakes which originated mostly in the eastern Atlantic region. Among these, is the so-called Lisbon earthquake of November 1, 1755, which had an estimated magnitude of 9 (Ben Sari, 1981)[3], and occurred in the Gorringe bank area.

Various studies concerning the seismicity of this area in the twentieth century have shown that the Strait of Gibraltar region is subject to three main tectonic trends:

- A N-S alignment of seismicity around 5°W between 35°N and 37°N (Ben Sari, 1981)[3].
- A NE-SW trend of seismicity in southern Spain, extending from (36.5°N, 4°W) to (38°N, 1°W) (Ben Sari, 1981)[3].
- A third trend of seismicity was reported by Ait Brahim et al., (1987)[4] in Northern Morocco with a NW-SE direction.

All published seismicity maps (e.g. Ramdani et al., 1992)[5] concerning this region show that the Strait of Gibraltar is itself very seismically active. Seismic Risk studies (Tadili and Ramdani, 1982)[6]; Ramdani et al., 1982[7]; Ben Sari, 1981[3]) show that there is a high probability that the area between 34°-38°N and 2°-6°W experiences an earthquake of magnitude higher that six, with a period of recurrence of 75 years, while the area between 6°-9°W has a very weak seismicity (Figure 1).

![Figure 1. Seismic risk vs latitude and longitude. Three-dimensional representation for magnitudes > 7.0. Dashed lines delimit area of study (Tadili, 1991).](image)

3. NETWORK DESCRIPTION

The network installed in Northern Morocco for the study of the seismicity of the Strait of Gibraltar consists of six short-period seismic stations (Table 1, Figure 2). Five of these stations are connected by UHF radio to the regional station of Cap Spartel, where the data are mixed and transmitted by telemetry to the central recording station in Rabat. In Rabat, these data are recorded both in analog and digital forms. The geophones used are the SS-1 Kinematics type with a central frequency of 1 Hz.

In parallel with the seismic array, a network consisting of four accelerographs is deployed at stations CPS, BMD, BIT and STY. These

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V = vertical component; S = short-period.
suit the type of data being handled as well as the empirical formula for magnitude calculation. Only P- and S-wave phases are used to locate the events.

The velocity model used to invert for the hypocentral coordinates (Table 3, Figure 3) is derived from the results of deep seismic soundings carried in Morocco, the Alboran sea and Spain (Ben Sari, 1987)[9]. This velocity model consists of an upper and a lower crust which are 15 km thick, and a Moho at a depth of approximately 30 km.

5. RESULTS AND DISCUSSION

During the year of 1991, 50 events were located in the area defined in figure 1. Since most of these events are of small magnitudes, many of them are recorded by one network only, either the Spanish or the Moroccan network. However, a number of events were recorded by both.

Most of the events recorded during this time span occurred in southern Spain, along a NE-SW direction of seismicity (Figure 4). On the other hand, the events recorded in northern Morocco are dispersed along a NW-SE direction of seismicity (Figure 4). Both of these seismic trends were reported by previous seismicity studies of northern Morocco and southern Spain (e.g. Ramdani et al., 1992[5]; and figure 8 of Ben Sari, 1987[9]). Only few events are located in the Alboran sea and the Atlantic ocean side of this area. Furthermore, no seismic events are recorded in the Strait of Gibraltar.

The absence of events in the strait is also in agreement with previous work covering the period of 1900-1989, thus providing further evidence of the lack of seismicity of the Strait of Gibraltar. Most of the events in southern Spain are shallow, with only few occurring at a depth around 30 km. A NE-SW cross-section along the south of the Iberian peninsula shows

4. DATA PROCESSING

A slightly modified version of Hypo71 (Lee and Lahr, 1975)[8] is used to locate the hypocenters of seismic events recorded by the Moroccan and Spanish Seismic Networks. The modifications concern mainly the input/output of the program. These were changed to

<table>
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the presence of two seismic zones (Figure 5). A zone of shallow seismicity extending from the surface to a depth of approximately 10 km, and a deeper zone at around 30 km depth, with no seismicity in-between. On the other hand, a NW-SE cross-section in northern Morocco shows that most of the seismicity occurs at a depth of 30 km (Figure 6). The depth control on these events is not very good, and they may have greater depths, thus suggesting that these quakes are probably sub-Moho events. The magnitudes of the events located in southern Spain in 1991 vary from 1.0 to 3.5, while those recorded in northern Morocco vary between 2.0 and 3.8. In general the events which occurred in southern Spain have smaller magnitudes than those in northern Morocco. Yet, they are shallower. However, the magnitudes used in this report are still heterogeneous, since some of them are mbLg magnitudes taken from the earthquake data reports of the USGS, while others are MD (duration) magnitudes. An effort is being done to homogenize these magnitudes.

Our results show that the newly installed networks for the study of the Strait of Gibraltar have substantially improved the determination of the hypocentral coordinates by reducing the errors on them, and has equally helped improving the threshold of the detected events. For the events in southern Spain the lowest detected event has a magnitude of 1.0, while for those in northern Morocco the lowest magnitude is 2.0. This is probably due to the higher density of stations in Spain. Therefore, it is imperative to increase the number of seismic stations in northern Morocco.

6. CONCLUSIONS AND SUGGESTIONS

Although the results of this 12-month seismicity study of the Strait of Gibraltar area are not representative of
the long-term seismicity, they, however, confirmed
and revealed a number of important findings. First,
these results confirmed the presence of two seismicity
trends in our study area: a NE-SW alignment of
seismicity in southern Spain and a NW-SE trend in
northern Morocco. While the earthquakes in Spain are
mostly near-surface events, those in Morocco are
probably sub-Moho events. The Strait of Gibraltar itself
did not manifest any seismicity during this period.

Furthermore, our results, obtained using two
networks specifically designed for this project, show
that the determined hypocenters have a better accuracy
and depth control than those determined using the
national networks. Although the threshold of the
detected events has improved, it still remains
unsatisfactory for the Moroccan network. It is therefore
suggested to rearrange the Moroccan network for the
Strait of Gibraltar, and to add two more stations. This
new configuration of the network should provide a
better azimuthal coverage of the area, will help
decrease the threshold of the detected events, and
hopefully allow a better depth control. It is also
suggested to add a three-component digital seismic
station in both Morocco and Spain. Such stations will
make it possible to perform spectral studies of both
local and regional events.
ACKNOWLEDGMENTS:-

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REFERENCES:-


