Vol.5, No.9, 1019-1024 (2013)
http://dx.doi.org/10.4236/ns.2013.59126
Natural Science

Time-seismicity evolution and seismic risk assessment of the Arabian plate

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Received 30 April 2013; revised 30 May 2013; accepted 7 June 2013

ABSTRACT

The seismicity of the Arabian plate, which is the aim of this paper, is controlled by the Zagros-Taurus collision zone in the North, the Indian expansion zone and the Arab golf in the South and the East, the Dead Sea Fault, the North continuity of the Red Sea, and the Syrian rift, which links the rigid Arabian plate to the mobile ophiolite belt of Cyprus-Southern Turkey in the West. These major elements with their related fracture system, make the Arabian plate an important seismic centre. To attain our purpose, a variable methodology is used in: measurements of movement rate-displacement in the field, the analysis of historical and recent seismic data, and physical effects on the structures. The movement rate-displacement, calculated in the field by different specialists, varies from 2 to 6 mm/year. This rate increases from 2 - 3 mm/year in the North, to 6 mm in the South. These estimations are confirmed by historical seismic data, the recent seismic recorded by the Arab seismic centers, and physical effects on the building structures in the region. The analysis of historical and recent seismic data recorded in the seismic centre show that the seismicity in this plate, tend to fade out with time. This result is in agreement with recent estimations on the movement rate, and in line with the decrease of major seismic intensity, which has occurred during the last millennium. A conclusion of time-evolution seismicity is traced, and a seismic zoning map, for the Arabian plate, using movement rate, seismic data, and tectono-geodynamic analysis, is proposed.

Keywords: Arab Plate; Seismicity-Time Evolution; Seismic Risk Map

1. INTRODUCTION

The European and African continents are crossed by several N-S-trending rifts, all together forming major structural features of the whole Earth: From North to South, firstly the Oslo Permian rift (Norway), is continued by the Neogene fracture system of Central-Southern Germany (Eifel, Rhine Graben), then the rift system of French massif Central and Rhone valley, ending finally with the great Africa rift, which is the major structure of the Arab plate.

These major crustal fractures, extending down in the underlying mantle, have been active at different times, repeatedly keeping the same approximate N-S direction [1]. Periods of major activity are marked by extensive volcanism, with a distinct tendency to show younger ages southwards: Permian in Norway, Neogene in Germany, Neogene to sub-actual one in the France, actual (present-day) one in Africa. These ages correspond mainly to the initial stage of rift-forming, whereas more ancient accidents (e.g. Norway) could repeatedly play again, at each phase of crustal extension.

In the Arab plat, the Dead Sea Fault, and the Syrian rift, which links the rigid Arabian plate to the mobile ophiolite belt of Cyprus-Southern Turkey [2,3], play a very important role in the regional geodynamic structure [4,5]. They make, with their related fracture system, this sous-plate an important seismic centre (**Figure 1**). The assessment and time-evolution of seismicity, in this plate, are the subject of this research.

2. GEOTECTONIC AND GEODYNAMIC FRAME

The Arabian plate roughly appears as a polygon, located between the major African plate (including Nubian and Somalian ones), and Eurasiatic and Indian plates, respectively [1]. It is delimitated by the Red Sea in the South-West, the Aden Gulf in the South, and the Zagros and Taurus chains in the North and North-East, respec-

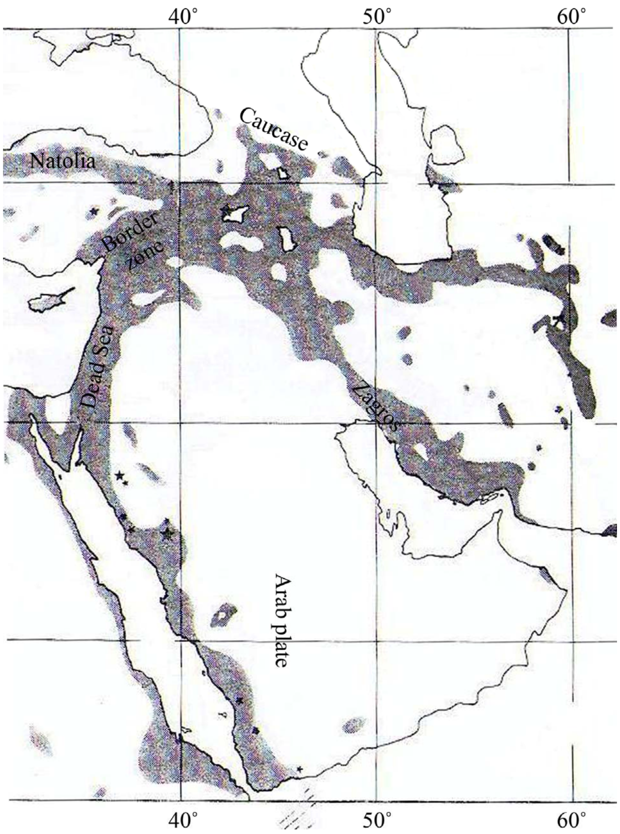

Figure 1. Seismic zone in the Arab plate (Unesco, 1983).

tively (**Figure 2**).

The geophysical investigations confirms the typical continental nature of this plate, with an average crust thickness of 40 Km, which changes, at the level of the Red Sea at 250 KM, to less than 15 Km [6].

The Arabian plate presents three types of active borders:

- Convergent borders: the collision zone of Bitlis-Zagros [7-9], the subduction Makran-Oman between Aurasia-Arabia, and the Anatolian fault at the north-west of the Arabian plate [10].
- Divergent borders: the oceanic rifts (Arabia-Nubia), and the Aden gulf (Arabia-Somalia) [11].
- Transform borders: the senester faults of the Levant (Arabia-Nubia), and the Dexter faults of Owen (Arabia-India), in the West and the East [12].

This plate is marked by the Syrian rift structure, named the Levant fault, corresponding to the northern part of the Dead Sea fault zone (DSFZ), and in continuity with the Red Sea rift zone [13].

3. SEISMICITY PARAMETERS ANALYSIS

The Arabian plate, with its world structure, Dead Sea Fault zone and its South and North extremities, is an attractive subject for the specialists, either their volcanology [14,15], or either, and especially, their seismology [16-21]. Three parameters define the seismicity of the Arab plate: the time-seismicity evolution, the movement rate, and the assessment seismic, which they will be briefly analyzed.

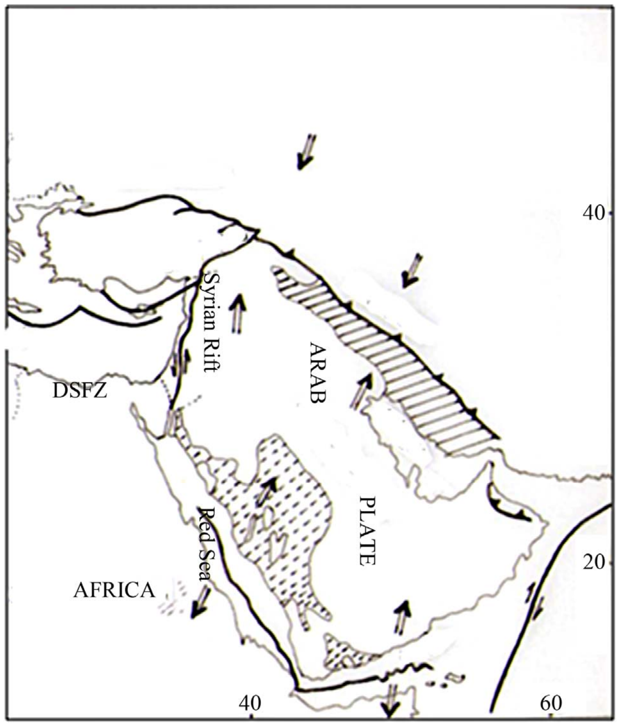

Figure 2. Geotectonic regional of the Arab plate (Bilal, 2005).

3.1. Seismicity-Time Evolution

The repetition of an earthquake (frequency return period of an earthquake in the same locality), namely the seismic cycle is controversial [22,23]. However, if an earthquake is unique for a given locality, the destruction of earthquake activity with time is of major importance.

In order to understand the seismicity-time evolution, an investigation study on the historical, and recent seisms has been executed.

For the historical record of ancient earthquakes, only were used these verified by different sources [24,25]. Available historical data covers a wide period with variable magnitude: Ancient time between 750 and 1800, with magnitude estimated at 7.5 - 6.5 [21], it becomes 6 - 5 between 1800 - 2000 [25-28], less than 5 for the period of 1960 to 2000 and between 4, 9 - 4 at present [18].

For recent seisms, we have collected good data, especially from the physical effects on the structures and the station seismic centers (**Figure 3**). They are distributed in the whole of the countries and in the off shore.

The results are represented by the histogram of **Figure 4**. They show that the seismic intensity tends to decreases with time, in agreement with recent estimates on the

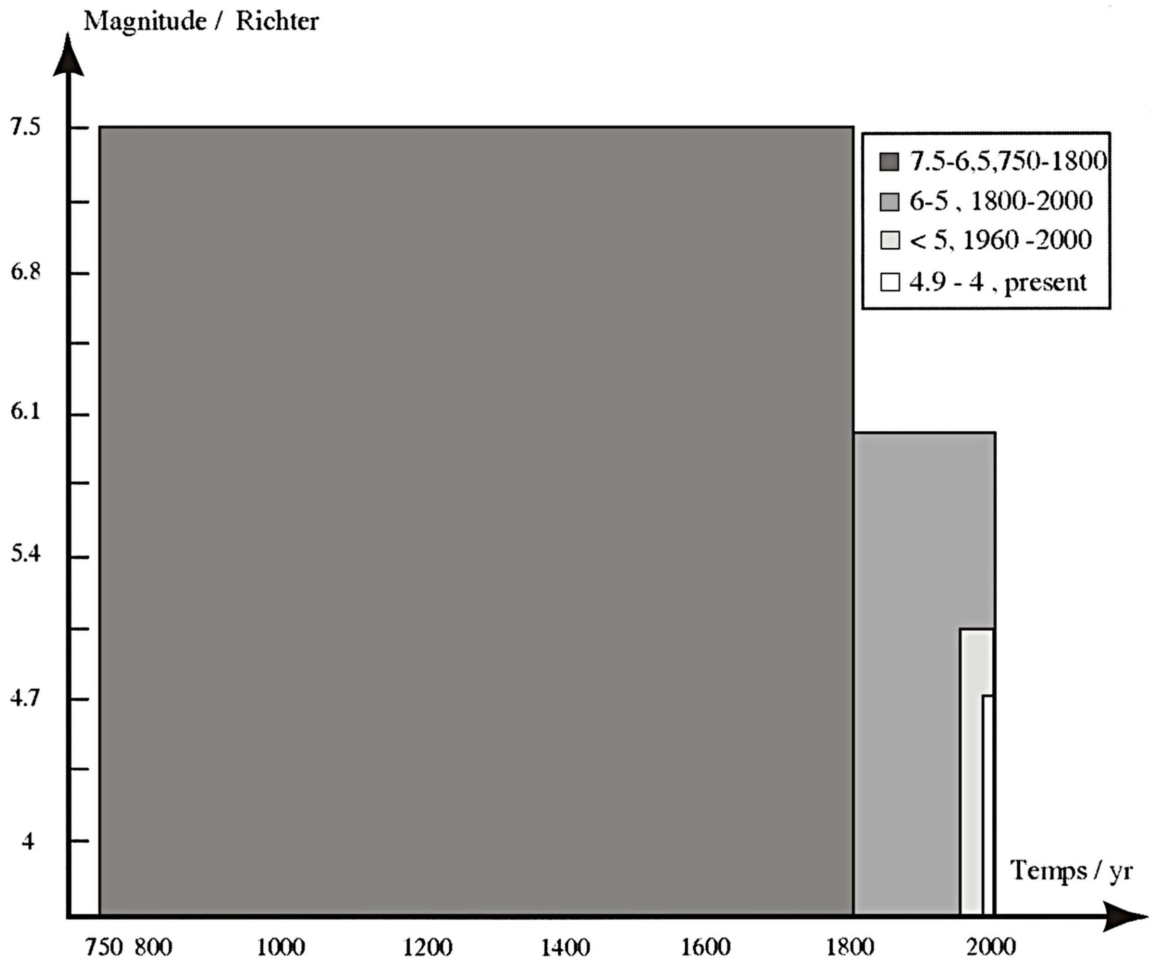

Figure 3. Structure of the Syrian rift and Dead Sea Fault Zone, from the satellite image, Landsat 2005, and epicenters of the seisms in 2005-2006 after the Syrian seismic centre.

movement rate [21].

3.2. Movement Rate-Displacement

The movement rate-displacement calculated by different methods vary from 2 to 6 mm/year: it is 2.7 - 3.3 mm/year along the Syrian rift [16,29], in line with estimates along the Wadi Araba fault, in the northern part of the Levant fault (4.6 +/− 2 mm/year, with a decreasing value of 2.3 mm/year for the last 12 ka [22], and 4.1 - 6 mm/year in different areas along the Arab plate [28,30]. These results are confirmed by physical effects on the building structures in the region (field measurement on houses, measurement by Bilal, 2004). It is accepted that the average value increases from 2 - 3 mm/year, in the North [16,21,29], to 4 - 6 mm/year in the South [30].

3.3. Assessement Seismic Risk—A Seismic Zonation Map

Using data obtained on the movement rate displacement, by deferments sources [16,21,28,29], the seismo-tectonic parameters [6,12,13,26], the historical and recent seismic data recorded by the seismic centers [12,23, 24,26], and the extrapolation of the assessment seismic risk of the northern part of the Arabian plate, established by Bilal (2009a) [16], a seismic zoning map for the Arabian plate is proposed (**Figure 5**). It distinguishes between three seismic zones: zone 1, associated with the active tectonics of the DSFZ, and the collisional and extensional other zones, the highest seismic zone intensity with major damage risk; zone 3, zone of low seismic intensity, which occupies the core of the whole plate, with lowest potential risk, and zone 2, the intermediary zone with intermediary potential risk. These results need to more verification by a qualified team.

4. CONCLUSIONS

The Arab plate includes one of the world structures, the Dead Sea Fault Zone (DSFZ), the continuity of Red Sea in the North, and the Syrian rift to its northern part. Structural analysis using variable techniques attests that

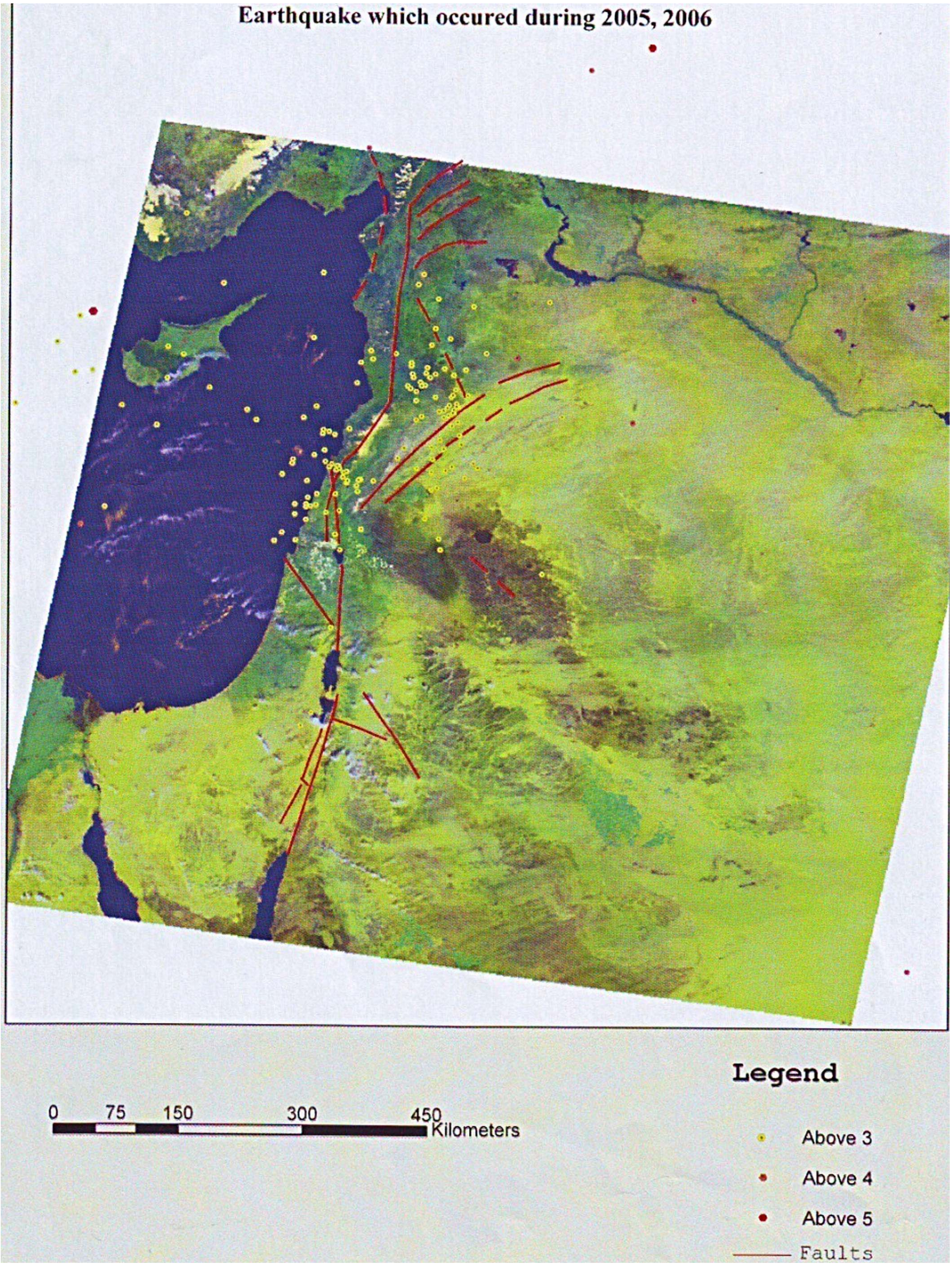

Figure 4. Seismicity-time evolution, after their magnitude and their age.

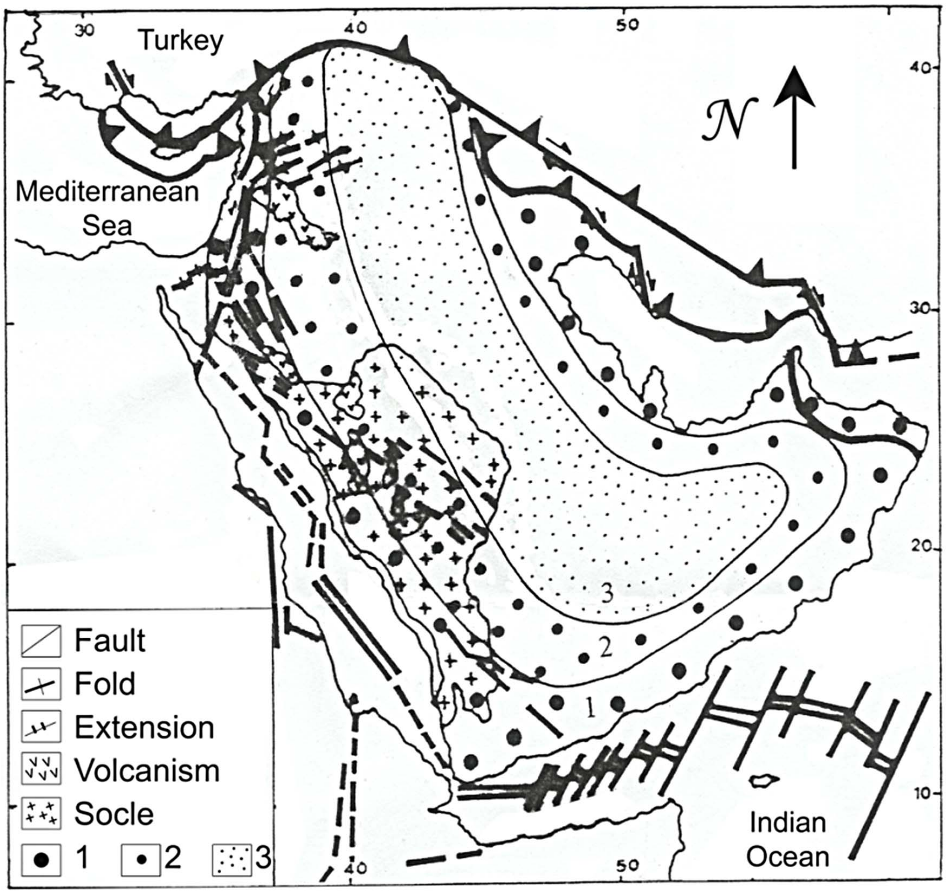

Figure 5. A seismic zoning map of the Arab plate. Zone 1, the highest seismic intensity zone; zone 2, the intermediary one and zone 3, the lowest one.

many faults have been recently or are still active to occurrence along this structure. Most major seisms in the plate occur along this structure.

Historical seismic data and recent seisms recorded in the seismic centre provide information indicating that the seismicity in this plate tends to fade out with time, in line with the decrease of major seismic intensity which has occurred during the last millennium.

A seismic zoning map for the Arab plate, using seismic data, and tectono-geodynamic analysis, is established. It distinguishes three seismic zones. The highest seismic zone intensity is associated with the world structure of the Dead Sea Fault Zone with its two extremities, and the Red Sea and the Syrian rift in the South and the North. The lower seismic intensity zone setting is in the centre of this plate.

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