

ABOUT THE PERIODIC NATURE OF EARTHQUAKES (CASE STUDY ON NORD-EAST MEDITERRANION)

© 2017 г. А. Е. Kazarian, М. К. Mkrtchyan

*Institute of Geological Sciences, National Academy of Sciences of Armenia
375019, 24a, ave. M. Baghramyan, Yerevan, Armenia
E-mail: earthquake@geology.am
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In this article, we present the results of the seismic analysis, including the territory of Armenia, Turkey, Greece and Italy. These results show that each region has its own specific cycles of seismic activity. These cycles have periods of 12 h to 24 h, which shows their connection with tidal processes. The connection between the earthquake focal mechanisms and periodicity of seismic activity has revealed. In territories with earthquakes mainly with deep hypocenter and normal focal mechanism characterized only with 24-hours periods.

1. Introduction

The question is whether seismic activity has a periodic nature discussed by many authors (Schuster, 1897; Tamrazyan, 1967, 1968, 1973; Tsuruoka et al., 1995; Saar and Manga, 2003; Métivier et al., 2009; Ide et al., 2016). Other believes the longstanding paradigm, that earthquakes are chaotic in nature and have no cyclical properties.

In some cases, lunar periodicity of seismic activity is noticeable, in others, a yearly one. However, many questions remain un-researched and unclear, namely: how many periods of active seismicity exist and how they link with focal mechanisms of earthquakes and geodynamic specifications of a specific region? In some regions, an observed connection of strong earthquakes to the full moon leads researchers to believe that the moon, in fact, is playing a major role in triggering earthquakes (eg. Ide et al., 2016). The research behind the mechanisms of this triggering however has not been conclusive. It is also unclear whether the periodic components of seismic activity change with time and space. The study in this matter will help to understand the nature of processes responsible for earthquake generation or triggering. This report focused on daily distribution of earthquakes.

2. Method and data

The periodicity of earthquakes in different regions can be studied by statistically analyzing local instrumental seismic catalogs. Using histograms, we reveal a periodic characteristic of seismic activity for different regions. The results are compared with the known geodynamical specification of the region.

The method is based on the assumption that if seismicity is a stochastic process, then the distribution of the number of earthquakes over daytime should

be uniform. Meaning that the cumulative number of earthquake over 24-hours time interval should remain stable for the whole region.

For the territory of Armenia, earthquakes within a one-hour time zone interval, from 1962 up to 2007 (17833 events), regardless of magnitude, were chosen for this analysis (fig.1, NorAtom, 2011). The time of each earthquake was converted to local time. Daytime was divided into minutes (1440 min), and the number of earthquakes per minute was counted. (fig.2).

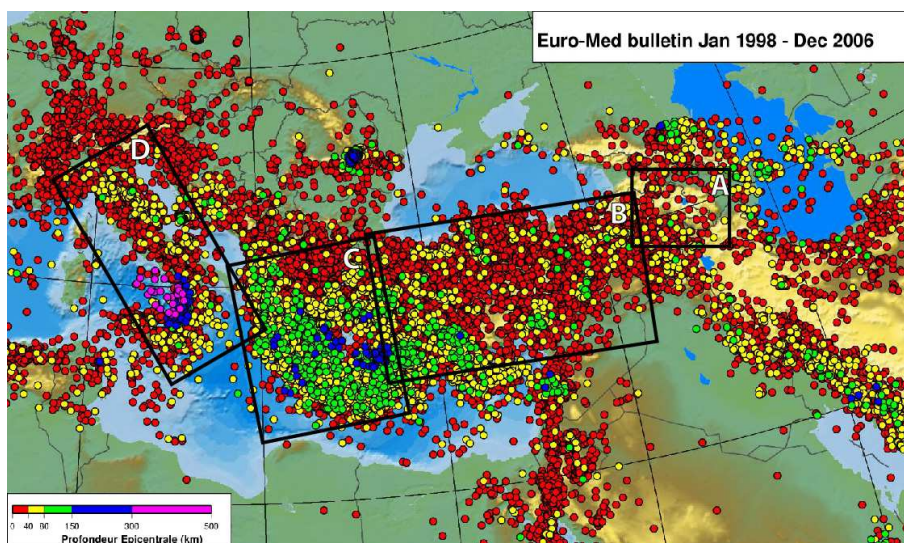


Fig. 1. Map of earthquakes.

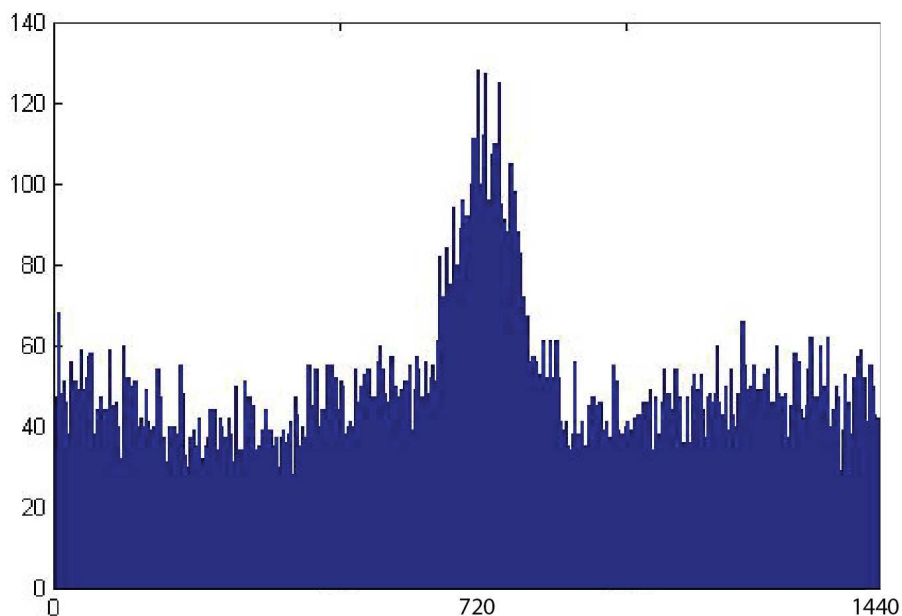


Fig. 2. Earthquakes daily distribution histogram of Armenia from 1962 till 2007.

The results (fig.2) show that the number of earthquakes around noon more than triples: (120 earthquakes versus 35). We also observed more frequent earthquakes around midnight (fig.2 - a, b) (60 versus 35). It is clearly apparent that seismic activity near noon and midnight, compared to the most passive period of the day, is significantly higher. This is a very strong indication that seismic activity of this region has a 12-hour and 24-hour periodicity. The fact that the most active time of day for seismic events is concentrated around midday and midnight leads us to the conclusion that there is a definite relation between earthquakes and earth's rotation.

The same kind of study was conducted on earthquakes in the territory of Turkey (2005 – 2016, 200204 events were recorded spanning over two time zones, <http://www.deprem.gov.tr/en/ddacatalogue>), Greece (1964 – 2015, 233356 events recorded spanning over one-time zone, <http://www.gein.noa.gr/en/seismicity/earthquake-catalogs>) and Italy (2005 – 2016, 173379 events spanning over one-time zone, <http://cnt.rm.ingv.it/en>).

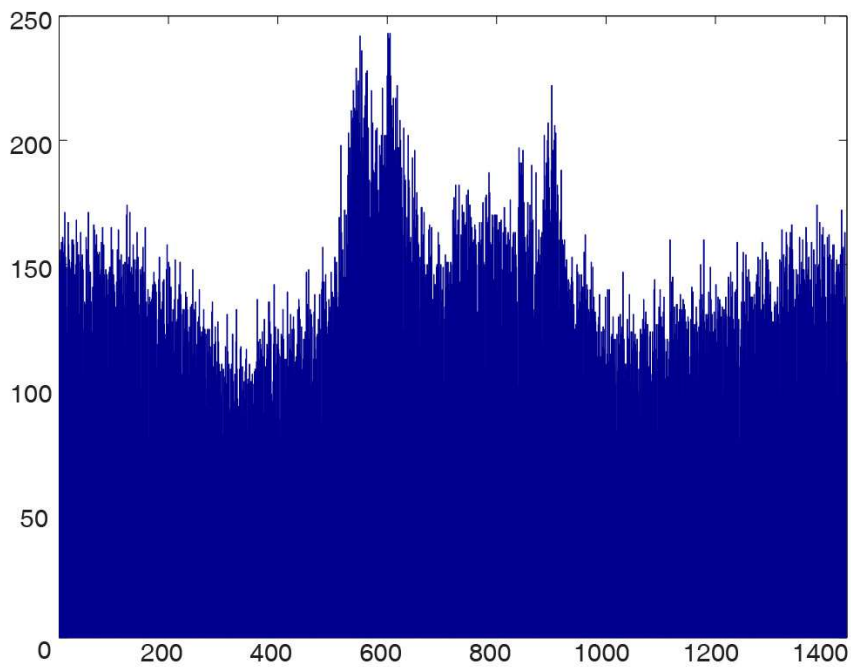


Fig. 3. Histogram of the daily distribution of earthquakes in Turkey from 2005 till 2016.

We can see from presented results that the periodic nature of earthquakes remains true for all mentioned regions. However, the periods are different for each region. This result shows that the periodicity of seismic activity depends on territory. For the territory of Turkey, we observe two peaks of daytime seismic activity. Those peaks are not equal in amplitude but are symmetrical in their distribution around midday, with a two-hour interval: first - the most active time occurring at 10:00 am, 230 versus 100 events, and the second peak

consisting of 200 events per minute versus 100, occurring at 2:00pm. In Turkey, between the midnight seismic activity and the most passive time of the day is 160 earthquakes and 100 earthquakes, respectively.

For Turkey, the skewing of the first peak to the left can partially be due to the territory's spreading over two time zones. However, the observed data shows that seismic activity on the territory of Turkey also has a periodic nature. The presence of more than two peaks during the daytime interval can be observed in fig. 4.

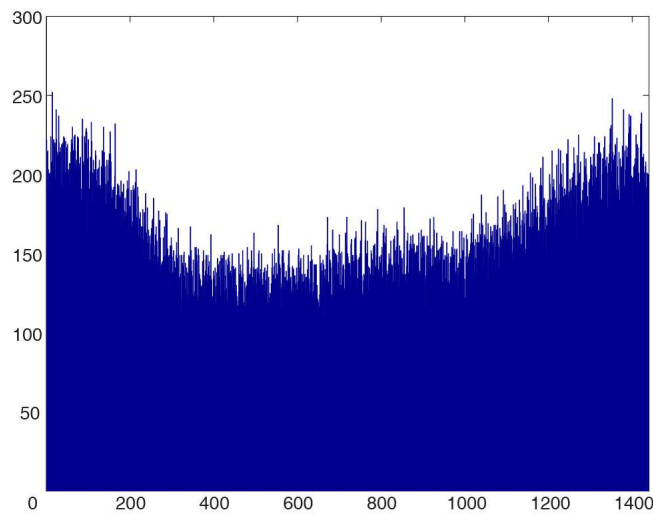


Fig. 4. Histogram of the daily distribution of earthquakes in Greece from 1961 till 2015.

It is interesting that for both catalogs of the territory of Armenia and the territory of Turkey, the main peak of seismic activity is bimodal (Mush effect).

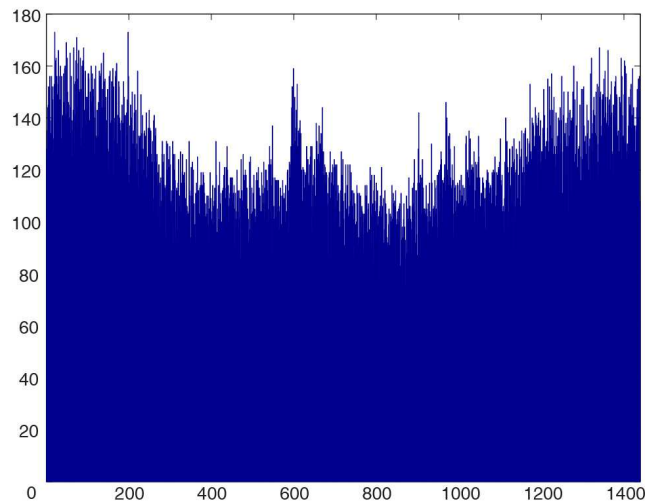


Fig. 5. Histogram of the daily distribution of earthquakes in Italy from 2005 till 2016.

The histogram of daily seismic activity for the territory of Greece shows almost no daytime activity for this region. At midday, the seismic activity here is very passive. It is rather the midnight seismic activity that more than doubles (250 versus 120).

The seismicity on the territory of Italy shows both midday and midnight seismic activity, though the daytime seismic activity has significantly less amplitude and is also slightly skewed to the left. We can also observe the bipolar Mush effect of the midday peak. The midnight activity here is much stronger though, with 170 earthquakes versus 100, at the lowest point.

We have to state that seismic activity on the territory spanning from Armenia to Italy shows strong periodicity for daily seismic activity. These periods depend on territory. It is interesting that all regions have midnight seismic activity over a 24 hours period. This is apparently the most consistent characteristic of the whole region. Daytime seismic activity shows different amplitudes and the distribution is skewed for the different regions.

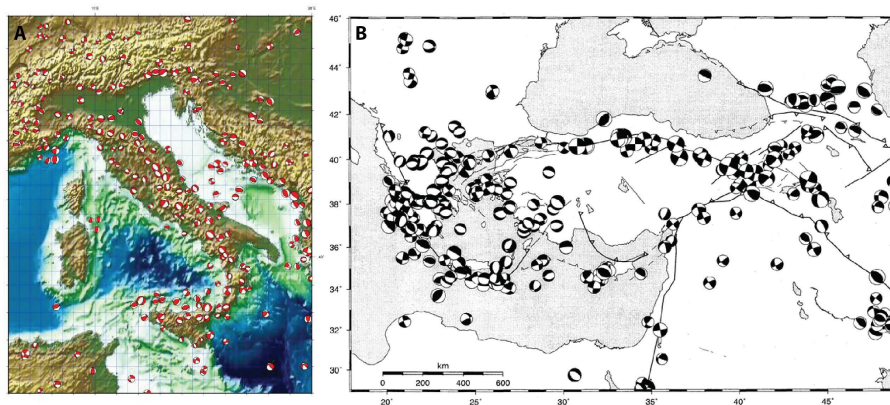


Fig. 6. A - Focal mechanisms (lower hemisphere projection) for shallow (depth of < 50 km) major earthquake. The equivalent focal mechanism plots are scaled with magnitude and located in the barycenter of the epicenters distribution weighted with magnitude (Gasperini report - <http://gaspdy.df.unibo.it/paolo/gndt/pq2000/SyntheticReport.htm>). B - Focal mechanisms (lower hemisphere projection) for shallow (depth of < 100 km) major earthquake ($M > 5.0$) in the eastern Mediterranean region (McClusky et al., 2000).

The study of focal mechanisms of earthquakes for our studied territory described in (McClusky et al., 2000 and in the report of Gasperini). This study shows that a significant majority of strong earthquakes on the territory of Greece is dominated by the normal type of "beachball plot" points, as opposed to Turkey and Armenia, which are dominated by Strike-slip "beachball plot" points (fig.5). The map of earthquakes also reveals that the earthquakes in Greece have more profound hypocenters (fig.6).

3. Discussion and conclusion

We can see that the daily distributions of earthquake activities in different

regions show strong evidence of 12 and 24-hour cycles. This periodicity is also observable when studying tides and therefore connected to the changes of the positions of the Sun and Moon throughout the day.

We can deduce from this research that:

1. There is a strong connection between the tidal forces and the predominant focal mechanism of the local earthquakes.
2. The depth of most earthquakes is connected to the tidal forces.
3. The seismic activity of Greece is deeper underground, which correlates with the 24-hour nature of its earthquake periodicity.

In other words, the forces responsible for earthquake generation are periodic by nature and related to those responsible for generating tides.

Our conclusion is that tidal forces most likely play a critical role in the earthquake generation process. They are seemingly in control of the geodynamic specifications of each separate region, including the focal mechanism of earthquakes and the overall depth of the dominant geodynamical processes of each region.

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Reviewer A. Karakhanian

**ԵՐԿՐԱՇԱՐԺԵՐԻ ՊԱՐԲԵՐԱԿԱՆՈՒԹՅԱՆ ԲՆՈՒՅԹԻ
ՎԵՐԱԲԵՐՅԱԼ
(Միջերկրական ծովի հյուսիս-արևելյան հատվածի օրինակով)**

Ա. Է. Ղազարյան, Մ. Կ. Մկրտչյան

Ամփոփում

Հոդվածում ներկայացված են Հայաստանի, Թուրքիայի, Հունաստանի և Իտալիայի սեյսմիկ տվյալների անալիզի արդյունքները, որոնք ցույց են տալիս, որ ամեն տարածք ունի իր առանձնահատուկ սեյսմիկ ակտիվացման ցիկլը: Այդ ցիկլերն ունեն 12 ժամ և 24 ժամ պարբերականություն, ինչը ցույց է տալիս նրանց կապը մակրնթացության պրոցեսների հետ: Բացահայտվել է երկրաշարժերի ֆոկալ մեխանիզմների և սեյսմիկ ակտիվացման պարբերականության կապը: Այն տարածքները, որոնք բնութագրվում են հիպոկենտրոնների համեմատաբար խորը տեղադրմամբ և ունեն նորմալ ֆոկալ մեխանիզմ, բնութագրվում են միայն 24 ժամյա սեյսմիկ ակտիվության պարբերականությամբ: Կապ է հաստատվում ռեգիոնալ երկրադինամիկայի առանձնահատկությունների և մակրնթացության ուժերի միջև:

**О ПЕРИОДИЧНОЙ ПРИРОДЕ ЗЕМЛЯТРАСЕНИЙ
(на примере северо-восточного Средиземноморья)**

А. Э. Казарян, М. К. Мкртчян

Резюме

В статье представлены результаты анализа сейсмичности, включающие территорию Армении, Турции, Греции и Италии показывающие, что каждый регион имеет свои специфические циклы сейсмической активизации. Эти циклы имеют периоды 12ч и 24ч, что показывает их связь с приливными процессами. Обнаружена связь между фокальными механизмами землетрясений и периодичностью сейсмической активности. Районы с землетрясениями имеющими преимущественно глубокое залегание гипоцентров с нормальным фокальным механизмом характеризуются 24 часовым периодом сейсмической активизации. Выявляется связь между геодинамической спецификой и характером приливных сил.