A New Catalogue of Eastern Mediterranean Earthquakes, 2150 BC – 2011

Z.Çağnan
Middle East Technical University Northern Cyprus Campus, Turkey

D.Kalafat
Kandilli Observatory and Earthquake Research Institute, Bogazici University, Turkey

SUMMARY:
Within the scope of this study, a homogenous earthquake catalogue for the region bounded by 28°-38°E Longitude and 33°-38°N Latitude was developed. The catalogue spans the time period of -2150 BC - 2011 and the magnitude range of 4.0-7.6. With a total of 2581 events, it corresponds to the most complete catalogue that was developed up to now for the region of Eastern Mediterranean. As part of the magnitude homogenization efforts, several previously suggested local and global empirical magnitude conversion relations were assessed statistically for their applicability to the developed catalogue. The catalogue was also cleaned from fore and aftershocks based on the Reasenberg, 1985 and Gardner and Knopoff, 1974 methods. Applicability of these methods to the region of interest was discussed. Results indicate that the developed catalogue of 2283 mainshocks is complete and Poissonian for the period 1965-2011 and Mw >4.0.

Keywords: Mediterranean Region, Earthquake Catalogue, Magnitude Scaling Relationship

1. INTRODUCTION - CATALOGUE DEVELOPMENT

Within the scope of this study, a homogenous and reliable earthquake catalogue for the region bounded by 28°-38°E Longitude and 33°-38°N Latitude was developed. The catalogue spans the time period of -2150 BC - 2011 and the magnitude range of 4.0-7.6. This catalogue was developed as part of the project titled Seismic Hazard Assessment for Cyprus and Neighboring Regions financed by the Scientific and Technological Research Council of Turkey (TUBITAK) for the period 2010-2013. This project aims to develop the first strong motion network for the Northern part of Eastern Mediterranean island Cyprus and conduct seismic hazard for the region of interest reliably through a complete and accurate catalogue as well as newly developed synthetic regional attenuation relationships. As the main objective of this project is to assess the seismic hazard for the island Cyprus and neighboring regions, we limited the geographic boundaries of the catalogue such that all seismic sources in the region of interest are covered. Due to this main project objective, for the post-1900 part of the catalogue a magnitude lower limit value of M_w=4 (Moment magnitude of 4) and for the pre-1900 part an intensity lower limit value of I=5 (MSK intensity of 5) were adopted. In the catalogue development phase, several international and regional observatory databases and related literature was searched thoroughly. The list of the sources searched is as the following:

- United States Geological Survey (USGS), Preliminary Determination of Earthquakes Database - PDE
- USGS, National Earthquake Information Service Database - NEIS
- USGS, Advance National Seismic System Catalogue - ANSS
- United States National Oceanic and Atmospheric Administration Seismicity Catalogue and Significant Earthquakes Database - NOAA
- Bulletins of International Seismological Summary, 1918-1963 - ISS

- Bulletins of International Seismological Center, United Kingdom, 1964-present - ISC
- Global Centeroid Moment Tensor Database - GCMT
- European-Mediterranean Seismological Center Database - EMSC
- Kandilli Observatory and Earthquake Research Center Database - ISK
- Scientific and Technological Research Council of Turkey Marmara Research Center Catalogue - TUBITAK
- Geophysical Institute of Israel Earthquake Catalogue - GII
- National Observatory of Athens Earthquake Catalogue - ATH
- Bulletins of Geological Survey Department, Cyprus - CSS
- Istituto Nazionale di Geofisica e Vulcanologia European Mediterranean Regional Centeroid Moment Tensors Database - INGV
- Swiss Seismological Center Moment Tensor Catalogue - ETH
- Ambraseys (1992), Ambraseys and Adams (1992), Ambraseys and Jackson (1998), Ambraseys (2009), Ambraseys (1965), Ambraseys (2001), Barka and Reilinger (1997), Ergunay and Yurdatapan (1973), Galanopoulos and Delibasis (1965), Hofstetter et al. (2007), Kalafat et al. (2007), Kiratzi and Louvari (2003), Khair et al. (2000), Papazachos et al. (2002), Papazachos et al. (1997), Papazachos et al (1991), Papadimitriou and Karakostas (2006), Papazachos et al. (2000), Papazachos and Papaioannou (1999), Pinar and Kalafat (1999), Pilidou et al. (2004), Pondrelli et al. (2002), Rotstein and Kafka (1982), Roumelioti et al. (2009), Sbeinati et al. (2005).

This search resulted in an earthquake catalogue of 17,870 entries, however including double entries, and entries with corresponding magnitude values less than 4.0 and intensity values less than 5. This catalogue includes parameters such as event date, time, epicentral location, depth, magnitude (moment magnitude-M_w, surface wave magnitude-M_s, body wave magnitude-M_b, duration magnitude-M_d and local magnitude-M_L), epicentral intensity, focal mechanism etc. as well as original sources from which these parameters were obtained. In the second phase of the study, these entries were combined based on the prioritization scheme illustrated in Table 1 resulting into a catalogue of 11,470 earthquakes without double entries. The prioritization scheme of Table 1 was developed based on our opinion of reliability level of different sources regarding the computation of listed parameters. For example, we believe that the M_d parameters computed by ISK are the most reliable. If for certain earthquake entries ISK based M_d values are not available, then ATH database is searched to fill these values. If such are not available either, then the CSS database is searched for corresponding M_d values.

Table 1. The priority scheme used in combining data from different sources

Priority	EQ Date-Time	Epicenter Location	Depth (km)	M_w	M_s	M_b	M_d	M_L	Fault Solution
1	ISC	ISC	ISC	GCMT	ISC	ISC	ISK	ISK	GCMT
2	NEIS	NEIS	NEIS	Lit.	NEIS	NEIS	ATH	ATH	Lit.
3	NOAA	NOAA	NOAA	ETHZ	NOAA	NOAA	CSS	GII	ETHZ
4	ISK	ISK	ISK	INGV	ISK	GII			INGV
5	ATH	ATH	ATH	ISK	ATH				ISK
6	GII	GII	GII						
7	PDE	PDE	PDE						
8	CSS	CSS	CSS						

Magnitude homogenization and foreshock-aftershock cleaning were then applied to this catalogue of 11,470 entries. With the completion of these phases of the study a final catalogue of 2283 mainshocks was then obtained. Below the magnitude homogenization and foreshock-aftershock cleaning phases are presented in detail. The characteristics of seismic activity of Eastern Mediterranean region are discussed in this article as well through the developed catalogue.

1.1. Magnitude Homogenization

The sources listed above report earthquake magnitudes in different scales; sometimes in multiple magnitude scales. In this study, we chose M_w as the unifying magnitude scale so that each entry in the catalogue has a corresponding M_w value. The M_w scale was chosen in order to prevent saturation related inaccuracies and also to match the magnitude scale employed by almost all recently developed ground motion attenuation relationships. Only 188 out of 11,470 earthquake entries had corresponding M_w values computed as part of moment tensor solutions. For the rest, M_w values had to be obtained by using empirical magnitude conversion equations. It is possible to find many global or regional magnitude conversion equations in the literature. Our initial strategy was to test these reliable, up to date global and local relations for applicability to the catalogue data. We had 115, 128, 105 and 95 magnitude pairs for M_w-M_s, M_w-M_b, M_w-M_d and M_w-M_L comparisons, respectively. The empirical equations employed in the applicability or goodness of fit tests are listed in Table 2 along with some of their important characteristics. Three different methods were used in the assessment of applicability or goodness of fit of these empirical relations to the catalogue developed:

(1) Trend analysis on distribution of residuals (between observed and computed values) with magnitude (Ang and Tang, 2007). In the trend analysis, the assumed null hypothesis H_o was that slope of the relationship between the residuals and the magnitude is zero. The assumed alternative hypothesis H_1 was that slope has a non-zero value. The level of significance value used in this analysis was 5%. Hence, the p values exceeding 5% in this analysis implies no significant relationship between the residuals and the magnitude.

(2) Comparison of frequency distribution of normalized residuals with standard normal distribution. Normalized residuals following standard normal distribution closely implies suitability of the magnitude conversion equation to the catalogue of interest.

(3) Analysis of variance (ANOVA) (Ang and Tang, 2007). In ANOVA, the assumed null hypothesis H_o was that slope of the relationship between the residuals and the magnitude is zero again. The assumed alternative hypothesis H_1 was that slope has a non-zero value. When the obtained F value exceeds the assumed level of significance value of 5%, this implies that null hypothesis is incorrect.

In all of these three methods, magnitude limitations of the empirical relations given in Table 2 were respected. Also while carrying out these analyses; we paid attention to the agreement between distribution of sources in the representative magnitude pairs (i.e. sources of M_s values in M_w-M_s pairs used) and distribution of overall sources in the catalogue corresponding to that particular magnitude scale (i.e. sources of M_s values in the catalogue). Only the results obtained from ANOVA will be presented here in Table 3 due to space limitations. In the light of these analyses, we reached the conclusion that M_w-M_s relation of Akkar et al. (2010), Scordilis et al. (2004), Ulusay (2004), Ekstrom and Dziewonski (1988); M_w-M_b relation of Johnston (1996) and M_w-M_L relation of Akkar et al. (2010) are suitable to the region of interest. Please note that although four M_w-M_s relationships were found suitable for the region of interest, only single M_w-M_b and M_w-M_L relationships were found acceptable and none M_w-M_d relation was found acceptable. We attribute this finding to the fact that M_d and M_L scales are local scales and are affected even by the calibration of instruments for the records which are used in magnitude computations (Papazachos et al., 1997, Margaris and Papazachos, 1999). The poorer correlation between M_b and M_w in comparison to that of M_s and M_w had been documented by other researchers as well (Akkar et al., 2010 and Scordilis et al., 2004). This behavior can be explained by the variability of M_b scale with the faulting mechanism of the events. As no M_w-M_d relation was found satisfactory for the region of interest, we developed an empirical relationship ourselves based on the 105 M-M_d pairs available (Figure 1). In our dataset M_d values are mainly computed by ISK. However Akkar et al. (2010) and Ulusay (2004) relations are based on data from Directorate of

Disaster Affairs, Turkey. In case of Baba et al. (2000) relation on the other hand, M_w is first related to M_L for Greece and then an empirical equation was suggested for M_L-M_d conversions. In this case M_d values were those computed by ISK. In case of Akkar et al. (2010) and Ulusay (2004), the poor goodness of fit can be attributed to different data source than employed in this study. In case of Baba et al. (2000), the poor goodness of fit can be attributed to not having a single equation to connect M_d to M_w.

Based on the analyses carried out, we used first the Scordilis (2006) relation to convert M_s values to M_w values. For other catalogue entries for which M_s values are not available, the Johnston (1996) relation was used to convert M_b values to M_w. For catalogue entries with M_L and M_d values only, the Akkar et al. (2010) relation was preferred to convert M_L values to M_w values. The reason for giving priority to M_L values over M_d values was the lower variability of M_L - M_w conversion relation in comparison to M_d - M_w conversion relation used in this study. For the pre-1900 part of the catalogue, intensity- M_w conversion relation of Ambraseys (2001) was used to obtain corresponding M_w values. Similar statistical analyses could not be applied to test goodness of fit of various intensity - M_w conversion relations as number of intensity - magnitude pairs in the catalogue are very limited. Hence Ambraseys (2001) relation was decided to be used which is based on regional data. Once the magnitude conversions were completed, the magnitude limitations mentioned in the previous section were applied and a final catalogue with 2581 entries was obtained.

Table 2. Empirical magnitude conversion equations used in the goodness of fit analysis

Study	Data Source	Conversion Type	Lower Limit	Upper Limit
Akkar et al. (2010)	Turkey	M_w-M_s M_w-M_b M_w-M_d M_w-M_L	3.0 3.5 3.9 3.7	7.7 6.3 6.8 6.0
Kalafat et al. (2007)	Turkey	M_w-M_b	4.2	6.5
Ulusay (2004)	Turkey	M_w-M_s M_w-M_b M_w-M_d M_w-M_L	4.0 4.0 4.5 4.0	8.0 6.5 7.5 7.5
Baba et al. (2000)	Turkey	M_w-M_d	3.5	6.0
Scordilis (2006)	Global	M_w-M_s M_w-M_b	3.0 3.5	8.2 6.2
Johnston (1996)	Stable Continental Regions	M_w-M_s M_w-M_b M_w-M_d	3.5 4.0 4.5	7.2 6.5 7.5
Ekstrom and Dziewonski (1998)	Global	M_w-M_s	4.0	7.5
Ambraseys (2001)	Middle East and Mediterranean Region	M_w-M_s	3.5	7.5
Grunthal and Wahlstrom (2003)	Central, Northern and Northwestern Europe	M_w-M_d	1.0	7.0
Bungum et al. (2003)	Southern Europe	M_w-M_s	3.0	7.5

Table 3. ANOVA tables for (a) M_w -M_s relation, (b) M_w -M_b relation, (c) M_w -M_d relation, (d) M_w -M_L relation of Akkar et al. (2010), (e) M_w -M_s relation, (f) M_w -M_b relation, (g) M_w -M_d relation, (h) M_w -M_L relation of Ulusay (2004), (i) M_w -M_s relation, (j) M_w -M_b relation of Scordilis et al. (2004), (k) M_w -M_s relation, (l) M_w -M_b relation, (m) M_w -M_L relation of Johnston (1996), (n) M_w -M_b relation of Kalafat (2007), (o) M_w -M_s relation of Ekstrom and Dziewonski (1988), (p) M_w -M_s relation of Ambraseys (2001), (r) M_w -M_s relation of Bungum et al. (2003), (s) M_w -M_L relation of Grunthal and Wahlstrom (2003) and M_w -M_d relation of Baba et al. (2000). Small F values are indicative of insignificant gradient in the fitted relationships hence absence of any bias.

(a)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.077	0.077	1.009
Error	112	8.523	0.076	
Total	113	8.600		

(b)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	1.162	1.162	12.603
Error	126	11.622	0.092	
Total	127	12.785		

(c)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	1.646	1.646	18.70
Error	104	9.158	0.088	
Total	105	10.805		

(d)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.243	0.244	1.930
Error	92	11.628	0.126	
Total	93	11.872		

(e)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.075	0.075	1.026
Error	75	5.449	0.072	
Total	76	5.523		

(f)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	2.674	2.674	28.412
Error	122	11.482	0.094	
Total	123	14.156		

(g)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.134	0.134	1.680
Error	68	5.418	0.080	
Total	69	5.552		

(h)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.0996	0.099	0.788
Error	92	11.628	0.126	
Total	93	11.728		

(i)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.017	0.017	0.244
Error	112	7.991	0.071	
Total	113	8.008		

(j)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.0964	0.096	1.046
Error	126	11.623	0.092	
Total	127	11.719		

(k)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.548	0.548	6.952
Error	99	7.804	0.079	
Total	100	8.352		

(l)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.0254	0.025	0.2681
Error	120	11.387	0.095	
Total	121	11.412		

(m)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.5366	0.5366	5.377
Error	67	6.6856	0.0998	
Total	68	7.2224		

(n)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.0016	0.0016	0.0210
Error	111	8.6896	0.0783	
Total	112	8.6911		

(o)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.0400	0.0400	0.551
Error	75	5.4488	0.0726	
Total	76	5.4888		

(p)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.0027	0.0027	0.040
Error	98	6.5799	0.0671	
Total	99	6.5826		

(r)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	1.646	1.646	18.70
Error	104	9.158	0.088	
Total	105	10.805		

(s)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	0.243	0.244	1.930
Error	92	11.628	0.126	
Total	93	11.872		

(t)

Source	Degree of freedom	Sum of Squares	Mean Square	F
Regression	1	1.0194	1.0194	11.45
Error	98	8.7281	0.0891	
Total	99	9.7473		

1.2. Identification of Mainshocks

As the primary aim for developing this catalogue was to later use it in regional seismic hazard assessment, separation of aftershocks, foreshocks and mainshocks from each other was an important step of this study. This separation is necessary because of the independent event arrival assumption behind the method used for seismic hazard assessment. It is possible to find several techniques in the literature for identification of aftershocks and foreshocks (i.e. Reasenberg, 1985 and Gardner and Knopoff, 1974). In this study, both techniques of Reasenberg (1985) and Gardner and Knopoff (1974) were applied to the earthquake catalogue developed and then results evaluated manually as well for each catalogue entry. Based on manual checks, we reached the conclusion that although the Reasenberg (1985) method yields acceptable results for the region of interest with default parameter values, Gardner and Knopoff (1974) method is not applicable with its default parameters for the Eastern Mediterranean region. A total of 298 out of 2581 earthquakes were identified as foreshocks and aftershocks in this study.

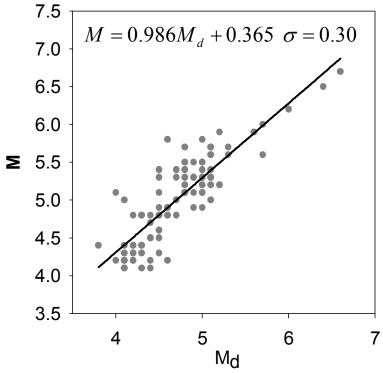

Figure 1. M_w-M_d relationship developed based on the data in the catalogue.

2. SEISMICITY OF EASTERN MEDITERRANEAN

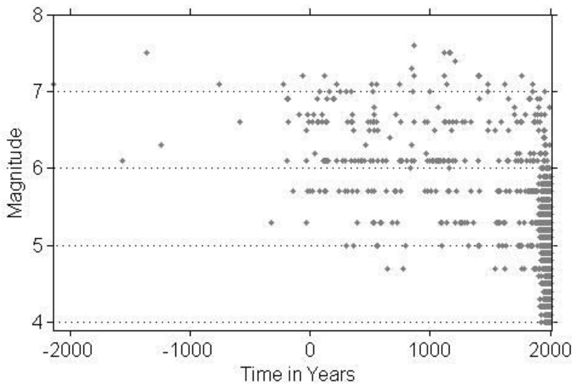

Figure 2. M_w distribution of earthquakes in the catalogue with time.

The magnitude against time distribution of the catalogue is shown in Figure 2. This figure illustrates that M_w<4.5 earthquakes are started to be detected in the region since only 1960s. The distribution of M_w>6.5 events appear to be uniform since 0 year, with a return period of approximately 100 years for earthquakes of M_w>7.0. With Figure 3 that illustrates number of earthquakes with moment magnitudes exceeding 4.0, 5.0, 6.0 and 7.0 vs. time, completeness periods for the catalogue were assessed. Results indicate that for events with M_w>4.0 the catalogue is complete up to 1960. The associated event rate for this period is 43 per year. For events with M>5.0 the catalogue is complete up to 1920. For the period of 1920-2011 and magnitude lower limit of 5.0, the event rate is approximately 5 per year. The catalogue developed is complete for the M_w>6.0 events until 1840 and M_w>7.0 events until 0 years. This final result can also be observed in the moment magnitude vs. time plot of whole catalogue given in Figure 2. For M_w>6.0 and M_w>7.0 events the annual rates are expectedly very low, with values of 0.3 and 0.02, respectively. For the period of 1960-2011 (for which the catalogue is complete and Poissonian), the b-value obtained in this study with the maximum likelihood method is 0.56±0.01 that is applicable the whole region of interest. This value is comparatively high in comparison to b values computed for neighbouring regions such as Turkey, Iran and Greece by other studies (Ambrasseys, 2001; Kalafat, 2010) suggesting that ratio of number of M_w>7 to M_w>4 earthquakes for the Eastern Mediterranean region is comparatively high.

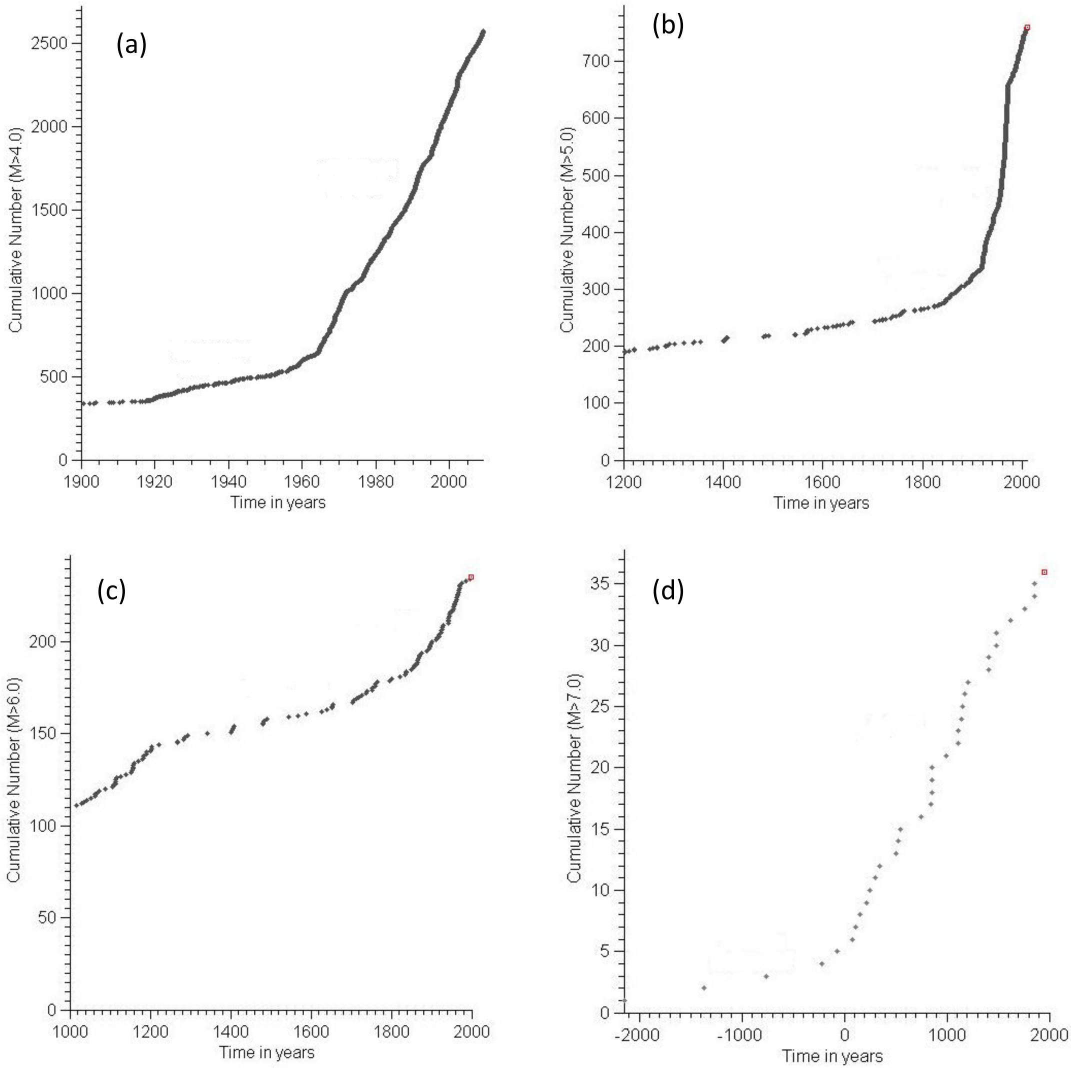

Figure 3. Number of earthquakes with moment magnitudes exceeding (a) 4.0, (b) 5.0, (c) 6.0, (d) 7.0 vs. time.

When the geographic distribution of the post-1900 shallow earthquakes in the region is studied, it can be seen that the level of seismic activity is highest at the northwestern part of the region as a result of the Hellenic Arc. The activity of Cyprus Arc decreases as we move from west (outside Paphos) towards east (outside Famagusta) and the eastern arm of the Cyprus Arc is rather silent until it joins the East Anatolian and Dead Sea faults at the Maras triple junction. The level of seismic activity of Dead Sea fault zone can be observed to be rather low in this century. The distribution of the post-1900 deep earthquakes in the region is consistent with the distribution of shallow earthquakes, except that deep earthquakes are meagre at the Dead Sea fault zone. The develop catalogue is in support of the existence of a subduction zone below the Mediterranean island of Cyprus and the fact that seismicity of the dead sea fault zone is periodic.

3. CONCLUSIONS

Within the scope of this study, a homogenous and reliable earthquake catalogue for the region bounded by 28°-38°E Longitude and 33°-38°N Latitude was developed. The catalogue spans the time period of -2150 BC - 2011 and the magnitude range of 4.0-7.6. With a total of 2581 events, it corresponds to the most complete catalogue that was developed up to now for the region of Eastern Mediterranean. The catalogue includes parameters such as event date, time, epicentral location, depth, magnitude (moment magnitude-M_w, surface wave magnitude-M_s, body wave magnitude-M_b, duration magnitude-M_d and local magnitude-M_L), epicentral intensity, focal mechanism etc. as well as original sources from which these parameters were obtained. Magnitude homogenization was applied to the catalogue through use of M_s-M_w Scordilis (2006), M_b-M_w Johnston (1996), M_L-M_w Akkar et al. (2010) magnitude conversion relationships as well as the M_d-M_w relationship developed within the scope of this study. For identification of these specific magnitude conversion relationships, a detailed statistical analysis was carried out. Within the scope of this study, mainshock entries were also separated from aftershock and foreshock entries of the catalogue. For this purpose, the Reasenberg (1985) and the Gardner and Knopoff (1974) methods as well as a manual check was applied. Results indicate that although the Reasenberg (1985) method can identify mainshocks in the region, the Gardner and Knopoff (1974) method is deficient when used with default parameters for the region of interest. Our results indicate that the developed catalogue of 2283 mainshocks is complete and Poissonian for the period 1965-2011 and Mw >4.0.

AKCNOWLEDGEMENT

This research is funded by the Scientific and Technical Research Council of Turkey with award No. 109Y346. The authors express their sincere gratitude for this grant.

REFERENCES

Akkar, S., Çağnan, Z., Yenier E., Erdogan, O., Sandikkaya, A. and Gulkan, P. (2010). Re-complied Turkish strong motion database and its preliminary exploration in terms of various seismological parameters. *Journal of Seismology*. **14:3**, 457-479.

Ambraseys, N.N. (1965). The seismic history of Cyprus. *Revenue Union Intern*. Secours, Geneva, **3**, 25-48.

Ambraseys, N.N. (1992). Reappraisal of the seismicity in Cyprus (1894-1991). *Boll. Geofis. Teor. Eds. Appl.* **34**, 41-80.

Ambraseys, N.N. (2001). Reassessment of earthquakes, 1900-1999, in the Eastern Mediterranean and the Middle East. *Geophys. J. Int.* **145**, 471-485.

Ambraseys, N.N. (2009). Reassessment of Earthquakes 1900-1999 in the Eastern Mediterranean and the Middle East, Cambridge University Press, 968 p.

Ambraseys, N.N. and J.A. Jackson (1998). Faulting associated with historical and recent earthquakes in the Eastern Mediterranean region. *Geophysics Journal*. **133**, 390-406.

Ambraseys, N.N. and R.D. Adams (1992). Seismicity of the Cyprus region. Imperial College, ESEE Research Report 92-9, London, 47-67.

Ang, A. and Tang, W. (2007). Probability Concepts in Engineering: Emphasis on Applications to Civil and Environmental Engineering, Wiley, 420 p.

Baba, A.B., Papadimitriou, E.E., Papazachos, B.C., Papaioannou, C.A. and Karakostas, B.G. (2000). Unified local magnitude scale for earthquakes of southern Balkan area. *Pure Appl. Geophys.* **157**, 765-783.

Bungum, H., Lindholm, C.D. and Dahle, A. (2003). Long period ground – motions for large European earthquakes, 1905-1992, and comparisons with stochastic predictions. *Journal of Seismology*. **7**, 377-396.

Ekstrom, G. and Dziewonski, A.M. (1988). Evidence of bias in estimations of earthquake size. *Nature*. **332**, 319-323.

Ergunay, O. and Yurdatapan, O. (1973). Sismisite çalışmaları ve Kıbrıs'ın sismisitesi hakkında bir inceleme, Bayındırlık ve İskan Bakanlığı Deprem Araştırma Dairesi, Ankara (Basılmamış).

Galanopoulos, A. and Delibasis, N. (1965). The seismic activity in the Cyprus area. *Prakt Akad Athenon*. **40**, 387–405.

Gardner, J.K. and Knopoff, L. (1974). Is the sequence of earthquakes in Southern California with aftershocks removed Poissonian?. *Bull. Seism. Soc. Am*. **64**, 1363-1367.

Grunthal, G. and Wahlstrom, R. (2003). An Mw based earthquake catalogue for Central, Northern and Northwestern Europe using a hierarchy of magnitude conversions. *Journal of Seismology*. **7**, 507-531.

Hofstetter, R., Klinger, Y., Amrat, A.Q., Rivera, L. and Dorbath, L. (2007). Stress tensor and focal mechanisms along the Dead Sea fault and related structural elements based on seismological data. *Tectonophysics*. **429**, 165-181.

Johnston, A.C. (1996). Seismic moment assessment of earthquakes in stable continental regions-I. Instrumental Seismicity. *Geophys. J. Int.* **124**, 318-414.

Kalafat, D. (2010). Statistical evaluation of Turkey earthquake catalogue: case study, Boğaziçi Üniversitesi Yayınları.

Kalafat, D., Güneş, Y., Kara, M., Deniz, P., Kekovalı, K., Kuleli, S., Gülen, L., Yılmazer, M. and Özel, N. (2007). Bütünleştirilmiş Homojen Türkiye Deprem Kataloğu (1900-2005, M≥4.0), Boğaziçi Üniversitesi Yayınları.

Khair, K., Karakaisis, G.F. and Papadimitriou, E.E. (2000). The seismic zonation of the Dead Sea transform fault area. *Annali Di Geofisica*. **43: 1**.

Kiratzi, A. and Lovari, E. (2003). Focal mechanisms of shallow earthquakes in the Aegean Sea and the surrounding lands determined by waveform modeling: a new database. *Journal of Geodynamics*. **36**, 251-274.

Margaris, V. and Papazachos, C.B. (1999). Moment magnitude relations based on strong motion records in Greece and surrounding area. *Bull. Seism. Soc. Am.* **89**, 111-119.

Papadimitriou, E.E. and Karakostas, V. (2006). Earthquake generation in Cyprus revealed by the evolving stress field. *Tectonophysics*. **423**, 61-72.

Papazachos, B.C. and Papaioannou, C.A. (1999). Lithospheric boundaries and plate motions in the Cyprus area. *Tectonophysics*. **308**, 193-204.

Papazachos, B.C., Karakostas, V.G., Kiratzi, A.A., Margaris, B.N. and Papazachos C.B. (2002). Uncertainties in the estimation of earthquake magnitudes in Greece. *Journal of Seismology*. **6**, 557-570.

Papazachos, B.C., Karakostas, V.G., Papazachos, C.B. and Scordilis, E.M. (2000). The geometry of the Wandati Benioffzone and lithospheric kinematics in the Hellenic Arc. *Tectonophysics*. **319**, 275-300.

Papazachos, B.C., Kiratzi, A.A. and Karakostas, B.G. (1997). Towards a homogenous moment magnitude determination for earthquakes in Greece and the surrounding area. *Bulletin of Seismological Society of America*. **87**, 474-483.

Papazachos, B.C., Kiratzi, A.A. and Karakostas, B.G. (1997). Toward a homogenous moment magnitude determination for earthquakes in Greece and surrounding area. *Bull. Seism. Am.* **87**, 474-483.

Papazachos, B.C., Kiratzi, A.A. and Papadimitriou, E. (1991). Regional focal mechanisms for earthquakes in the Aegean area. *Pageoph*. **136: 4**, 405-420.

Pilidou, S., Priestley, K., Jackson, J., and Maggi, A. (2004). The 1996 Cyprus earthquake: a large, deep event in the Cyprus Arc. *Geophysical Journal International*. **158: 1**, 85-97.

Pinar, A., and Kalafat, D. (1999). Source processes and seismotectonic implications of the 1995 and 1996 Cyprus, Eastern Mediterranean region earthquakes. *Tectonophysics*. **301: 3-4**, 217-230.

Pondrelli, S., Morelli, A., Ekstrom, G., Mazza, S., Boschi, E., and Dziewonski, A.M. (2002). European-Mediterranean regional centroid moment tensors 1997-2000. *Physics of the Earth and Planetary Interiors*. **130**, 71-101.

Reasenberg, P. (1985). Second-order moment of Central California seismicity, 1969-1982. *Journal of Geophysical Research*. **90**, 5479-5495.

Rotstein, Y. and Kafka, A. (1982). Seismotectonics of the southern boundary of Anatolia, Eastern Mediterranean region: Subduction, collision and arc jumping. *Journal of Geophysical Research*, **87**, 7694-7706.

Roumelioti, Z., Benetatos, C. and Kiratzi, A. (2009). The 14 February 2008 Earthquake (M6.7) Sequence offshore Peloponnese (Greece): Source model of the three strongest events. *Tectonophysics*. **471**, 272-284.

Sadigh, K., Chang, C.Y., Egan, J.A., Makdisi, F. and Youngs, R.R. (1997). Attenuation relationships for shallow crustal earthquakes based on California strong motion data. *Seismological Research Letters*. **68**, 180-189.

Sbeinati, M.R., Darawcheh, R. and Mouty, M. (2005).The historical earthquakes of Syria. *Annals of Geophysics*. **48**: **3**.

Scordilis E.M. (2006). Empirical global relations converting Ms and Mb to moment magnitude. *Journal of Seismology*. **10**, 225-236.

Uhrhammer, H. (1986). Characteristics of Northern and Southern California Seismicity. *Earthquake Notes*. **57**.

Ulusay, R., Tuncay, E., Sonmez, H. and Gokceoglu, C. (2004). An attenuation relationship based on Turkish strong motion data and iso-acceleration map of Turkey. *Engineering Geology*. **74**, 265-291.