SEISMIC SOURCES AND MAIN SEISMIC FAULTS IN THE AEGEAN AND SURROUNDING AREA

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Abstract

A seismic source is defined, in the present work, as the part of the seismogenic layer of the earth's crust with a circular horizontal dimension (E, R), where E is the epicenter of the largest earthquake (mainshock) ever occurred in this seismic source and radius equal to the half fault length of this largest earthquake $(R=L/2)$. In addition to foreshocks and aftershocks other smaller mainshocks occur in other smaller faults of this source or in parts of the main fault.

All available historical and instrumental data concerning strong $(M \geq 6.0)$ shallow $(h \leq 60 km)$ and intermediate depth $(60km < h \leq 100km)$ shocks which occurred in the Aegean area between 464 B.C. and 2008 are used in the present work in an attempt to identify the seismic sources in this area, as well as to determine the basic parameters of the largest fault in each source. A particular procedure is followed to identify 155 seismic sources in this area and determine the basic parameters of the largest fault in each source. Declustering has been also performed to define mainshocks in the Aegean area and the completeness of this mainshock catalogue has been determined. Results are summarized in table (1).

1. Introduction

It is well known that the generation of strong earthquakes is a result of seismic slip on large seismic faults and that the seismic energy (and seismic moment) released by an earthquake is proportional to the dimensions of the ruptured fault and to the slip on this fault (Aki, 1966). It is also known that fault rupture is due to the relative movement of huge crustal blocks (Reid, 1911).

The largest earthquake in a region (characteristic earthquake) is due to the break of the largest (main) fault of this region and this break is repeated at relatively long time intervals (Schwartz and Coppersmith, 1984). Smaller earthquakes occur more frequently by rupture of parts (segments) of the main fault or of smaller faults in the nearby region (vicinity of the main fault). The region which includes the main (largest) fault as well as the nearby smaller faults and has a (linear) dimension equal to the length of the main fault is called *focal region* in the present work.

Much work has been done to locate and study seismic faults in the Aegean area by using seismological and geological data. Thus, Papazachos and his colleagues (2001) combined seismological and geological data to determine properties of 159 seismic faults where 567 strong shallow earthquakes occurred in the Aegean area since antiquity.

The purpose of the present paper is to use seismological data (location of earthquakes, fault plane so-

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lutions) to define focal regions and the corresponding main faults where all known strong (M³6.0) earthquakes with depth h≤100km occurred since 464 BC in the Aegean area (34°N-43°N, 18°E-30°E).

2. The Data

The data used in the present study are instrumental, which concern earthquakes that occurred in the Aegean area since 1911 when the first seismograph was installed in Athens (a two-horizontal component Mainka type mechanical seismograph), and historical, which concern strong earthquakes (M³6.0) that occurred in the same region since 464 BC. The parameters (origin time, epicenter coordinates and magnitude) for the instrumental period (1911-2008) are based mainly on seismographic records and partly on macroseismic information (Papazachos et al., 2009) while these parameters for historical earthquakes are entirely based on macroseismic information (Papazachos and Papazachou, 2003).

The data required for the present study must be *accurate* to a reasonable degree and *homogeneous* in respect to the magnitude of earthquakes. These data must also be *complete*, that is, the data sample used must include all earthquakes which occurred in a certain region during a certain time interval and have magnitudes larger than a certain value. Accuracy concerns location of earthquake focus and earthquake magnitude. The present study deals with shallow (h≤60km) and intermediate-depth (60km<h≤100km) earthquakes. The error in the epicenter coordinates is about 20 km. The error in the magnitude is 0.3 or less. All magnitudes are in the moment magnitude scale. Completeness of the instrumental data is as follows:

$$M≥5.2, 1911-2008 \tag{1}$$

That is, the data samples include all earthquakes which have moment magnitude equal to or larger than 5.2 and occurred in the Aegean area between 1.1.1911 and 31.12.2008. The completeness for the historical data (464BC-1910) is examined in section (7). The earthquake catalogues used in the present study can be found at the site http://geophysics.geo. auth.gr/ss/station_index_en.html/.

3. Determination of Focal Regions in the Aegean

The focal region of a shallow mainshock is defined, in the present work, as the part of the seismogenic layer which cuts the earth's surface in a circle with center, E, the epicenter of the mainshock and radius equal to the half of the length of the fault ruptured during the generation of the mainshock (the focal region, actually, is a cylindrical part of the crust with height equal to the thickness of the seismogenic layer). In a first approximation the length, L (in km), of the faults in the Aegean area is given by the relation:

$$\log L = 0.51 \cdot M - 1.85 \tag{2}$$

where M is the moment magnitude of the earthquake (Papazachos and Papazachou, 2003). Relation (2) is used to calculate the fault length, L_{max}, of the largest earthquake ever occurred in the focal region and the radius of this focal region is $R=L_{max}/2$. Smaller mainshocks also occur in the focal region by rupturing of other smaller faults or parts of the main fault. Thus, to determine E and R for each focal region of the Aegean area the following procedure has been applied by using the earthquake catalogue (M≥6.0 since 464BC, M≥5.2 since 1911) described in section (2).

First, the epicenter of the largest earthquake of the catalogue is considered as the center, E, of the largest focal region in the Aegean and its magnitude is used to calculate L by relation (2) and the radius R (=L/2) of this region. All earthquakes with epicenters within this region are excluded from

the original catalogue and the same procedure is applied in the remaining part of the catalogue to determine the second largest focal region in the Aegean area. This procedure is repeated for the third, fourth, etc. largest focal region of the Aegean till all earthquakes with M≥6.0 are excluded from the catalogue. In cases when more than one earthquakes of equal magnitude are the largest in the remaining catalogue, they are sorted by decreasing origin time and the corresponding focal regions are defined in this order, i.e. the most recent largest earthquake is firstly considered, then the second most recent largest earthquake, etc. For the mainshocks of the catalogue with M<6.5 the radius of the focal region based on relation (2) is within the error range of the epicenter location. For this reason, in such cases this radius is taken equal to 15 km. It must be also noted that the well documented earthquakes in the Aegean area have moment magnitudes M≤7.6. For this region the maximum radius of the focal regions in the Aegean area was considered equal to 53 km. There are, however, two earthquakes in the catalogue (365 A.D., 1303) for which larger magnitudes have been estimated, but such big earthquakes have a very large return period (~1000 yrs) and only parts of their faults usually break. Magnitudes equal to 7.7 have been assigned for both these earthquakes for the purpose of the present paper.

After the application of the procedure described above 218 shallow circular focal regions have been identified in the Aegean and its surrounding area. A mapping of these regions revealed that in many cases there is overlap of adjoining focal regions.

In addition to the shallow (h≤60km) focal regions defined in the present work, there have been also defined in the southern part of the Aegean area four (4) focal regions of intermediate focal depth (60km<h≤100km) where very strong destructive earthquakes have occurred (D_1, D_2, D_3, D_4 in fig. 6.6 of Papazachos and Papazachou, 2003). Available information for these four focal regions is given in table (1) with code numbers 152, 153, 154 and 155 whereas data completeness is given by relations (1) and (13).

4. Orientations of the Largest Faults and Their Slip Vectors

The orientation of a seismic fault is defined by its strike, ξ (the angle between the intersection of the fault and horizontal plane with the north direction), and by its dip, δ (the angle between the intersection of the fault plane and the normal to the fault strike vertical plane and the horizontal projection of this intersection). The slip vector, which shows the slip direction of the hanging wall of the fault, is determined by the rake, λ (the angle between the slip vector and the strike direction of the fault) and defines the kind of faulting (normal, thrust, strike-slip dextral or strike-slip sinistral).

To define the strike, ξ, the dip, δ, and the rake, λ, for the main fault of a focal region, i.e. the fault where the largest earthquake in this region has occurred, all reliable fault plane solutions which are available for earthquakes located in the corresponding focal region have been used to determine a typical solution by a method proposed by Papazachos and Kiratzi (1992). This typical fault plane solution is adopted as the fault plane solution for the corresponding main fault.

In many cases we encountered the following situation: the typical fault plane solution for a certain focal region, (B), was of the same type with the solution determined earlier for an adjoining focal region, (A), where the magnitude of the largest earthquake was larger than the magnitude of the largest earthquake in region (B). Taking this fact into account we incorporated all data (earthquakes and fault plane solutions) of the region (B) in the region (A) in the cases of significant overlap of both regions. This resulted in 151 typical fault plane solutions. We then compared the values of strike, dip and rake of these solutions with the corresponding values determined for the major faults

in the Aegean and surrounding area (Papazachos et al., 2001). We found that the values of the attributes (strike, dip, rake) of the majority of these 151 typical fault plane solutions were close to those of Papazachos et al. (2001) which were based on a large amount of well documented seismological and geological data. For this reason, the information on the strike, ξ, dip, δ, and rake, λ, listed in table (1) for almost all typical fault plane solutions comes from the work of Papazachos et al. (2001). In the same table corresponding symbols are used to denote thrust faults in the subduction area (TS), thrust faults in the continental area (TC), normal faults (N), strike-slip dextral faults (SD) and strike-slip sinistral faults (SS). Figure (1) shows on a map of the Aegean area these 151 main faults denoted with the corresponding symbols. The length of the symbols used to denote these faults is proportional to the length calculated according to the relations presented in the next section whereas the center of each fault coincides with the center of the respective focal region.

5. Length, Width and Slip of Main Faults

Several empirical relations between the basic fault parameters (fault length, width, fault slip) and the magnitude of the corresponding earthquake have been proposed (Kanamori and Anderson 1975, Bonilla et al. 1984, Wesnousky 1986, Wells and Coppersmith 1994, Smith and Stock 2004, Papazachos and Papazachou 2003, among others). There are, however, differences among these relations which stem from uncertainties of the data used. Papazachos et al. (2004) used a considerable number of published reliable global data which are homogeneous (fault parameters estimated by the same method, earthquake magnitudes in the same scale), fairly accurate (accurate fault parameters, magnitudes) to relate the fault length, L (in km) and the fault width, w (in km) of the fault as well as the mean slip (displacement) of a fault, u (in cm) with the moment magnitude, M for three kinds of faults (strike-slip faults, dip-slip continental faults and dip-slip faults in subduction regions). These relations are as follows:

(a) Strike-slip faults (F_1)

$$logL = 0.59M - 2.30,$$
$$logw = 0.23M - 0.49, \tag{3}$$
$$logu = 0.68M - 2.59,$$

which hold for $6.0 \leq M \leq 8.0$,

(b) Dip-slip continental faults (F_2)

$$logL = 0.50M - 1.86,$$
$$logw = 0.28M - 0.70, \tag{4}$$
$$logu = 0.72M - 2.82,$$

which hold for $6.0 \leq M \leq 7.5$ and for both normal and thrust faults in continental regions,

(c) Dip-slip faults in subduction regions (F_3)

$$logL = 0.55M - 2.19,$$
$$logw = 0.31M - 0.63, \tag{5}$$
$$logu = 0.64M - 2.56,$$

which hold for $6.7 \leq M \leq 9.2$. These relations have been used to calculate the three parameters for each
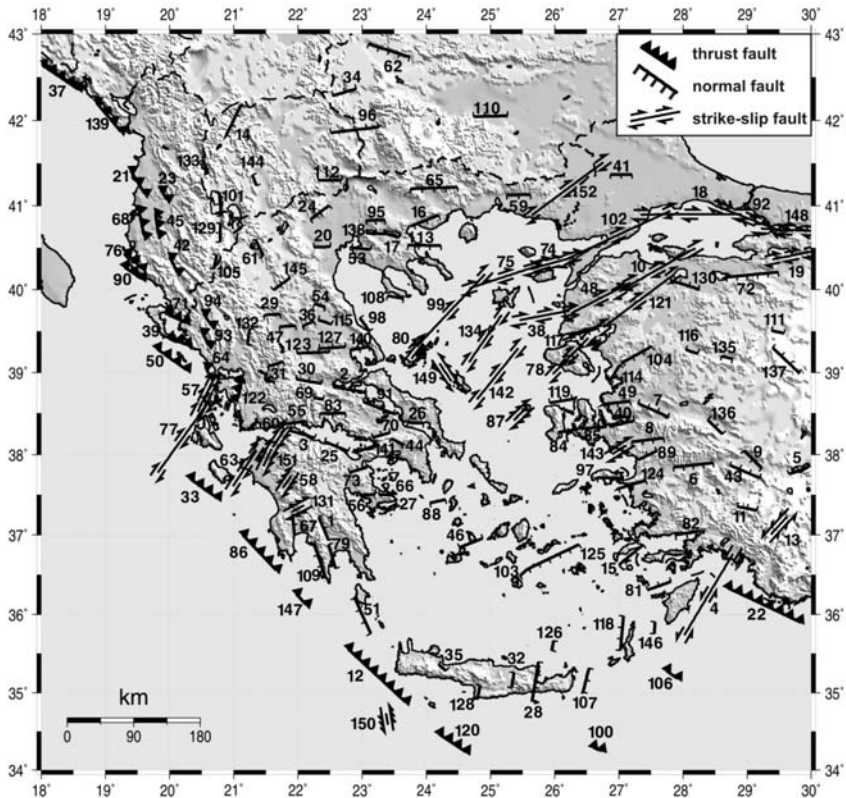
Fig. 1: The main seismic faults of shallow (h≤60km) mainshocks in the Aegean area. The center of each fault coincides with the center of the respective focal region whereas its length has been determined by a set of relationships appropriate for the kind of each fault. The numbers correspond to the code numbers listed in table (1).

of the shallow main faults defined in the present work for the Aegean area. In table (1) the corresponding symbols (F1, F2, F3) are shown to denote the kind of each of the shallow main faults of the Aegean area determined in the present work. Thus, by applying the proper set of relations (3, 4, 5) the corresponding values of L, w, u, have been calculated by using the corresponding magnitude, M, and these values are listed in table (1).

6. Declustering of Data

Declustering of data means the use of the original catalogue described in section (2) to create a catalogue that includes mainshocks only. Earthquakes of the original catalogue included in a focal region are spatially and temporally clustered and a procedure must be applied to make a temporal declustering of these earthquakes by excluding associated shocks. Such shocks are the ones preceding (preshocks) or following (postshocks) each mainshock in the focal region. Such declustering is performed in the present work by assuming that the preshock period is equal to the postshock period and independent of the mainshock magnitude. As a measure of clustering the ratio, $C_v = \sigma/T$, is used where T is the mean repeat time of the earthquakes of the cluster and σ is its standard deviation (Kagan and Jackson, 1991). C_v takes a value: equal to 1 for Poissonian distribution, larger than 1 for clustered shocks, equal to zero for periodic generation of shocks and an intermediate value (e.g. C_v=0.5) for
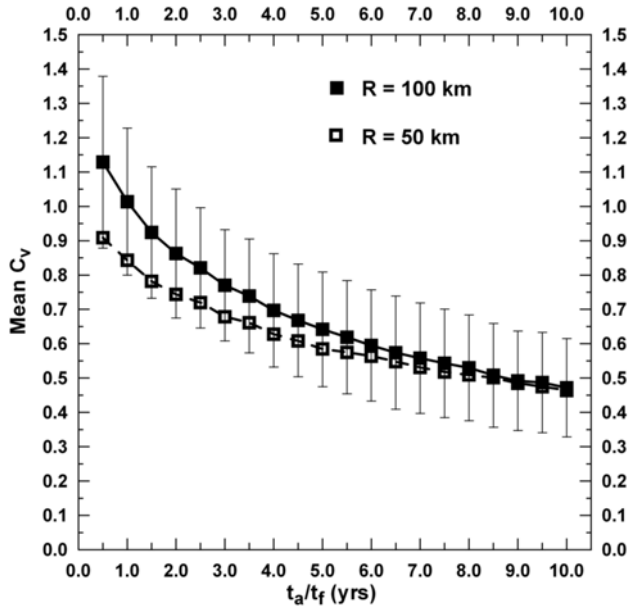
Fig. 2: Variation of the average value of the ratio C_v (=σ/T) with the duration of the time windows (in years) before (t_f) and after (t_a) a mainshock. All earthquakes that occurred in these time windows are considered as associated shocks (preshocks and postshocks, see text for explanation).

quasi-periodic behavior as are the earthquakes which follow the time predictable model. Thus, the optimum time duration of associated shocks (preshocks, postshocks) for which a proper declustering is obtained is that one for which C_v takes its smallest value. To define this optimum time duration the following procedure was followed:

By using a circle with center coinciding with the center, E, of each focal region and a constant radius, R (e.g. R=50 km), the sample of all earthquakes which occurred during the instrumental period (M≥5.2, 1911-2008) and have epicenters within the circle is defined. Considering the largest earthquake of the sample as the largest mainshock we excluded from the initial sample all shocks which occurred within a time window ±0.5 yrs from the origin time of the largest mainshock. This procedure is repeated on the remaining sample and so on till all mainshocks of the region are defined. If the number of these mainshocks is larger than three (n≥3), the mean return period, T, its standard deviation, σ, and their ratio, C_v, for Δt=±0.5 yrs are defined. This is repeated for several time windows (0.5, 1.0, …, 9.5, 10.0 yrs) and the corresponding pairs of time windows and C_v are formed. This procedure is followed for the mainshocks occurred in the instrumental period in each one of the regions with centers, E, and the same radius (e.g. R=50 km) and the average $C_{v,ave}$ value is calculated for each of the defined time windows. Figure (2) is a plot of $C_{v,ave}$ as a function of Δt for R=50 km and another such plot for R=100 km. It is obvious that in both plots the value of $C_{v,ave}$ decreases with time up to Δt=8.5 yrs where $C_{v,ave}$=0.50 and that for larger time windows $C_{v,ave}$ is practically constant. It is, therefore, concluded that declustering must be made in each originally defined focal region by excluding preshocks and postshocks which occurred in a time window ±8.5 yrs from each mainshock of the focal region. It is also concluded that σ=0.50 · T, which is an important result used in the next section to define completeness of the historical data.
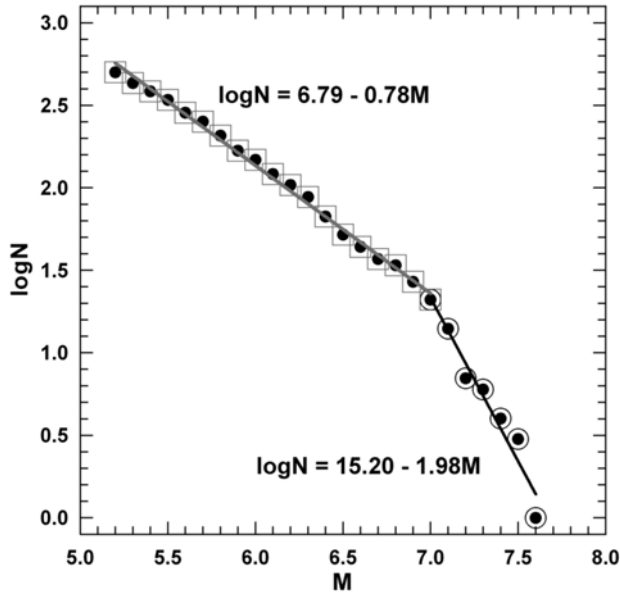
Fig. 3: The cumulative frequency-magnitude distribution of the shallow mainshocks with M≥5.2 which occurred in the Aegean area during 1911-2008.

To decluster the initial sample of earthquakes included in each focal region and define the main-shocks of this region, the following procedure is applied: The largest earthquake of the focal region is considered as mainshock and all shocks of the region which occurred within a time window ± 8.5 yrs from the origin time of the largest mainshock are excluded. The same procedure is applied on the remaining sample to determine the second largest mainshock, etc. till all mainshocks of the focal region are defined. Thus, the mainshocks of all focal regions form the catalogue of mainshocks of the whole Aegean area.

Figure (3) shows the cumulative frequency-magnitude distribution of all mainshocks of the Aegean area which occurred during the instrumental period (1.1.1911-31.12.2008). The data are fitted in the least squares' sense by the following relations:

$$\log N = a_1 - b_1 M, \text{ for } 5.2 \leq M < 7.0 \tag{6}$$

$$\log N = a_2 - b_2 M, \text{ for } M \geq 7.0 \tag{7}$$

with
$$b_1 = 0.78, \, a_1 = 6.79, \, a_{1r} = 4.80 \tag{8}$$

$$b_2 = 1.98, \, a_2 = 15.20, \, a_{2r} = 13.21 \tag{9}$$

Parameters a_{1r} and a_{2r} are the reduced values of a_1 and a_2 to one year. The parameter a_2 can be also calculated by the relation:

$$a_2 = a_1 + 7.0(b_2 - b_1) \tag{10}$$

Then, the mean return periods for the mainshocks are given by the relations:

$$T = 10^{b_1 M - a_{1r}} \text{ for } M < 7.0 \tag{11}$$

$$T = 10^{b_2 M - a_{2r}} \text{ for } M \geq 7.0 \tag{12}$$

The values of the scaling parameters ($b_1=0.78$, $b_2=1.98$) can be considered constant and holding for all focal regions. For this reason, if instrumental data for mainshocks with $M \leq 7.0$ are available for a particular focal region, relation (6) can be used to calculate a_1 and relation (10) to calculate a_2 for this region. Then, relation (11) or relation (12) can be used to calculate the mean return period.

7. Completeness of Historical Mainshocks

Another basic requirement of any historical earthquake catalogue, in addition to the homogeneity in the magnitude determination, is the assessment of its completeness, i.e. the assessment of the minimum magnitude above which the catalogue is considered to be fully reported. Traditional methods of estimating completeness of an earthquake catalogue are the frequency-magnitude and the time-magnitude distributions. Both these procedures led to the conclusion that earthquakes in the whole Aegean area investigated in the present work (34^oN-43^oN, 18^oE-30^oE) are complete for the period and magnitude range defined by relation (1) and by the relation:

$$M \geq 6.5, \quad 1845-2008 \tag{13}$$

Furthermore, completeness is defined for historical mainshocks with $M^3 6.5$ in each circular region (E, R=100km) where E are the centers of the 151 shallow focal regions. For this purpose we used the information for the mainshocks that occurred during the instrumental period (1911-2008) and are located within the circle (E, R=100km) to determine the value a_1 by the relation (6) assuming $b_1=0.78$. Then, we used these two values and $b_2=1.98$ to calculate a_2 by the relation (10). After reducing a_1 and a_2 to one year (a_{1r}, a_{2r}) we can use the relations (11, 12) to calculate mean return periods for any historical earthquake. For example, we considered all mainshocks which are located within the circle (E, R=100km) and for each of them we calculated its mean return period, T, by applying relation (11) or (12) according to its magnitude. Then, the time period $T^*=T+2 \cdot \sigma$ (with $\sigma=C_v \cdot T=0.50 \cdot T$) is calculated and subtracted from the origin time, t_e, of the earliest strong ($M \geq 6.0$) mainshock of the instrumental period to define a time $t=t_e-T^*$. If the mainshock occurred after this time, t, it is included in the complete data, otherwise it is not. In this way each circular region (E, R=100km) includes epicenters of mainshocks which occurred during the instrumental and historical times and form complete samples of mainshocks. Information on the completeness of mainshocks in each focal region is given in table (1).

8. Conclusions

The present work aimed at facilitating seismic hazard studies by proposing a methodology of identification of focal regions. Such a region includes the main fault where the largest mainshock occurs, and smaller faults where smaller mainshocks also occur. These focal regions can be considered as spatial clusters of earthquakes. Clustering is usually attributed to foreshocks and mainly to aftershocks but even if these shocks are omitted from the data clustering still prevails, because spatial clustering occurs not only in the rupture zone of a mainshock but also in a broader area where other mainshocks occur.

The proposed methodology is applied in the Aegean area where 155 focal regions and their respective main faults were identified. This number of focal regions can be compared to that of Papazachos et al. (2001) who, using a large amount of seismological (distribution of epicentres, macroseismic information, focal mechanisms) and geological data (surface fault traces, stratigraphic and geomorphological data), determined the properties of 160 faults where the known major ($M \geq 6.0$) shallow earthquakes have occurred in the Aegean area. Fault dimensions and maximum slip were determined by appropri-

Table 1. Information on the focal regions and their main faults. After the code number, N, and the name of the focal region, the year of occurrence and the moment magnitude, M, of the largest mainshock ever occurred in this region are given. The next two columns show the geographic coordinates (north latitude, east longitude) of the center, E, of the main fault of this region whereas its length, L (in km), width, w (in km) and maximum slip, u (in m) are listed in the following three columns. The strike, ξ, the dip, δ, and the rake, λ, of the main fault are shown next. The next two columns show the type, T, of the main fault (N=normal, TC=thrust in continental regions, TS=thrust in subduction regions, SS=strike-slip sinistral, SD=strike-slip dextral) and the formulae, F, used to calculate L, w, and u (relations 2, 3, 4). The last column gives information on the data completeness in the focal region, in addition to the completeness of the whole catalogue (1911, M≥5.2, 1845, M≥6.5). The symbol, C, denotes that only the whole catalogue completeness applies in this case.

N	Name	Year	M	Lat	Lon	L (km)	w (km)	u (m)	ξ	δ	λ	T	F	Completeness
1	Sparti	-464	6.8	37.08	22.40	35	16	1.19	340	47	-98	N	F2	1842-6.6, 1750-7.1
2	Skarfia	-426	7.0	38.79	22.80	44	18	1.66	282	47	-90	N	F2	1817-6.6
3	Heliki	-373	6.8	38.25	22.07	35	16	1.19	290	30	-79	N	F2	1817-6.6
4	Rhodes	-227	7.5	36.25	28.40	133	17	3.24	30	80	-41	SS	F1	1741-6.7, 1513-7.1, 1481-7.2, 1303-7.3, 227 BC-7.5
5	Acigol	-90	6.6	37.80	29.80	28	14	0.86	248	35	-105	N	F2	C
6	Aydin	-27	7.2	37.87	28.16	55	21	2.31	83	42	-99	N	F2	1653-7.1
7	Turgutlu	17	7.0	38.54	27.53	44	18	1.66	294	45	-115	N	F2	C
8	Torbali-a	47	7.0	38.18	27.45	44	18	1.66	83	45	-115	N	F2	C
9	Laodicaea	60	6.8	37.94	29.09	35	16	1.19	133	42	-99	N	F2	C
10	Sarikoy	160	7.4	40.24	27.60	116	16	2.77	240	70	-155	SD	F1	1766-6.6, 1659-7.0, 1556-7.1, 1343-7.2, 740-7.4
11	Aphrodisias	241	6.6	37.33	29.00	28	14	0.86	280	42	-99	N	F2	C
12	Elaphonnesus	365	7.7	35.22	23.23	111	57	2.33	315	17	99	TS	F3	C
13	Cibyra	417	6.5	37.12	29.50	34	10	0.68	221	85	19	SS	F1	C
14	Tetovo	518	7.0	42.01	21.00	44	18	1.66	30	49	-87	N	F2	C

N	Name	Year	M	Lat	Lon	L (km)	w (km)	u (m)	ξ	δ	λ	T	F	Completeness
15	Cos island	556	7.0	36.75	27.19	44	18	1.66	50	48	-78	N	F2	C
16	Paggaeon Mt	620	6.8	40.83	24.00	35	16	1.19	70	53	-93	N	F2	1797-6.6
17	Volvi	677	6.4	40.65	23.46	22	12	0.61	286	37	-84	N	F2	1829-6.7
18	N. Marmara	740	7.5	40.90	28.13	133	17	3.24	89	90	177	SD	F1	1766-6.8, 1556-7.1, 1509-7.2, 740-7.4
19	Iznik	1065	7.1	40.43	29.84	77	14	1.73	77	90	177	SD	F1	1766-6.6, 1719-6.7
20	Veroea	1211	6.4	40.51	22.38	22	12	0.61	271	45	-94	N	F2	C
21	Dyrrachio	1273	6.8	41.28	19.50	35	16	1.19	334	27	93	TC	F2	C
22	Kastelorizo	1303	7.7	36.12	29.26	111	57	2.33	294	27	99	TS	F3	1741-6.8, 1609-7.2, 1481-7.3, 1303-7.4
23	Elbasan	1380	6.0	41.13	19.91	14	10	0.32	331	27	93	TC	F2	1833-6.6
24	Edessa	1395	6.7	40.92	22.34	31	15	1.01	56	45	-84	N	F2	C
25	Xylokastro	1402	6.8	38.10	22.60	35	16	1.19	295	30	-79	N	F2	C
26	Eretria	1417	6.4	38.39	23.83	22	12	0.61	93	40	-90	N	F2	C
27	Hydra	1457	6.3	37.35	23.45	19	12	0.52	243	48	-78	N	F2	C
28	Hierapetra	1508	7.2	35.15	25.70	55	21	2.31	10	47	-98	N	F2	C
29	Meteora	1544	6.4	39.70	21.60	22	12	0.61	90	30	-90	N	F2	C
30	Lamia	1545	6.8	38.89	22.17	35	16	1.19	283	47	-88	N	F2	1794-6.6
31	Agrafa	1566	6.4	39.10	21.65	22	12	0.61	76	50	-82	N	F2	1817-6.6
32	Kasteli	1595	6.4	35.16	25.35	22	12	0.61	190	47	-98	N	F2	C
33	Zante	1633	7.0	37.58	20.53	46	35	0.83	310	18	118	TS	F3	1767-6.6, 1752-6.7, 1636-7.1, 1469-7.2
34	Kyustendil	1641	6.7	42.33	22.73	31	15	1.01	256	53	-93	N	F2	C

N	Name	Year	M	Lat	Lon	L (km)	w (km)	u (m)	ξ	δ	λ	T	F	Completeness
35	Chania	1646	6.0	35.32	24.25	14	10	0.32	313	47	-98	N	F2	C
36	Pinias	1661	6.2	39.59	22.16	17	11	0.44	69	43	-90	N	F2	C
37	Dubrovnic	1667	7.2	42.50	18.30	55	21	2.31	310	29	85	TC	F2	C
38	Tenedos	1672	7.0	39.69	25.84	68	13	1.48	260	90	177	SD	F1	1809-6.6, 1756-6.7, 1737-6.8, 1672-7.0
39	Corfu	1674	6.5	39.37	20.15	25	13	0.72	294	43	90	TC	F2	1820-6.6, 1786-6.7, 1769-6.8
40	Izmir	1688	6.8	38.38	27.05	35	16	1.19	256	45	-115	N	F2	C
41	Arkadople	1689	6.6	41.37	27.04	28	14	0.86	90	53	-93	N	F2	C
42	Tepeleni	1701	6.4	40.30	20.06	22	12	0.61	339	27	93	TC	F2	C
43	Denizli	1702	7.0	37.79	28.96	44	18	1.66	292	42	-99	N	F2	C
44	Parnitha	1705	6.3	38.16	23.55	19	12	0.52	119	57	-80	N	F2	C
45	Berat	1713	6.6	40.79	19.80	28	14	0.86	357	27	93	TC	F2	C
46	Melos	1733	6.8	36.90	24.70	35	16	1.19	250	45	-90	N	F2	C
47	Trikala	1735	6.4	39.56	21.84	22	12	0.61	89	43	-90	N	F2	C
48	Etili	1737	7.2	39.90	26.72	89	15	2.02	243	90	177	SD	F1	1809-6.6, 1766-6.9, 1737-7.0, 1659-7.2, 1354-7.4
49	Foca	1739	6.8	38.63	26.98	35	16	1.19	84	45	-115	N	F2	C
50	Paxoi	1743	7.1	39.16	20.03	49	19	1.96	310	43	90	TC	F2	1809-6.6, 1786-6.7, 1769-6.8, 1743-7.0
51	Cythera	1750	7.2	35.98	23.01	55	21	2.31	158	50	-80	N	F2	C
52	Didymotecho	1752	7.4	41.20	26.20	116	16	2.77	54	90	177	SD	F1	1798-6.8, 1750-7.1, 1494-7.5
53	Anthemous	1759	6.5	40.49	22.99	25	13	0.72	278	53	-93	N	F2	C
54	Elassona	1766	6.1	39.81	22.34	15	10	0.37	109	47	-87	N	F2	C

N	Name	Year	M	Lat	Lon	L (km)	w (km)	u (m)	ξ	δ	λ	T	F	Completeness
55	Nafpaktos	1769	6.8	38.39	21.94	35	16	1.19	85	40	-125	N	F2	1817-6.6
56	Argos	1769	6.4	37.50	23.09	22	12	0.61	266	48	-78	N	F2	C
57	Lefkada	1769	6.7	38.70	20.55	45	11	0.92	30	77	178	SD	F1	1786-6.6, 1767-6.7, 1723-6.9, 1636-7.1, 1469-7.2
58	Ladonas	1783	6.1	37.66	21.83	20	8	0.36	37	89	176	SD	F1	1791-6.6, 1769-6.8, 1752-7.0
59	Komotini	1784	6.7	41.13	25.44	31	15	1.01	90	53	-93	N	F2	1752-6.6, 1719-6.8
60	Patra	1804	6.4	38.20	21.70	30	10	0.58	37	89	176	SD	F1	1820-6.6
61	Kastoria	1812	6.5	40.50	21.40	25	13	0.72	160	49	-87	N	F2	C
62	Sofia	1818	7.2	42.81	23.42	55	21	2.31	110	53	-93	N	F2	C
63	Kyllini	1820	6.9	37.83	21.17	59	13	1.26	37	89	176	SD	F1	1767-6.6, 1752-6.7, 1723-6.9, 1658-7.0, 1636-7.1, 1469-7.2
64	Preveza	1826	6.2	39.00	20.60	17	11	0.44	340	43	113	TC	F2	1786-6.6, 1767-6.7, 1743-6.9, 1469-7.2
65	Drama	1829	7.3	41.21	24.12	62	22	2.73	90	53	-93	N	F2	C
66	Epidavros	1837	6.3	37.50	23.37	19	12	0.52	275	43	-100	N	F2	C
67	Messini	1846	6.6	37.13	21.93	28	14	0.86	358	47	-98	N	F2	C
68	Fier	1851	6.8	40.80	19.56	35	16	1.19	353	27	93	TC	F2	C
69	Gravia	1852	6.0	38.68	22.32	14	10	0.32	281	47	-88	N	F2	1817-6.6, 1794-6.7
70	Thebe	1853	6.5	38.24	23.30	25	13	0.72	256	40	-90	N	F2	C
71	Egoumenitsa	1854	6.5	39.65	20.12	25	13	0.72	300	43	90	TC	F2	1786-6.8
72	Bursa	1855	7.4	40.18	29.08	69	24	3.22	83	45	-90	N	F2	1766-6.7, 1719-6.9, 1509-7.2
73	Corinth	1858	6.5	37.81	22.94	25	13	0.72	255	43	-100	N	F2	1817-6.6
74	Saros	1859	6.9	40.32	25.97	59	13	1.26	75	55	-145	SD	F1	1672-6.6, 1471-7.0, 1354-7.1

N	Name	Year	M	Lat	Lon	L (km)	w (km)	u (m)	ξ	δ	λ	T	F	Completeness
75	Lemnos	1864	7.3	40.16	25.24	102	15	2.37	253	88	-170	SD	F1	1776-6.6, 1765-6.7
76	Vlora	1866	6.6	40.34	19.45	28	14	0.86	320	27	93	TC	F2	C
77	Cephalonia	1867	7.4	38.20	20.20	116	16	2.77	40	57	172	SD	F1	1786-6.6, 1767-6.7, 1752-6.8, 1723-7.1, 1469-7.2
78	Lesvos	1867	7.0	39.20	26.25	68	13	1.48	45	89	-172	SD	F1	1809-6.6, 1739-6.8
79	Gythio	1867	6.8	36.73	22.53	35	16	1.19	346	47	-98	N	F2	1798-6.9
80	Alonessos	1868	6.3	39.26	23.86	26	9	0.49	40	77	175	SD	F1	C
81	Symi	1869	6.8	36.36	27.63	35	16	1.19	250	48	-78	N	F2	C
82	Marmaris	1869	6.8	37.03	28.11	35	16	1.19	80	42	-99	N	F2	1653-7.1, 1513-7.2
83	Delfoi	1870	6.8	38.50	22.54	35	16	1.19	91	40	-90	N	F2	1817-6.6
84	N. Chios	1881	6.5	38.29	26.20	25	13	0.72	82	45	-115	N	F2	C
85	Urla	1883	6.8	38.33	26.61	35	16	1.19	266	45	-115	N	F2	C
86	Filiatra	1886	7.3	36.78	21.40	67	43	1.29	320	32	106	TS	F3	1811-6.8
87	Psara	1890	6.2	38.49	25.46	23	9	0.42	229	84	-153	SD	F1	C
88	Kythnos	1891	6.4	37.42	24.18	22	12	0.61	80	48	-78	N	F2	C
89	Efessos	1893	6.6	37.99	27.45	28	14	0.86	244	45	-115	N	F2	C
90	Chimara	1893	6.6	40.20	19.43	28	14	0.86	309	27	93	TC	F2	C
91	Atalanti	1894	7.0	38.57	23.25	44	18	1.66	294	50	-70	N	F2	C
92	Cimanzic	1894	7.2	40.84	29.05	89	15	2.02	110	70	-155	SD	F1	1766-6.6, 1719-6.7, 1509-7.1, 1343-7.2, 740-7.4
93	Paramythia	1895	6.3	39.41	20.56	19	12	0.52	337	43	113	TC	F2	1825-6.6
94	Jannina	1898	6.3	39.64	20.59	19	12	0.52	332	43	113	TC	F2	1820-6.7

N	Name	Year	M	Lat	Lon	L (km)	w (km)	u (m)	ξ	δ	λ	T	F	Completeness
95	Sohos	1902	6.5	40.83	23.21	25	13	0.72	90	53	-93	N	F2	C
96	Kresna	1904	7.3	41.89	22.88	62	22	2.73	266	53	-93	N	F2	1818-6.7
97	Samos	1904	6.8	37.71	26.87	35	16	1.19	91	45	-115	N	F2	C
98	Keramidi	1905	6.4	39.58	23.04	22	12	0.61	327	50	-82	N	F2	C
99	Athos	1905	7.5	39.75	24.38	133	17	3.24	225	89	-172	SD	F1	C
100	Stravo Trough	1910	6.0	34.27	26.67	13	17	0.19	291	47	99	TS	F3	C
101	Ochrid	1911	6.7	41.02	20.79	31	15	1.01	179	49	-87	N	F2	C
102	Ganos	1912	7.6	40.65	26.98	153	18	3.78	245	80	165	SD	F1	1826-6.6, 1766-6.7, 1752-6.8, 1737-6.9, 1659-7.1, 1354-7.4
103	Santorini	1919	6.1	36.53	25.52	15	10	0.37	50	40	-90	N	F2	C
104	Bergama-a	1919	7.0	39.22	27.29	44	18	1.66	61	45	-115	N	F2	1809-6.8
105	Erseke	1919	6.3	40.33	20.71	19	12	0.52	196	49	-87	N	F2	1812-6.7
106	Stravo sea Mt.	1922	6.3	35.23	27.83	19	21	0.30	303	25	90	TS	F3	1513-7.2
107	Zakros	1922	6.8	35.16	26.49	35	16	1.19	14	47	-98	N	F2	C
108	Valta	1923	6.4	39.91	23.52	22	12	0.61	102	53	-93	N	F2	1776-6.8
109	Mani	1927	7.1	36.68	22.34	49	19	1.96	164	44	-79	N	F2	1750-7.1
110	Plovdiv	1928	7.0	42.05	25.00	44	18	1.66	270	37	-84	N	F2	C
111	Emet	1928	6.2	39.49	29.48	17	11	0.44	281	43	-94	N	F2	C
112	Valadovo	1931	6.7	41.30	22.50	31	15	1.01	273	53	-93	N	F2	C
113	Ierissos	1932	7.0	40.53	23.97	44	18	1.66	93	53	-93	N	F2	C
114	Bergama-b	1939	6.6	38.98	26.93	28	14	0.86	31	45	-115	N	F2	1772-6.6, 1739-6.8

N	Name	Year	M	Lat	Lon	L (km)	w (km)	u (m)	ξ	δ	λ	T	F	Completeness
115	Larissa	1941	6.3	39.61	22.42	19	12	0.52	291	47	-88	N	F2	C
116	Bigadik	1942	6.2	39.25	28.14	17	11	0.44	287	45	-115	N	F2	C
117	Edremit	1944	6.9	39.49	26.46	39	17	1.41	74	46	-114	N	F2	1809-6.6, 1737-6.7, 1672-6.9
118	Karpathos	1948	7.1	35.76	27.05	49	19	1.96	185	47	-98	N	F2	C
119	N. Chios	1949	6.7	38.65	26.10	31	15	1.01	261	45	-115	N	F2	C
120	Ptolemy Mt	1952	7.0	34.35	24.41	46	35	0.83	305	29	105	TS	F3	C
121	Yenise	1953	7.4	39.86	27.30	116	16	2.77	233	70	-160	SD	F1	1809-6.6, 1766-6.7, 1737-7.1, 1659-7.2, 1354-7.4
122	Katouna	1953	6.3	38.80	21.10	19	12	0.52	195	60	135	TC	F2	1743-6.6, 1723-6.7, 1658-6.9, 1636-7.0, 1469-7.1
123	Sofades	1954	7.0	39.24	22.24	44	18	1.66	271	47	-88	N	F2	C
124	W. Buyuk	1955	6.9	37.63	27.21	39	17	1.41	73	45	-115	N	F2	C
125	Amorgos	1956	7.5	36.73	25.99	78	25	3.80	65	40	-90	N	F2	C
126	Dionysades	1956	6.0	35.60	25.97	14	10	0.32	10	47	-98	N	F2	C
127	Farsala	1957	6.8	39.30	22.54	35	16	1.19	269	47	-88	N	F2	C
128	Pitsidia	1959	6.3	35.01	24.82	19	12	0.52	193	44	-79	N	F2	C
129	Koritsa	1960	6.5	40.68	20.79	25	13	0.72	185	49	-87	N	F2	C
130	Manyas	1964	6.9	40.06	28.02	39	17	1.41	287	46	-95	N	F2	1659-7.0, 1556-7.1, 1509-7.2, 740-7.4
131	Megalopole	1965	6.1	37.33	22.00	20	8	0.36	245	57	159	SD	F1	1820-6.6
132	Arta	1967	6.4	39.43	21.23	22	12	0.61	11	49	-87	N	F2	1820-6.6
133	Peshkope	1967	6.3	41.46	20.56	19	12	0.52	161	49	-87	N	F2	C
134	Ag. Efstratios	1968	7.1	39.41	24.92	77	14	1.73	216	86	145	SD	F1	C

N	Name	Year	M	Lat	Lon	L (km)	w (km)	u (m)	ξ	δ	λ	T	F	Completeness
135	Demirci	1969	6.1	39.18	28.69	15	10	0.37	104	34	-90	N	F2	C
136	Alasehir	1969	6.6	38.34	28.50	28	14	0.86	313	34	-90	N	F2	C
137	Gediz	1970	7.1	39.15	29.60	49	19	1.96	312	35	-90	N	F2	C
138	Stivos	1978	6.5	40.67	23.21	25	13	0.72	275	46	-70	N	F2	1829-6.7
139	Shkodra	1979	7.1	42.04	19.05	49	19	1.96	325	29	85	TC	F2	1667-7.2
140	N. Aghialos	1980	6.5	39.29	22.96	25	13	0.72	82	43	-90	N	F2	C
141	Peraxora	1981	6.7	38.07	23.06	31	15	1.01	253	44	-84	N	F2	C
142	East of Skyros	1981	7.2	38.98	25.11	89	15	2.02	40	67	-166	SD	F1	C
143	Torbali-b	1992	6.2	38.06	27.01	23	9	0.42	238	85	-167	SD	F1	C
144	Bitola	1994	6.1	41.30	21.32	15	10	0.37	343	49	-87	N	F2	C
145	Kozani	1995	6.6	40.07	21.75	28	14	0.86	237	45	-101	N	F2	C
146	Katavia	1996	6.2	35.83	27.56	17	11	0.44	184	47	-98	N	F2	C
147	Tainaro	1997	6.4	36.19	22.05	21	23	0.34	320	32	106	TS	F3	1798-6.8, 1750-7.1
148	Izmit	1999	7.5	40.70	30.00	133	17	3.24	91	76	179	SD	F1	1766-6.6, 1719-6.8
149	N. Skyros	2001	6.4	39.00	24.30	30	10	0.58	238	85	-161	SD	F1	C
150	SW of Crete	2004	6.0	34.66	23.39	17	8	0.31	172	87	10	SS	F1	C
151	Andravida	2008	6.3	37.96	21.52	26	9	0.49	29	89	-178	SD	F1	1820-6.6, 1811-6.7, 1766-7.1
152	NE Peloponnes	1898	7.0	38.10	22.40	-	-	-	128	62	118	-	-	C
153	Cythera	1903	7.2	35.90	22.60	-	-	-	61	70	144	-	-	C
154	Crete	1856	7.7	35.00	24.70	-	-	-	37	47	146	-	-	C
155	Rhodes	1926	7.6	36.40	28.00	-	-	-	80	65	77	-	-	C

ate global relations for each kind of faulting. We found that the lengths of thrust and normal faults are smaller than the lengths proposed by Papazachos et al. (2001) for the same faults whereas strike-slip faults are larger. The earthquakes within each focal region were declustered in time, in order to identify the mainshocks of the region. It is found that the mainshocks exhibit quasi-periodic behaviour when the preshock and postshock time periods are both equal to 8.5 years. Regarding the completeness of the historical part of the earthquake catalogue used we found that this catalogue is complete since 1845 for mainshocks with M≥6.5 in the whole Aegean area. In many focal regions, however, completeness for earthquakes with magnitudes larger than 6.5 are extended further back in time.

9. Acknowledgements

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