# CHAPTER 5

# Seismic History and Hazard


**GEER/EERI/ATC Cephalonia, Greece 2014**

**Report Version 1**

# 5.1 Historical Earthquakes

## INTRODUCTION

Cephalonia has a remarkable seismic history which can be traced back to antiquity. This section presents macroseismic data and the high historic seismicity of the region. The effects of the 18 strongest earthquake events ($6.3 \leq M \leq 7.4$) since the middle of the 15th century are listed. The main seismotectonic feature of the greater geographic region of Cephalonia, the Central Ionian Islands area, is the Cephalonia Transform Fault (CTF) is shown on Figure 5.1.1 (Scordilis et al., 1984) and also discussed in the Geology Section (6.1) of this report.


**Figure 5.1.1.** Key seismotectonic features of the broader Aegean area. The Cephalonia Transform Fault (CTF) is shown within the black rectangle (modified after Scordilis et al., 1984).

Current ongoing studies compare observed and theoretically estimated intensity distributions from historical records to regional probabilistic seismic hazard studies. Findings of these studies will be incorporated in a future version of this report.

## HISTORIC SEISMIC HAZARD MAPPING

The Cephalonia island has been located within the highest seismic zoning in all revisions of seismic hazard mapping of Greece. Three versions of such maps, dated from 1939 to 2001 are presented on Figure 5.1.2.

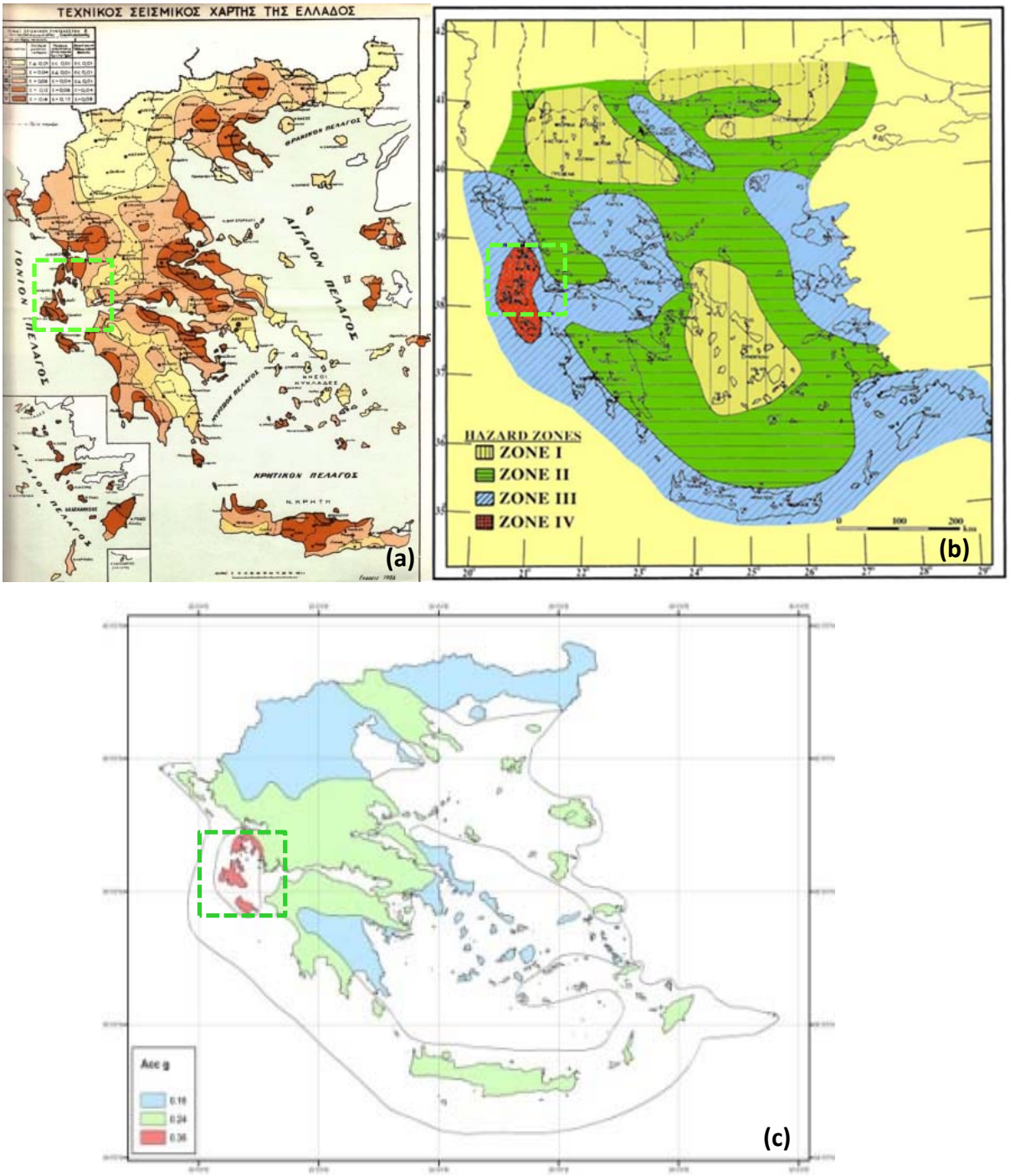



**Figure 5.1.2.** Seismic hazard maps of Greece published in: (a) 1939; (b) 1995; and (c) 2001 (referenced in current Greek Seismic Code). Cephalonia region shown in dashed green rectangle.

The first seismic hazard map of Greece was published in 1939 in the Technical Chronicles Magazine (Vol. 184). Shown on Figure 5.1.2a, the 1939 mapping assigned 3 different zones to Cephalonia with design acceleration values ranging from 0.08 to 0.16 g. A revised version of this map was adopted in the seismic code of 1956 which included the Aegean sea islands of Dodecanese that merged with Greece after World War II. The seismic hazard zonation of Figs. 5.1.2b, c formed the basis for the 1995 and current national seismic codes, respectively.

## HISTORIC EARTHQUAKE RECORDS [1469–1983]

Recognizing the importance of historical macroseismic observations in evaluating seismic hazard and mitigating seismic risk, the Geophysical Laboratory of the Aristotle University of Thessaloniki (AUTH), has been archiving macroseismic data since the 1980s. Papazachos and Papazachou (1989) have published a catalogue of strong earthquakes (M>6.0) in the Aegean and surrounding area between 550 BC and 1986. Papazachos et al. (1997a,b) successively published an updated catalogue of these earthquakes including macroseismic data from bulletins of the Observatory of Athens (1900-1939 and 1950-1996) resulting into a database of 37,000 macroseismic observations from 900 earthquakes. The database has proven invaluable for studies on attenuation relations, development of synthetic isoseismal maps, estimating upper bound intensity of rupture zones, and performing probabilistic seismic hazard studies (Papazachos and Papaioannou, 1998; Papazachos et al., 1998).

Using information from this database, the regional seismic hazard map based on macroseismic intensity observations over the past six centuries is currently being revised, specifically incorporating use of: (i) macroseismic intensity to estimate the magnitude and epicenter of the causative earthquake for each historic reference, and (ii) early analogue recordings to estimate source parameters of several strong events from the past 150 years.

Earthquake information for the 18 strongest ($M \geq 6.0$) historical events of magnitude between 6.3 and 7.4 since the second half of the 15$^{th}$ century AD, are summarized on Table 5.1.1 and discussed in the following paragraphs. Historic data of earthquakes with available macroseismic intensities at long distances (low intensities) were used and macroseismic effects at short distances. The low intensities were used to calculate the earthquake magnitude and the scaling relation by Papazachos & Papaioannou (1997) was applied to assess the macroseismic intensity near the epicenter. Since macroseismic effects on old buildings near the epicenter are known, a relation between them and the intensity estimated in a modern macroseismic scale

was attained. Generally, these effects correspond to the five high intensities of the Modified Mercalli (MM) scale, shown on Table 5.1.2. Available macroseismic intensities were used to determine the maximum macroseismic intensity, $I_o$, at the center of the rupture zone using the Papazachos (1992) methodology, which showed that all historic events had $I_o \geq$ VIII, while recorded earthquakes after 1960 had an $I_o$ cutoff value of VI.

**Table 5.1.1.** Information on source parameters of strong (M≥6.0) earthquakes in the area of Cephalonia from 1469 to 1983 (Papazachos and Papazachou, 2003).

| Year | Date Time | Latitude | Longitude | Magnitude | Locality | max Intensity $I_o$ |
|---|---|---|---|---|---|---|
| 1469 | Spring | 38.30 | 20.50 | 7.2 | Cephalonia | IX |
| 1636 | 30-Sep midnight | 38.10 | 20.30 | 7.2 | Cephalonia | IX (Makropoulo) |
| 1638 | 16-Jul | 38.20 | 20.40 | 6.4 | Cephalonia | VIII |
| 1658 | August 24 | 38.20 | 20.40 | 7.0 | Cephalonia | IX (Lixouri) |
| 1714 | August 28 | 38.10 | 20.50 | 6.4 | Cephalonia | VIII |
| 1741 | June 23 | 38.15 | 20.40 | 6.4 | Lixouri | VIII |
| 1759 | June 13 | 38.20 | 20.50 | 6.3 | Argostoli | VIII |
| 1766 | July 24 | 38.10 | 20.40 | 7.0 | Cephalonia | IX |
| 1767 | July 22 | 38.30 | 20.40 | 7.2 | Cephalonia | X (Lixouri) |
| 1862 | March 14 | 38.30 | 20.40 | 6.5 | Argostoli | IX |
| 1867 | February 4 4:19 | 38.39 | 20.52 | 7.4 | Cephalonia | X (Lixouri) |
| 1912 | January 24 16:22:51 | 38.11 | 20.67 | 6.8 | Cephalonia | X Asprogerakas |
| 1915 | January 27 1:09:56 | 38.36 | 20.60 | 6.6 | Ithaca | IX (Exogi) |
| 1915 | August 7 15:04:03 | 38.50 | 20.62 | 6.7 | Ithaca | IX |
| 1953 | August 12 9:23:52 | 38.30 | 20.80 | 7.2 | Cephalonia | X+ (Argostoli) |
| 1972 | September 17 14:07:15 | 38.21 | 20.31 | 6.3 | Cephalonia | VII (Chavriata) |
| 1983 | January 17 12:41:31 | 38.10 | 20.20 | 7.0 | Cephalonia | VI (Argostoli) |

**Table 5.1.2.** Modified Mercalli (MM) intensities and corresponding effects.

| MM Intensity | Effect |
|---|---|
| Intensity VII | Cracks (fissures) in many structures (houses, walls, castles, etc). Minor damage in several structures. Collapse of some weak structures and non-structural components. |
| Intensity VIII | Significant damage in many structures. Destruction of several structures. Collapse of some ordinary structures. |
| Intensity IX | Extensive damage. Destruction of many structures. Collapse of several structures. |
| Intensity X | Extensive destructions. Collapse of many structures. |
| Intensity XI | Collapse of almost all structures. |

Figure 5.1.3 shows the spatial distribution of epicenters of the earthquakes in Table 5.1.1. Colored circles represent data of the early instrumental period (after 1900), while grey circles show epicenters of the historical (prior to 1900) period. Clearly most of the epicenters are at the western part of the island. Key features and references for these events are provided in the following paragraphs.

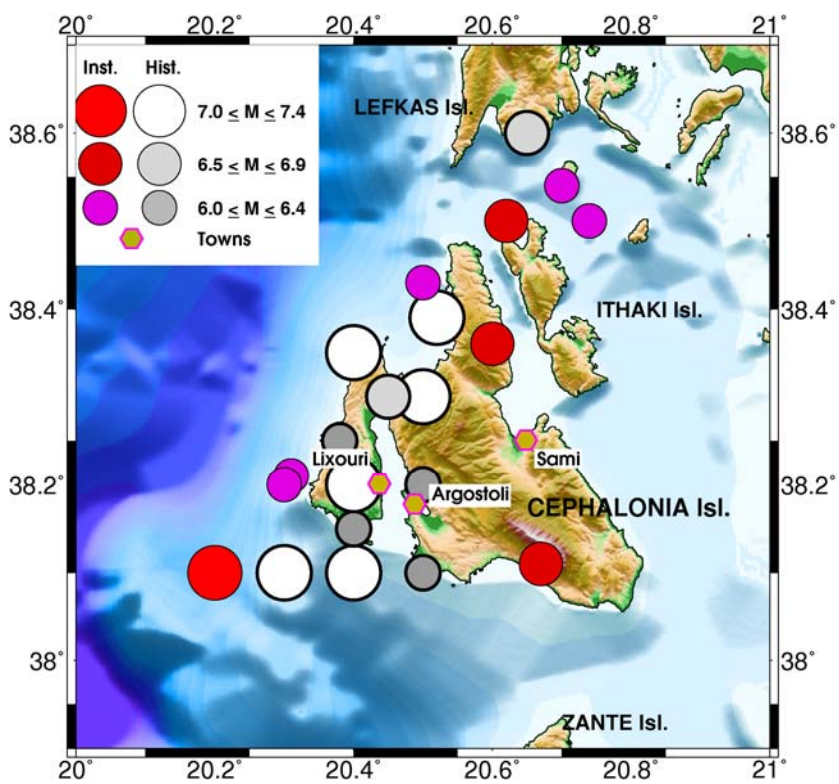



**Figure 5.1.3.** Epicenters of strong (M ≥ 6.0) earthquakes at the broader area of Cephalonia since 1469. Historical events in gray circles and instrument-based epicenters in colored circles.

**1469, Spring season, 38.3º N, 20.5º E, h = n, M 7.2, Cephalonia (IX)**

According to Papazachos & Papazachou (2003), information for the 1469 strong earthquake is given by George Frangis and other sources (Aravantinos, 1856; Barbiani & Barbiani, 1864). In the spring of 1469, numerous earthquakes occurred and were strongly felt in the Ionian islands of Lefkada, Cephalonia and Zante (Zakynthos), with disastrous effects. Many of the state buildings collapsed killing many of the inhabitants. In Cephalonia, the walls were entirely destroyed and a small town entirely collapsed. The 1469 shock was felt in Epiros. Aftershocks continued for many months and kept the inhabitants at unrest.

**1636, September 30, 38.1º N, 20.3º E, h = n, M 7.2, Cephalonia (IX, Makropoulo)**

The 1636 earthquake caused severe destruction in Cephalonia based on Papazachos & Papazachou (2003). It devastated the villages Eikosmia, Eleio, Makropoulo, Valta, Koronoi, Solomata, Heraklio, and Pyrgio. In the mountain Ainos many trees were uprooted, while the chapel of Aghios Eleftherios remained undamaged. Omala experienced minor damage, but the area around the fortress, including Livatho, Argostoli, and Lixouri, suffered significant damage. The earthquake caused rockslides and the Acropolis to sink in the sea at the location where Kakkava appears. 520 people lost their life. A captain of a ship observed an intense sea wave out of Cephalonia. The aftershocks continued up to the spring of 1637 (Perrey, 1848; Mallet, 1854; Schmidt, 1867a; Partsch, 1890; Romas, 1975).

**1638, July 16, 38.2º N, 20.4º E, h = n, M 6.4, Cephalonia (VIII)**

Based on Papazachos & Papazachou (2003), a note in the historical record of Cephalonia (Pentogalos, 1973; Mouyiaris, 1994) mentioned that the 1638 earthquake completed the disaster of the 1636 earthquake. It completely destroyed the buildings which survived the 1636 earthquake and several new structures and resulted in the collapse of the archiepiscopate building.

**1658, August 24, 38.2º N, 20.4º E, h = n, M 7.0, Cephalonia (IX, Lixouri)**

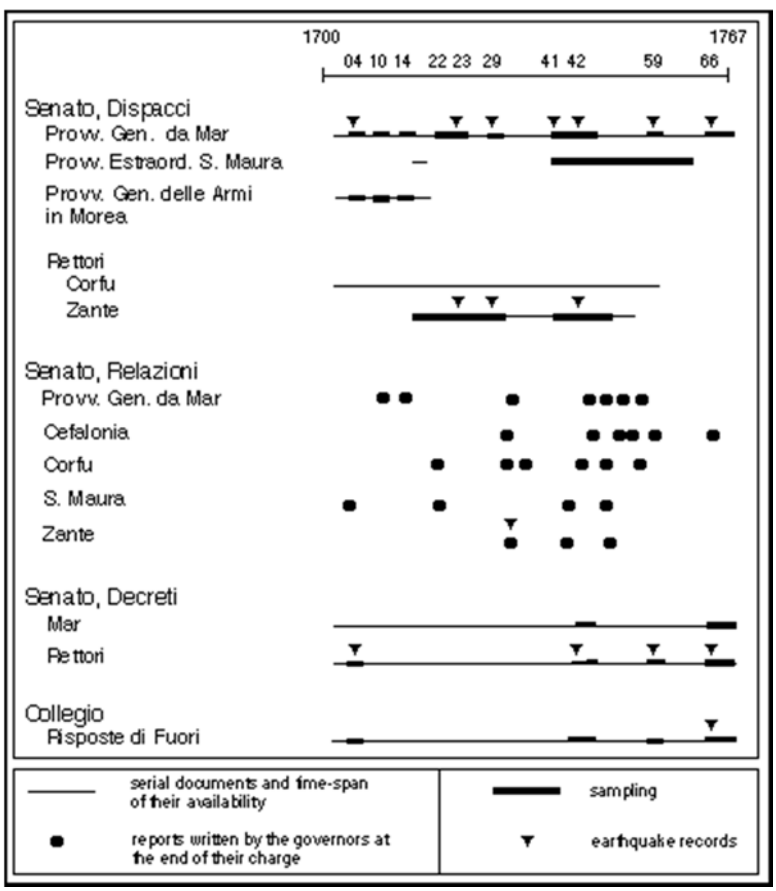
Similar to the 2014 events, the 1658 earthquake hit the Paliki peninsula as described in Papazachos & Papazachou (2003) based on information by Schmidt (1867), Partsch, (1890) and Tsitselis (1960). In Lixouri, 500 houses collapsed and 20 people were killed. In the month following the mainshock, almost all village houses in the peninsula area collapsed and about 300 more people died. A whole hill with a church disappeared and the monastery of Gera was severely damaged.

**1714, August 28, 38.1º N, 20.5º E, h = n, M 6.4, Cephalonia (VIII)**

Reports by Barbiani and Barbiani (1864) and Chiotes (1886-87) summarized in Papazachos & Papazachou (2003) state that the 1714 earthquake of Cephalonia was very strong and caused overturn and collapse of about 280 houses. Gaps were evident on the earth's surface at several locations and new hot springs were created. The inhabitants stayed outdoor for two months.

Albini et al. (1994) states that "A damaging earthquake in Cephalonia is mentioned in a 18th century history of Epirus (Michael, XVIII) after the earthquake in Patras of 27 July 1714 [Old Style Julian calendar, OS]. On 28 August 1714 (OS), another more dreadful earthquake occurred in Cephalonia, where the Venetian admiral was at anchor with his fleet. The earth opened, hot water flowed out; 280 houses were destroyed, water issued from the earth, and the inhabitants lived two months in the gardens". However, this event has not been mentioned in the examined contemporary dispatches originating from the Ionian Islands and addressed to the Venetian authorities (Daltri & Albini, 1991).

**Table 5.1.3.** Venetian documentary sources of information regarding the Ionian islands, available from the State Archives of Venice (ASVe, 1712-1764). Modified from Albini, et al. (1994).



The Provveditore Generale da Mar Agostino Sagredo stayed for some time in Morea and was back in Corfu on August 20th, according to the Venice State Archives (ASVe, 1714a). He was substituted by Daniele Dolfin, who visited Cephalonia early in October (ASVe, 1714b). In that period the Venetian governors were focused on the war with the Ottoman Empire for the control of Morea. There is no mention of this earthquake in the dispatches and letters of the Provveditore of Cephalonia and of the consul in Patras to the Cinque Savi alla Mercanzia (ASVe, 1693-1722; ASVe, 1712-1764) presented in Table 5.1.3 (Albini et al., 1994). The earthquake was reported in the European press (Theatrum Europaeum, 1714) where the events in Patras and Cephalonia are amalgamated into one shock dated September 3rd, 1714 N.S. (referring to New Style Julian Calendar, N.S.). This erroneous information is repeated by other contemporary sources (Amato, 1715).

**1741, June 23, 38.15º N, 20.40º E, h = n, M 6.4, Lixouri (VIII)**

Papazachos & Papazachou (2003) report that the earthquake destroyed houses in the northwest part of Cephalonia, especially in Lixouri, Argostoli, and Kastro (Aghios George). The parochial temple in Lixouri was completely destroyed in addition to some public buildings. In the fortress of Assos, many buildings collapsed and the remaining were severely damaged. The aftershocks continued for five months causing extra damages in the west part of Cephalonia (Albini et al., 2000). Albini et al (1994) states that *"On 23 June 1741 (N.S.) an earthquake affected the Ionian Islands"* In the southwest part of the Cephalonia Island, all the houses, particularly those in the districts of Lixouri, Argostoli, and Borgo (Castro, now called Aghios Georgios) were shattered. The parish church of Lixouri collapsed, as did a number of public buildings. In the fort of Assos many dwellings collapsed and the rest of the buildings were ruined, apparently without loss of lives (ASVat, 1743a). Venetian documents do not supply the date and briefly describe the damage in Argostoli and in the Assos Fortress (ASVe, 1741b). There is no evidence that the earthquake was felt elsewhere. It was followed by aftershocks that continued intermittently for five months (ASVe, 1741a), causing great concern and additional damage in the western part of Cephalonia (ASVat, 1743a).

**1759, June 13, 38.2º N, 20.5º E, h = n, M 6.3, Argostoli (VIII)**

A journal entry of a monk reported that earthquakes began on June 2nd 1759 and lasted until June 5th (Papazachos & Papazachou, 2003). The shock was felt in Zante (Tsitselis, 1960) and Albini et al. (1994) mention these earthquakes in the western part of Cephalonia (Fig. 5.1.4). Tsitselis (1904) states that according to a local contemporary note "*earthquakes began [in*

*Cephalonia] on the June 2nd [1759 O.S.] and continued until June 5th; the one which happened at noon destroyed many houses and the other on the 3rd caused the collapse of most houses in the villages and in the town.*" A dispatch from the Venetian authorities in Cephalonia mentions: "*in the night between June 13 and 14 [N.S.], at about six hours, there was a violent earthquake, which was followed by a series of weaker shocks ... The following morning, about 16 hours later, there occurred a much stronger shock that produced great ruin*" (ASVe, 1759a).

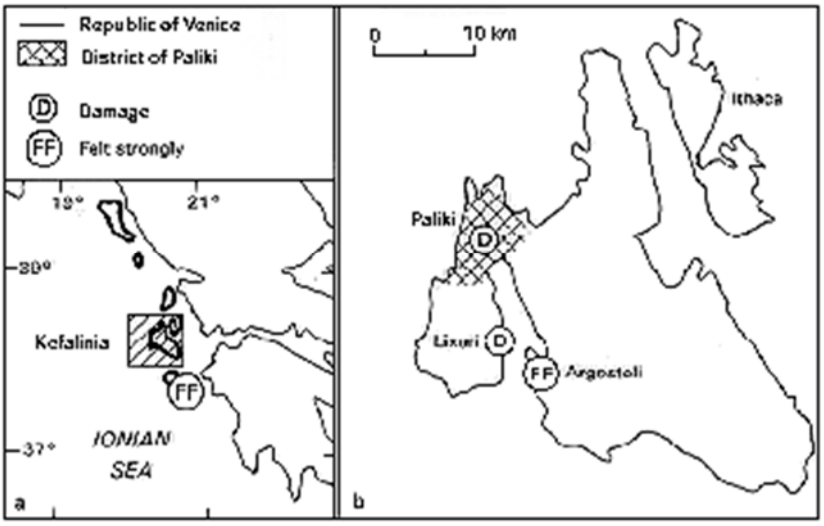



**Figure 5.1.4.** Effects of the earthquakes of June 1759 (from Albini et al., 1994).

The damage of the two shocks was concentrated in the district of Paliki and Lixouri, where most of the houses, windmills, and churches collapsed and a few lives were lost (ASVe, 1759b). In Argostoli the shock was strongly felt but did not cause significant damage. The severe damage of country villages is stressed by the Provveditore Generale da Mar, Francesco Grimani, in his 12 September dispatch (ASVe, 1759c). The main shock was felt strongly in Zante (AGP, 1628-1807). There is no evidence that the earthquake was felt at Arta and Patras (ASVe, 1728-1794; ASVe, 1712-1764). Strong aftershocks continued to be felt in Cephalonia until June 5th (Tsitselis, 1904).

**1766, July 24, 38.1º N, 20.4º E, h = n, M 7.0, Cephalonia (IX)**

The violent shock of 1766 occurred at 5 am, followed by three more earthquakes on the same day (Papazachos & Papazachou, 2003). Houses, churches, and monasteries collapsed, no bell towers remained standing and 20 people were killed. Sulfur smell covered the island. Many inhabitants moved to Moria and others stayed outdors all summer. On October 18th, about 3 months after the mainshock, a resident of Cephalonia wrote that the earth had not quieted down. (Perrey, 1848; Barbiani & Barbiani, 1864; Katrames, 1880; Partsch, 1890; Tsitselis, 1960).

Albini et al. (1994) state the occurrence date as July 22nd (N.S.) and reports the a destructive earthquake in Cephalonia, preceded by a foreshock before dawn, had the main shock occurred one hour after sunrise on 11 July 1766 (O.S.) lasting, with intermissions, three minutes. The earthquake was followed by three other shocks in the same day. The western part of Cephalonia suffered the most (Albini et al., 1994). A manuscript note from Michalitzata (Vergotis, 1867) says that most of the houses in t Paliki were destroyed and those left standing were damaged. Damage extended to Assos (ASVe, 1766e, f), Lixouri (ASVe, 1766b) and Argostoli, where, among others, the Latin church of San Nicolò in Argostoli (ASVe, 1766d) and a number of manor houses were ruined (Fig. 5.1.5). An estimated 20 people were killed in the island.

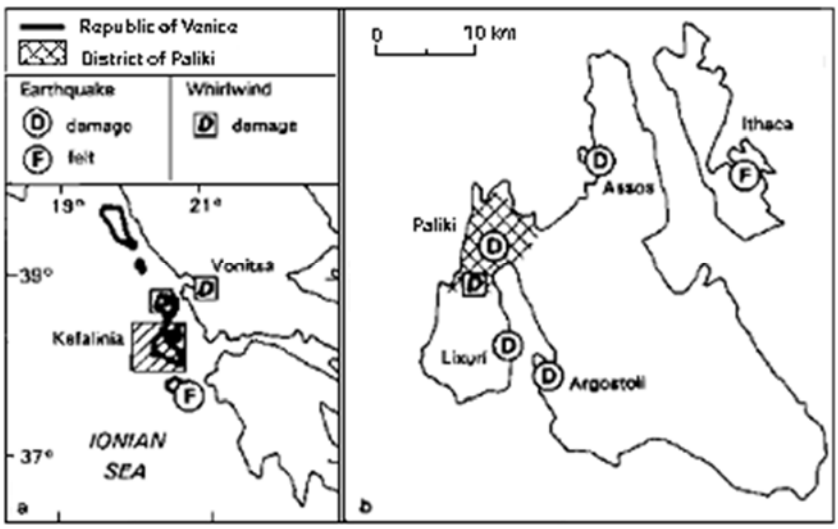



**Figure. 5.1.5.** Localities damaged by the whirlwind of 31 May [square] and by the earthquake of July 1766 [circle] (from Albini et al., 1994).

**1767, July 22, 04: 38.3º N, 20.4º E, h = n, M 7.2, Cephalonia (X, Lixouri)**

The 1767 event is reported as the strongest felt earthquake up to that time in Cephalonia (Barbiani & Barbiani, 1864; Stamatelos, 1870; Katramis, 1880; Partsch, 1887; Maragakis, 1977; Kavasakales & Polymenakos, 1988; and Newspaper Neologos Patron dated 29.09.1953. Based on the available information, Papazachos & Papazachou (2003) mention that felt seismic activity started a month before the mainshock and intensified on July 11th. The earthquake occurred in the early morning of July 22nd and destroyed most of the Cephalonia houses and damaged many of the remaining ones. In Lixouri, all houses collapsed and 50 people were killed. Another event occurred on July 24th, with same intensity as the first, but smaller duration, resulting in collapse of damaged stone houses and churches.

Similar to the 2014 events, the villages on the west of Paliki peninsula suffered the most severe damage with evidence of landslides, liquefaction, and large open cracks on the ground

surface (one reaching 100 m in length and 1 m in width). A total of 2,642 houses were destroyed and 2,946 were damaged. The total death toll was 253 in the whole island. In the monastery of Bardianon (south of Lixouri) all buildings collapsed up to their foundations. A new wooden church was built in replacement, while the overall damage was restored in 1770.

**1862, March 14, 38.3º N, 20.4º E, h = n, M 6.5, Argostoli (IX)**

Based on information by Barbiani (1864), Sieberg (1932), and Montandon (1953), Papazachos & Papazachou (2003) mentioned that the violent shock destroyed Argostoli and caused some damage in Lixouri. Some damage was also observed in Corfu but no damage was observed in Zante, where another shock was felt on March 26$^{th}$.

**1867, February 4, 04:19, 38.39º N, 20.52º E, h = n, M 7.4, Cephalonia (X, Lixouri)**

According to Papazachos & Papazachou (2003), large destructions occurred in villages located in the western part of Paliki peninsula, where Lixouri is located and where only two houses were saved. The villages Katoe, Anoe, Nisochori, Thynnios, Dellaportata, Kouraklata, Metaxata, Kaligata, Schoenias, Aghia Thecla, Poriorata, and Baroskes were entirely destroyed. A total of 2,612 houses were destroyed, 2,946 suffered damage and at least 224 people were killed. Withdraw of the sea was observed before and after the earthquake. A minor sea wave was observed. Fissures of the ground were observed and the widest of these crossed the pavement of Lixouri, where all houses collapsed. Phenomena of liquefaction and rock falls were observed, similar to the 2014 events.

In Argostoli, houses located on the seaside, suffered damage and four of them were destroyed entirely. The earthquake caused much smaller damage in Ithaca and in Lefkada, where two villages were destroyed. Negligible was the damage in Zante (Zakynthos), Corfu, and in the neighboring mainland. The felt area was elliptic in shape, defined by Epidamnos (Dyrrachio), Olympus of Thessaly, Pagases, West Euboea, Kea, Maleas, Tarado, and Otrado of Italy. Just before the earthquake, a horse in Argostoli cut its bonds, got out from the stable and started to run. The earthquake was preceded in the night by other shocks. Aftershocks continued daily for months until the end of April, some felt as far as Athens (Schmidt, 1867b; Vergotes, 1867; Spanopoulos, 1867; Ioseftypaldos, 1868; Alisandratos, 1962).

**1912, January 24, 16:22, 38.11º N, 20.67º E, h=n, M 6.8, Cephalonia (X, Asprogerakas)**

The 1912 earthquake partly destroyed Cephalonia and Zante (Zakynthos) according to Papazachos & Papazachou (2003). Large parts of the Cephalonia villages of Asprogerakas,

Poros (Pronos), Scala, and Chionata (Elios) and some villages in the northern part of Zante were destroyed. In Poros (very near Asprogerakas), 8 people were killed and 40 were injured.

In Argostoli, two fissures, 5 to 7 cm wide and 70 to 110 m long, were observed in the dock, while in the cobbled street of Zante observed fissures were about 20 m in length. Some damage was also observed in Ithaca. In Gastoune, 10 houses had major cracks and in the village of Roviata a house collapsed. The earthquake shook almost all of Greece and was very strongly felt in Lefkada, Messologhi, Agrinio, and Kyparissia. The aftershocks continued up to April and some of these were strong enough to cause additional damage in the already damaged houses. (AOA, 1916; Eginitis, 1916a). The largest aftershock occurred three hours after the mainshock (h= 19:52:35, M5.9). Isoseismals are cited by Goulandris (1916), in the atlas of UNESCO (Shebalin et al., 1974b) and by Papazachos et al. (1997b).

**1915, January 27, 01:09:56, 38.36º N, 20.60º E, h = n, M 6.6, Ithaca (IX, Exogi)**

Information on the sequence of 1915 events were compiled by Papazachos & Papazachou (2003), according to which the villages of Exogi and Kolieri many houses collapsed and the remaining were seriously damaged. The neighboring villages also suffered serious damage. Many small fissures, 3 to 5-m long with EW or NW-SE direction were observed in Ithaca.

Ground subsidence of up to 60 cm was observed in several locations. The earthquake was violently felt all Ionian islands, western Greece and northwest Peloponnese. The earthquake was felt as two shocks in the town of Kyparissia, while reports of preceding sounds were reported in the town of Magoulades at the island of Corfu. The felt area reached Avlona and the Italian coast (Lecce, Otranto, Alessano) (Eginitis, 1916b; Michailovic, 1951). It was followed by aftershocks, the largest of which occurred on February 20$^{th}$ (h = 08:13:24, M5.0) and was strongly felt in Lefkada. Isoseismals of the earthquake are cited in the atlas of the Geophysical Laboratory of the AUTH (Papazachos et al., 1982, 1997b).

**1915, August 7, 15:04:03, 38.50º N, 20.62º E, h = n, M 6.7, Ithaca (IX)**

During the 1915 earthquake, in the Cephalonia villages of Exogi, Kolieri, Platithrias, Kolyvia, Stavros, Sami and Aghioi Saranda of Ithaca, out of 350 houses, 50 collapsed, 100 became uninhabitable and more than 100 were significantly damaged (Papazachos & Papazachou, 2003). Cracks 2 to 15 m long and 10 cm wide with NW-SE direction were observed on the ground surface. In the area of Platithrias ground subsidence occurred. In Lefkada island no major damage was observed in the main town, while 4 houses of Vasiliki

village became uninhabitable. In the same island, a large part of Aghios Petros suffered large destruction, especially villages of Kontaraena, Eughiros, and Nydri. A part of the cape Doukato tumbled down to the sea. Large rocks fell from the mountains of Stavrota and Vournika.

In Cephalonia, villages located in the opposite side of Lefkada suffered serious damage. In the village of Feredinata, from the 130 houses, 30 overturned. Just before the earthquake, the sea between Cephalonia and Lefkada was upset and two opposite large waves were formed and directed south. In Lefkada, the earthquake was preceded by noise, which came from the sea. In Preveza, many houses were seriously cracked, while small damage was reported in the island of Paxoi. The felt area was spread in great distances, reaching from Corfu, Ioannena, Karditsa, Larisa, Volos, Lamia, Trikala, and Kyparissia to the coast of Hepiros and Albania (Avlona), as well as in the Italian coast (Lecce, Otranto, Dica, Alessanso, Callipole, Tarisano) (AOA, 1926; Michailovic, 1951). The mainshock was followed by a large number of aftershocks, the largest of which occurred on August 11$^{th}$ (h= 09:10, M6.4) and caused considerable damage. Isoseismals of the earthquake are cited in the atlas of the Geophysical Laboratory of University of Thessaloniki (Papazachos et al., 1982, 1997b).

**1953, August 12, 09:23:52, 38.3$^{o}$ N, 20.8$^{o}$ E, h = n, M 7.2, Cephalonia (X+, Argostoli)**

The 1953 earthquakes were a sequence of destructive shocks, the largest of which occurred on August 12$^{th}$ with a surface wave magnitude $M_s$ = 7.2 (Papazachos & Papazachou, 2003). Many foreshocks occurred, two of which were particularly destructive. The first foreshock occurred on August 9$^{th}$ (h = 07:41, $M_s$ = 6.4) and the second on August 11$^{th}$ (h = 03:32, $M_s$ = 6.8). It was followed by many aftershocks the largest of which occurred (h = 12:05, $M_s$ = 6.3) on the same day as the main shock. Significant damage was caused in all Ionian islands and mainly in Cephalonia, Zante, and Ithaca, which were almost entirely totaled. Out of 33,300 houses in these islands, 27,659 collapsed, 2,780 were seriously damaged, 2,394 were slightly damaged, and only 467 survived. 455 people were killed, 21 disappeared, and 2,412 were injured. In the island of Lefkada, 122 houses were seriously damaged and 341 were lightly damaged. The damage expanded in Aetolia and Elia, where 18 and 46 settlements were damaged, respectively. In total, 60 houses of Aetolia were destroyed and 293 suffered damage, while in Elia 50 houses were destroyed and 1546 suffered damage. Clear traces of upward motion was observed at several locations in the east and south coast of Cephalonia. The largest intensities (IX-X) were observed in the Cephalonia towns of Argostoli, Lixouri, Valsamata,

Asprogerakas, Havdata, and Aghia Efthimia. In Zante intensities were between (IX) and (IX+). The mainshock was also felt in lower Italy (BGINOA, 1953; Galanopoulos, 1955). Isoseismals of the mainshock and largest foreshocks are cited in Papazachos et al. (1982). Photos from the 1953 earthquakes are shown on Figs 5.1.6 to 5.1.10.

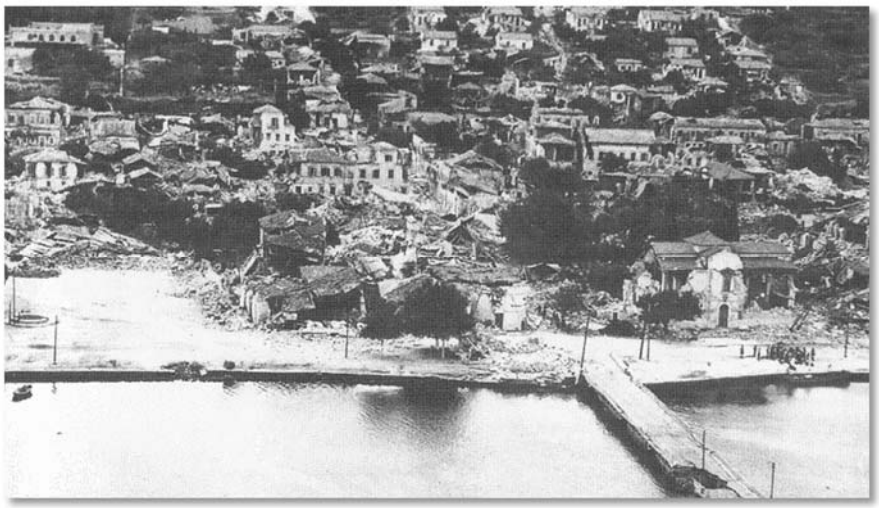


**Figure. 5.1.6.** Damage to Argostoli waterfront after the 1953 earthquakes (kefalonitikanea.gr, 2013).

**Figure. 5.1.7.** Massive collapse of Cephalonia housing stock following the 1953 earthquakes (web).

**Figure. 5.1.8.** Temporary tents used to house thousands of homeless and serve as hospitals for the injured under very difficult conditions after the 1953 earthquakes (ionian-island.co.uk/greece).

**Figure. 5.1.9.** Damage to the Argostoli obelisk monument "Kolona" (GPS coordinates 38°10'26.25"N, 20°29'45.59"E) following the 1953 earthquakes (ionian-island.co.uk/greece). The monument was rebuilt. Its upper drum toppled after the 2nd event of 2014 (see Bridges Section 8.5 of this report).

**Figure. 5.1.10.** Photograph of mother and child at Argostoli port following the 1953 earthquakes (t53vorini-gr.blogspot.com).

### 1972, September 17, 14:07, 38.21º N, 20.31º E, h=n, M6.3, Cephalonia (VII, Chavriata)

The 1972 M 6.3 earthquake caused damage in the southwest part of Cephalonia (Papazachos & Papazachou, 2003). 108 old houses had to be demolished and 57 buildings and two bridges had significant cracks. No life was lost and only one person was injured. The most significant damage and overall intensities were observed in the Cephalonia towns of Chavriata (VII), Damoulianata, Kouvalata, Aghia Thekla, Matzouvinata, Skinea, and Delaportata (VI+) (BGINOA, 1972). Isoseismals are cited in the Atlas of the Geophysical Laboratory of the University of Thessaloniki (Papazachos et al., 1982, 1997b). Foreshocks preceded, the largest of which occurred on August 14th (h = 19:22, M4.4) and a large number of aftershocks followed, the largest of which occurred on October 30th (h = 14:32, M5.4).

**1983, January 17, 12:41:31, 38.1º N, 20.2º E, h = n, M 7.0, Cephalonia (VI, Argostoli)**

The 1983 large M 7.0 earthquake had epicenter in the Ionian sea area southwest of Cephalonia (Papazachos & Papazachou, 2003), causing generally small damage (Intensity VI) in the island. The largest aftershock occurred on March 23rd (h=23:51, M 6.4) and caused larger damage in Cephalonia (VI in Aghia Thekla) due to the proximity of the epicenter to populated areas. The recorded Peak horizontal Ground Acceleration (PGA) values were 173 and 142 cm/sec$^2$ (0.17 and 0.14 g) from the main event in two lateral directions, and 180 and 219 cm/sec$^2$ (0.18 and 0.22 g) from the March 23rd aftershock (Theodulidis et al., 2004). Isoseismals of the January 17th event are given by Papazachos et al. (1997). Comparisons of the recorded ground motions from the 1983 earthquake are presented in Chapter 7 of this report.

# 5.2 Seismic Hazard Evaluation *{in progress}*

Future versions of this report will present comparisons of observed and theoretically estimated intensity distributions from historical records to regional probabilistic seismic hazard studies.