BGSG

Volume 59

Research Paper

A Note on the Impacts of the 1810 Seismic Sequence on Crete

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DOI number:
http://dx.doi.org/10.12681/bgsg.29122

Keywords:
Crete, earthquake, isoseismal, earthquake victims, structural damage

Citation:
Stiros, S. and Horsch, G. (2022), A Note on the Impacts of the 1810 Seismic Sequence on Crete. Bulletin Geological Society of Greece, 59, 104-117.

Publication History:
Received: 05/01/2022
Accepted: 19/05/2022
Accepted article online: 03/06/2022

The Editor wishes to thank two anonymous reviewers for their work with the scientific reviewing of the manuscript and Ms Emmanouela Konstantakopoulou for editorial assistance.

Abstract

An intermediate depth earthquake sequence with an unusually strong aftershock hit Crete in 1810 and was felt in a very broad area. This seismic sequence was believed to have caused a death toll of about 2000-3000 and destroyed a major part of houses in the wider Heraklion area. In this article we present an unpublished note for this earthquake sequence from the memoirs of Frangiskos Limbritis, military and political personality in Crete, and analyze certain other notes from Crete and conclude that the death toll in Heraklion which was mainly affected was of the order of 300 and that structural damage was smaller than what believed in the past and was mostly rapidly repaired, especially in the meizoseismal area which roughly covers the present-day Heraklion prefecture (max intensities VIII-IX).

Keywords: *Crete, earthquake, isoseismal, earthquake victims, structural damage*

Περίληψη

Μια σεισμική ακολουθία ενδιαμέσου βάθους με ένα ασυνήθιστα μεγάλο μετασεισμό έσεισε την Κρήτη το 1810 και έγινε έντονα αισθητή σε πολύ μεγάλη περιοχή . Η σεισμική αυτή ακολουθία θεωρείται ότι προκάλεσε το θάνατο 2000-3000 ατόμων και κατέστρεψε το μέγιστο μέρος των οικοδομών στην ευρύτερη περιοχή του Ηρακλείου. Στο άρθρο αυτό παρουσιάζεται πληροφορία από τα αδημοσίευτα απομνημονεύματα του Φραγκίσκου Λιμπρίτη, οπλαρχηγού και εκπροσώπου της Κρήτης, και αναλύονται διάφορες άλλες πληροφορίες από την Κρήτη. Τα δεδομένα αυτά οδηγούν σε μία εκτίμηση 300 περίπου θυμάτων από το σεισμό στο Ηράκλειο που είχε ιδιαίτερα πληγεί, και σε σχετικά περιορισμένες καταστροφές στις οικοδομές που στην πλειοψηφία τους επισκευάστηκαν σύντομα, κυρίως στην πλειόσειστη περιοχή που σε πρώτη προσέγγιση καλύπτει τον σημερινό Νομό Ηρακλείου (μέγιστη ένταση VIII-IX).

Λέξεις-κλειδιά*: Κρήτη, σεισμός, ισόσειστες, θύματα, καταστροφές*

1. INTRODUCTION

The 19th century was a politically and socially turbulent period for Crete, culminating with the independence of the island from the Ottoman Empire in 1898, followed by the annexation of the island to Greece in 1912 and the exchange of populations with Turkey in 1923. As a result, more than 30000 Muslims left the island, which then received tens of thousands of Christian people from parts of modern Turkey. These events, in combination with devastating earthquakes, especially the 1856 earthquake, had a catastrophic impact on local archives, and hence on our knowledge of earthquakes which hit the island in the 19th century.

Among these events are the February 16/17, 1810, earthquakes (new calendar), which are assigned to a highly destructive, intermediate depth earthquake sequence. There is much information about the effects of this earthquake sequence in the far field (mainland Greece and Aegean Islands, Asia Minor, Cyprus, Middle East, Northern Africa, Southern Italy and Trieste, Malta), documenting an intermediate depth seismic sequence (see Ambraseys 2009), but the existing information on Crete is rather limited and confused by impacts of a revolution in the 1820's and of plague outbursts. For this reason, it was so far believed that this earthquake destroyed two thirds of the houses of Heraklion and killed about 2000-3000 people (Platakis, 1950; Papazachos and Papazachou, 1997; Ambraseys, 2009; Papadopoulos, 2011). This conclusion derives from three main types of sources. First, information received and communicated by John Galt, when he was in Chios, a few months after the event. John Galt was a well-known Scottish novelist, entrepreneur and political person, an influential friend of Lord Byron, who had personally felt the earthquake in Tripolis, southern Greece mainland. Second, by information derived from memoirs of people who had personal experience of the earthquake in Crete. And third, by information in various sources, especially later sources.

In this note we present new information for these earthquakes derived from the unpublished memoirs of Frangiskos Limbritis, one of the leaders of armed groups fighting for the liberation of Crete in the Heraklion area, and subsequently one of the deputies of Crete. This information, combined with information from certain other reliable diary notes in the Heraklion area, permits to recognize reports exaggerating the earthquakes and

(i) to estimate a realistic death toll;

(ii) to present some results on the response of the buildings during this seismic sequence;

(iii) to identify the meizoseismal area of the seismic sequence in Crete.

2. SEISMICITY IN CRETE

Crete is well-known for its seismicity, both concerning frequency and magnitude, occasionally exceeding the level of M8 (Papazachos and Papazachou, 1997; Ambraseys, 2009). The Aegean Arc earthquakes which affect Crete are essentially of two types, intermediate-depth earthquakes, and shallow earthquakes. Intermediate depth earthquakes in the Hellenic Arc are felt in a very broad zone, from Malta and Italy to Cyprus and the Middle East and northern Africa; the 1856 shock, highly destructive in Heraklion is a characteristic example (Papazachos and Papazachou, 1997; Ambraseys, 2009; Papadopoulos, 2011). Shallow earthquakes, on the contrary, tend to affect a restricted area in Crete. The 2021, M6.0 Arkalochori seismic sequence south of Heraklion, is the most recent and a characteristic example of the second type of earthquakes in Crete. This event is especially noteworthy because it occurred after a long interval of pre-seismic microearthquakes and was associated with an impressive peak ground acceleration (vertical PGA 0.80; ITSAK, 2021). The 1810 earthquake sequence examined in this article corresponds to an intermediate depth seismic sequence. A characteristic of these earthquakes in the Aegean Arc is that they consist of a single main shock and few week aftershocks (Papazachos and Papazachou, 1997, p. 150). The 1810 earthquake seems to deviate from this rule.

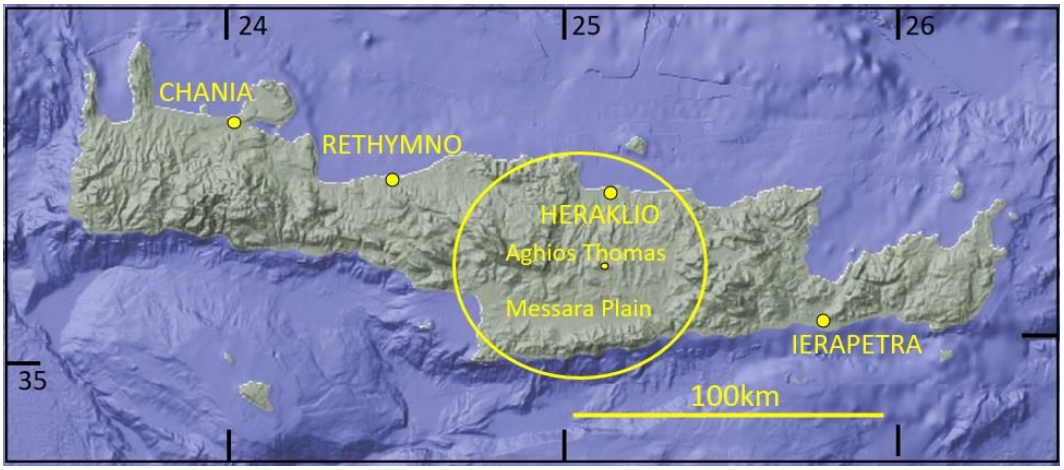

Fig. 1: Location map. A circle roughly denotes the meizoseismal area of the 1810 earthquake, surrounded by the isoseismal of intensity VIII. Based on Geomapapp®.

3. HISTORICAL SOURCES FOR THE 1810 IN THE HERAKLION AREA

Information for the 1810 earthquake comes from various sources, most of which are summarized in Ambraseys (2009) and Papadopoulos (2011). Key information, both unpublished and published, especially contemporary or nearly contemporary with the earthquake, is examined below; additional information is discussed in section 4.3.

3.1 The Limbritis unpublished diary

The excerpt from the unpublished Limbritis memoirs (in Greek in Annex 1) refers to events in his home village of Aghios Thomas, about 25 km SSW of Heraklion (Fig. 1), covers paragraph 8 in pages 15 and 16 in his hand-written memoirs and specifies that:

"*On February 4-5, 1810 [old calendar, current calendar, 16/17 February], a great earthquake occurred in the whole of Crete, by midnight. Especially in the Heraklion region, where too many houses collapsed, and many people were killed and buried by debris. At Agios Thomas 17 people were killed, buried by collapsed parts of houses, many houses survived the first earthquake. But at the second earthquake around the evening of the following day, Saturday, more houses collapsed. While I was rushing to survive in the yard where stood my mother and by brothers and sisters, a tall wall of the upper part of our house fell down and I risked being buried*."
(Excerpt from the unpublished memoirs of Frangiskos Limbritis, additions in brackets; see Appendix 1 and Fig. A1).

Limbritis was born in 1795 in the "small town of Aghios Thomas in the county of Monokrousiou" and died in 1876. Agios Thomas is described as a small town with numerous garden cultivations in a rocky area, near the remains of an ancient fortress (paragraph 6 in his memoirs). Limbritis, already 15 years old in 1810, was coming from a distinguished family and he was acting as the head of the family because his father and brother had escaped from their village to avoid problems with certain Turks; for this reason, he was expected to have strong personal memories of the events and to have behaved as an adult. The information on the 1810 earthquake seems to come from diary notes he used to compile his memoirs, mainly focusing on political and military events. His memoirs were subsequently reviewed by him, as hand-made corrections/additions/comments reveal, and they should be considered as reliable and precise.

The memoirs of Limbritis were found and are analyzed by his descendants, especially one of us (GH), and only a small part of this diary has been published so far by M. Vourlotis ("Short memoir of Frangiskos Limbritis for the revolution in Crete, 1825-1830", Publication of Crete Region, 2018, p. 201-208).

3.2 The Nikoletakis memoirs

In the memoirs of Georgios Nikoletakis (circa 1760-1820), medical doctor of the Great Castle, as was at that time Heraklion known, it is mentioned that:

"*On Friday 4 January* [to be corrected to February] *1810 at 5 h 30m of the night, dawn of Saturday, there was a great and frightening earthquake not seen before; and another shock followed at 9 h on the same day of Saturday which ruined all the houses and the mosques in Chora [Megalo Castro], burying 300 people; and many villages and manors* [perhaps church complexes] *were also ruined*"
(from Ambraseys 2009, p. 627, citing Nicoletakis, G., Chronika Simiomata 1760–1820 Chapters 12 and 17, in Greek), Historical Museum of Crete; additions in brackets).

The dating of the earthquakes in this diary is erroneous, because month and hour of occurrence of the earthquake is specified by various other reports. Perhaps this error was due to illegible characters in the diary, but the combination of month and days of the week specifies well the dating of the two shocks.

These memoirs of the (only?) doctor of Heraklion, who had a personal and professional view of the impacts of the earthquakes in this town and the wider area, are rather underestimated in favor of reports of a higher death-toll.

3.3. Report for the Messara Plain

"In the plain of Messara 17 villages were completely destroyed and 63 people were killed".
This report is mentioned by Ambraseys (2009, p. 626, referring to Gentleman's Magazine 1810, 372–373). This reference has not been verified, but Ambraseys is a trusted source.

3.4. Praktikidis report

In a book entitled "*Geography of Crete compiled in 1818*" by Z. Praktikidis, re-published by the Technical Chamber of Crete in 1983, it is mentioned that:

"*On February 5th, 1810, there took place a horrible earthquake and ruined the two thirds of the town and some nearby villages; the buildings were brought to shape right away, but 3000 people died*".
(www.candia.doc, 16 Feb 2018).

This report is questionable. It specifies that the buildings were repaired/reconstructed(?) right away («*έγειναν αμέσως*»), clearly indicating a rapid recovery from the earthquake. This source also specifies that the meizoseismal area in Crete can be identified with the town of Heraklion and some nearby villages.

3.5. The Stavrakis' 1880 report

In this book on the "Statistics of the population of Crete", written about 70 years after 1810, Stavrakis mentions that "*1810, 6 February. During this period the town of Heraklion was ruined by an earthquake and 2000 people were lost. Favre dates this earthquake to 6 March. Modern generation knows this earthquake from tradition, at that time plague was prevailing*" (www.candia.doc, 16 Feb 2018).

4. DISCUSSION

4.1 Timing of the two major shocks

Information from the Limbritis diary, compared with other literary evidence, clearly indicates that the 1810 seismic sequence comprised a first main shock at around midnight of Friday/Saturday 4 to 5 February 1810 followed by a second major shock the following morning of Saturday 17 February 1810 (new calendar, February 4/5 old calendar). This clarifies that the seismic sequence contained two strong shocks (perhaps a main event and a main aftershock) and specifies their origin time; this is important because there are some ambiguities in the existing reports (occurrence of the earthquake in January or March; see Ambraseys 2009).

4.2 Contradictory reports for death toll

The reports for death toll of the 1810 seismic sequence are contradictory. On one hand, the letter of John Galt and the reports of Praktikides and of Stavrakis have been the

basis of the analysis by Platakis (1950), Papazachos and Papazachou (1997), Ambraseys (2009) and Papadopoulos (2011) that 2000-3000 people were killed because of the earthquake in Heraklion (or in the whole of Crete). On the other hand, in his report Nikoletakis estimates the number of victims to only 300, and this estimate is expected to be reliable since he was (the?) doctor of Heraklion. These two estimates of fatalities are very different. It is therefore necessary to investigate which estimate is reliable using various arguments.

First, the high number of fatalities may perhaps include a contribution from an epidemic of plague, according to the (later) Stavrakis report (see above). However, no plague is mentioned in the Nikoletakis report, and it is unlikely for a doctor of Heraklion to have ignored such an information. Hence the plague epidemic may have been confused by later authors with the epidemic which occurred about ten years later, with the arrival of Egyptian troops.

Second, in absence of official reports, the report of a doctor (of *the* doctor?) of Heraklion at the time of the earthquake is a priori more reliable than of any other report, especially from foreigners who may have been impressed and exaggerated the earthquake impacts.

Third, the Limbritis report provides clear information that Heraklion was primarily affected by the earthquakes, but it does not mention any dramatic impacts of this disaster (*ex silentio* evidence), as would be the case with a loss of one third of the population of Heraklion.

Fourth, in 1810 Heraklion was a town of around 10000 people, and the loss of a substantial part of its population, up to one-third as the Praktididis and Stavrakis reports indicate, would imply loss of whole families, of authorities, and of specific craftsmen, among others. Apart from high disturbance of living conditions, such a catastrophe would have led to mass burials or to new cemeteries for the Christian and Muslim, and eventually for the Jewish population. Still, no such evidence exists and hence a high toll seems unlikely.

Fifth, a comparison of the death toll in 1810 with that of the devastating 1856 earthquake is enlightening, since during this last earthquake the death toll in Heraklion was about 500 (Ambraseys 2009) while the population was higher than in 1810, and nearly all buildings of Heraklion were demolished or damaged. Hence an extreme death toll in 1810 is rather unlikely.

Apart from Heraklion, there are available estimates for the death toll in Aghios Thomas, 25 km SSW of Heraklion, 17 victims (Limbritis report) in a small town, and for the Messara plain, 63 victims, though a nearly total destruction of buildings was claimed (see above section 3.3). This last area comprises several villages of different size, and although many villages were founded on loose sediments of the plain, the death toll was not too high. Few victims were reported beyond the limits of the present-day Heraklion prefecture (Ambraseys, 2009).

Given that the main destruction was reported for Heraklion, the estimates of death toll from the Messara plain and Aghios Thomas permit to assume that the total death toll in Crete did not exceed a few hundreds. Hence the total death toll in 1810 is several times smaller than the figure of 2000 to 3000 reported by the Galt and later reports.

4.3 Structural damage

The existing information for structural damage in the Heraklion area is also a matter of debate. According to the Galt report and the Praktikidis reports, 1/3 to 2/3 of the houses of Heraklion were destroyed by the 1810 earthquakes, but according to the Praktikides report, the recovery was rather immediate. This indicates another contradiction. Major death toll and major structural damage are not consistent with a rapid recovery of the town in the conditions of 1810.

Just to notice that the 1856 earthquake destroyed or damaged all the buildings of Heraklion, except for a few tens of buildings, and this is the reason for the rarity of remains of buildings of the Venetian period in this town. A high death toll in 1810 could have been combined with relatively limited structural damage if people were trapped into collapsed congregational buildings (markets, religious buildings etc.) or buildings delimiting narrow streets with high circulation during the time of the earthquake (the case of the 1881 Chios earthquake), but this was not the case with shocks which occurred at midnight and the following morning.

The Limbritis report provides enlightening information for structural damage in 1810. The information provided is that most of the houses in Aghios Thomas survived the first shock, and people slip out, but many more buildings were damaged (collapsed?) during the second. Furthermore, the author noticed that he risked having been killed by the collapse of a wall of the upper part of his house. This structural damage can be assumed similar to that shown in Fig. 2, in a house damaged by the 2021 Arkalochori

earthquake, about 20 km east of Agios Thomas. This comparison is reasonable because the structural style of the house of Fig. 2 is similar to the style existing in the area for centuries (with the exception of the rooftiles which are later), until the advent of concrete in the middle of the 20th century. With the exceptions of some Venetian mansions, of wooden houses and of religious buildings and fortifications, the striking majority of houses in the wider Heraklion area were of one or two stories made with unhewn rocks and earth, with first a floor made of wood and with roofs made also of wood and earthen material, and more rarely with slate.

Structural damage like that of Fig. 2 can lead to loss of life, either inside the houses or outside (for people on the narrow streets), but the buildings can be easily and rapidly restored. This result is consistent with the Praktikidis report that damage in buildings was right away repaired, and it is indirectly confirmed by Limbritis diary providing no indication that his and other families spend lot of time away from the houses during winter; this would be a problem not to ignore.

Fig. 2: Structural damage in a traditional house during the 2021 Arkalochori earthquake (after ITSAK, 2021), estimated to represent a model for the damage implied by Limbritis. The only exception is the rooftiles which derive from a later renovation; Originally the roof was made of wood and earthen material. This type of damage in weak walls could be easily repaired shortly after an earthquake.

A high death toll would have been reflected in abandonment of parts of the town, especially since the overall condition of the Ottoman Empire did not permit support from the central government for the reconstruction of a damaged town; in fact, Ambraseys who has carefully analyzed Ottoman sources has found no evidence of

financial support for Crete shortly after 1810. It is therefore inferred that the 1810 earthquakes produced damage which was to a major degree rapidly repaired.

Of course, ruins of the earthquake existed for many years after 1810 (see Papadopoulos 2011), but this is reasonable; in at least one case this was due to legal implications (see information from an Ottoman document for a legal case for the ruins of soap industry; candia.doc, 18 February 2016).

The estimate of a death toll of around 300 in Heraklion, in a population of around 10000, combined with rather moderate structural damage is consistent with the argument of Ambraseys (2009) that many public buildings in this town were structurally deficient and hence vulnerable to earthquakes, and in some cases, some of them had suddenly collapsed without any specific reason.

There is another point to notice. Nikoletakis mentioned that the shocks destroyed all mosques, most probably including their minarets, and there is evidence that the minaret at Ierapetra also collapsed. Minarets and fortifications in Cairo were also damaged (Ambraseys, 2009). Probably the area of Cairo was the only remote area in which the earthquake caused some damage; in many other areas (Malta, Italy, Cyprus, Minor Asia, Aegean Islands, and continental Greece) the earthquakes were felt, and they occasionally produced some terror, as can be derived from the data summarized by Ambraseys (2009). This indicate dominant strong energy in long-periods for the first main shock, apparently deeper than the second one (major aftershock?); The latter was probably characterized by higher content in short-period waves, and this is probably an explanation for increased destruction reported by Limbritis.

4.4 Parameters of the 1810 earthquake

The fact that this earthquake was felt in a very broad area clearly indicates a strong earthquake sequence of intermediate depth. From the previous discussion it may be derived that damage in Heraklion was of intensity VIII/IX (MMS), and that the isoline of intensity VIII covers the area shown in Fig 1. Clearly, these estimates correspond to the cumulative effects of both earthquakes and hence to an upper bound for earthquake intensities.

A question is whether additional parameters of the earthquake can be estimated. At this point, the conservative approach of Ambraseys (2009) is adopted. In fact, this author was limited to suggest that the 1810 earthquakes reflected a strong intermediate depth

seismic sequence, with a second main shock probably shallower. Although the meizoseismal area seems well defined (Fig. 1), it is not attempted to estimate an epicenter at its center, because the amplification of intermediate shocks in the broader area of Crete is especially high and anomalous; for this reason, true epicenters are often >100 km away from epicenters estimated from intensity contours (Kkallas et al. 2018).

5. SUMMARY AND CONCLUSIONS

New evidence and analysis of existing data indicate that the February 1810 (new calendar) Crete earthquakes correspond to a strong, intermediate depth seismic sequence with epicenter near Heraklion. A new result is that this seismic sequence produced a much smaller death toll than what was previously thought, 300 fatalities in Heraklion area and a total death toll several times smaller than what was thought before. The 1810 earthquakes were also associated with rather moderate structural damage, possibly collapse of certain relatively long-period, weak walls of houses, especially in the wider area of Heraklion, so that the town and nearby villages rapidly recovered.

A noteworthy point for this earthquake is that it comprised two strong shocks, while the majority of intermediate depth earthquakes in the Hellenic Arc are identified with a single major shock and few, week aftershocks (Papazachos and Papazachou, 1997, p. 150).

6. ACKNOWLEDGEMENTS.

Comments of two anonymous reviewers are appreciated.

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APPENDIX 1

Information for the 1810 earthquake in the Heraklion area.

A1. Excerpt from the unpublished diary of Frangiskos Limbritis

§ 8. Το 1810, Φβρ 4-5 έγινε σεισμός μέγας εις όλην την Κρήτην, περί το μεσονύκτιον. Ιδίως δε εις τα μέρη του Ηρακλείου, ένθα έπεσον πάμπολαι οικίαι, και πολοί επλακώθησαν. Εις τον άγιον θωμάν επλακώθησαν 17, πολλές οικίες εβαστάχθη σαν εις τον πρώτον σεισμόν. εις δε τον β΄ τον περί το δηλινόν της επομένης ημέρας Σαβάτου, έπεσαν περισσότεραι οικίαι. ενώ εγώ έτρεχον να σωθώ εις το μέρος της αυλής ένθα ήσαν η μήτηρ μου και τα αδέλφιά μου, έπεσεν εις υψηλος τείχος του ανωγαίου μας και παρ' ολίγον με ενταφίαζαν.

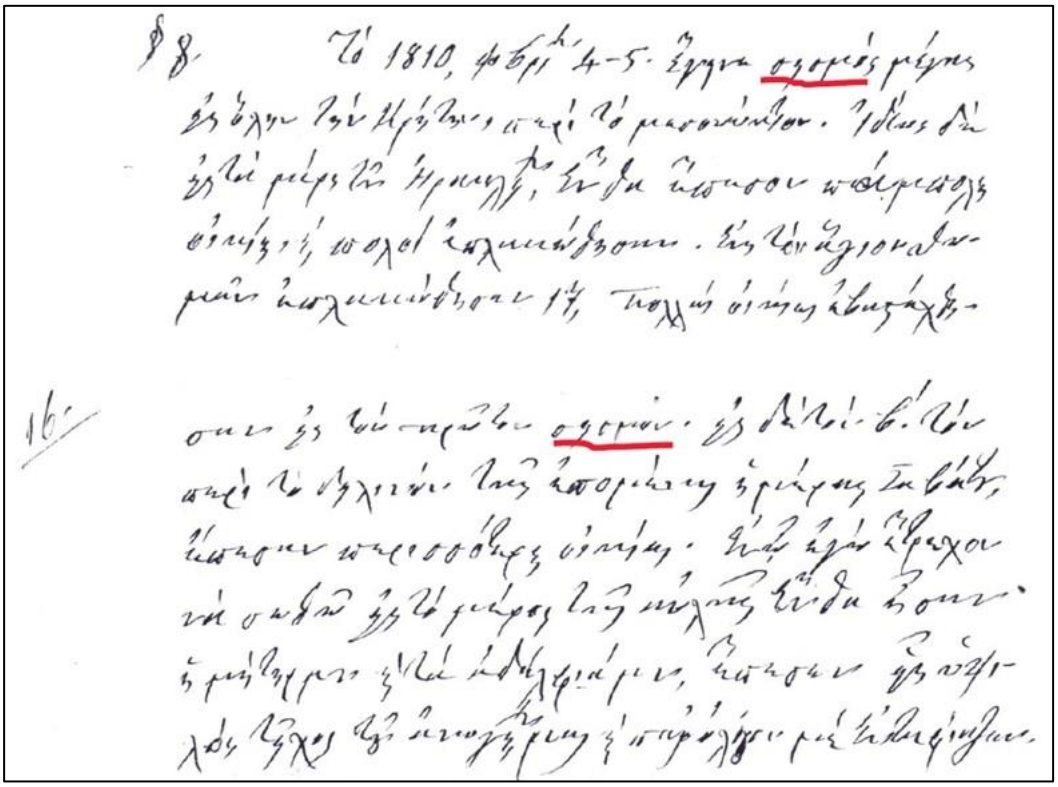

Fig. A1. A copy of the manuscript of Limbritis, paragraph 8 referring to the 1810 earthquake. The term earthquake is underlined.

A2. Excerpt from the Ambraseys (2009) description of the 1810 seismic sequence.

AD 1810 Feb 16 Hellenic Arc

This was a large-magnitude, intermediate-depth earthquake in the Hellenic Arc, followed by an almost equally strong, probably shallower, earthquake about ten hours later. Its maximum effects were experienced in the island of Crete. It is said that one third to three quarters of Candia (Heraklion) was destroyed or damaged beyond repair, and that only a few houses were left standing, the shock killing about 2000 people (AN AE Smyrne 33; Galt 1813, 82). Some of the damage was still visible in 1817, but these early statements seem to be exaggerated, since the town was very quickly rebuilt and much of the damage repaired (Sieber 1823, 60; Tancoigne 1817; Anon. 1818, 14). Note that the high vulnerability of public buildings in Iraklio is proverbial: in 1815 the roof of the Valide Cami fell in of its own accord (Nicoletakis 147).

South of Heraklion the earthquake destroyed the convent of Assomatos, which was later rebuilt, and the monastery of Khalepas, west of the city. The region between Rethymno and Iraklion was much damaged (Sieber 1823, 60; Cockerell 1903, 114). Canea (Hania) suffered considerably, but only one person was killed, while damage in Rethymno was more serious, and many people lost their lives (AN AE Smyrne 33). In the plain of Messara 17 villages were completely destroyed and 63 people were killed (PGM 1810, 372–373). Ierapetra was also damaged and its sole minaret was half demolished (Sieber 1823, 60). It is estimated that in all about 3000 people were killed in Crete.

AD 1810 Feb 17 Hellenic Arc

This was an aftershock of the earthquake of 16 February, which was felt in Heraklion three hours before night, on 17 February 1810 (N.S.) (AN AE ˆIles Candia 1810, 3.23).

The shock was also felt in Argos and Tripolitsa during the evening of 17 February after dinner (Galt 1813, 82) and late in the afternoon of Saturday (17 February N.S.) in Cairo, where, though its intensity was less than that of the first shock, it still caused some panic (al-Jabarti, vii. 90–91, 95). It was also perceptible in much of southern Italy and Sicily; see also PAOP 1810, 4.14, 17 and PMU 1810, 5.2. It was not followed by known aftershocks.