Preliminary report on the geological effects triggered by the 2014 Cephalonia earthquakes

Papathanassiou G., Ganas A., Valkaniotis S., Papanikolaou M., Pavlides S.

gpapatha@geo.auth.gr

aganas@gein.noa.gr

INSTITUTE OF GEODYNAMICS
NATIONAL OBSERVATORY OF ATHENS

SCHOOL OF GEOLOGY
A.U.TH.

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1.Introduction

Two strong earthquake events, ML (NOA) 5.8 and ML 5.7 occurred on Jan. 26, 2014 13:55 UTC and Feb. 3, 2014 03:08 UTC, respectively, in the island of Cephalonia inducing extensive structural damages and geo-environmental effects, mainly in the western and central part. According to the National Observatory of Athens, Institute of Geodynamics (NOA; www.gein.noa.gr) the epicentre of the first event (Fig. 1; NOA web report) was located near the town of Argostoli (the capital), while the second one was located to the north of village Livadi (Palliki Peninsula). Both earthquakes occurred on near-vertical, strike-slip faults with dextral sense of motion, in response to ENE-WSW horizontal strain in central Ionian Sea (Ganas et al., 2013).

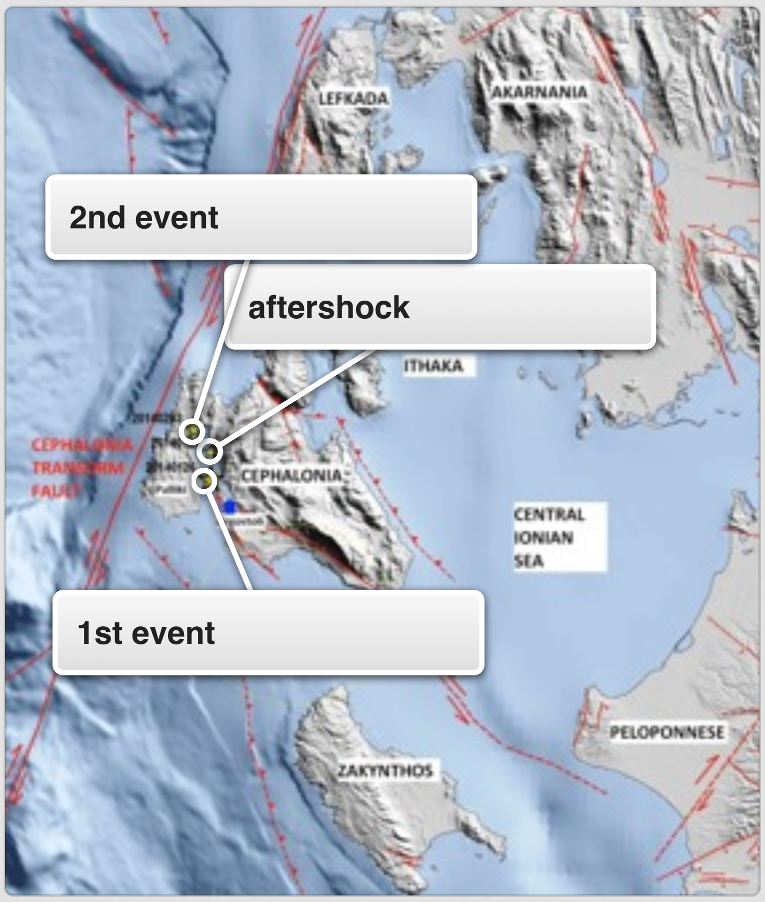


Figure 1. Earthquake epicentres recorded by National Observatory of Athens (NOA)

This report is the outcome of three post-earthquake field surveys organized by NOA in collaboration with Earthquake Geology Group (http://eqgeogr.weebly.com/) of Department of Geology of AUTh. The field surveys took place immediately after the occurrence of both earthquakes (Jan 28-31, 2014; Feb 4-6, 2014 & Feb. 6-9, 2014) and thus, we were able to report the triggered geo-environmental effects. In the following pages, a brief description of the earthquake-induced failures is presented while more information will be published after data processing.

2. Geoenvironmental effects

During both events, the majority of earthquake-related phenomena were liquefaction, road-fill failures, rock falls, small landslides and stonewall failures (Fig. 2). These phenomena were widespread in the Palliki peninsula and the area around Argostoli Bay (Fig.1) In the northern and eastern part of island only few isolated rock falls and landslides in loose materials were observed. It must be noted that most environmental effects were created after the first event in Jan. 26 and were reactivated one week later in the second (Feb. 3) event. Although a relative increase in severity for phenomena during the second event was observed, this cannot be accurately stated because a) the unstable conditions established by the earlier failures and b) almost continuous rain fall and even a heavy storm followed the week after the first earthquake.

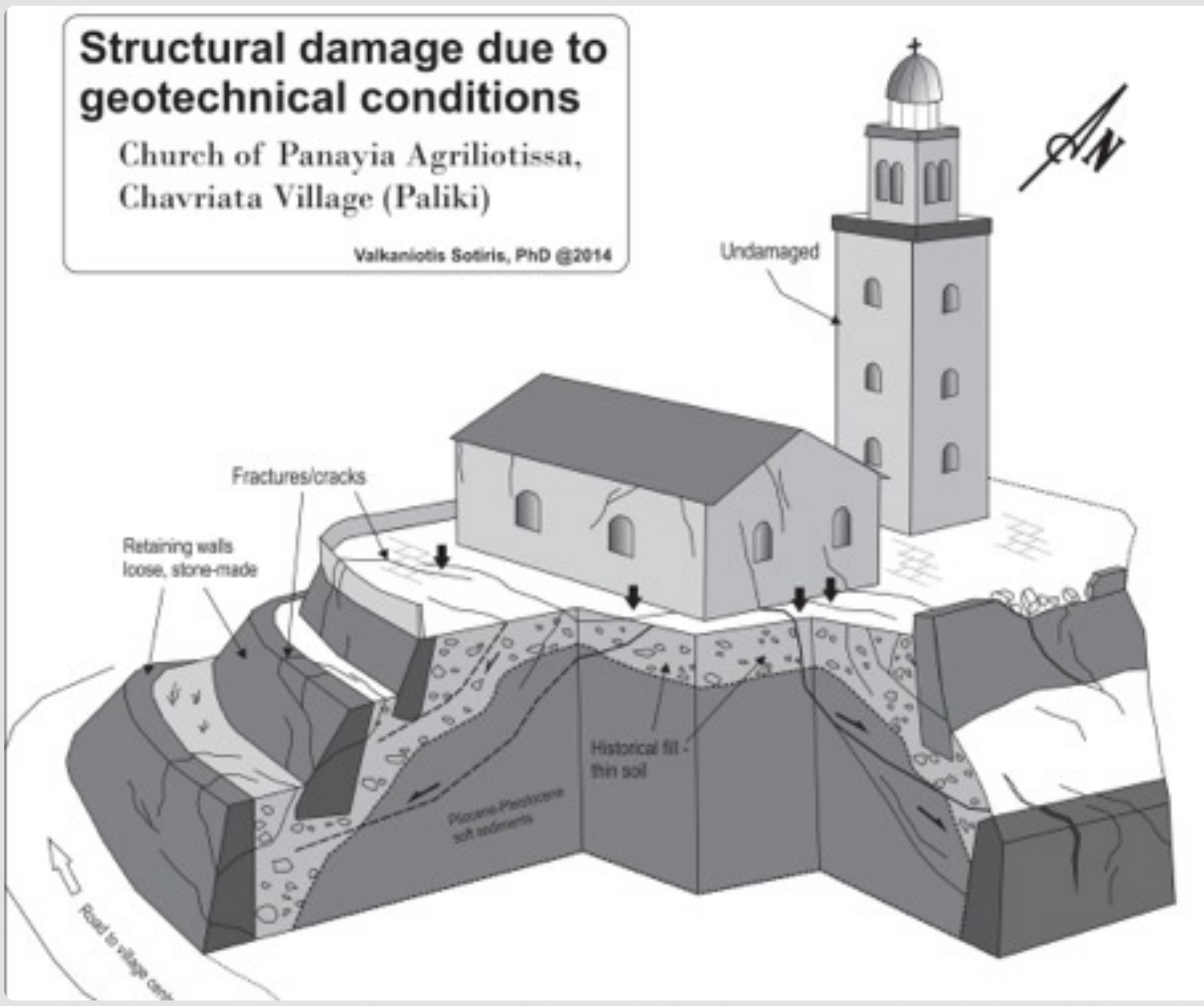


Figure 2. Sketch of structural damages at the church of Panayia Agriliotissa (by Valkaniotis S.)

The documentation of the earthquake-induced environmental effects was realized using the recently released Earthquake Geo Survey App (for android OS).

2.1 Slope failures

Road cracks/breaks and road-fill failures were observed in an area with radius of ~10 km around the epicentre of Jan 26, 2014. Road failures were especially severe in the south/central part of Palliki peninsula and in the east coast of Argostoli Bay (Fig.1; road Argostoli - Lixouri), and resulted in days-long closure of these roads for traffic. On the south Palliki, we observed many road failures because of artificial fills of poor quality and material, that were used to connect villages on hills with Neogene soft sediments.

Figure 3. Large-scale landslide in the area of Soullari (photo taken on 8/02/2014, view to the south)

Figure 4. Rock falls (photo taken on 29/01/2014)

Landslides of small/medium size were widespread in soft Neogene and Quaternary sediments, but also locally observed in clastic formations of Miocene flysch deposits. One of the most impressive mass movement phenomena was the Soullari large landslide, situated north from the Soullari (Fig. 3) village in Palliki peninsula. The landslide was activated during the first earthquake (Jan 26, 2014) on homogenous silt/clay Pliocene-Pleistocene sediments, in a small field on top of a hill and it was reactivated after the second event (Feb 3, 2014). The re-activation was most probably assisted by the presence of rain water in the week following the first earthquake, and caused further movement of the block down-hill, along with a break of the block piece in two smaller ones and collapse of the surrounding scar-walls.

2.2 Liquefaction phenomena

Extensive liquefaction was triggered in near-shore extensions of land towards the sea and reclaimed land in the waterfront areas of Argostoli and Lixouri, inducing structural damages to quays, sidewalks and piers (Fig. 5). Most of the areas affected where those that had been artificially filled after the devastating 1953 earthquakes, a series of three (3) events that totally ruined the majority of houses in the island.

The most remarkable characteristics of liquefaction phenomena triggered by the 2014 earthquakes are:

- the repeated liquefaction at the same sites within a period of one week and
- the boiling of sandy material with gravels in the quay of Lixouri during the second earthquake.

In addition, scattered liquefaction phenomena of small-scale were also reported at several locations of Palliki peninsula. In particular, in Soullari, a local-scale sand crater was identified and at the south area of Palliki, brown sandy material ejected through a crack.

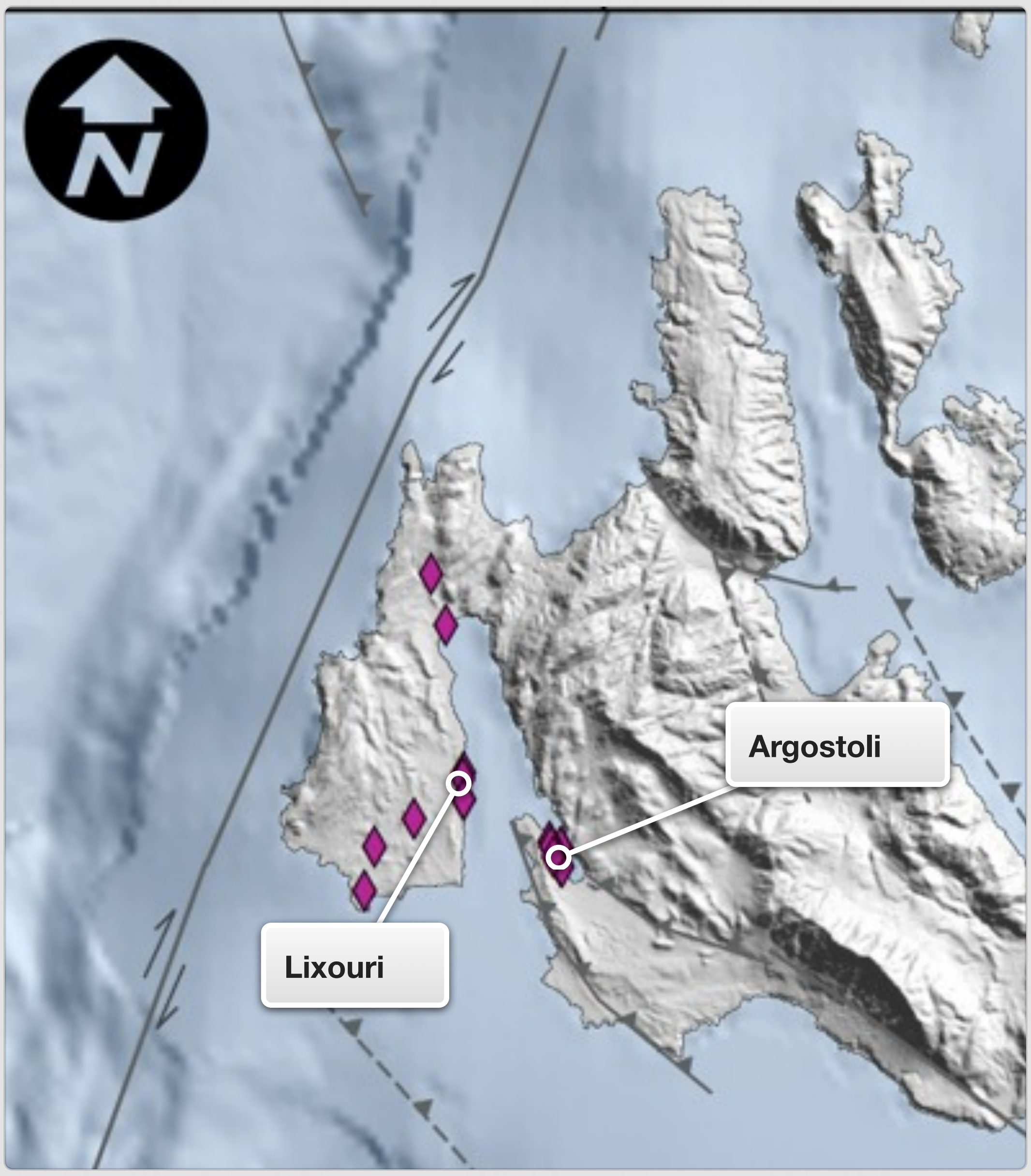


Figure 5. Map showing the distribution of liquefaction phenomena in the island of Cephalonia

2.2.1. Argostoli

In the town of Argostoli, clear evidences of liquefaction occurrences like sand boils and ground fissures with ejection of silty sand-water mixture (Fig. 6), have been triggered by the first and second event according to eyewitnesses and mapped by our team during the post-earthquake field surveys. These liquefaction phenomena were observed in the quays of the town inducing small-scale structural damages. However, it should be pointed out that typical lateral spreading phenomena were not observed at the broader area of the gulf of Argostoli.

Figure 6. Liquefaction phenomena in the waterfront area in Argostoli (photo taken on 8/02/2014)

2.2.2. Lixouri

In the waterfront area of Lixouri, the liquefaction of the subsoil layers induced severe damages to port facilities and caused the complete loss of functionality for 24 hours. In particular, quay wall displacement toward the sea, opening of cracks and significant vertical and horizontal displacement of the sidewalk in the backyard of the quay wall and lateral spread of the pavement in a pier were observed and documented (Fig. 7, 8).

Figure 7. Liquefaction-induced damages in the quay in Lixouri (7/02/2014)

Figure 8. Ejected material in the quay of Lixouri (photo taken on 7/02/2014)

Furthermore, buckling and thrust phenomena, similar to the ones documented after the Emilia 2012 (Papathanassiou et al, 2012) and Great East Japan 2011 earthquakes (Yasuda et al., 2012), respectively, were observed in one site at the sidewalk and in an alley in Lixouri town. Taking into account the results by Yasuda et al. (2012), we can assume that these failures may have occurred because of a sloshing of the liquefied layer. However, further investigation will be performed in order to analyze in detail both cases.

3. Environmental Seismic Intensity scale - ESI 07

In order to assess the macroseismic intensity in the studied area, we applied the ESI-07 scale (Michetti et al., 2007; see table below) due to the fact that the generated geological effects were widespread and extensive. Thus, taking into account the length and width of the ground cracks and sand boils of liquefaction phenomena and the dimensions of slope failures, we concluded that macroseismic intensity should be evaluated as VI and VII in the area of Argostoli and Lixouri and as VII, V, V in Soullari, Livadi and Akrotiri, respectively, regarding the sites where landslides and rock falls were observed and documented (Fig. 9).

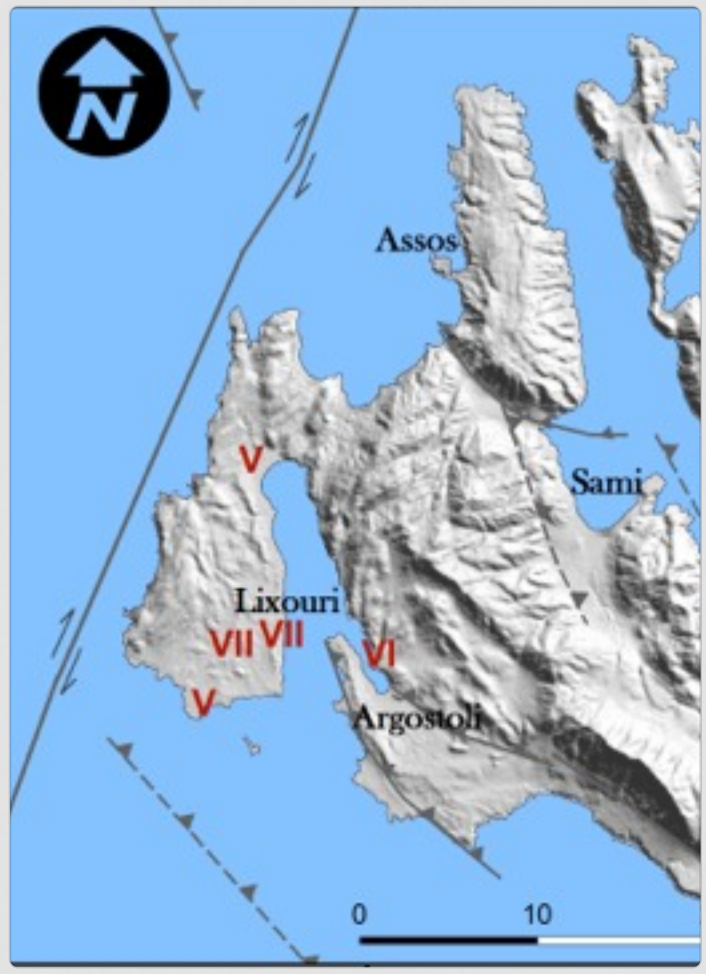
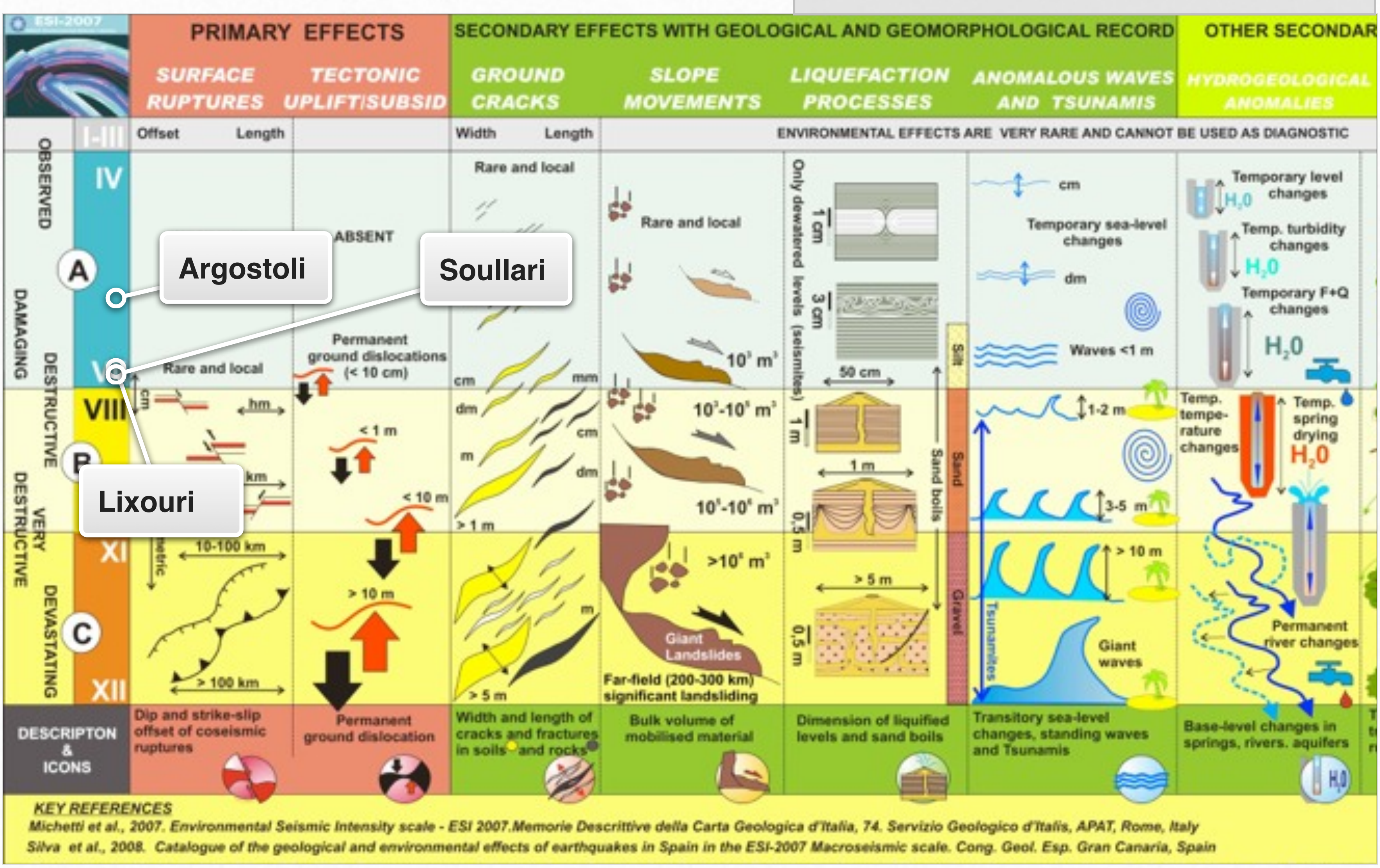


Figure 9. Map showing the evaluated intensities



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