

National and Kapodistrian

University of Athens

Newsletter of Environmental, Disaster, and Crises Management Strategies



Issue No.11 | November 2018



THE NOVEMBER 24, 2018 SLOPE FAILURES IN PLOMARI TOWN (LESVOS ISLAND, NORTHEAST AEGEAN SEA, GREECE)

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About

Non-periodic publication of the Post-graduate Studies Program "Environmental Disasters & Crises Management Strategies" of the National & Kapodistrian University of Athens, issued after significant events for the immediate information of the scientific community and the general public. The publication includes also scientific data from various research teams from universities, organizations and research institutes.

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Cited as

Lekkas, E., Lozios, S., Skourtsos, E., Andreadakis, E., Mavroulis, S., Spyrou, N-I. (2018). The November 24, 2018 Slope Failures In Plomari Town (Lesvos Island, Northeastern Aegean Sea, Greece). Newsletter of Environmental, Disaster and Crisis Management Strategies, 11.

This study was funded by the Environmental, Disaster and Crises Management Strategies Post graduate Program of the Department of Geology and Geoenvironment of the National and Kapodistrian University of Athens.

Publishers:

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Scientific Mission

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The scientific team visited the affected area shortly after the generation of the slope failures in order to conduct a geological reconnaissance of the affected area and to assess the effects on the natural environment and buildings by using not only traditional field mapping but also modern and innovative techniques (UAV mapping)

https://edcm.edu.gr



SITES OF SLOPE FAILURES IN GREECE





Topographic map of Greece with 1238 landslides based on data from Koukis and Ziourkas (1989, 1990), Koukis and Ziourkas (1991), Koukis et al. (1994, 1997, 2005) and Vasileiadis (2010).

The Plomari area (red circle) is located in the southeastern part of Lesvos Island (Northeastern Aegean Sea, Greece)



SITES OF SLOPE FAILURES IN GREECE





Slope failures in Greece (circles) and destructive slope failures (crosses). Data from Eleftheriou et al. (1993), Sakkas et al. (2016).



LANDSLIDES FREQUENCY IN GREECE





Map of landslide frequency in Greece (number of landslides / 100 km²) based on Koukis et al. (2015). In the Northeastern Aegean Region, the landslide frequency comprises 1-5 landslides per 100 km².

GEOTECTONIC SETTING OF LESVOS ISLAND (NORTHEASTERN AEGEAN SEA)



From Papanikolaou (2015), Geology of Greece

HISTORICAL AND RECENT SEISMICITY OF LESVOS ISLAND



Significant historical and instrumentally recorded earthquakes and their epicenters that affected the geodynamic evolution of the North Aegean and Lesvos (Seismological data from Aristotle University of Thessaloniki Seismological Network, 2017; University of Athens Seismological Laboratory, 2017)



Areas with high contrasts in seismic intensities during large earthquakes in Lesvos. The maximum intensities have undoubtedly been observed in the southern and eastern part of Lesvos during the 1845, 1867, 1953 and 1981 earthquakes (data from Papazachos & Papazachou, 2003; Taxeidis, 2003; Ambraseys, 2009).

From Lekkas et al. (2017), Mavroulis et al. (2018)

THE JUNE 12, 2017 LESVOS EARTHQUAKE DAMAGE TO THE BUILT ENVIRONMENT



From Lekkas et al. (2017), Mavroulis et al. (2018)

MAIN BUILDING TYPES IN PLOMARI TOWN REINFORCED-CONCRETE BUILDINGS WITH INFILL WALLS





MAIN BUILDING TYPES IN PLOMARI TOWN MASONRY BUILDINGS WITH LOAD-BEARING WALLS



THE JUNE 12, 2017 LESVOS EARTHQUAKE DAMAGE TO THE BUILT ENVIRONMENT OF PLOMARI TOWN





Masonry Buildings





RC Buildings

THE JUNE 12, 2017 LESVOS EARTHQUAKE DAMAGE TO THE BUILT ENVIRONMENT OF PLOMARI TOWN



Traditional masonry buildings and mixed type buildings





SLOPE FAILURES IN PLOMARI AREA DURING THE 2017 LESVOS EARTHQUAKE

Landslides and rockfalls along artificial slopes of the Plomari-Melinta road network during the 2017 Lesvos earthquake









SLOPE FAILURES IN PLOMARI AREA DURING THE 2017 LESVOS EARTHQUAKE





SLOPE FAILURES IN PLOMARI AREA DURING THE 2017 LESVOS EARTHQUAKE



Rockfalls along natural slopes of Palaiochori area during the 2017 Lesvos earthquake





DETAILED GEOLOGICAL MAP OF THE PLOMARI-MELINTA-PALAEOCHORI ROAD NETWORK with areas affected by the generation of slope failures



GEOTECHNICAL MAP OF THE PLOMARI-MELINTA-PALAEOCHORI ROAD NETWORK with areas affected by the generation of slope failures



GEOTECHNICAL MAPS OF SOUTHEASTERN LESVOS MAP with areas affected by the generation of slope failures



BUILDING DAMAGE INDUCED BY THE 2017 LESVOS EARTHQUAKE



Distribution of uninhabitable buildings with respect to their construction material, (b) number and (c) ratio of uninhabitable" masonry buildings based on the latest Census (EL.STAT., 2011).

From Papadimitriou et al. (2018)

SLOPE FAILURES INDUCED BY THE 2017 LESVOS EARTHQUAKE



Plomari is located within the zone that suffered significant impact from the 2017 Lesvos earthquake. This zone comprised earthquake environmental effects induced by the 2017 Lesvos earthquake that included ground cracks in the western part of the affected area (Vatera, Agia Katerina, along the Polychnitos fault) and slope movements including landslides and rockfalls in the eastern part of the affected area (Palaeochori, along the road from Plomari to Melinta, Akrassi, Agios Isidoros) and damage to buildings including non-structural and structural damage.

Despite the fact that Plomari was within the meizoseismal area with already geotechnically unstable areas, no slope failures were observed within its residential area.

From Lekkas et al. (2017), Mavroulis et al. (2018)



SEISMICITY IN THE NORTHEASTERN AEGEAN SEA DURING THE LAST 4 MONTHS (AUGUST-NOVEMBER 2018)



During the last 4 months (August-November 2018), only 8 seismic events with magnitudes ranging from 2.4 to 4.1 were generated in the offshore southeastern Lesvos area without effects on the natural and built environment of Lesvos Island and Plomari town

Date	Coordinates (lat, long)	Magnitude
28 OCT	38.704, 26.426	3.3
07 NOV	38.795, 26.565	3.7
07 NOV	38.78, 26.537	4.1
07 NOV	38.798, 26.562	3.1
07 NOV	38.788, 26.494	2.6
09 NOV	38.92, 26.444	2.8
09 NOV	38.842, 26.526	2.6
14 NOV	38.842, 26.526	2.4

Data from the Permanent Regional Seismological Network operated by the Aristotle University of Thessaloniki, doi:10.7914/SN/HT

http://geophysics.geo.auth.gr/ss/CATALO GS/preliminary/prelcat.cat



ROCKFALL SITE IN PLOMARI TOWN



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ROCKFALL SITE IN PLOMARI TOWN AFTER THE JUNE 12, 2017 LESVOS EARTHQUAKE







THE NOVEMBER 24, 2018 PLOMARI ROCKFALL







ROCKFALL SITE IN PLOMARI TOWN COMPARISON BETWEEN JUNE 2017 (POST- LESVOS EARTHQUAKE) AND NOVEMBER 2018





2017

2018



ROCKFALL SITE IN PLOMARI TOWN COMPARISON BETWEEN JUNE 2017 (POST- LESVOS EARTHQUAKE) AND NOVEMBER 2018











ROCKFALL SITE IN PLOMARI TOWN











ROCKFALL SITE IN PLOMARI TOWN COMPARISON BETWEEN JUNE 2017 (POST- LESVOS EARTHQUAKE) AND NOVEMBER 2018





GEOLOGY OF THE ROCKFALL SITE IN PLOMARI TOWN



Geological map of Lesvos Island (Lekkas et al., 2017; Mavroulis et al., 2018)

The Plomari area is located in the southeastern part of Lesvos Island. It comprises Permian-Triassic green schists.



EXPOSED SURFACES OF JOINT WALLS AFTER PLOMARI ROCKFALLS MAIN DETACHMENT AND SLIDING PLANE







EXPOSED SURFACES OF JOINT WALLS AFTER PLOMARI ROCKFALLS MAIN DETACHMENT AND SLIDING PLANE





EXPOSED SURFACES OF JOINT WALLS AFTER PLOMARI ROCKFALLS MAIN DETACHMENT AND SLIDING PLANE





MAIN DETACHMENT SURFACE NOT EXPOSED AFTER THE PLOMARI ROCKFALLS POSSIBLE FUTURE DETACHMENT PLANES



MAIN JOINTS PARTIALLY FILLED WITH LARGE FRAGMENTS AND MATRIX POSSIBLE FUTURE DETACHMENT PLANES



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SECONDARY JOINTS AFFECTING THE STABILITY OF THE SLOPE





SECONDARY JOINTS AFFECTING THE STABILITY OF THE SLOPE





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MAPPING OF THE SLOPE FAILURE SITE WITH UNMANNED AERIAL VEHICLE



MAPPING OF THE SLOPE FAILURE SITE WITH UNMANNED AERIAL VEHICLE





- 3D MODEL
- 3D TECTONIC MAPPING
- FIELD MEASUREMENTS
- 3D FRACTURE GEOMETRY











MAPPING OF THE SLOPE FAILURE SITE WITH UNMANNED AERIAL VEHICLE

Digital surface model



Orthomosaic

THE NOVEMBER 24, 2018 SLOPE FAILURES IN PLOMARI TOWN

On November 24, 2018 a large rockfall was generated in the central part of Plomari town, located in the southeastern part of Lesvos Island (Northeastern Aegean Sea, Greece). The rockfall occurred along a steep slope in the western part of Profitis Ilias hill, which is composed of Permian-Triassic schists. This steep slope is characterized by a great variety of joints with different characteristics [length, continuity, separation, surface characteristics (smoothness and waviness), condition of the discontinuity] that forms a geotechnically unstable zone with generation of slope failures during historical and recent times based on various sources including reports and eyewitnesses.

The last episode along this geotechnically unstable zone is the generation of the 2018 rockfalls, which resulted in damage to buildings founded on the base of the slope, fortunately without casualties. Green schists blocks were detached from the steep slope and moved downward toward the adjacent buildings resulting in destruction.

The induced damage affected non-structural and structural elements of masonry buildings and structural elements of a reinforced concrete building. More specifically, detachment of large pieces of plaster from the load-bearing walls and destruction of the roof were observed in the first category and partial collapse of the infill walls and heavy damage of columns in the second category attributed to crushing with the rockfall materials.

It is significant to note that Plomari is located within the zone that suffered significant impact from the June 12, 2017 Lesvos earthquake. This zone comprised earthquake environmental effects induced by the 2017 Lesvos earthquake that included ground cracks in the western part of the affected area (Vatera, Agia Katerina, along the Polychnitos fault) and slope movements including landslides and rockfalls in the eastern part of the affected area (Palaeochori, along the road from Plomari to Melinta, Akrassi, Agios Isidoros) and damage to buildings including non-structural and structural damage in settlements of the southeastern part of Lesvos Island. Despite the fact that Plomari was within the meizoseismal area with already geotechnically unstable areas, no slope failures were observed within its residential area.

The 2018 Plomari rockfalls was the result of the synergy of endogenic and exogenic processes in the affected area. The endogenic processes include tectonic deformation of the crust resulting in the lithological heterogeneity and the mechanical anisotropy of the geological formations and the earthquake loads purely induced by the ground accelerations transferred by moderate and strong earthquakes to the high and steep slopes, while the exogenic processes comprising repeated cycles of mechanical, chemical and organic weathering and aeolian and water erosion that contribute to the decreased cohesion and formations loosening along the steep slope. It is significant to note that during the last month before the generation of the rockfalls, no significant seismic events or extreme rainfall events occurred.

Based on all available morphological, geological, geotechnical, seismological and meteorological data, the scientific team proposed the evacuation of buildings close to the steep slope until the completion of the protection measures adopted for landslide risk assessment and mitigation.



PROPOSED MEASURES FOR POPULATION PROTECTION





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