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The October 30, 2020, Mw 6.9 Samos (Greece) earthquake

E. **Lekkas**, S. **Mavroulis**, M. **Gogou**, G.A. **Papadopoulos**, I. **Triantafyllou**, K.-N. **Katsetsiadou**, H. **Kranis**, E. **Skourtsos**, P. **Carydis**

N. **Voulgaris**, P. **Papadimitriou**, V. **Kapetanidis**, A. **Karakonstantis**, I. **Spingos**, V. **Kouskouna**, I. **Kassaras**, G. **Kaviris**, K. **Pavlou**, V. **Sakkas**, A. **Karatzetzou**

N. **Evelpidou**, E. **Karkani**, I. **Kampolis**

P. **Nomikou**, D. **Lambridou**, P. **Krassakis**

M. **Foumelis**, C. **Papazachos**

A. **Karavias**, D. **Bafi**, T. **Gatsios**, O. **Markogiannaki**, I. **Parcharidis**

A. **Ganas**, V. **Tsironi**, I. **Karasante**

D. **Galanakis**, K. **Kontodimos**

D. **Sakellariou**

N. **Theodoulidis**, C. **Karakostas**, V. **Lekidis**, K. **Makra**, V. **Margaris**, K. **Morfidis**, C. **Papaioannou**, E. **Rovithis**, T. **Salonikios**

A. **Kourou**, M. **Manousaki**, T. **Thoma**, N. **Karveleas**

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About

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Publishers:
Dr. Efthymis Lekkas
Dr. Nikolaos Voulgaris
Dr. Stylianos Lozios
Technical Editing:
Dr. Spyridon Mavroulis
Communication:
Dr. Spyridon Mavroulis (smavroulis@geol.uoa.gr)
PhD C. Alexia Grambas (agram@geol.uoa.gr)
PhD C. Katerina-Nafsika Katsetsiadou (knavsika@geol.uoa.gr)

Scientific Mission

Of the National and Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Department of Dynamic Tectonic Applied Geology

Contributors

UNIVERSITY OF ATHENS, DEPARTMENT OF GEOLOGY & GEOENVIRONMENT
FACULTY OF DYNAMIC TECTONIC APPLIED GEOLOGY: Efthymios Lekkas, Spyridon Mavroulis, Marilia Gogou, Gerassimos A. Papadopoulos, Ioanna Triantafyllou, Katerina-Navsika Katsetsiadou, Haralambos Kranis, Emmanouil Skourtsos, Panayotis Carydis
FACULTY OF GEOPHYSICS – GEOTHERMICS: Nicholaos Voulgaris, Panayotis Papadimitriou, Vasileios Kapetanidis, Andreas Karakonstantis, Ioannis Spingos, Vassiliki Kouskouna, Ioannis Kassaras, George Kaviris, Kyriaki Pavlou, Vasileios Sakkas, Anna Karatzetzou
FACULTY OF GEOGRAPHY – CLIMATOLOGY: Nicky Evelpidou, Eleanna Karkani, Isidoros Kampolis Paraskevi Nomikou, Danai Lambridou, Pavlos Krassakis
ARISTOTLE UNIVERSITY OF THESSALONIKI: Michalis Foumelis, Costas Papazachos
HAROKOPEIO UNIVERSITY OF ATHENS: Andreas Karavias, Despoina Bafi, Theodoros Gatsios, Olga Markogiannaki, Dr. I. Parcharidis
NATIONAL OBSERVATORY OF ATHENS: Athanassios Ganas, Varvara Tsironi, Ilektra Karasante
HELLENIC SURVEY OF GEOLOGY AND MINERAL EXPLORATION: Dimitrios Galanakis, Konstantinos Kontodimos
HELLENIC CENTER OF MARINE RESEARCH: Dimitrios Sakellariou
INSTITUTE OF ENGINEERING SEISMOLOGY AND EARTHQUAKE ENGINEERING: Nikolaos Theodoulidis, Christos Karakostas, Vasileios Lekidis, Konstantia Makra, Vasileios Margaris, Konstantinos Morfidis, Christos Papaioannou, Emmanuel Rovithis, Thomas Salonikios
EARTHQUAKE PLANNING AND PROTECTION ORGANIZATION: Assimina Kourou, Maria Manousaki, Thekla Thoma, Nikolaos Karveleas

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Issue No. 21, November 2020

INTRODUCTION OF THE 21st ISSUE OF THE EDCMS NEWSLETTER

This Newsletter is the outcome of a fruitful collaboration and knowledge sharing between geologists, seismologists, physicists, geographers, oceanographers and civil engineers interested in mapping and monitoring the October 30, 2020, Mw 6.9 Samos earthquake and its effects. It comprises:

- review of the geology, neotectonics and active tectonics of Samos and the surrounding area,
- review of the historical and recent seismicity with all known historical and instrumental earthquakes onshore and offshore Samos,
- presentation of seismotectonic information for the affected area conducted by the NKUA (Sector of Geophysics-Geothermics), including the seismotectonic context, the relocation of the epicenters and the focal mechanisms of the mainshock and the aftershock sequence, the spatiotemporal evolution of the aftershock sequence and the compilation of shakemaps
- the presentation of the environmental effects triggered by the mainshock on Samos Island deduced from post-earthquake field survey conducted by scientific teams of the NKUA (Sector of Dynamic Tectonic Applied Geology and Sector of Geography and Climatology) and the Hellenic Survey of Geology and Mineral Exploration of Greece, shortly after the generation of the mainshock
- the presentation of damage to buildings and infrastructures conducted by scientific teams of the NKUA
- the presentation of results from interferometric analysis of synthetic aperture radar (InSAR) data and the combination of seismological data and spaceborne observations conducted by the Aristotle University of Thessaloniki (AUTH)
- the presentation of results from interferometric analysis of SAR data and geodetic data (GNSS) conducted by the scientific team of the Geodynamic Institute of the National Observatory of Athens (GI-NOA)
- the presentation of results from mapping and monitoring the October 30, 2020 earthquake based on Copernicus earth observation products, conducted by the Earth Observation Team of the Harokopio University of Athens.

ISSN 2653-9454
Issue No. 21, November 2020

GEOTECTONIC LOCATION AND GEOLOGY OF SAMOS

Samos Island occupies a key position at the transition between Aegean domain and western Turkey. The metamorphic succession of Samos consists of 4 distinct tectono-metamorphic units, from base to top:

The **Kerketeas marbles** crop out in the western part of the island in a tectonic window below the overlying Ampelos unit. The Kerketeas unit consists of dolomitic marbles with local schist on top. Incipient HP-LT metamorphism and a subsequent greenschist overprint is recorded.

The **Ampelos unit** outcrops over the central part of the island. It is mainly made of schists and marbles with minor occurrences of metabasites. The lower part contains slices of gneiss that provided Carboniferous and Triassic radiometric ages on zircons. This unit can be correlated with the lower part of the Cycladic Blueschists Unit. The Ampelos nappe underwent an Eocene blueschist-facies metamorphic event (520 °C, 19 kbar), followed by an Oligo-Miocene overprint under greenschistfacies conditions (455-485 °C, 6-7 kbar)

The **Selçuk nappe** crops out in the center of the island as discontinuous outcrops of metabasites.

The **Vourliotes nappe** crops out in the eastern part of the island where it is mainly made of schists and marbles. The upper marble formation has been dated as Upper Cretaceous on the basis of rudists found within the metabauxite outcrops at the eastern part of the island. It recorded the same metamorphic conditions as the Ampelos nappe.

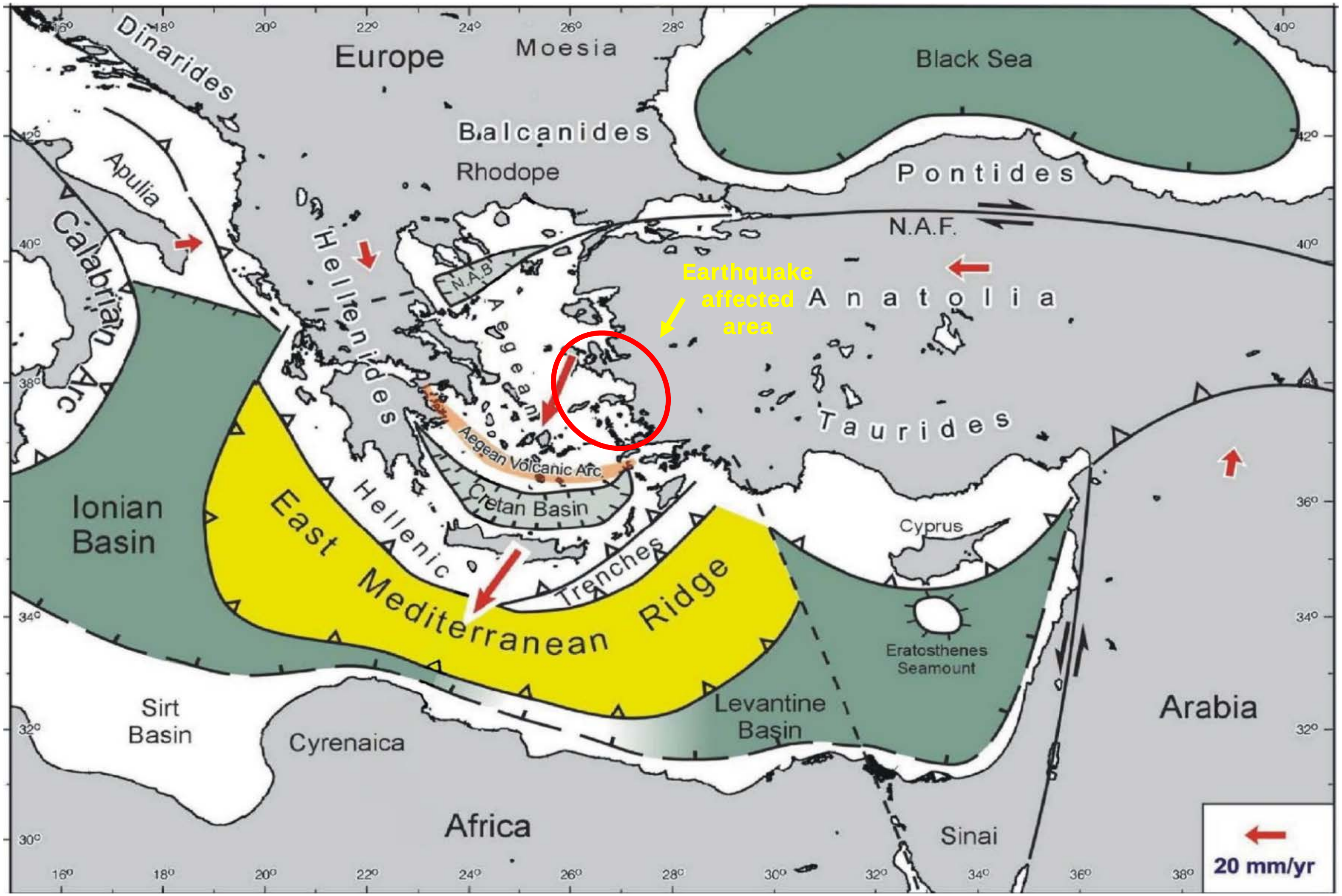
The **Kallithea nappe** and the Katavasis Complex are only found in the westernmost part of the island, on top of Kerketeas marbles. The Kallithea nappe is made of sandstones, serpentinized peridotite lenses, spilite and diabase with red radiolarites and fossiliferous ammonitico rosso-type limestones overlain by an Upper Triassic to Jurassic massive limestone series.

The underthrusted **Katavasis Complex** is mainly composed of marbles, amphibolites and quartzites, formed under amphibolite-facies conditions. It is locally intruded at ~10 Ma by igneous dykes cut by a distinct low-angle normal fault, suggesting a younger activity of this fault that is interpreted as an extension of the North Cycladic Detachment System.

From *Roche et al. (2019) and references therein*

ISSN 2653-9454
Issue No. 21, November 2020

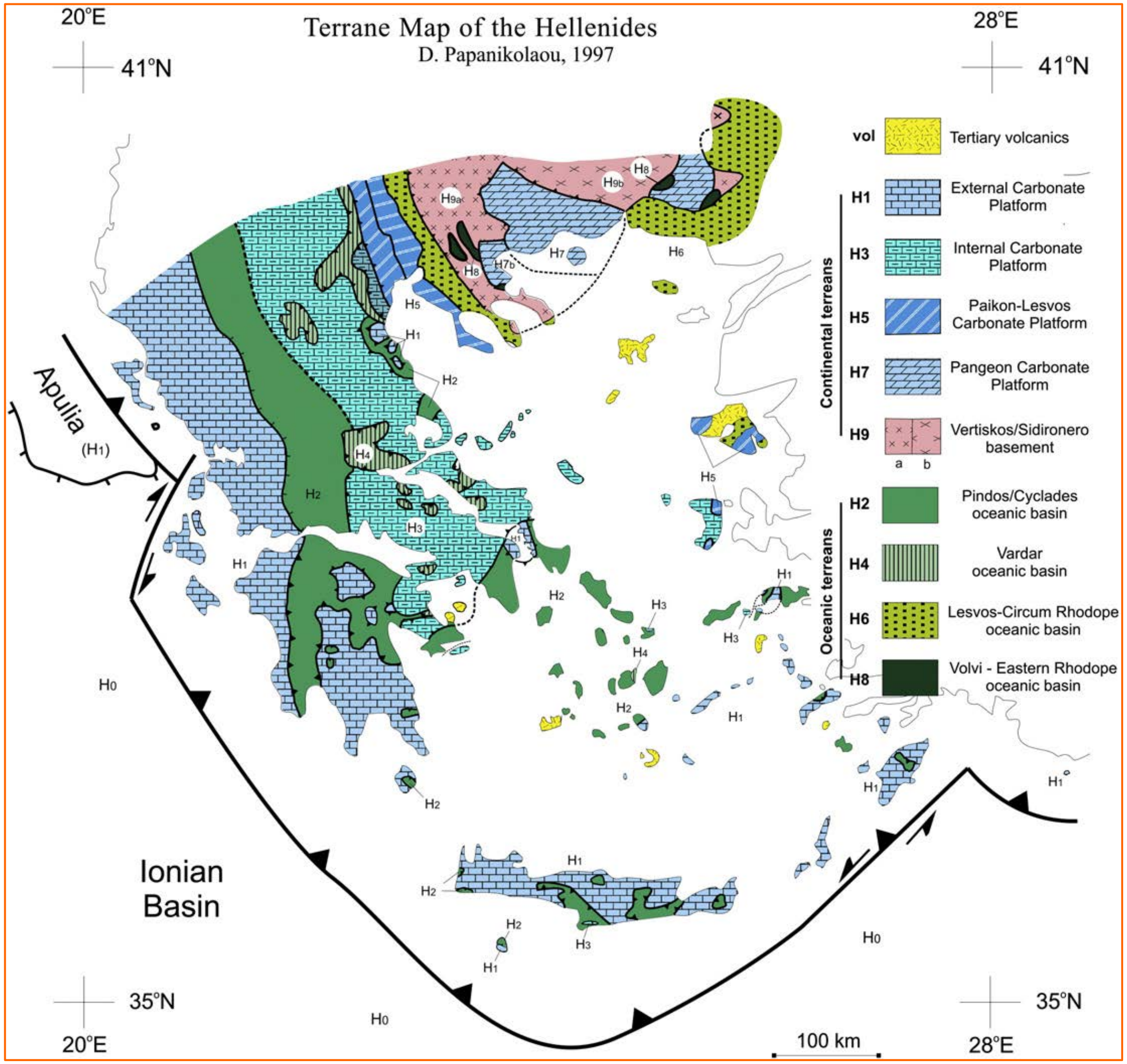
MAIN TECTONIC ELEMENTS IN THE EASTERN MEDITERRANEAN REGION
THE HELLENIC ARC & TRENCH SYSTEM



From *Papanikolaou et al. (2004)*

ISSN 2653-9454
Issue No. 21, November 2020

GEOTECTONIC MAP OF GREECE
TECTONOSTRATIGRAPHIC TERRANES



Samos comprises geological formations belonging to the following tectonostratigraphic terranes:

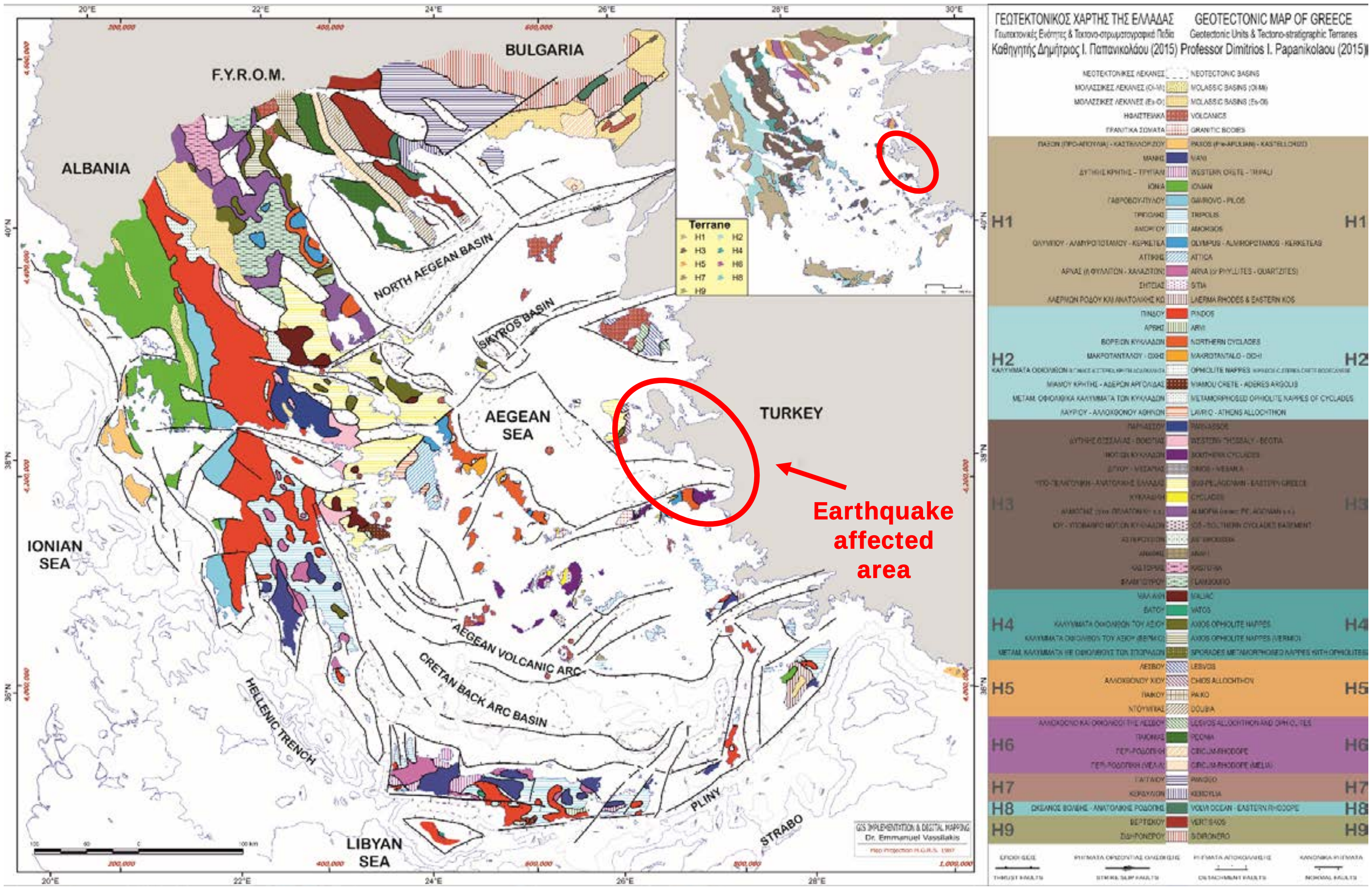
H1: the External Carbonate Platform

H2: Pindos / Cyclades oceanic Basin

H3: Internal Carbonate Platform)

From *Papanikolaou (1997)*

GEOTECTONIC MAP OF GREECE
TECTONOSTRATIGRAPHIC TERRANES



As regards the geotectonic units, the geological setting of Samos includes formations from the relatively autochtonous unit of Kerketeas below the tectonic nappes of the blueschist units of Agios Ioannis, Ampelos and Vourliotes as well as the non-metamorhic nappe of Kallithea (From *Papanikolaou, 2015*)

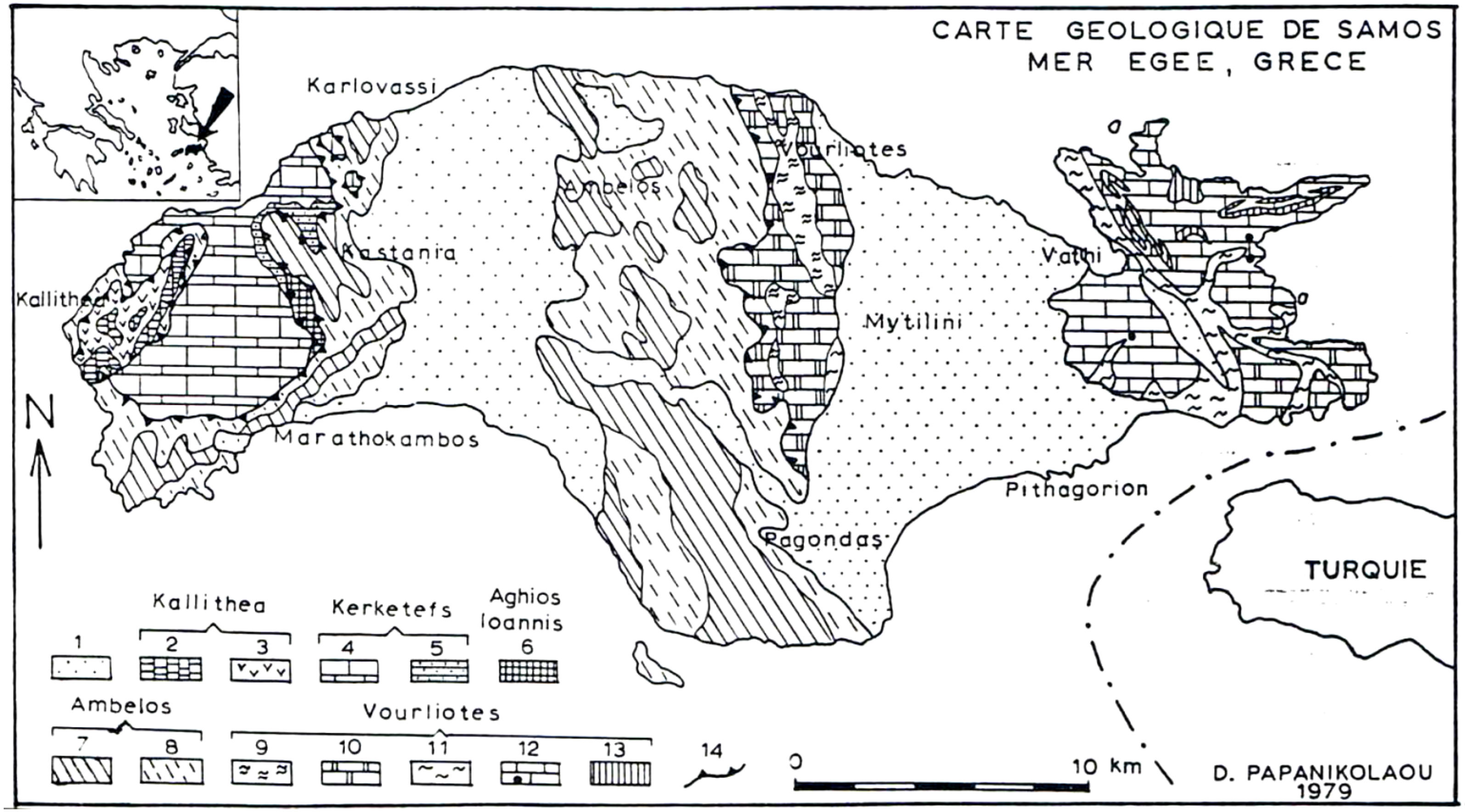
ISSN 2653-9454
Issue No. 21, November 2020

GEOLOGY OF SAMOS

Geological Map of Samos Island
compiled by *Theodoropoulos (1979)* and published by *Institute of Geology and Mineral Exploration*

ISSN 2653-9454
Issue No. 21, November 2020

GEOLOGY OF SAMOS

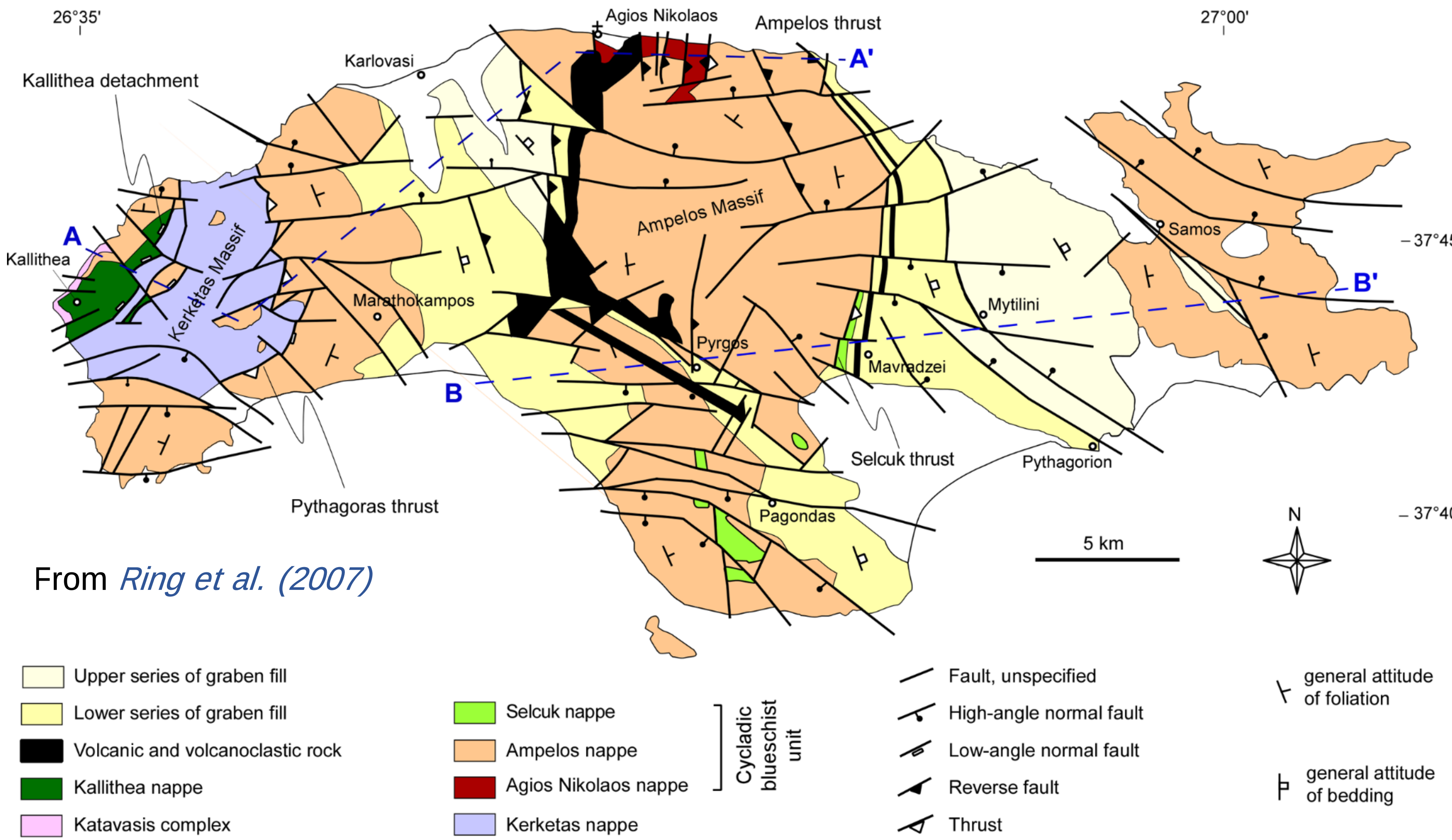


1: Neogene deposits, **2**: Eastern Triadic - Jurassic limestones, **3**: radiolarites, sandstones and limestones of the Middle - Upper Triadic, **4**: Kerketeas marbles, **5**: Kerketeas phyllites, **6**: metamorphic formations of Agios Ioannis, **7**: Ampelos marbles, **8**: Ampelos slates, **9**: Vourliotes lower slates, **10**: Vourliotes lower marbles, **11**: Vourliotes intermediate slates, **12**: Vourliotes upper marbles, **13**: Vourliotes upper marbles, **14**: Thrust.

From *Papanikolaou (1979)*

ISSN 2653-9454
Issue No. 21, November 2020 | 10

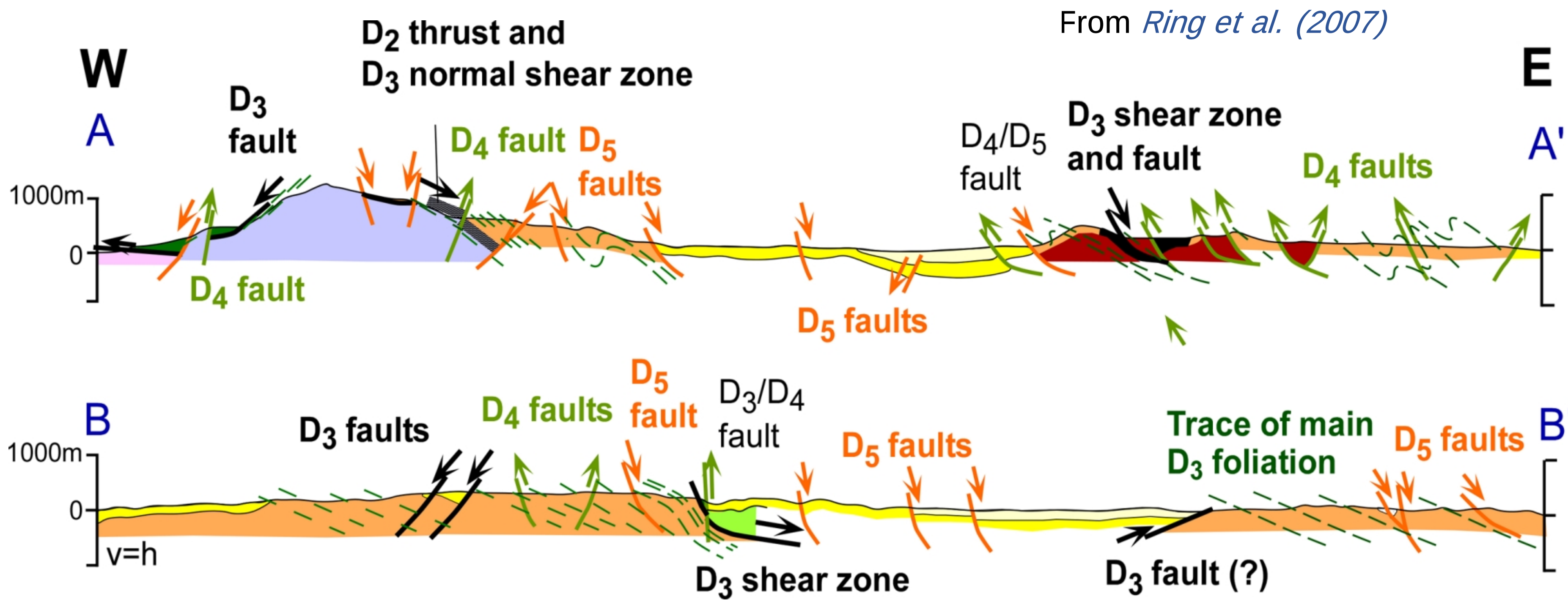
GEOLOGICAL MAP OF SAMOS



From *Ring et al. (2007)*

Lower series of graben fill comprise Basal Conglomerate, Pythagorion and Hora Formations. Upper series of graben fill include Mytilini and Kokkarion Formations. The D1 Ampelos and Selçuk thrusts are the basal thrusts of the Ampelos and Selçuk nappes, respectively.

GENERAL ARCHITECTURE OF SAMOS & IMPORTANT TECTONIC CONTACTS



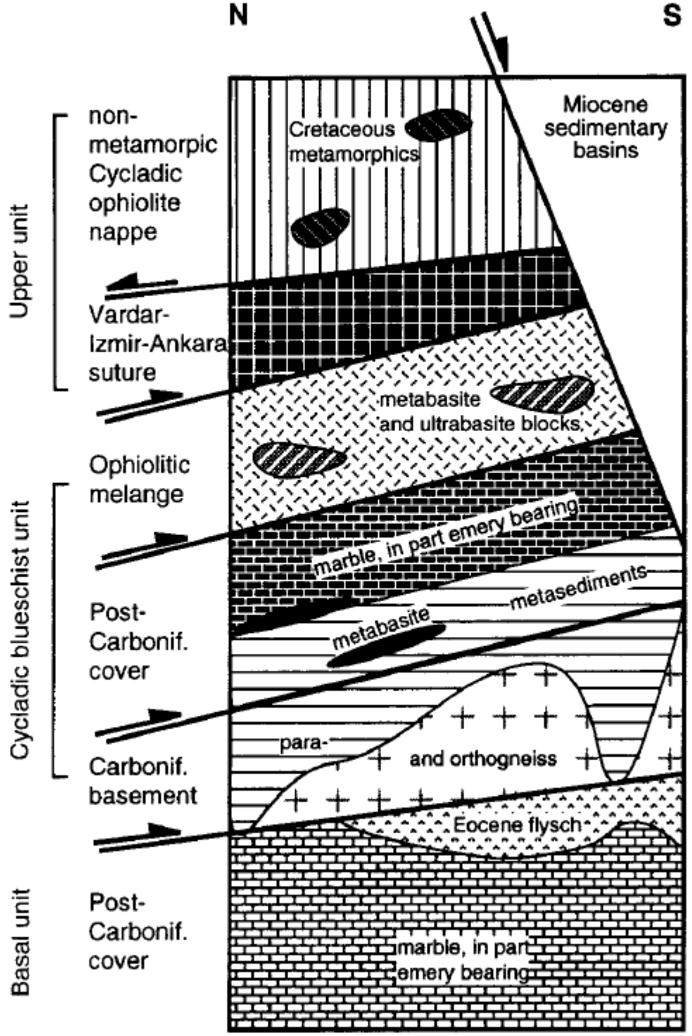
The location of the sections is presented in the previous slide

The D2 Pythagoras thrust put the Cycladic blueschist unit on top of the Kerketas nappe. The Kallithea detachment is a late-D3 low-angle normal fault. Widespread Middle and mainly Late Miocene volcanic and volcanoclastic rocks occur at the eastern and northeastern margin of the Karlovasi and Pyrgos graben. Subordinate volcanics also occur at the western side of the Mytilini basin. Numerous reverse (D4) and normal (D5) faults with a listric geometry overprinted all earlier ductile contacts.

ISSN 2653-9454
Issue No. 21, November 2020

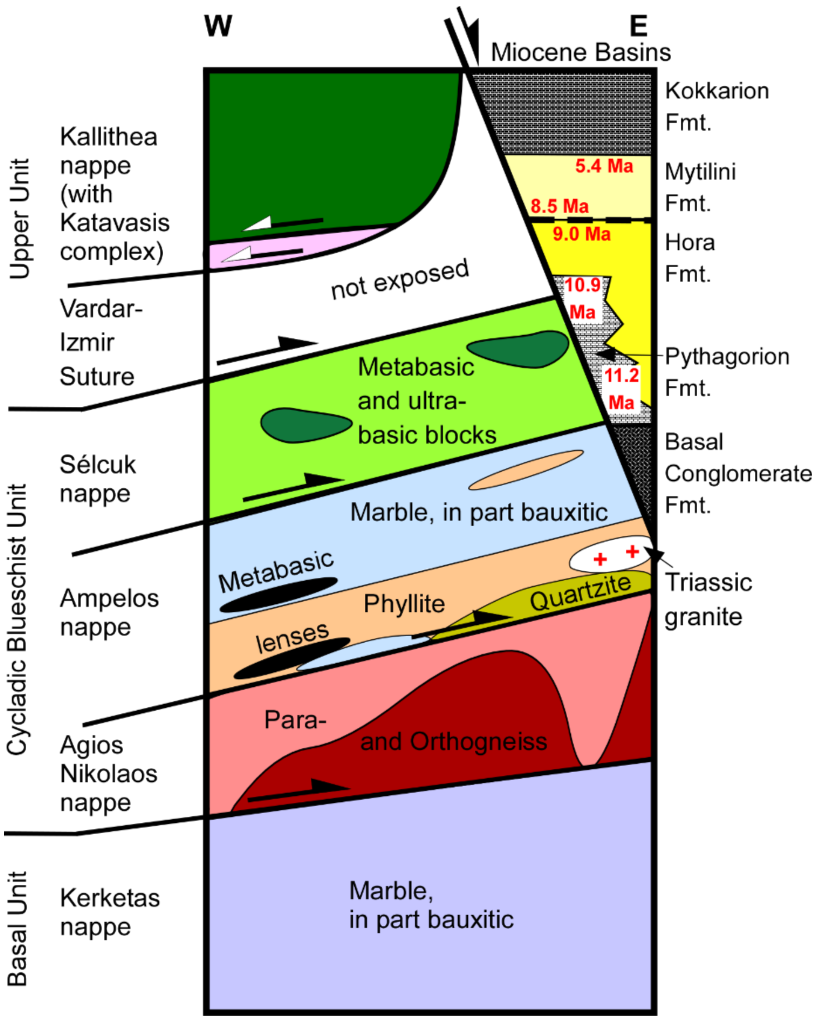
IDEALIZED COMPARATIVE TECTONOSTRATIGRAPHIC COLUMNS

AEGEAN NAPPE PILE



From *Ring et al. (1999)*

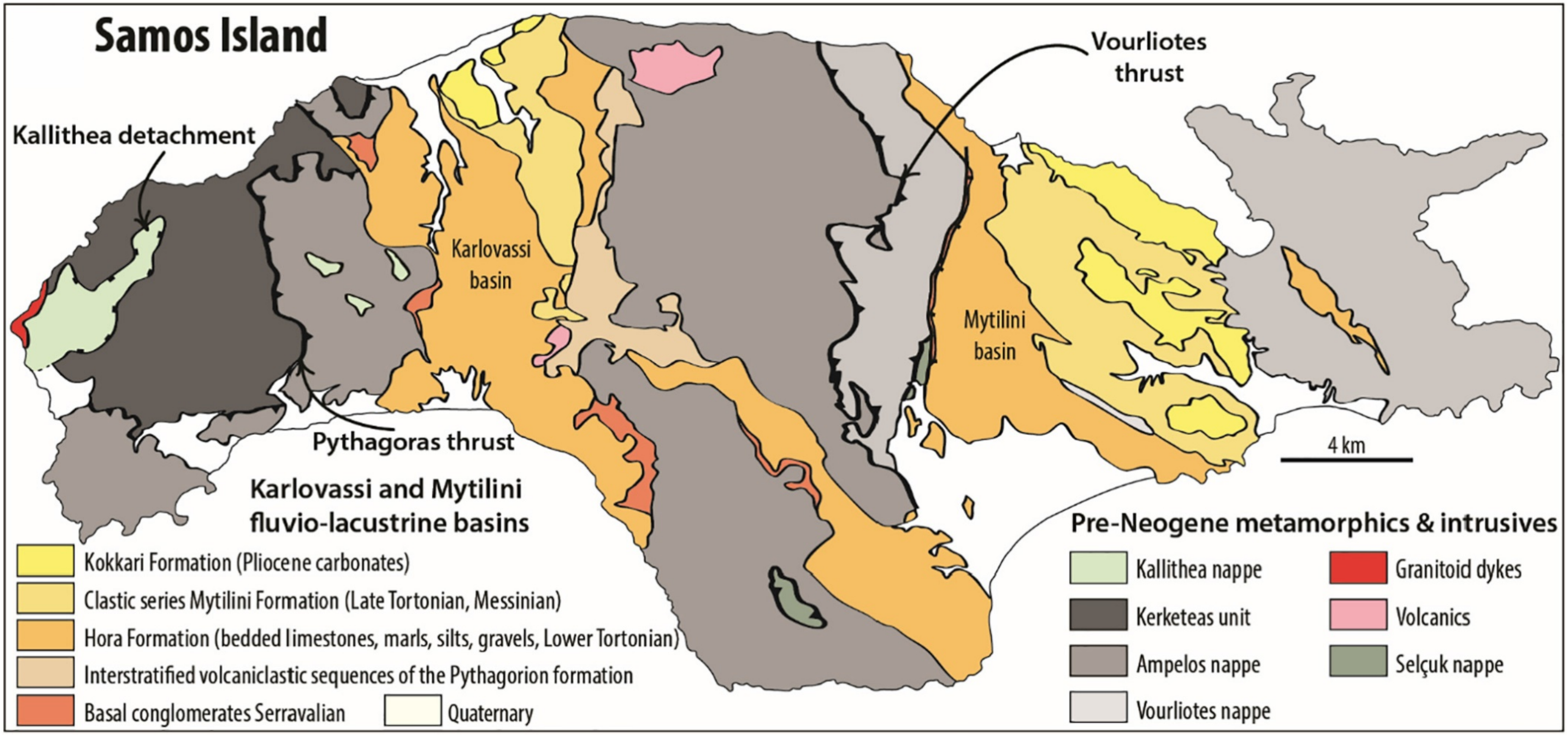
SAMOS NAPPE PILE



From *Ring et al. (2007)*

ISSN 2653-9454
Issue No. 21, November 2020

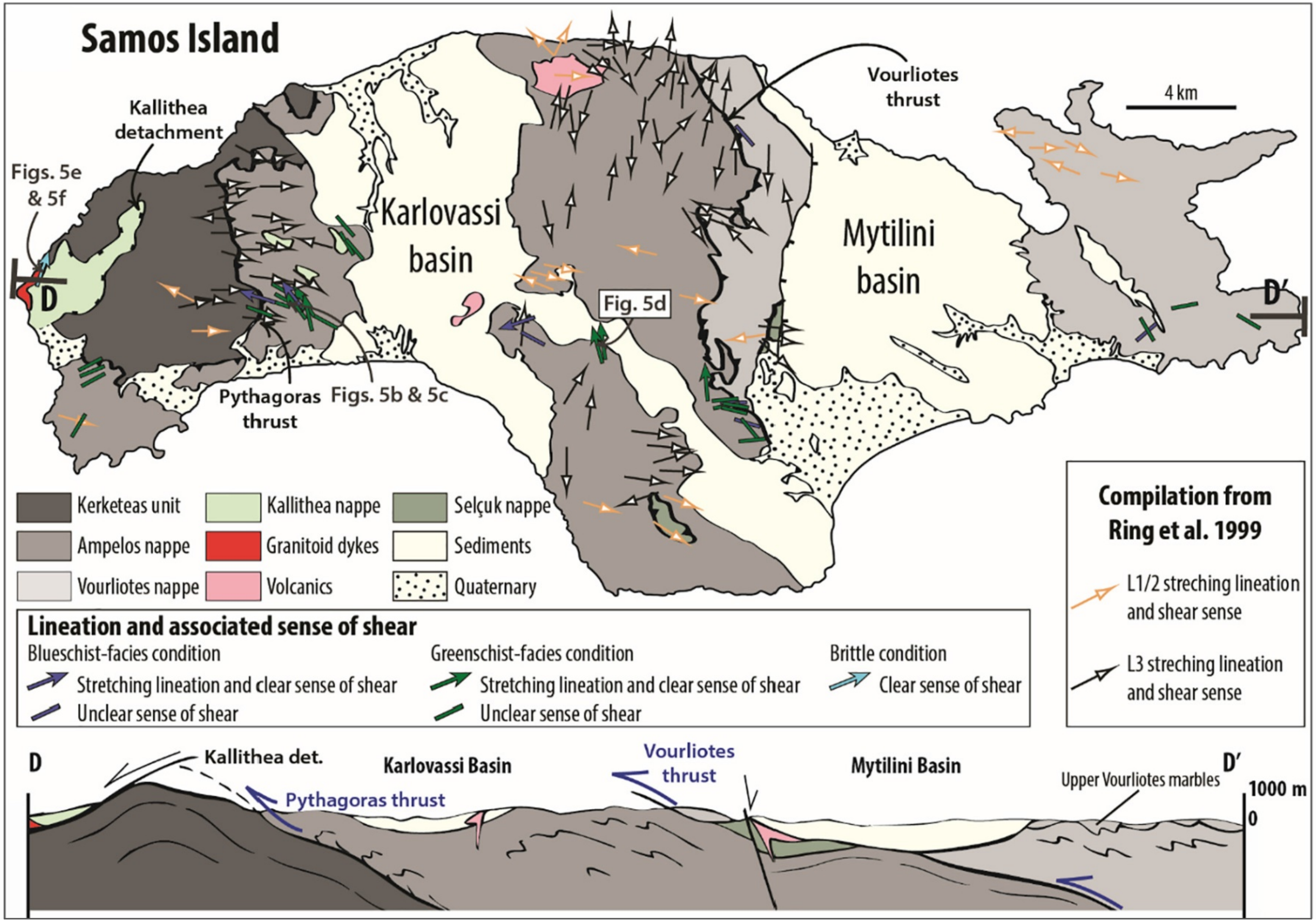
GEOLOGICAL MAP OF SAMOS



From *Roche et al. (2019)*

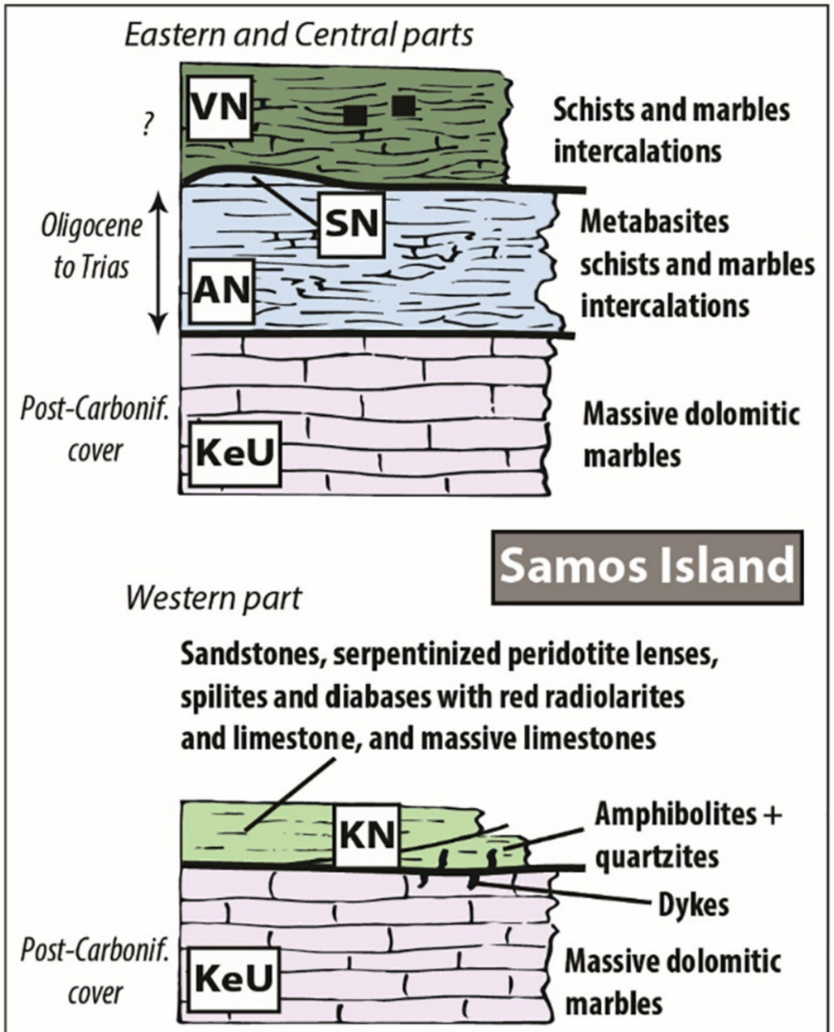
ISSN 2653-9454
Issue No. 21, November 2020

UNITS AND NAPPES OF SAMOS ISLAND

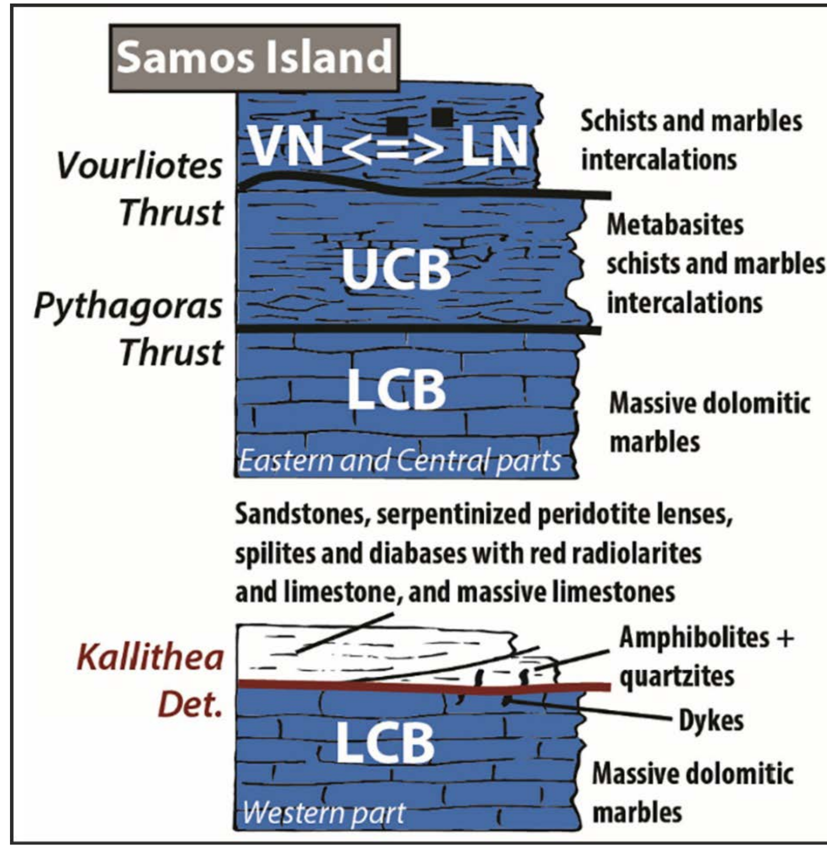


From *Roche et al. (2019)*

UNITS AND NAPPES OF SAMOS ISLAND



From *Roche et al. (2019)*



AN (Ampelos nappe); **KeU** (Kerketas unit); **KN** (Kallithea nappe); **LCB** (Lower Cycladic Blueschist Nappe); **SN** (Selçuk nappe); **UCB** (Upper Cycladic Blueschist Nappe); **VN** (Vourliotes nappe)

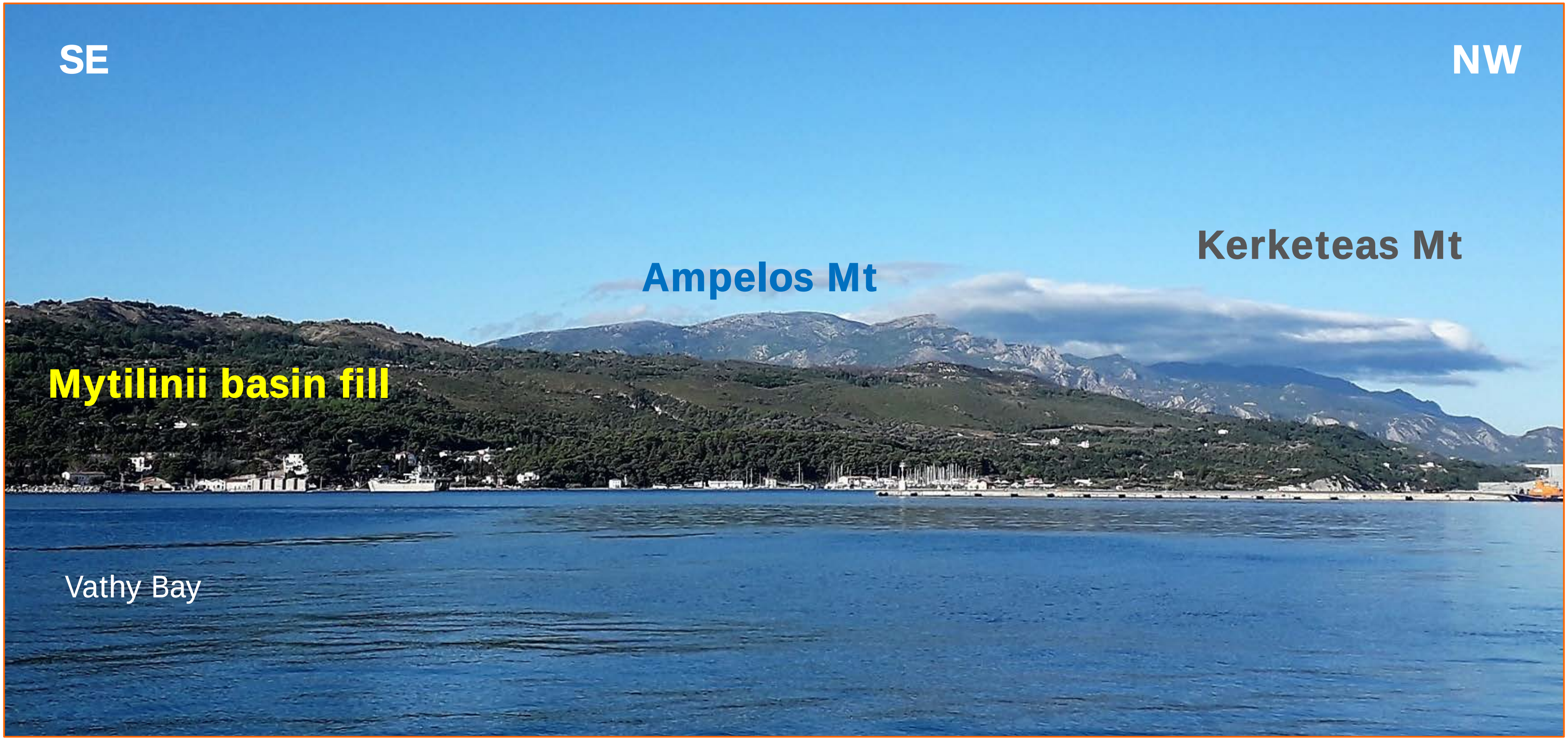
ISSN 2653-9454
Issue No. 21, November 2020

UNITS AND NAPPES OF SAMOS ISLAND

Panoramic view of Kerketeas Mt from the East (Noechori village). It is located at the western part of Samos. It is composed of white to grey, medium to thick bedded and sometimes unbedded, coarse-crystalline marbles, which are strongly faulted. Their visible thickness exceeds 1500 m. Pythagoras thrust is observed at the eastern part of the mountain, separating the Kerketeas nappe from the overlying Ampelos nappe comprising marbles and slates. The Neogene formations of Karlovasi basin can be also observed in the lowland.

ISSN 2653-9454
Issue No. 21, November 2020

UNITS AND NAPPES OF SAMOS ISLAND



Partial view of the formations of the Mytilinii basin fill, the Ampelos Mt comprising the Ampelos nappe at the central part of Samos island and the Kerketeas peak under the clouds. Photos taken from Vathy port.

ISSN 2653-9454
Issue No. 21, November 2020

CURRENT STRESS REGIME AND ACTIVE FAULTS OF SAMOS

The current stress regime was initiated in Pliocene-Quaternary (Mountrakis et al., 2003) and is associated with the regional Aegean Sea NNE-SSW trending extension. As a result of this extension, new E-W striking faults were formed, while older NW-SE and NE-SW faults were also reactivated as strike-slip faults (Mountrakis et al., 2003).

Recent studies comprising field surveys and neotectonic mapping describe 15 **main faults** dissecting Samos:

1. Pythagorion fault
2. Marathokampos-Kerketeas fault
3. Kyparision faults
4. Kokari-Vathy fault
5. Karlovasi-Drakei fault
6. Vathy-Zoothohos Pigi fault
7. Paleokastron-Posidonion fault
8. Kotsikas-Psili Ammos fault
9. Mitilini fault
10. Zervou fault
11. Myloi-Pyrgos fault
12. Faults of Pagonda-Iraion and Tsopela
13. Ydrousa fault
14. Mani Evangelistrias faults
15. Limniona faults

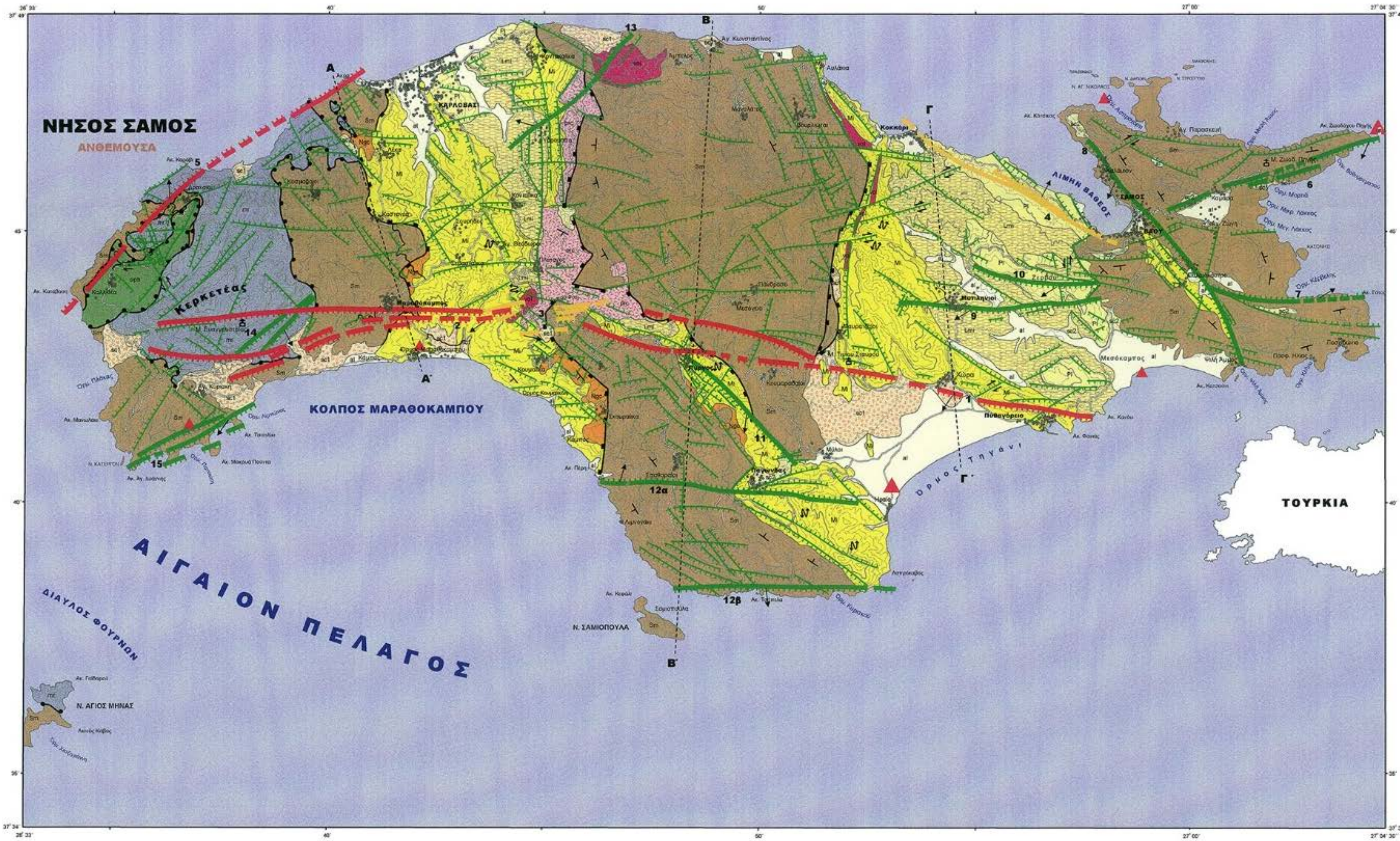
The **active faults** of Samos are the following:

1. the **Karlovasi fault** that defines the northwestern coastline of the island,
2. the **Marathokampos fault** that is almost parallel to the southwest coastline of the island,
3. the **Pythagorion fault** which is the most characteristic extends from its southeastern shores to Mount Ampelos,
4. the **Vathy fault** that partially defines the northeastern coast of the island and finally
5. the **Northern Samos offshore fault** that forms a very deep basin northwest of Samos

From *Mountrakis et al. (2006)*, *Pavlides et al. (2009)* and *Chatzipetros et al. (2013)*

ISSN 2653-9454
Issue No. 21, November 2020

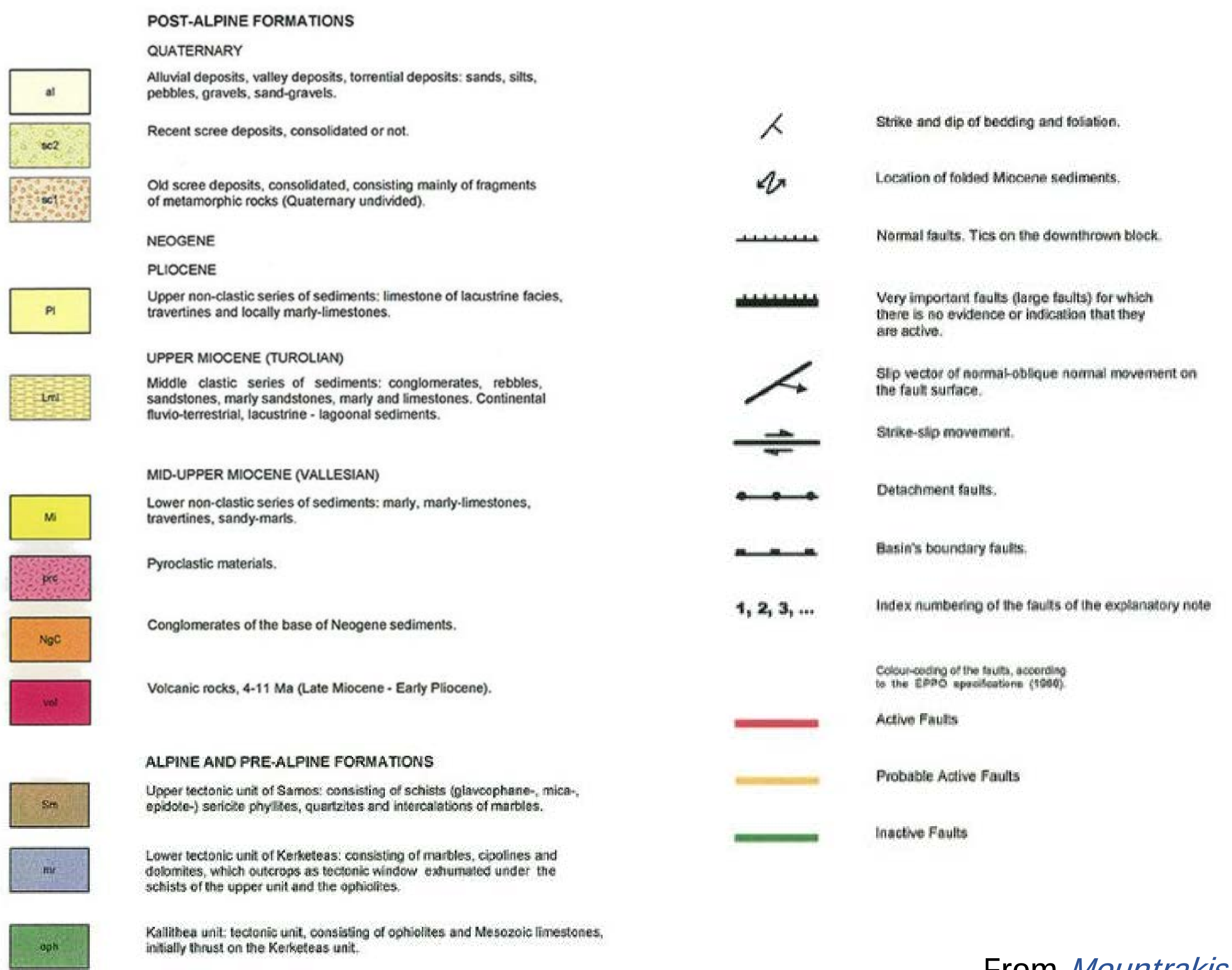
NEOTECTONIC MAP OF SAMOS



From *Mountrakis et al. (2006)*

ISSN 2653-9454
Issue No. 21, November 2020

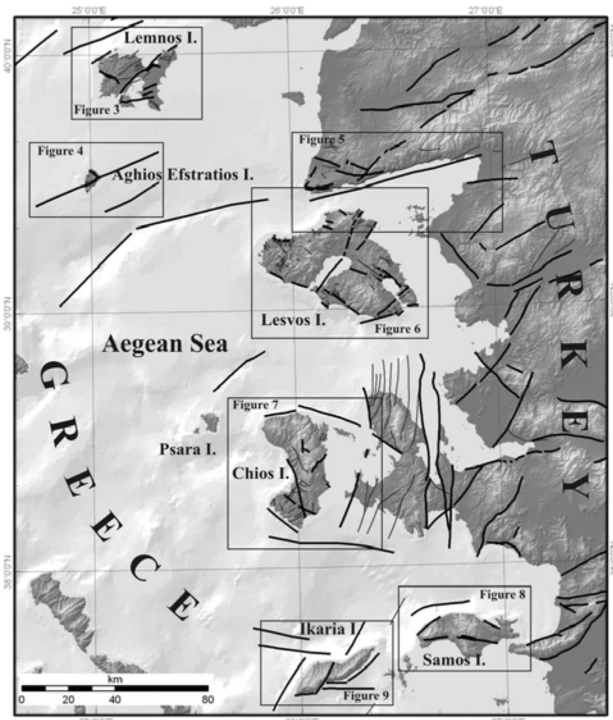
NEOTECTONIC MAP OF SAMOS
LEGEND

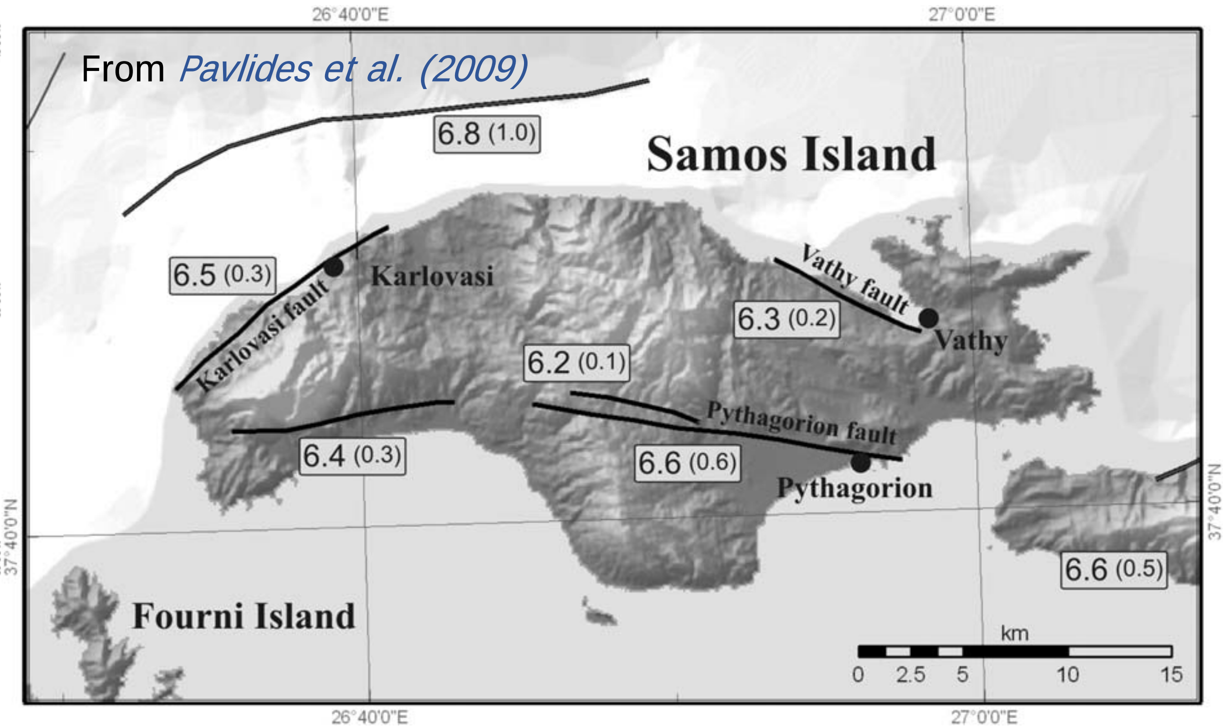


From *Mountrakis et al. (2006)*

ISSN 2653-9454
Issue No. 21, November 2020

ACTIVE FAULTS AND EARTHQUAKE POTENTIAL IN SAMOS ISLAND



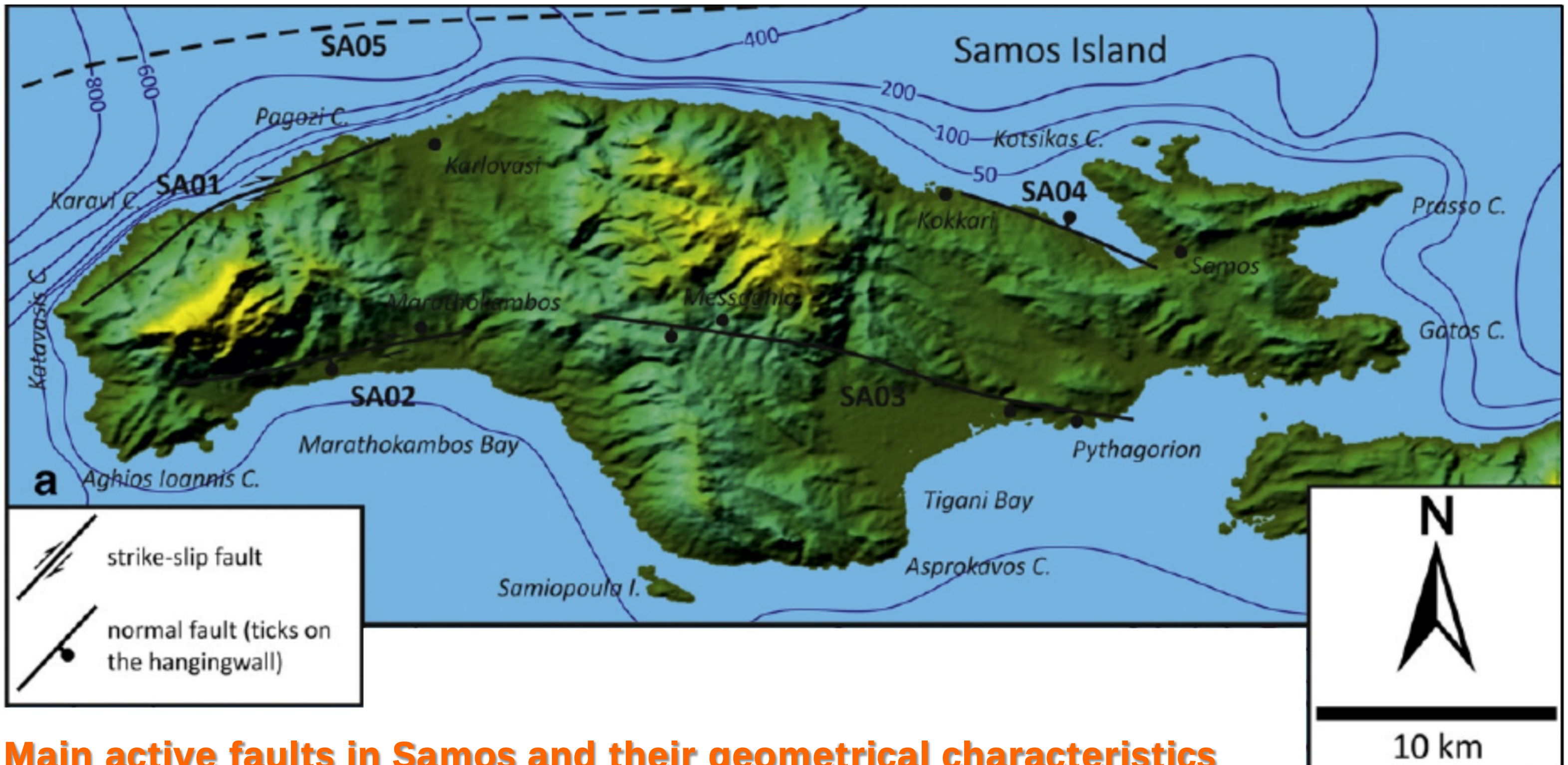


Samos has been shaped by major faults with clear neotectonic character and significant length:

- The **Pythagorion fault**, striking WNW-ESE, is the prominent fault of the island having earthquake potential on the order of **6.6**. Pythagorio village is mainly situated on the hanging-wall and partly on the fault trace, so this fault is essential for possible activation.
- The **Vathy** and **Karlovasi faults** (earthquake potential **6.3** and **6.5** respectively) define the linear shorelines. However, the dip direction (to the NE and NW respectively) decrease seismic hazard for occupied areas.
- There is a **major offshore fault north of Samos** with earthquake potential of **6.8** and great possibility of future seismic source.

ISSN 2653-9454
Issue No. 21, November 2020

ACTIVE FAULTS IN SAMOS ISLAND



Main active faults in Samos and their geometrical characteristics

Code	Name	Sense	Dip direction (°) (min)	Dip direction (°) (max)	Dip (°)	Rake min	Rake max	Length (km)	Max. mag.
SA01	Carlovassi	D	315	330	75	180	210	12.9	6.4 (W&C)
SA02	Marathokambos	ND	160	180	70	220	250	10.8	6.4 (P&C)
SA03a	Pythagorion fault zone (Pythagorion segment)	N	190	200	45	260	280	18.0	6.6 (P&C)
SA04	Vathy	N	20	40	50	260	280	7.9	6.3 (P&C)
SA05	North Samos	N	310	350	40	240	280	26.6	6.8 (P&C)

From *Chatzipetros et al. (2013)*

ISSN 2653-9454
Issue No. 21, November 2020

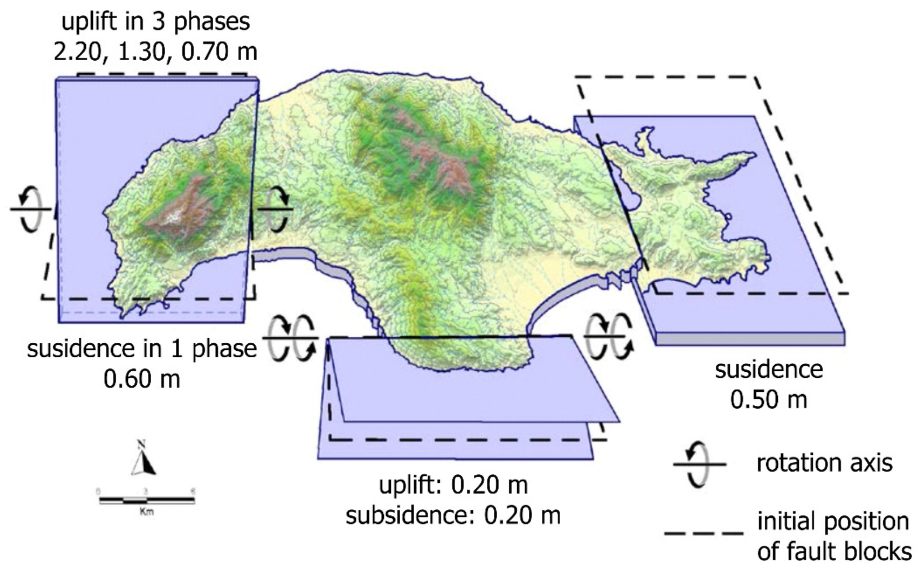
MAIN FAULT BLOCKS OF SAMOS – ROTATION AND TILTING

Samos consists of 4 different fault blocks with different tectonic behavior:

a) The **western fault block** has been rotated around an E-W trending horizontal axis. Its northern part has emerged during three main tectonic phases characterized by variations in their size, range and frequency. On the contrary, its southern part has been subsided into a single tectonic phase. The western part seems to have functioned as a tectonic dipole only in the last phase, with an uplift of 0.70 m on its northern side and a subsidence of 0.60m on its southern side. During the two older phases, the northern side behaved as an independent fault block. More specifically, this fault block rotated around an E-W trending axis, in a clockwise direction, while the southern part of the western side remained stable. To the east, this fault block is bordered by the fault zone along the western margin of the Karlovasi basin.

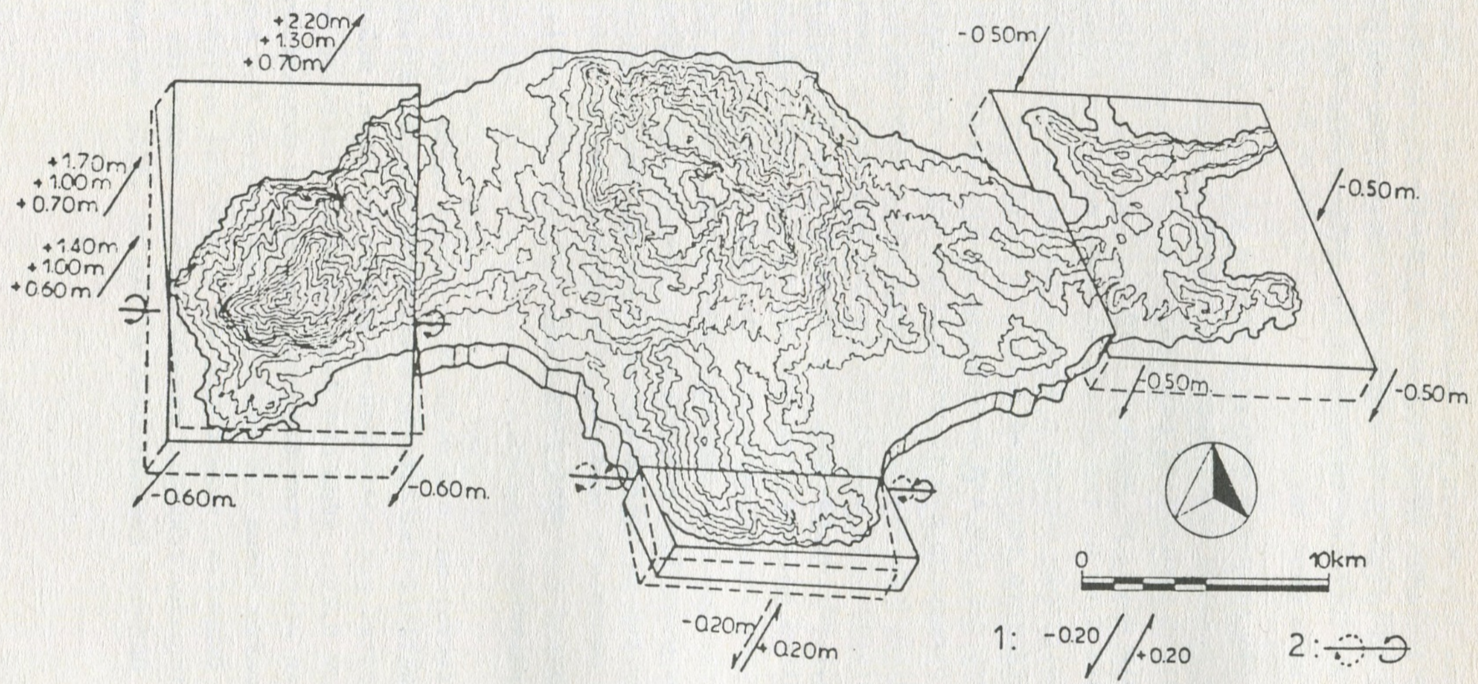
b) The **southern part of central Samos**, is a second fault block that has undergone successive phases of uplift and subsidence of the order of 0.20 m around an E-W trending axis. The uplift has been considered older, while the subsidence recent. The northern boundary of this fault block coincides with the E-W trending fault zone passing through Limnonaki area, while the eastern and western boundaries coincides with the eastern and western fault zones of the Karlovassi and Mytilinioí basin respectively.

c) The **eastern fault block** has suffered a total subsidence of 0.50 m. The western boundary of this fault block coincides with the Vathy – Psili Ammos fault zone.



ISSN 2653-9454
Issue No. 21, November 2020

ROTATION AND TILTING OF FAULT BLOCKS IN SAMOS



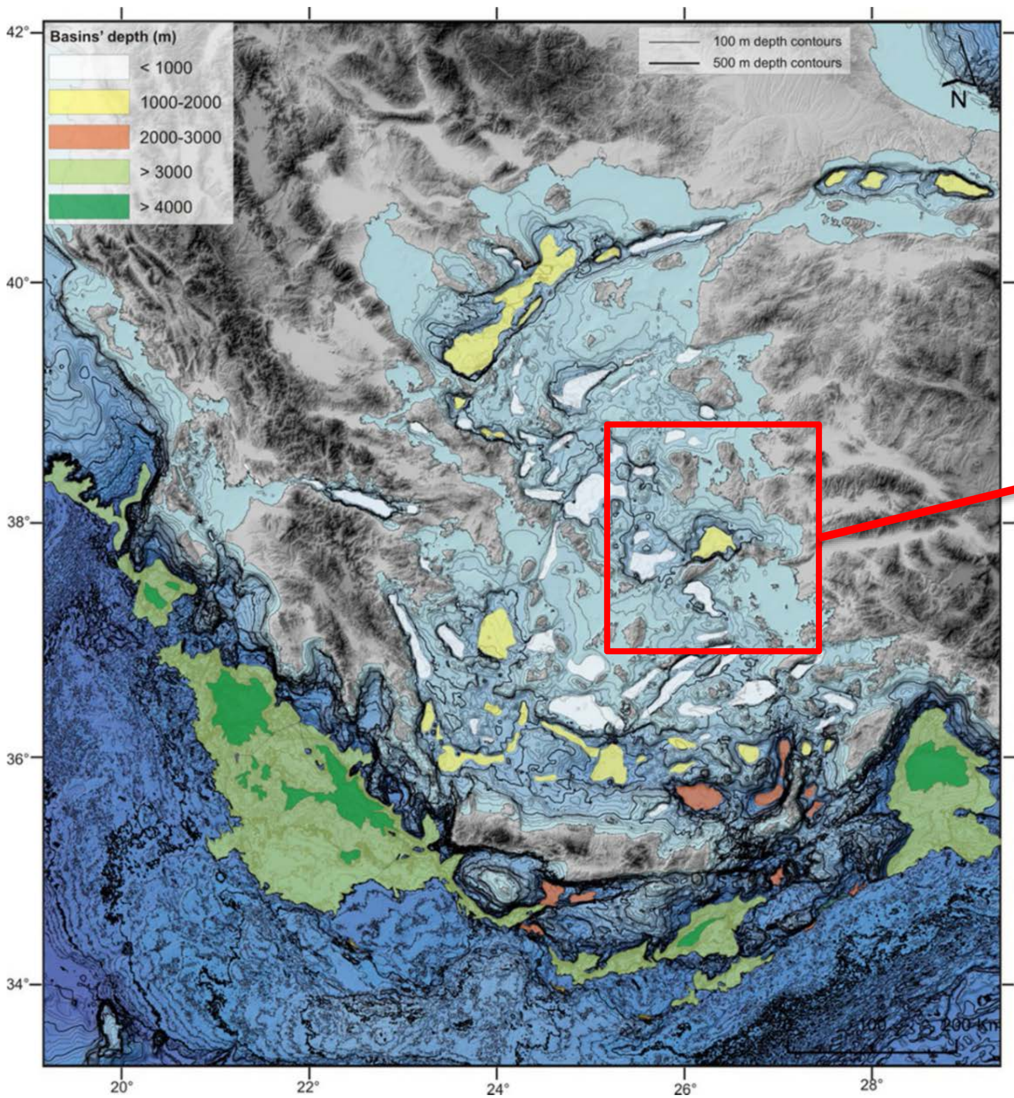
Σχ.5. Σχηματική απεικόνιση των τεκτονικών τεμαχών της νήσου Σάμου.
1. διεύθυνση και μέγεθος των κάθετων τεκτονικών κινήσεων
2. διεύθυνση περιστροφής γύρω από άξονα.

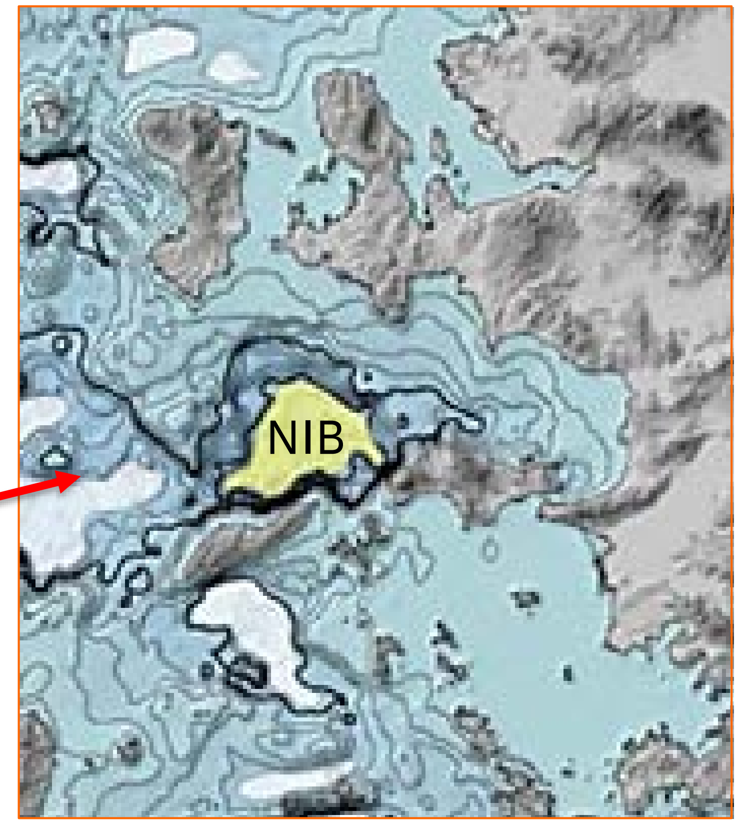
Fig.5. Block diagram of the tectonic block of Samos island
1. Direction and magnitude of the vertical tectonic movement
2. Direction of rotation around tilt axis

From *Mourtzas and Stauropoulos (1989)*

ISSN 2653-9454
Issue No. 21, November 2020

FAULTS AND BLOCKS OFFSHORE NORTHERN SAMOS



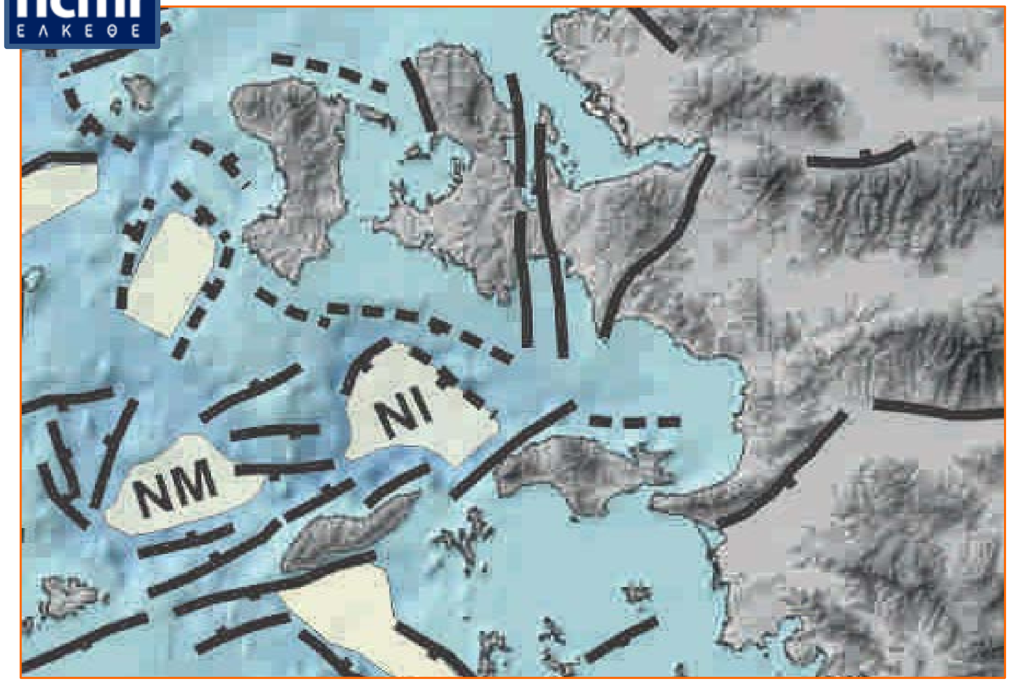


The main basin formed and developed north of Samos is the North Ikaria Basin (NIB)

From *Sakellariou and Tsampouraki (2018)*

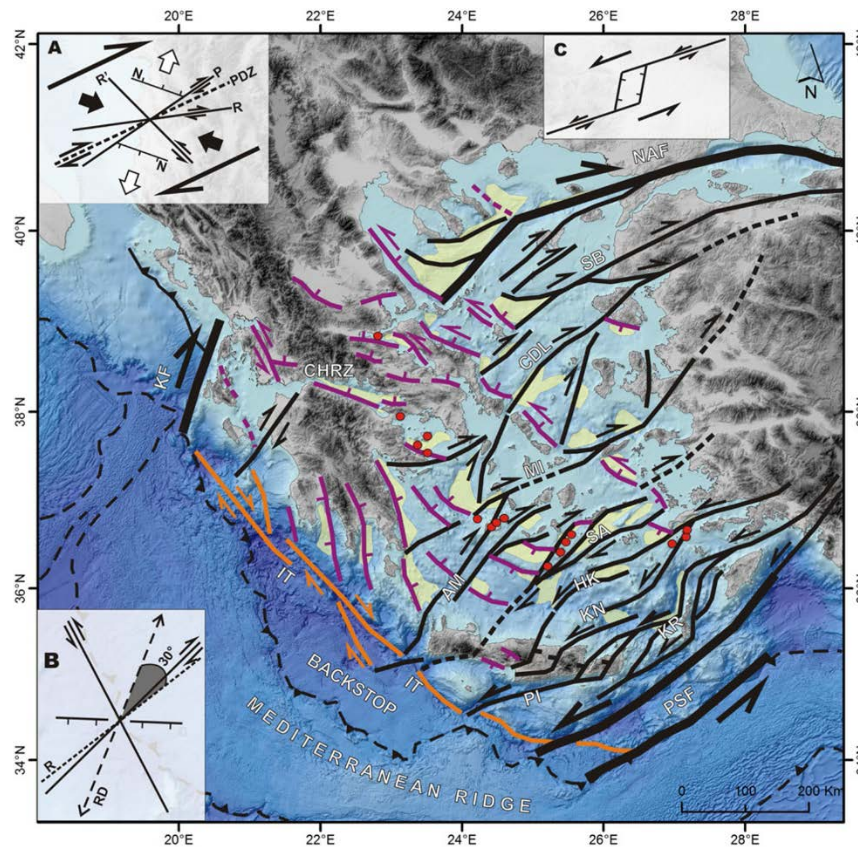
ISSN 2653-9454
Issue No. 21, November 2020

FAULTS AND BLOCKS OFFSHORE NORTHERN SAMOS



▲ The main basin formed and developed north of Samos is the North Ikaria Basin (NIB) consists of a Plio-Quaternary, wide, asymmetric depression bounded to the south by major en echelon arranged faults, which imply a transcurrent component (Mascle and Martin, 1990).

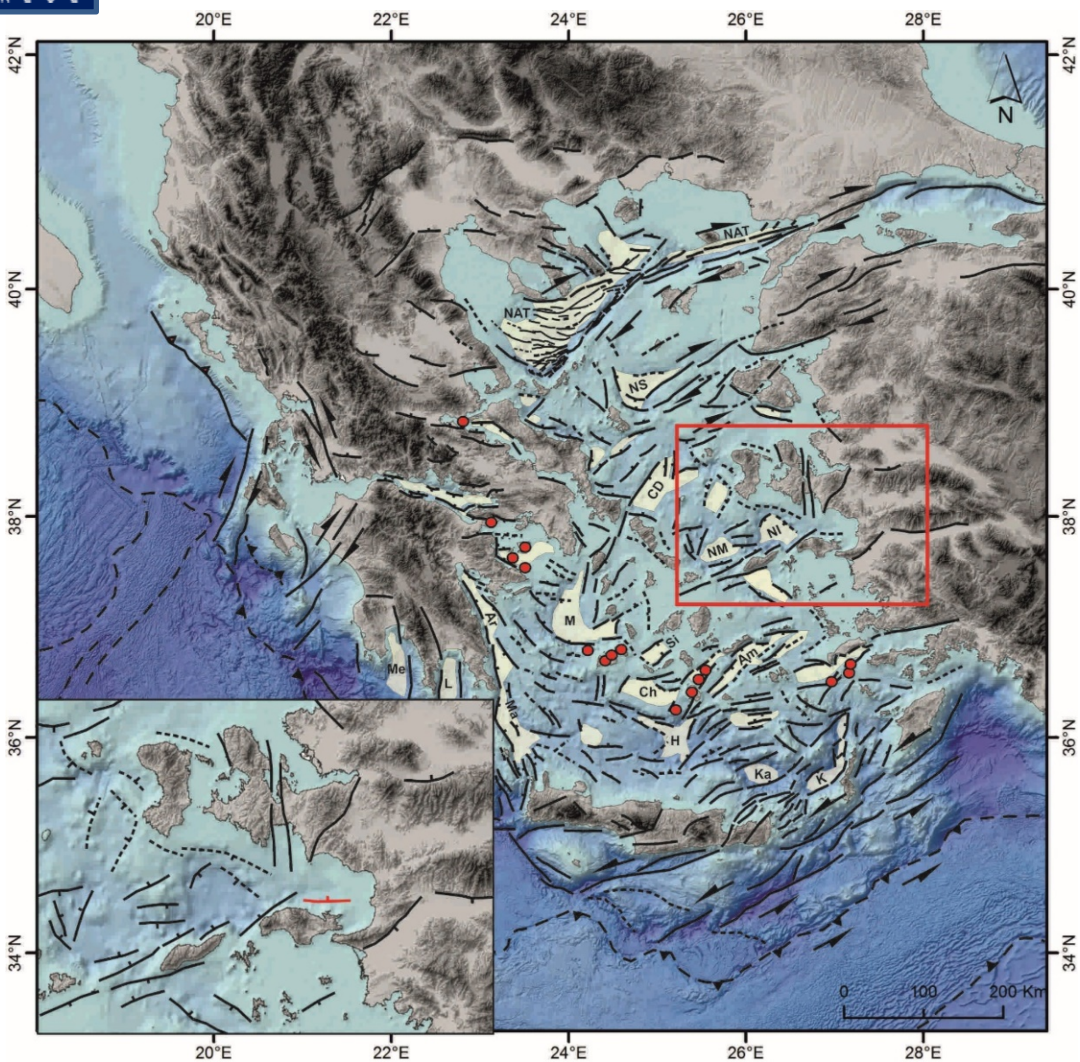
▼ Strike-slip deformation is evident on the Samos Island, on the southern margin of the NIB. NNE-SSW-directed extension has resulted in the creation of E-W faults and the reactivation of older NW-SE and NE-SW faults as strike-slip ones (Chatzipetros et al., 2013).



From *Sakellariou and Tsampouraki (2018)*

ISSN 2653-9454
Issue No. 21, November 2020

FAULTS AND BLOCKS OFFSHORE NORTHERN SAMOS



The earthquake affected area of the Eastern Aegean Sea is highlighted with the red frame, while the causative fault is located in northern Samos.

From *Sakellariou and Tsampouraki (2018)*

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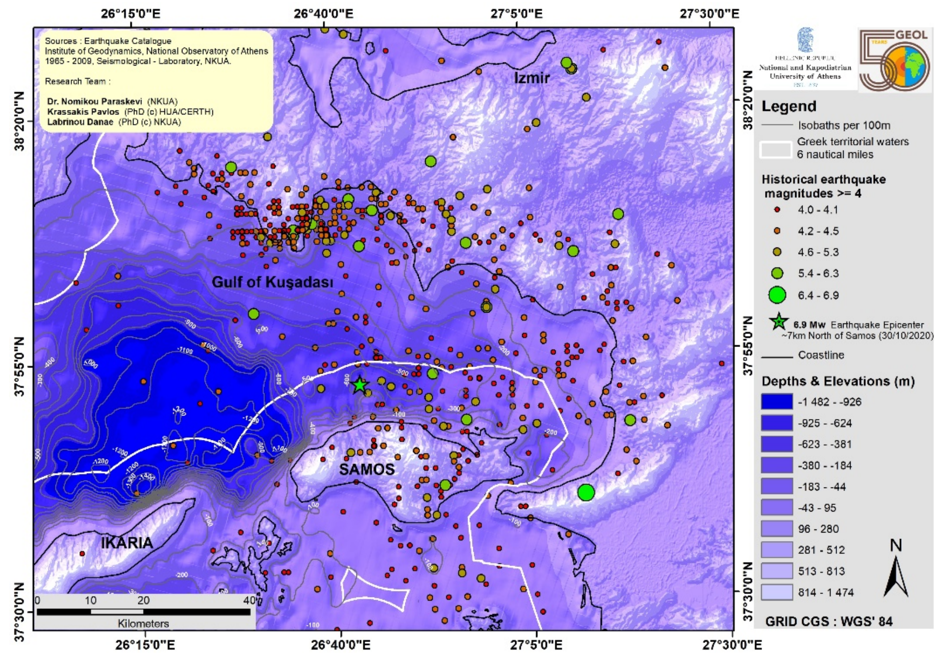
University of Athens
Faculty of Geology and Geoenvironment
Department of Geography – Climatology

SEABED MORPHOLOGY NORTH OF SAMOS

The seabed morphology of the **Kusadasi Bay** located north of Samos is gentle with sparse and wide isobaths that gradually lower the seabed of the basin from S to N. It is characterized by E-W direction, following the E-W trending major axis of Samos with a length of about 40 km from Kerketeas Mt in its western part to Profitis Ilias in its eastern end. It shows a wider range of slopes to the north. The flat horizontal part of the basin is observed at a depth of -600 m and occupies a small area in its central part. The continental shelf develops mainly on the northern slopes of the Gulf up to 100m, while it has limited extend on the southern slopes, north of Samos where steep morphological slopes are observed due to the existence of the marginal fault.



The **Kusadasi Bay** is characterized by asymmetry in its slopes. The slopes in the northern part (towards Turkey) are gentle, while slopes in the southern part (towards Samos) are steep. The steep relief of NW Samos (Mount Kerketeas) continues underwater at depths up to -1160m according to the denser arrangement of isobaths and the abrupt change in the seabed morphology. The thickening of the isobaths reveals a more intense relief with moderate morphological slopes (~ 10°), which decreases as we approach the flat part of the basin that does not exceed -600m depth. The northern part of the basin has a smooth seabed relief without depth fluctuations with gradual increase up to the flat part of the basin.

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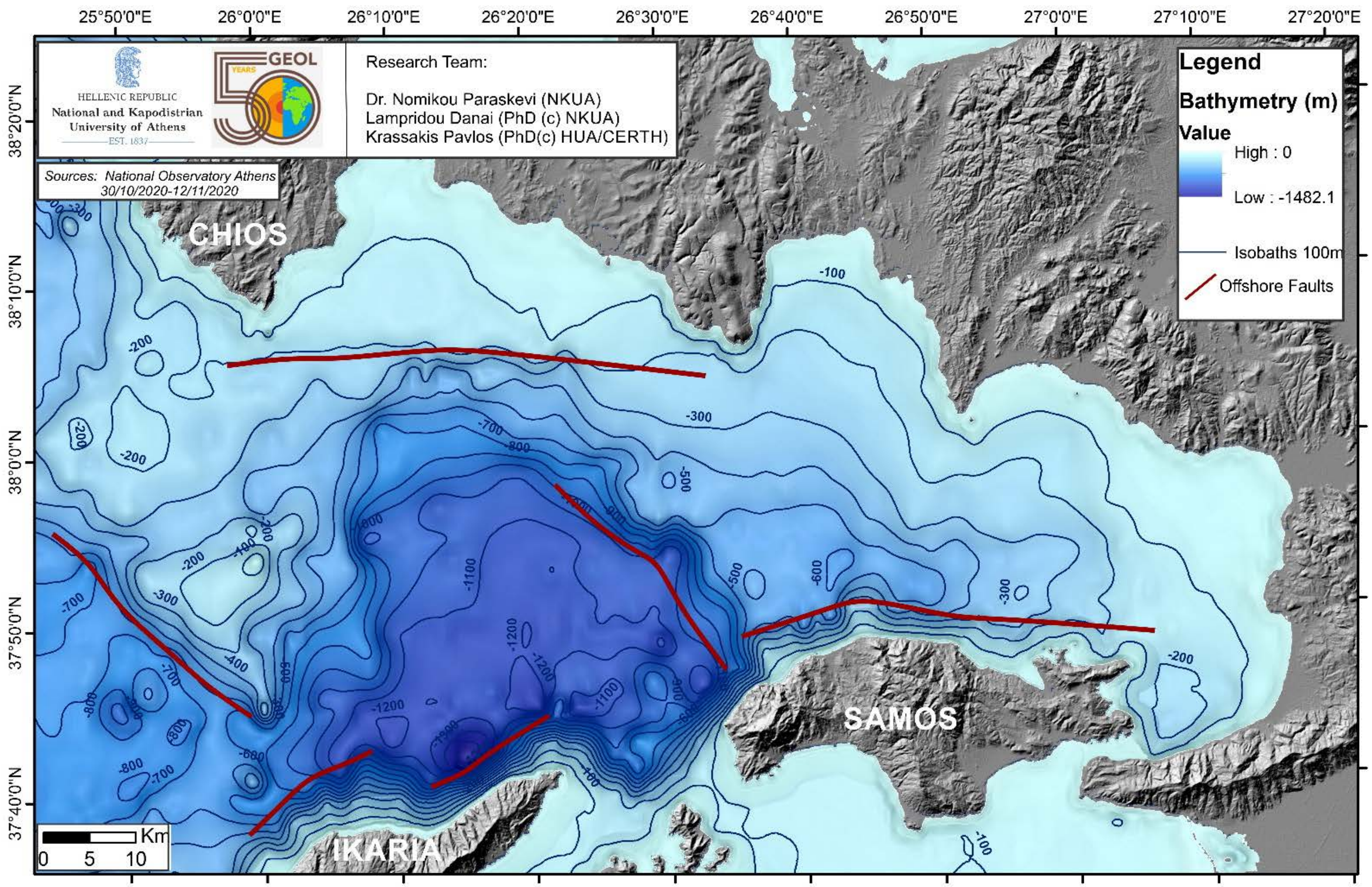
SEABED MORPHOLOGY NORTH OF SAMOS



The **central basin of the Ikarian Sea**, formed north of Ikaria, presents a rectangular arrangement with length of 52 km in NE-SW direction and length of 47 km in NW-SE direction. Its southern slopes show large morphological slopes (~20º), while its northern slopes are characterized by gentle morphological slopes. The deepest part of the basin is at -1430m and is observed on the south side of the basin, where it is bounded by ENE-WSW striking marginal faults.

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Issue No. 21, November 2020

SEISMICITY IN SAMOS AND THE SURROUNDING AREA

The wider area of Samos is seismically active as not only recent but also historical earthquakes have struck the island with considerable damage on the local population, the natural environment, the buildings and the infrastructures. Characteristic example is the **August 11, 1904**, Samos earthquake with **Mw=6.8** and **I=VIII** and **July 16, 1955**, Samos earthquake with **Mw=6.9** and **I=VII**.

The **1904 earthquake** is very similar to the October 30, 2020 event. This earthquake caused damage to the villages of Ano Vathy, Chora, Pyrgos, Koumaeika, Skouraeika, Kontaeika and Agia Triada, which are built on recent deposits. In Chora, hundreds of buildings and the great monastery of the Holy Trinity were destroyed. Damages were generated throughout the island. The earthquake caused 4 fatalities and 7 injured. In Samos, 540 houses were completely destroyed. It was strongly felt in Patmos, where it also caused damage, as well as in Chios, Ikaria and Western Asia Minor (Smyrni, Nea Ephesus, Phocaea, Aydin). It was also strongly felt in Santorini and Naxos and slightly felt in Athens. It was moderately felt in Suez and the Red Sea. The main earthquake was followed by aftershocks, the largest of which occurred on the August 12 and 18 as well as on October 6 and aggravated damage induced by the mainshock.

Recently, in **2009**, a seismic swarm struck Samos. It initially generated in Pythagorion area on June 20 with an earthquake of magnitude 5.1 followed by over 80 aftershocks within the next ten days. In general, swarms of earthquakes have also been observed:

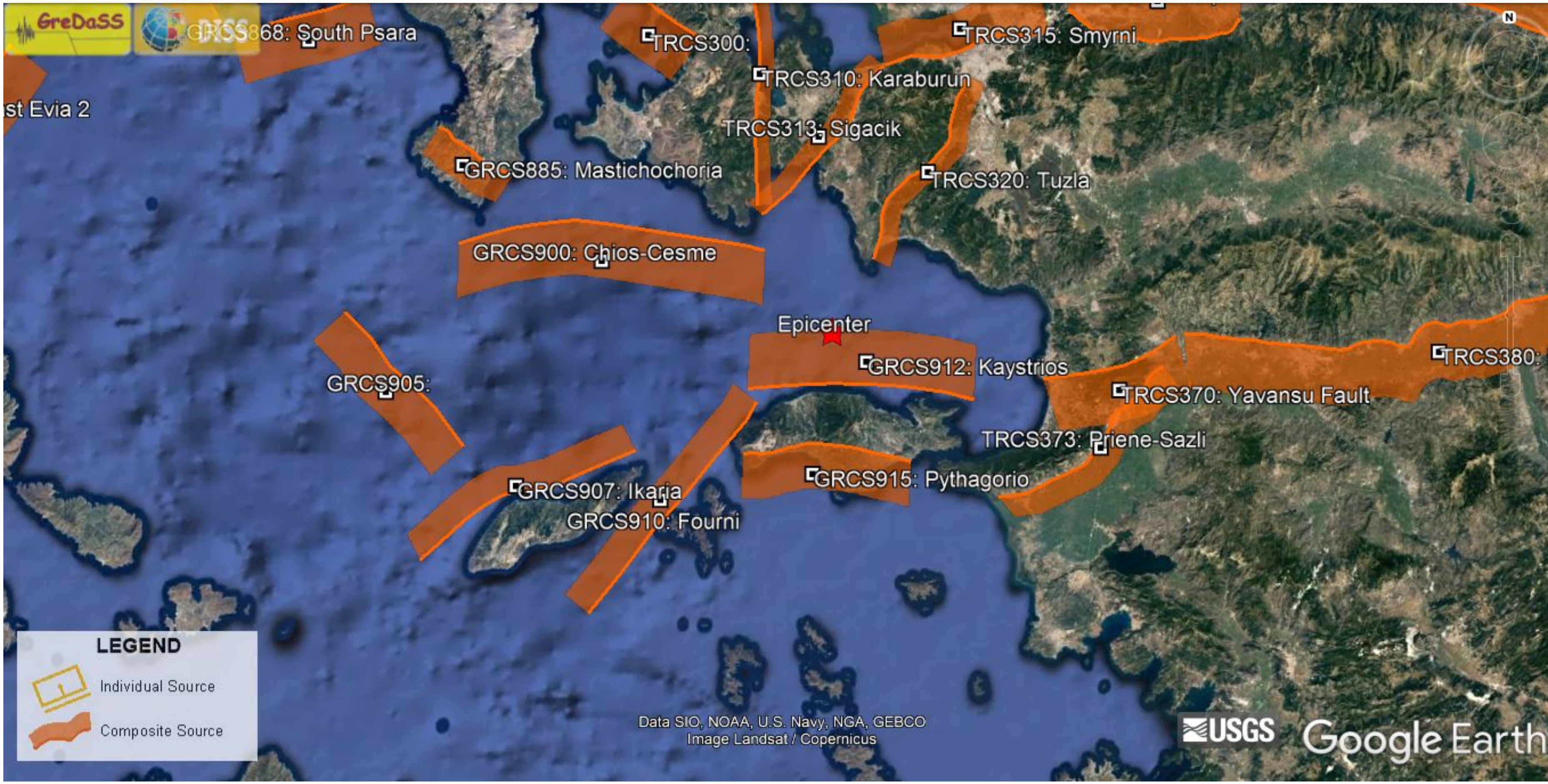
(a) in the northeastern part of the island, where the focal mechanisms indicate the existence of a fault dipping to the south,

(b) in the northern and central part of the island, which did not coincide with the known faults of the island and

(c) in offshore northern Samos.

ISSN 2653-9454
Issue No. 21, November 2020

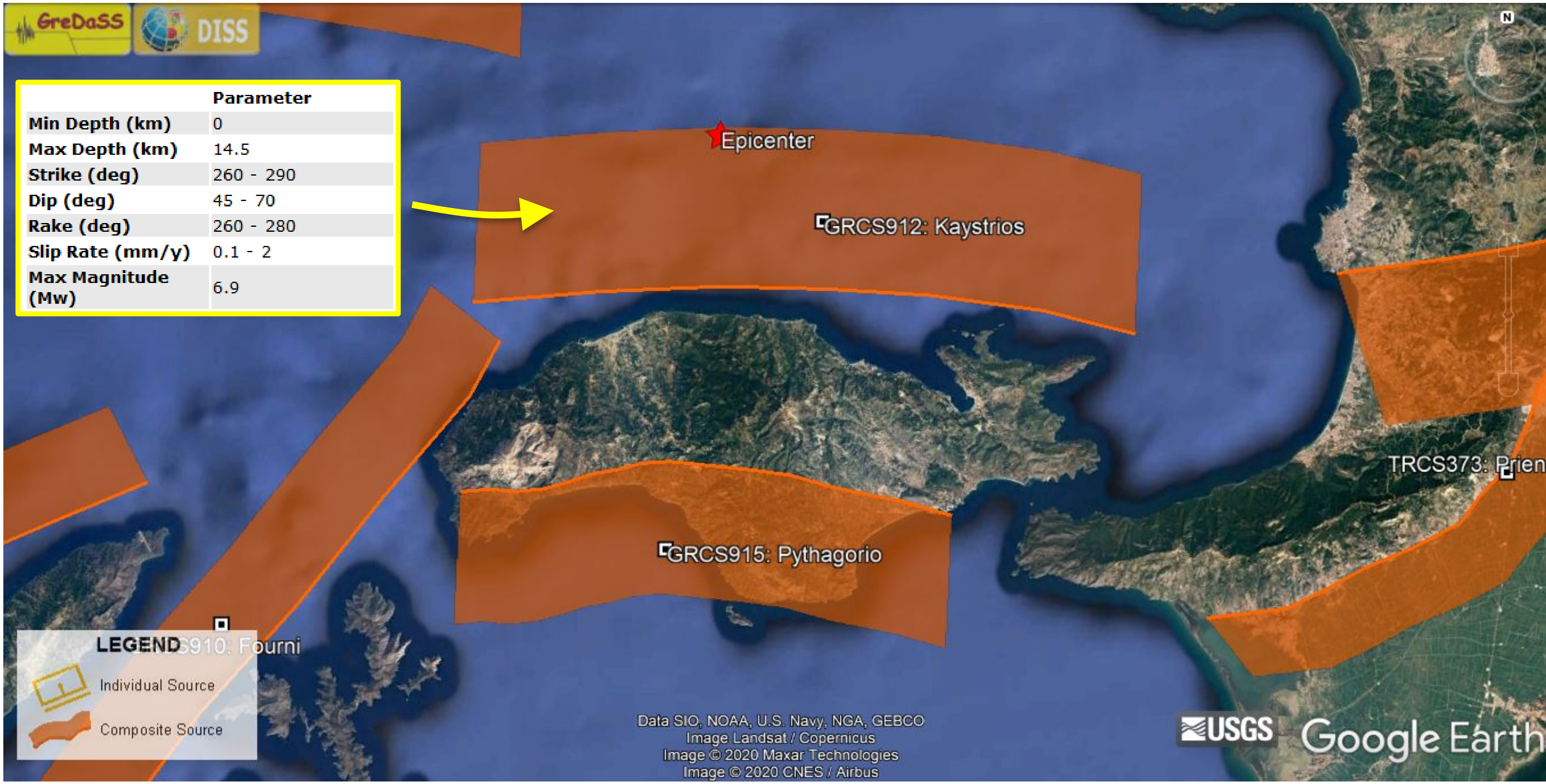
SEISMOGENIC SOURCES IN EASTERN AEGEAN & WESTERN TURKEY
BASED ON THE GREEK DATABASE OF SEISMOGENIC SOURCES



From http://gredass.unife.it/gredassGM/
and http://gredass.unife.it/HTMLs_2.0/GRCS912INF.html

ISSN 2653-9454
Issue No. 21, November 2020

SEISMOGENIC SOURCES IN SAMOS AREA
BASED ON THE GREEK DATABASE OF SEISMOGENIC SOURCES



From http://gredass.unife.it/gredassGM/
and http://gredass.unife.it/HTMLs_2.0/GRCS912INF.html

ISSN 2653-9454
Issue No. 21, November 2020

HISTORICAL AND RECENT EARTHQUAKES
IN SAMOS ISLAND

Date of occurrence	Latitude N	Longitude E	Focal Depth	Magnitude	Intensity
200 BC	37.7	26.9	n	6.3	VIII (Samos)
47 AD	38.1	27.5	n	7.0	VIII (Samos)
1751, June 18	37.7	27.1	n	6.4	VIII (Samos)
1831, April 3	37.7	26.8	n	6.0	VII (Samos)
1846, June 13	37.6	27.0	n	6.0	VII (Samos)
1865, October 11	37.6	27.0	n	6.0	VII (Samos)
1868, May 3	37.6	26.9	n	6.0	VII (Samos)
1873, January 31	37.7	27.1	n	6.5	VII (Samos)
1875, July 5	37.7	26.9	n	< 6.0	V (Samos)
1877, October 14	37.7	27.0	n	6.0	VIII (Samos, Kokkari)
1893, March 12	38.0	27.2	n	6.6	VII (Samos)
1904, August 11	37.66	26.93	n	6.8	VIII (Samos)
1955, July 16	37.55	27.05	n	6.9	VII (Samos)

From *Papazachos and Papazachou (2003)*

ISSN 2653-9454
Issue No. 21, November 2020

HISTORICAL AND RECENT EARTHQUAKES FELT IN SAMOS ISLAND

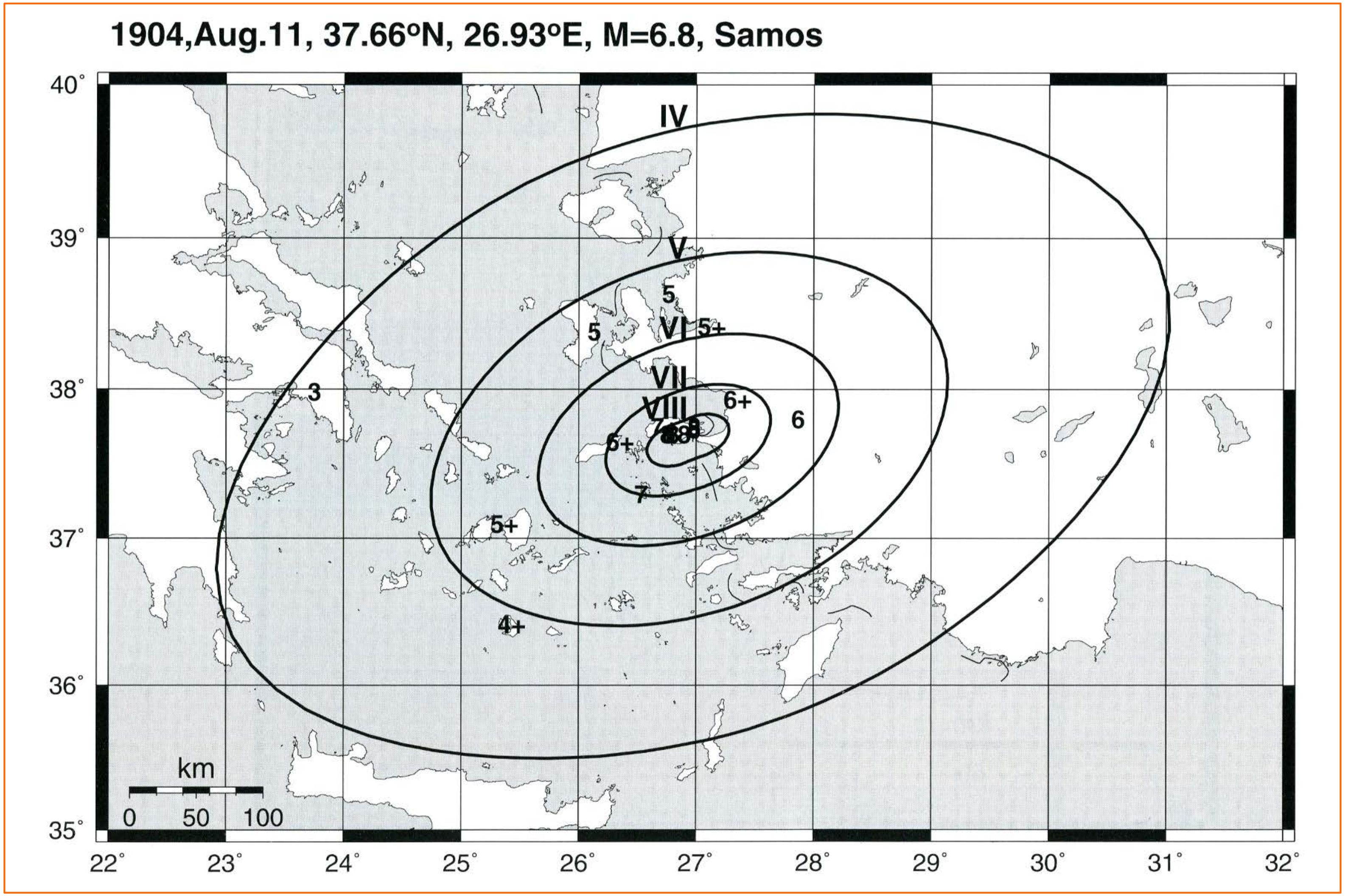
From *Taxeidis (2003), Ambraseys (2009)*

Date of occurrence	Epicentral area
201-197 BC	Samos
46-47 AD	Militus
1733, December 23	Aegean Sea
1751, June 18	Samos
1766, August 1	Samos
1771, September 1	Turgutlu
1771, November 19, 26	Turgutlu
1804, October 8	Samos
1817, October 30	Samos
1817, October 31	Izmir
1831, April 3	Samos
1834, July 25	Soke
1845, October 9	Samos
1846, June 25	Izmir
1846, July 3	Samos
1855, February 18	Samos
1860, August 22	Saros
1861, January 20	Samos
1863, August 29	Samos
1865, September 8	Samos
1865, October 23	Samos
1866, April 25	Samos
1868, April 18	Samos
1868, May 16	Samos
1868, August 9	Samos
1869, March 28	Samos
1869, May 31	Samos
1870, November 7	Balat

Date of occurrence	Epicentral area
1870, November 14	Samos
1870, December 13	Samos
1872, August 5	Samos
1872, September 23	Samos
1873, February 1	Samos
1874, March 16	Samos
1874, August 22	Samos
1874, November 16	Samos
1875, January 8	Samos
1875, February 1	Samos
1875, April 26	Samos
1875, May 11	Samos
1875, June 17	Samos
1875, July 7	Samos
1875, August 31	Samos
1875, December 10	Samos
1876, July 4	Samos
1876, September 1	Samos
1876, September 17	Samos
1877, October 13	Samos
1878, April 9	Samos
1878, August 31	Samos
1879, June 23	Samos
1879, July 17	Samos
1880, September 12	Samos
1893, May 20	Samos

ISSN 2653-9454
Issue No. 21, November 2020

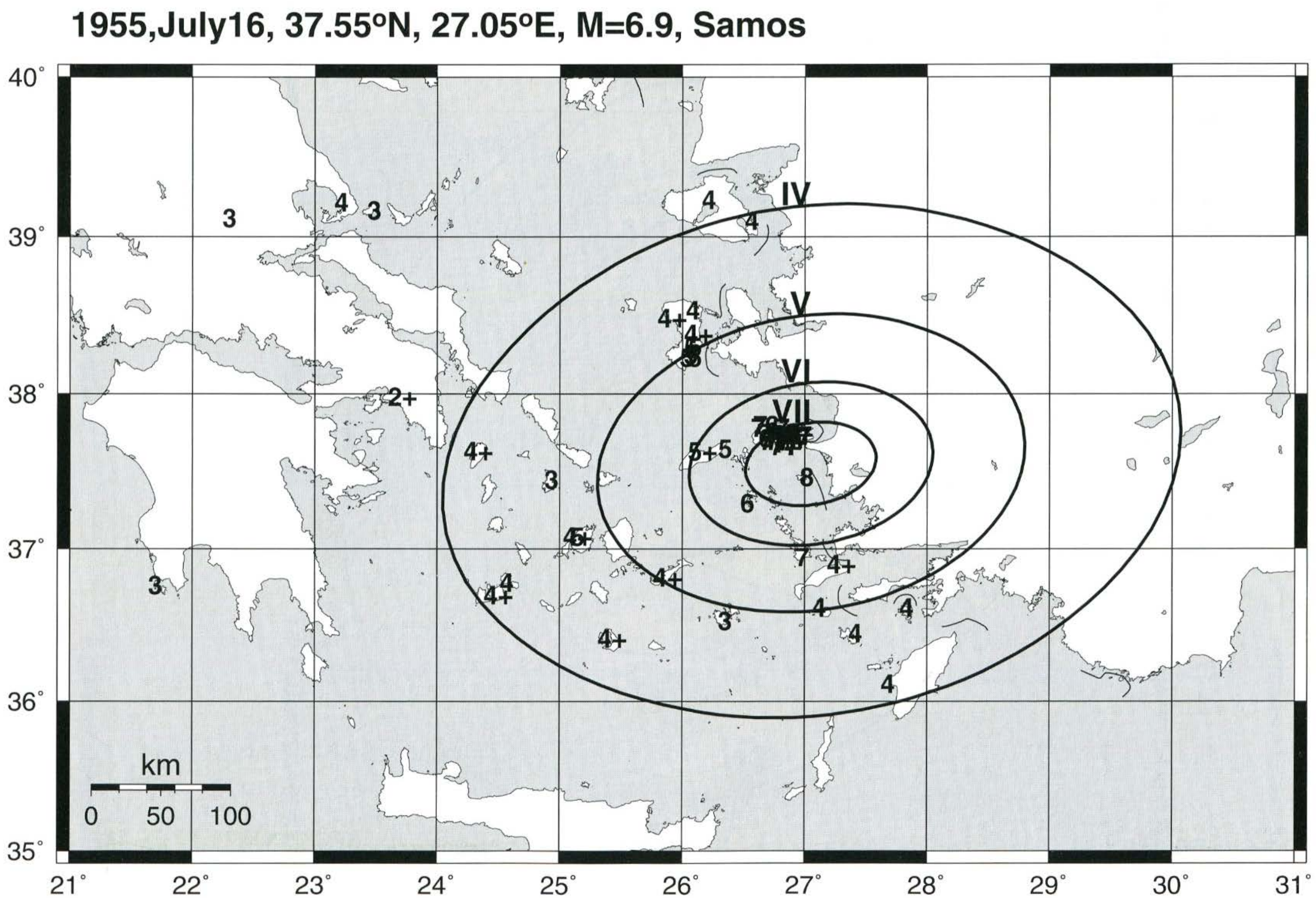
ISOSEISMAL MAPS OF PREVIOUS EVENTS
WITH IMPACT ON SAMOS ISLAND



From *Papazachos et al. (1997)*

ISSN 2653-9454
Issue No. 21, November 2020

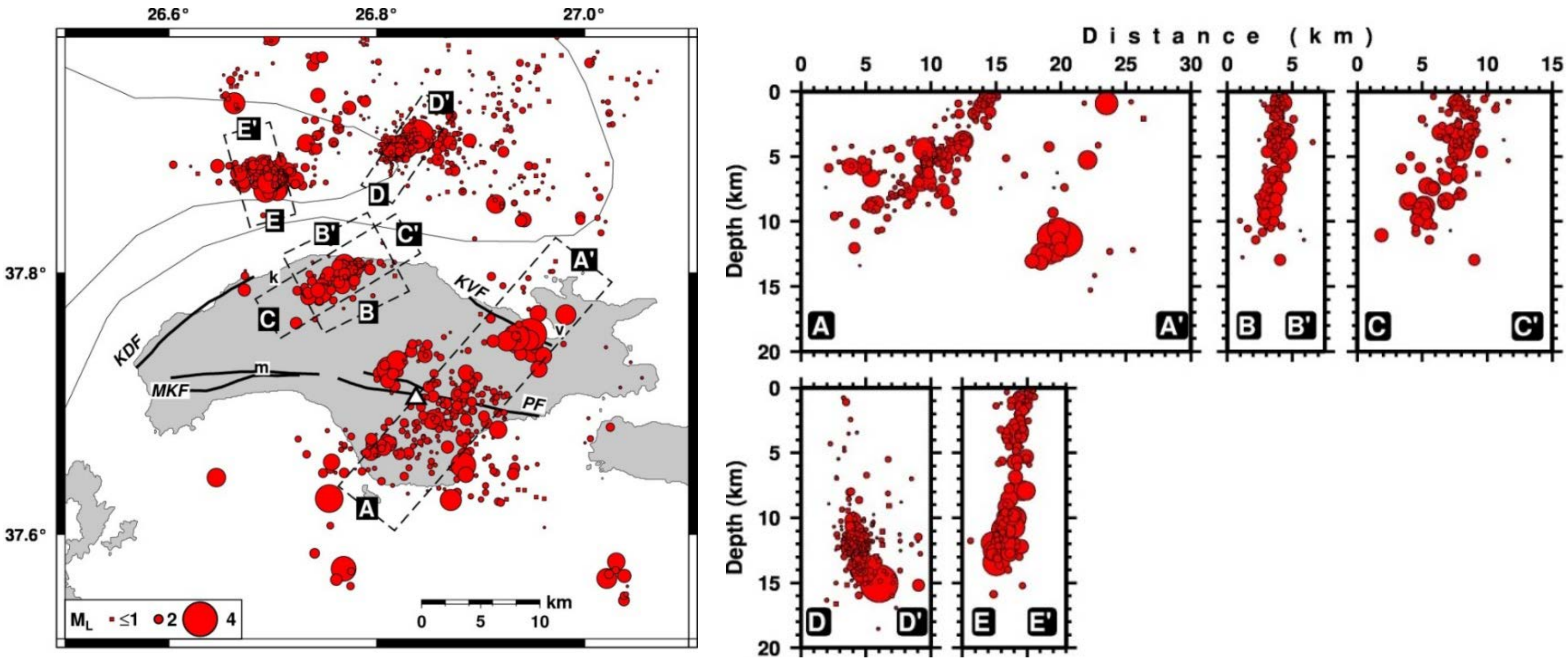
ISOSEISMAL MAPS OF PREVIOUS EVENTS
WITH IMPACT ON SAMOS ISLAND



From *Papazachos et al. (1997)*

ISSN 2653-9454
Issue No. 21, November 2020

HISTORICAL AND RECENT EARTHQUAKES
IN SAMOS ISLAND

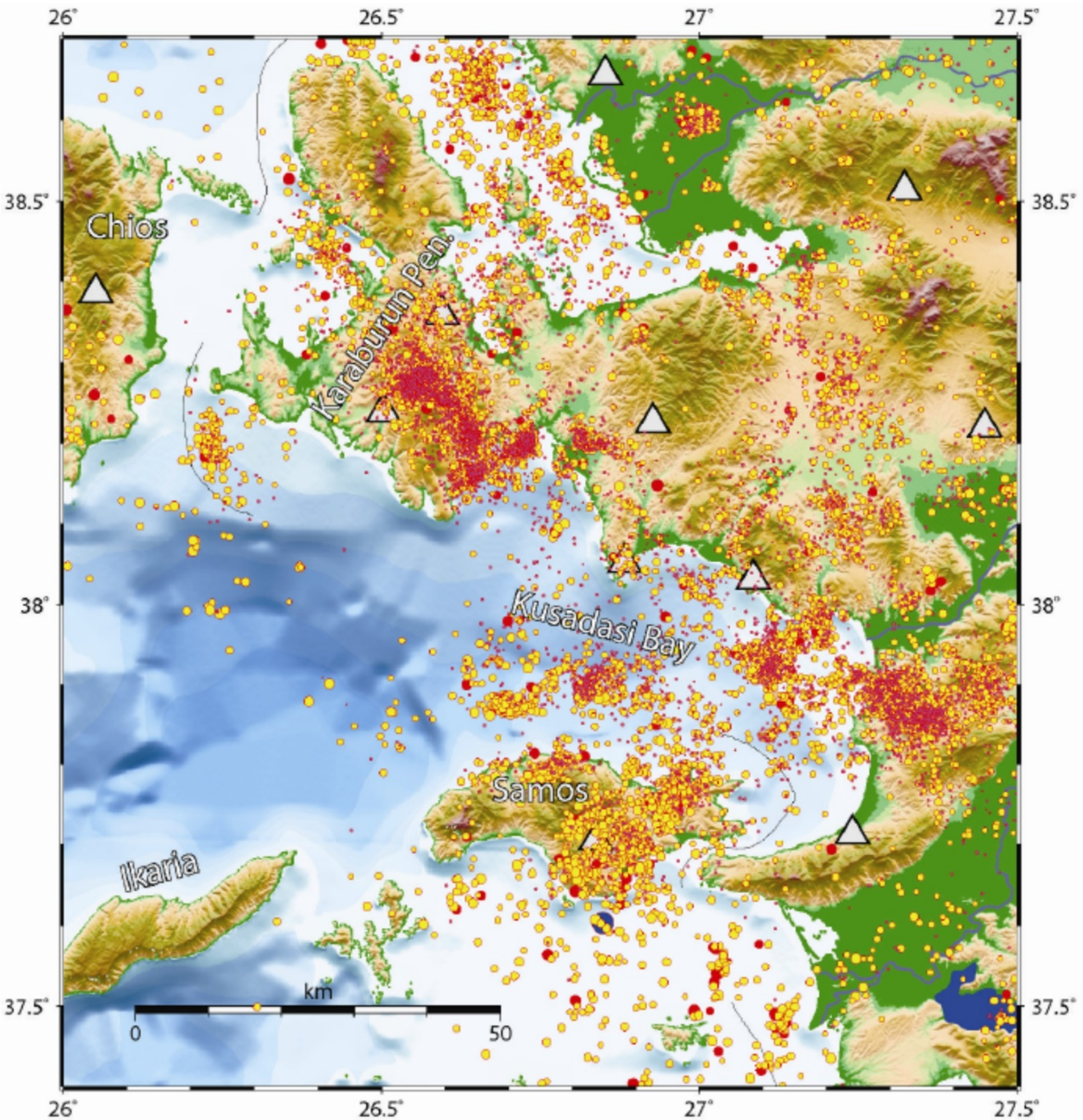


Recently, in **2009**, a seismic swarm struck Samos. It initially generated in Pythagorion area on June 20 with an earthquake of magnitude 5.1 followed by over 80 aftershocks within the next ten days. In general, swarms of earthquakes have also been observed: (i) in the northeastern part of the island, where the focal mechanisms indicate the existence of a fault dipping to the south, (ii) in the northern and central part of the island, which did not coincide with the known faults of the island and (iii) in offshore northern Samos.

From *Tan et al. (2014)*

ISSN 2653-9454
Issue No. 21, November 2020

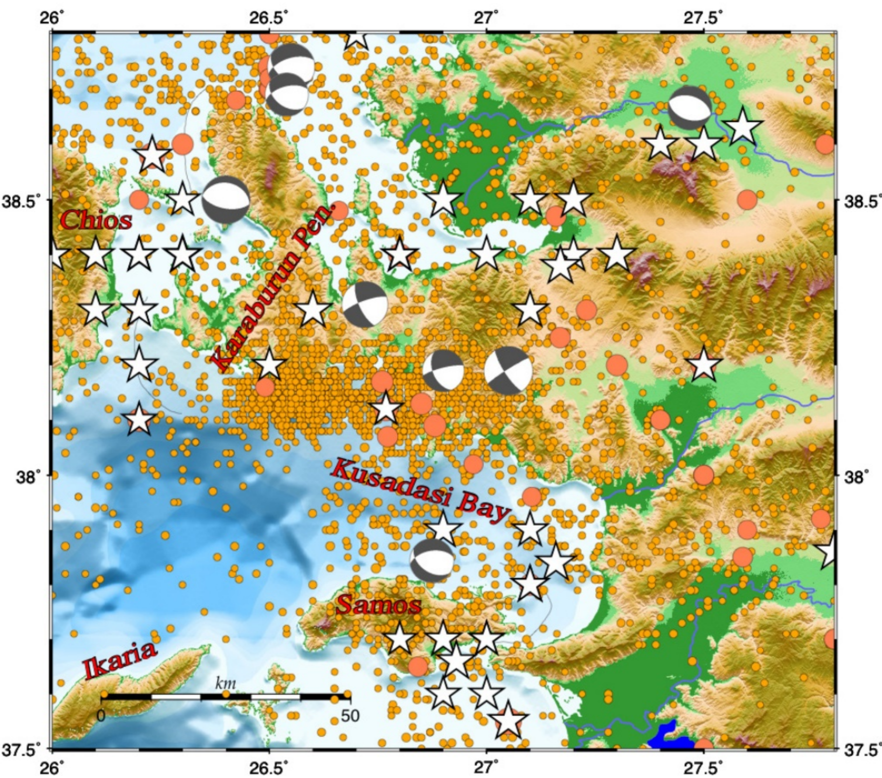
MICROSEISMICITY IN SAMOS ISLAND



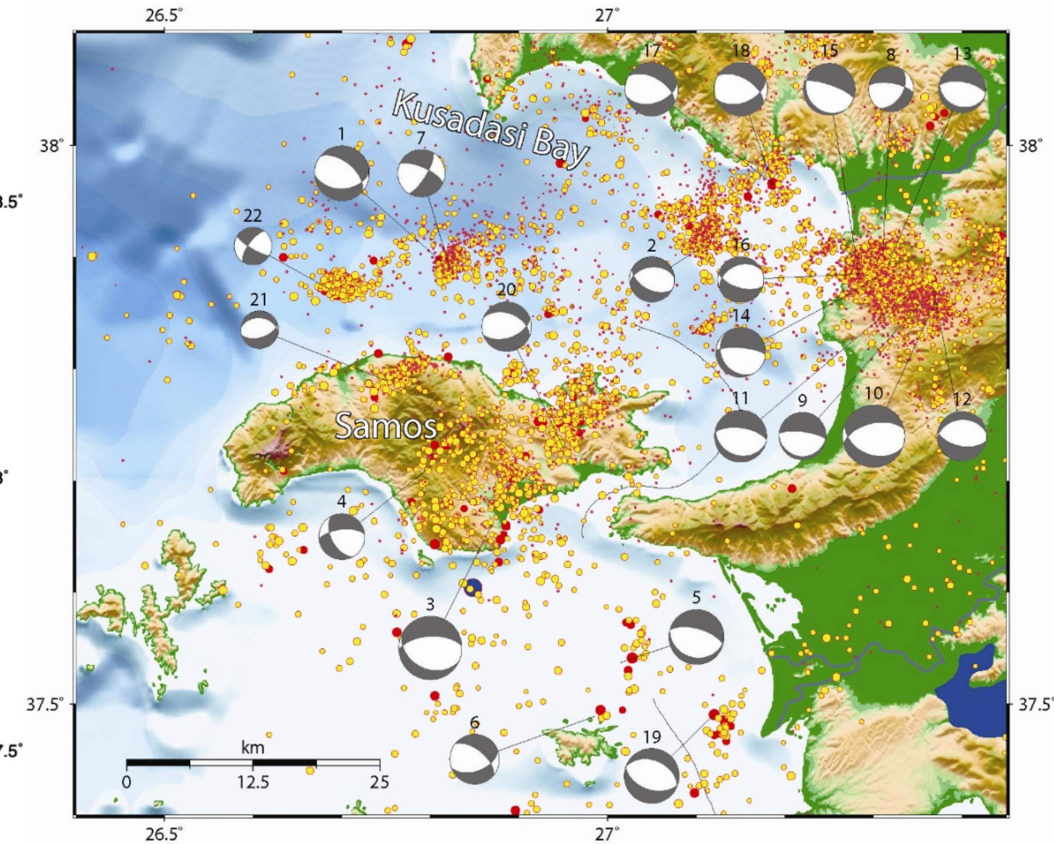
Spatial distribution of local microseismicity monitored for about 5 years (2007-2012). Triangles denote the positions of local temporary seismological stations in western Turkey, and permanent ones onto the Islands of Chios and Samos, belonging to the National Hellenic Unified Seismological Network.

From *Tan et al. (2014)*

REGIONAL AND LOCAL SEISMICITY



Regional seismicity in the central-eastern Aegean area (more than 13500 events between July 2007 and September 2012). Stars denote epicenters of the known historical earthquakes with M > 6.0, whereas larger and smaller circles earthquakes of M > 5.0 and M > 3.5, that occurred since 1911 and 1981, respectively.



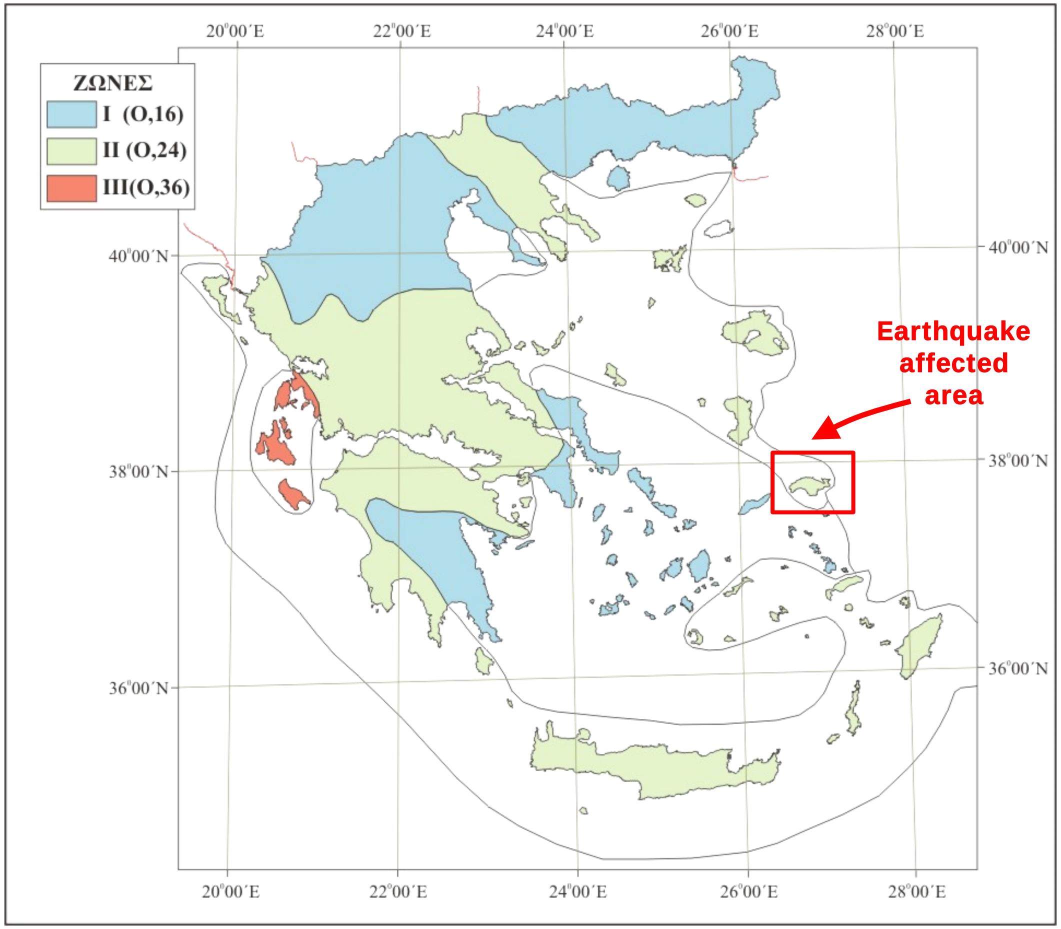
Spatial distribution of local seismicity in the study area, along with fault plane solutions determined by Tan et al. (2014).

From *Tan et al. (2014)*

ISSN 2653-9454
Issue No. 21, November 2020

SEISMIC ZONES IN GREECE

Based on the aforementioned data, the area affected by the October 30, 2020 falls in the second seismic zone of Greece, which is characterized by a ground acceleration coefficient of 0.24 g corresponding to the second largest seismic strength demand according to the Greek Code for Seismic Resistant Structures.



From *Earthquake Planning and Protection Organization (2003)*

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Issue No. 21, November 2020

THE OCTOBER 30, 2020, Mw 6.9 SAMOS ISLAND EARTHQUAKE

On October 30, 2020 (11:51:26 UTC time) an earthquake struck the Eastern Aegean and the Minor Asia. The earthquake occurred in a region mainly characterized by dextral strike-slip faulting along NE-SW striking faults, parallel to the North Aegean Trough (NAT), while conjugate sinistral strike-slip and ~E-W normal faulting is also present.

Based on various seismological observatories and institutes including the National and Kapodistrian University of Athens (NKUA), the National Observatory of Athens (NOA), the Global Centroid Moment Tensor Catalog (GCMT), the United States Seismological Survey (USGS), the National Institute of Geophysics and Volcanology (INGV), the Kandilli Observatory and Earthquake Research Institute (KOERI), the Earthquake Research Department (ERD), the University of Nice Sophia-Antipolis, Valbonne, France (OCA), the Institute of Physics of the Globe of Paris (IPGP), the German Research Centre for Geosciences (GFZ), the magnitude has been assessed as Mw 6.9 or 7.2. Based on the provided focal plane solutions, the mainshock was generated by the activation of a E-W striking normal fault offshore northern Samos.

The main shock was felt in several areas of Greece and Turkey, from the Aegean Islands to Peloponnese in Greece and from the Minor Asia to Instabul in Turkey. The most affected areas were the Samos Island in the Eastern Aegean Sea and Izmir in the Minor Asia.

Unfortunately, it claimed 117 lives, in particular 115 in Izmir city and 2 in Vathy town of Samos Island. As regards the injured, 1034 were reported in Turkey and 19 in Samos. The fatalities and injuries are attributed mainly to partial or total collapse of buildings and secondarily to debris falling.

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Issue No. 21, November 2020

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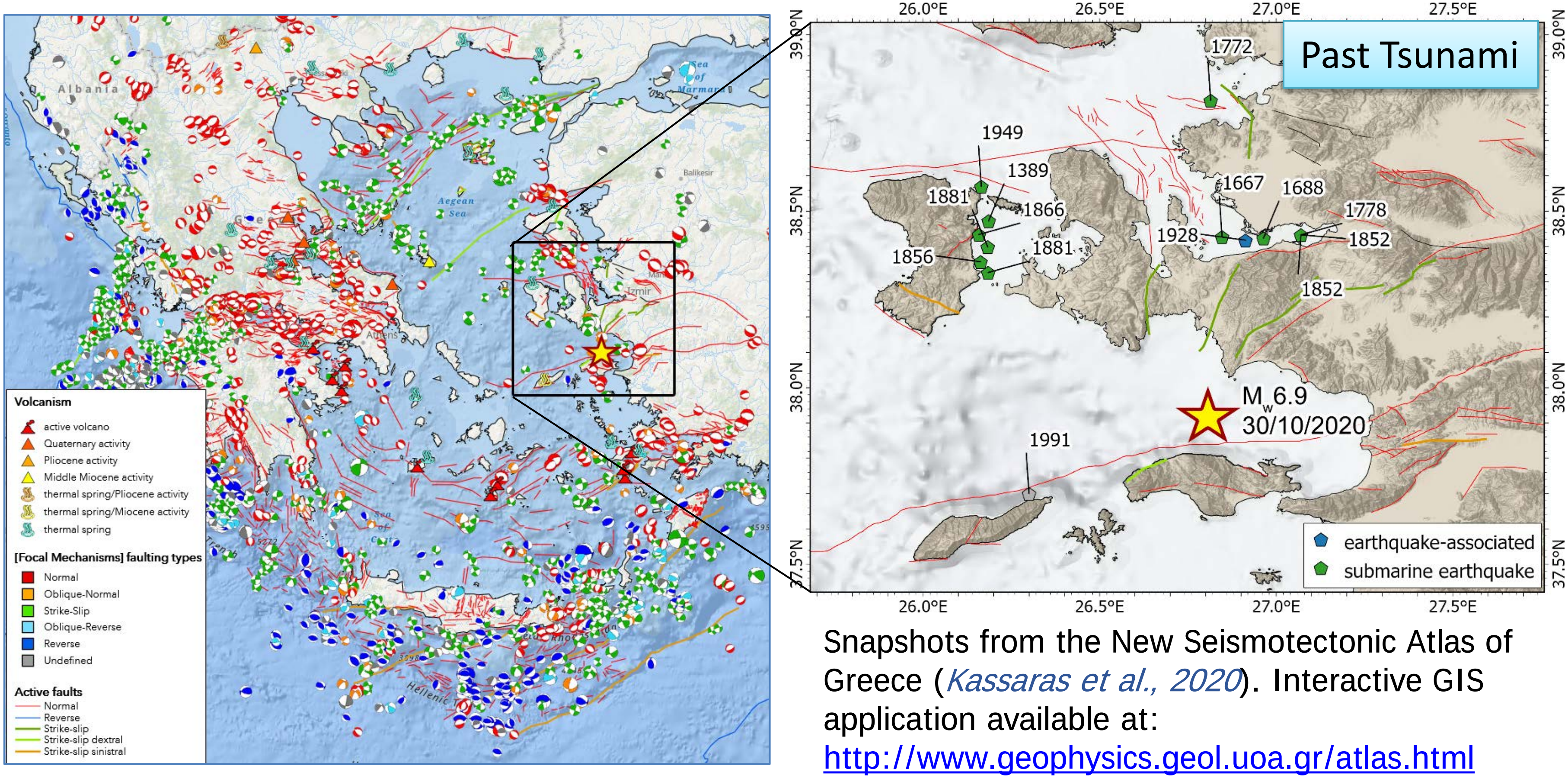
Department of Geophysics-Geothermics

THE 2020 SAMOS EARTHQUAKE
THE SEISMOTECTONIC CONTEXT



Snapshots from the New Seismotectonic Atlas of Greece (*Kassaras et al., 2020*). Interactive GIS application available at: http://www.geophysics.geol.uoa.gr/atlas.html

Past tsunami from *Papadopoulos, G. A. (2001)*. Tsunamis in the east Mediterranean: 1. A catalogue for the area of Greece and adjacent seas.

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Issue No. 21, November 2020

EPICENTER LOCATION
FOR THE OCTOBER 30, 2020, Mw 7.0 EARTHQUAKE

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Issue No. 21, November 2020

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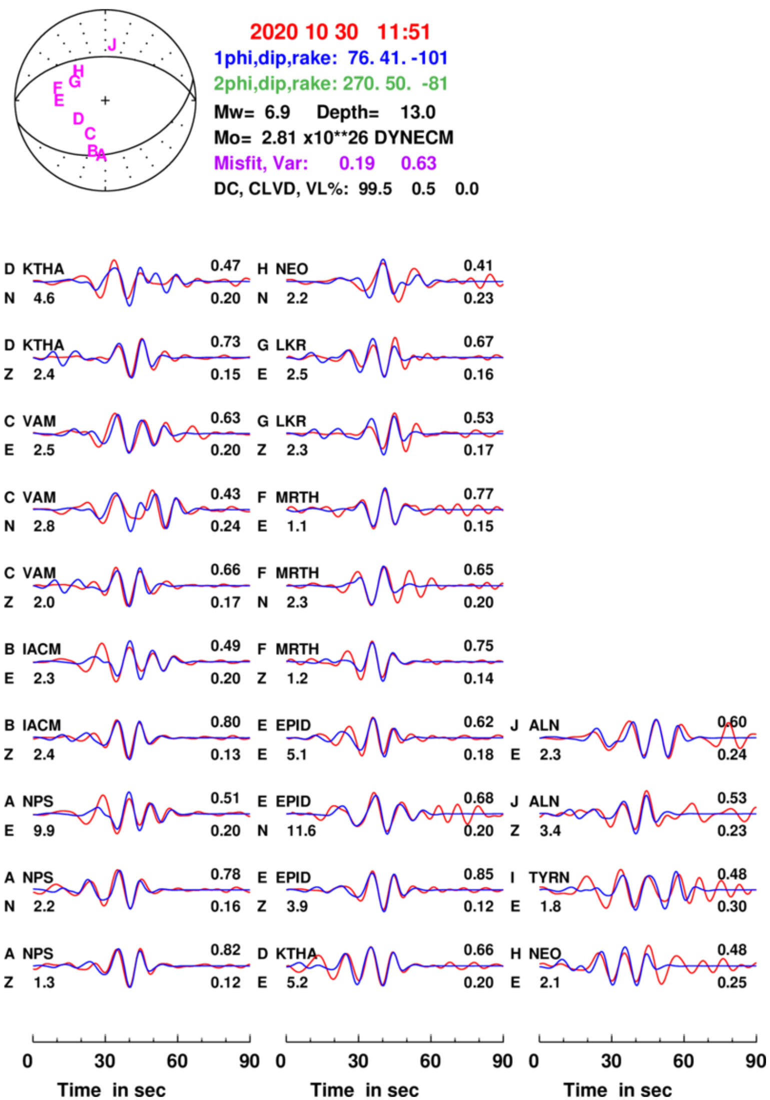
THE 2020 SAMOS EARTHQUAKE
FOCAL MECHANISM OF THE MAINSHOCK

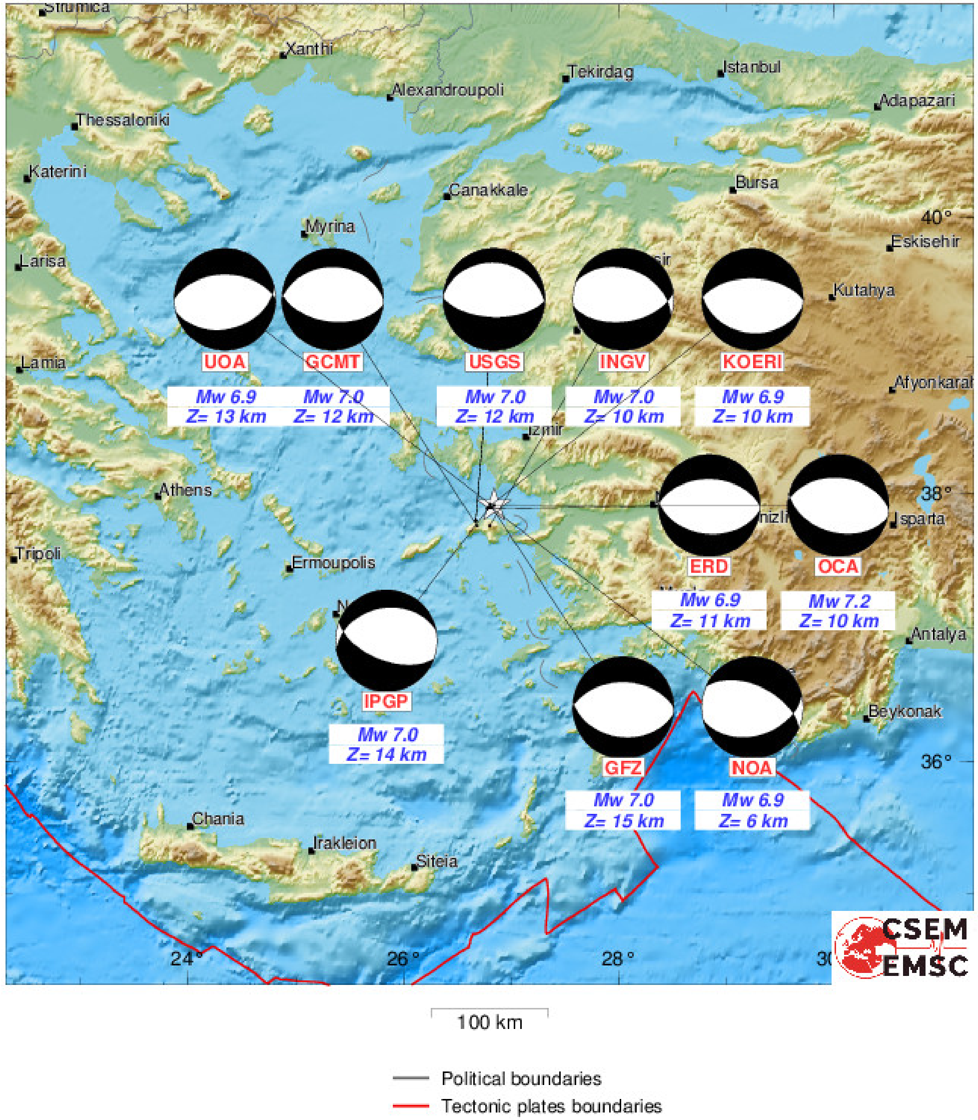


The focal mechanism of the 30 October 2020 Samos mainshock was determined using regional moment tensor inversion. After the calculation of Green functions, using the frequency-wavenumber integration method, synthetic waveforms were obtained and compared with the recorded ones, following the procedure proposed by Papadimitriou et al. (2012).

The figure on the left presents the source parameters for the Samos 2020 mainshock, where the red waveforms represent the recorded signals and the blue the synthetic ones. The obtained focal mechanism reveals normal faulting in an ~E-W direction. The focal depth was determined at 13 km, whereas the seismic moment was calculated $M_0=2.81\cdot10^{26}$ dyn·cm, representing a moment magnitude equal to $M_w=6.9$.

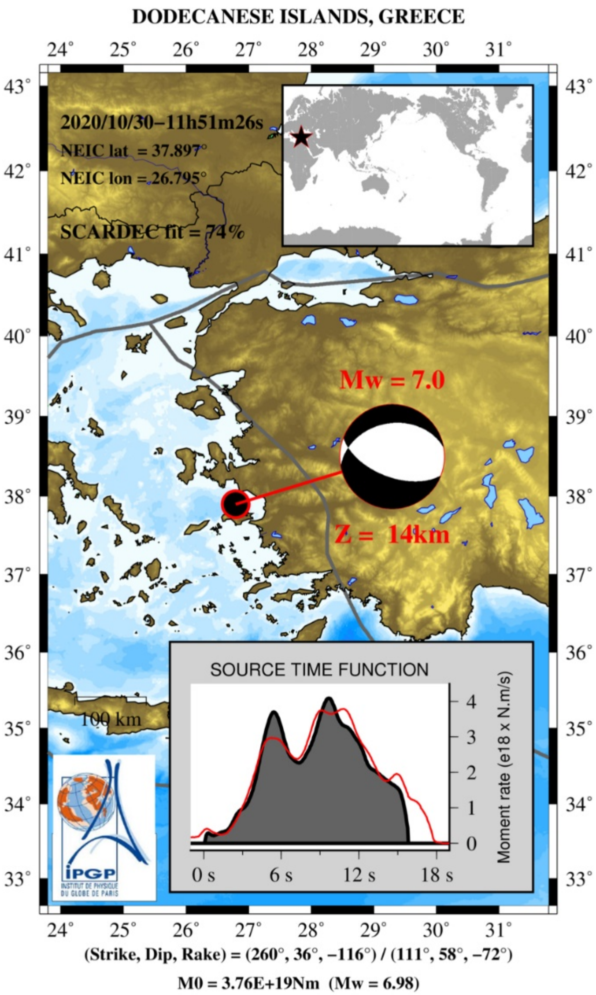
ISSN 2653-9454
Issue No. 21, November 2020

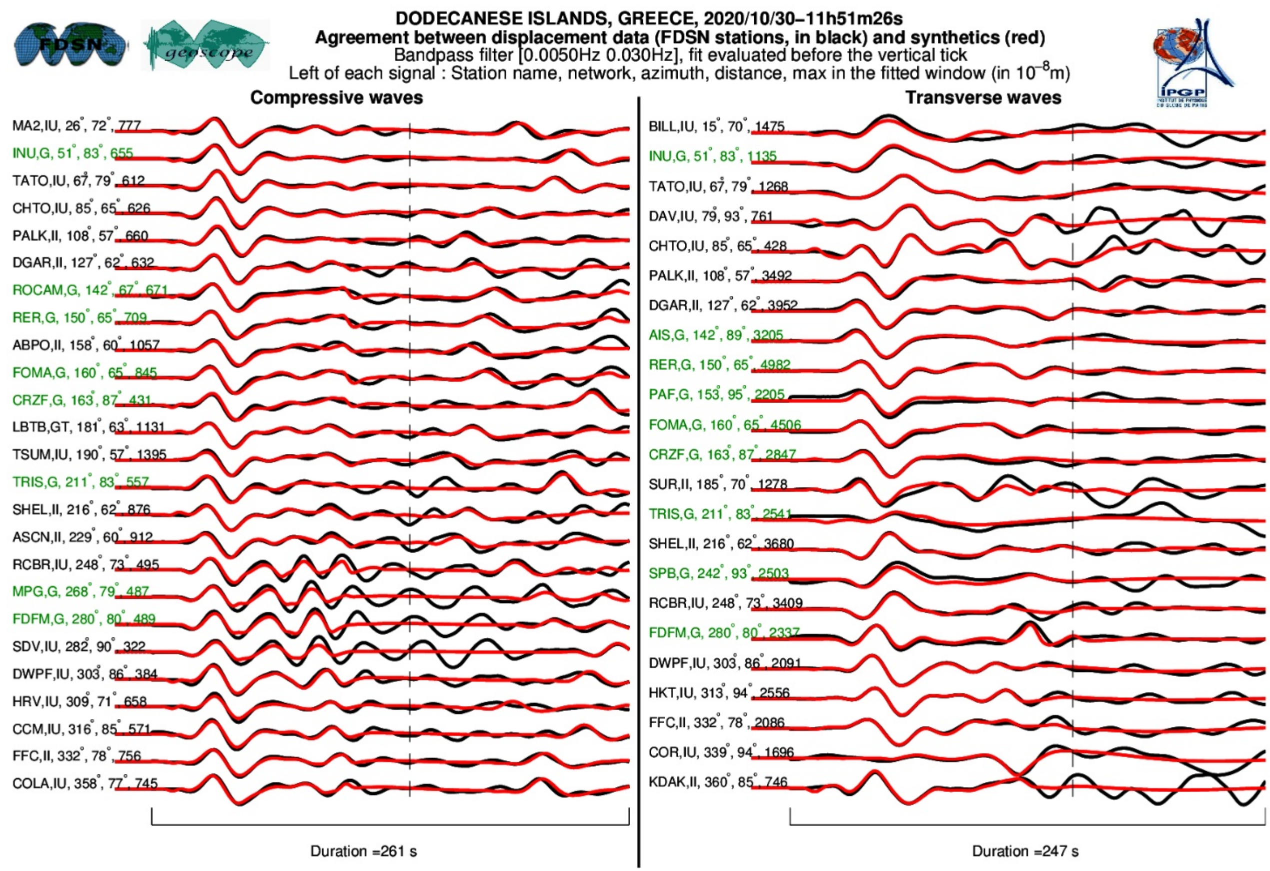
QUICK SOLUTIONS AND REGIONAL MOMENT TENSORS
FOR THE OCTOBER 30, 2020 EARTHQUAKE



ISSN 2653-9454
Issue No. 21, November 2020 | 46

QUICK SOLUTION FOR THE OCTOBER 30, 2020, Mw 7.0 EARTHQUAKE





http://geoscope.ipgp.fr/index.php/en/catalog/earthquake-description?seis=us7000c7y0

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Environmental, Disaster, and Crises Management Strategies
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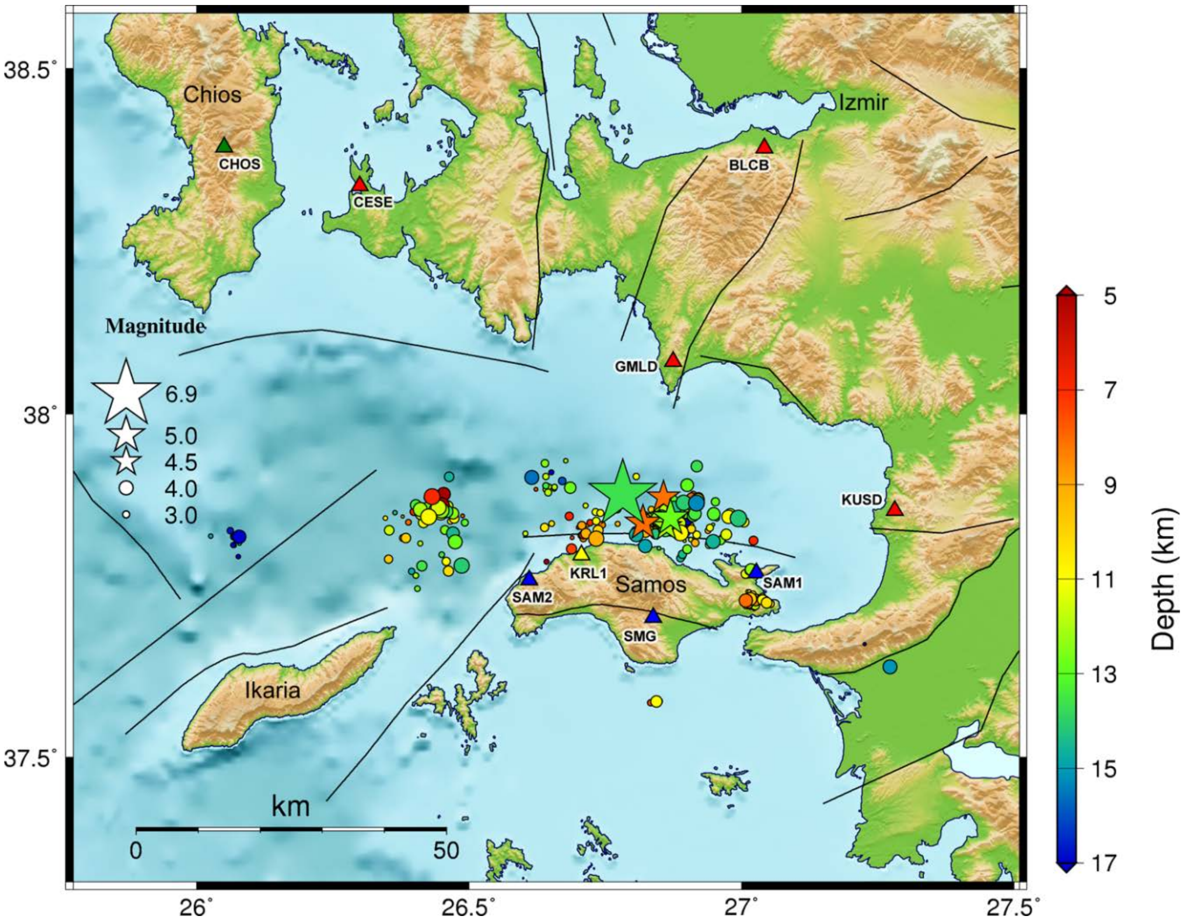
THE 2020 SAMOS EARTHQUAKE
PRELIMINARY RELOCATION OF THE AFTERSHOCK SEQUENCE



Preliminary relocation of over 300 aftershocks that occurred between 30 October and 8 November 2020. The locations of available stations in the region are presented by triangles (Network codes: blue=HL, yellow=HI, green=HT, red=KO). The major events with M≥4.5 are depicted by stars.

The mainshock's epicenter is located offshore, ~10 km north of Samos Island. The main part of the aftershock sequence spans ~50 km in an approximate E-W direction. Certain isolated clusters are located further west, north of Ikaria Island, and at the eastern edge of Samos Island. Focal depths mostly range between 10 km and 15 km.

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
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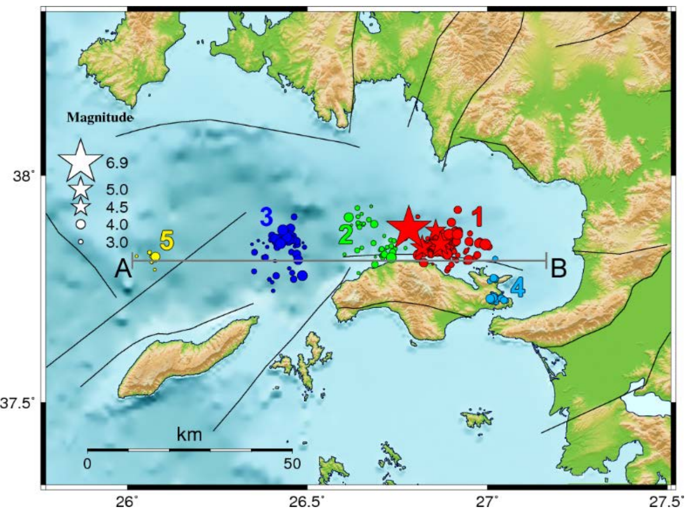
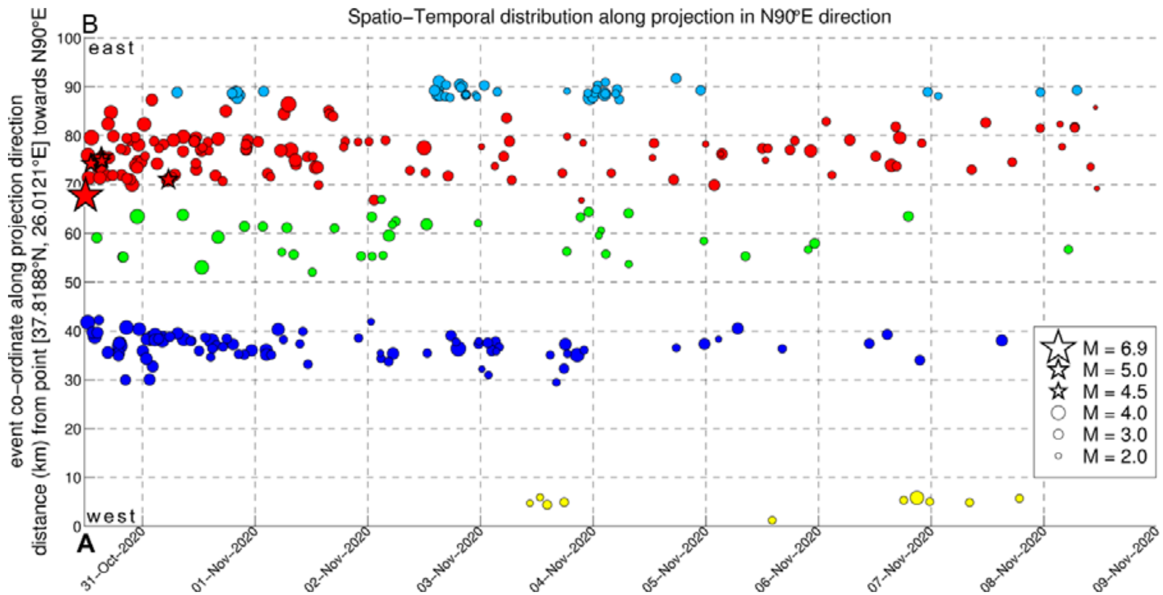
SPATIOTEMPORAL EVOLUTION OF AFTERSHOCK SEQUENCE (30 OCTOBER - 8 NOVEMBER 2020)





The preliminary results for the 2020 Samos aftershock sequence reveal the existence of several distinct spatial groups (labelled 1-5 on the map on the left). Soon after the mainshock, the whole zone of groups 1-3 was activated, with most aftershocks occurring at group 1 (red), east of the mainshock. This group is associated with the major aftershocks ($M_w \geq 4.5$, stars) of the sequence. The largest aftershock was an $M_w = 5.0$ event that occurred on 30 October 2020, 15:14:57 UTC in group 1. The spatiotemporal evolution along the profile A-B shows that, as the sequence evolved, it was gradually extended to ~60 km in the E-W direction. Group 4 (cyan) at the eastern part of Samos Island, notably south of the main aftershock zone, was activated on 31 October with a few events, while two distinct bursts occurred during 2-4 November 2020. The isolated group 5 (yellow) presented some activity on 3 and 6-7 November. No aftershocks with $M \geq 4.5$ were recorded after 31 October 2020. The activity of the aftershock sequence appears to be gradually diminishing, so far without any major secondary outbreak.

ISSN 2653-9454
Issue No. 21, November 2020

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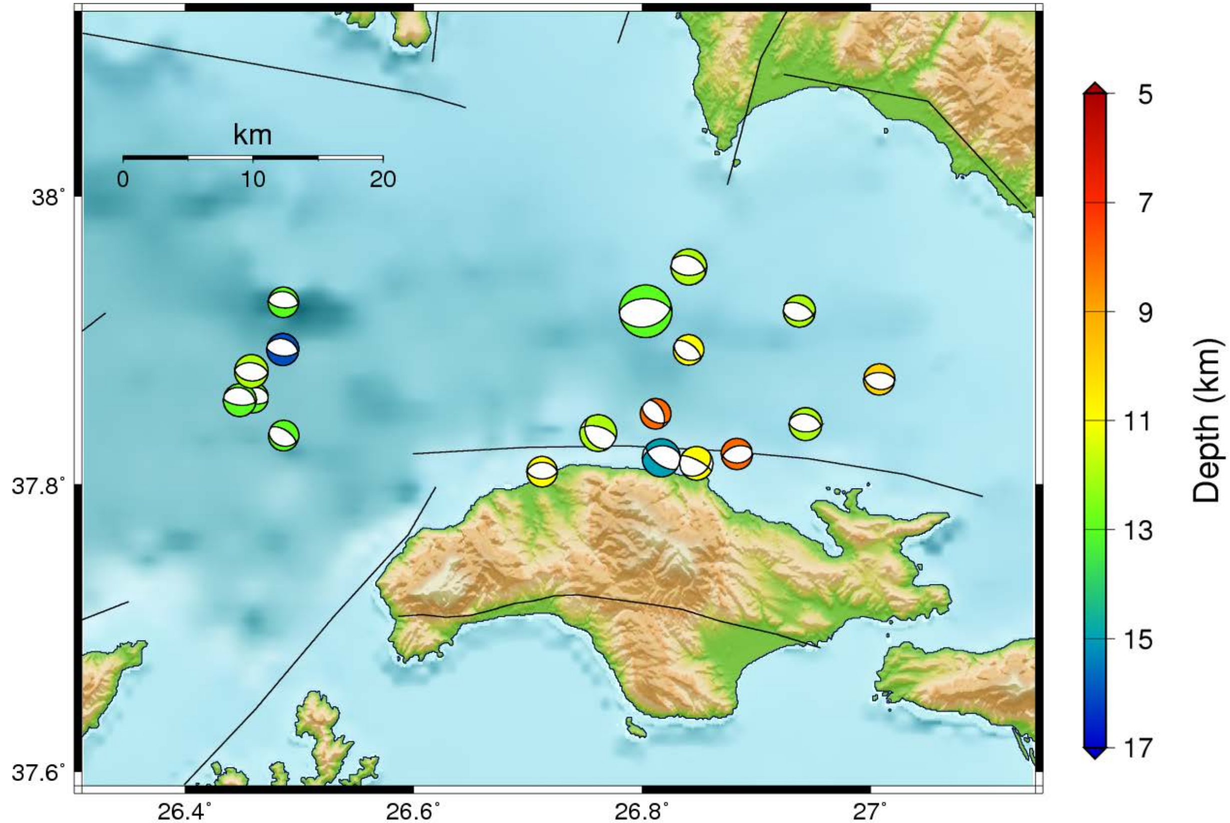
FOCAL MECHANISMS OF AFTERSHOCK SEQUENCE



Focal mechanisms of the 2020 Samos mainshock and major aftershocks were resolved at the Seismological Laboratory of the National and Kapodistrian University of Athens (SL-NKUA), also using regional waveform modelling.

The fault-plane solutions of the major aftershocks are consistent with E-W to NW-SE normal faulting, similar to the focal mechanism of the 30 October 2020 Samos mainshock.

For more information, visit the web-page of Significant Earthquakes in Greece during 2020 at SL-NKUA:
http://www.geophysics.geol.uoa.gr/stations/gmaps3/leaf_significant.php?mapmode=mech&lng=en&year=2020

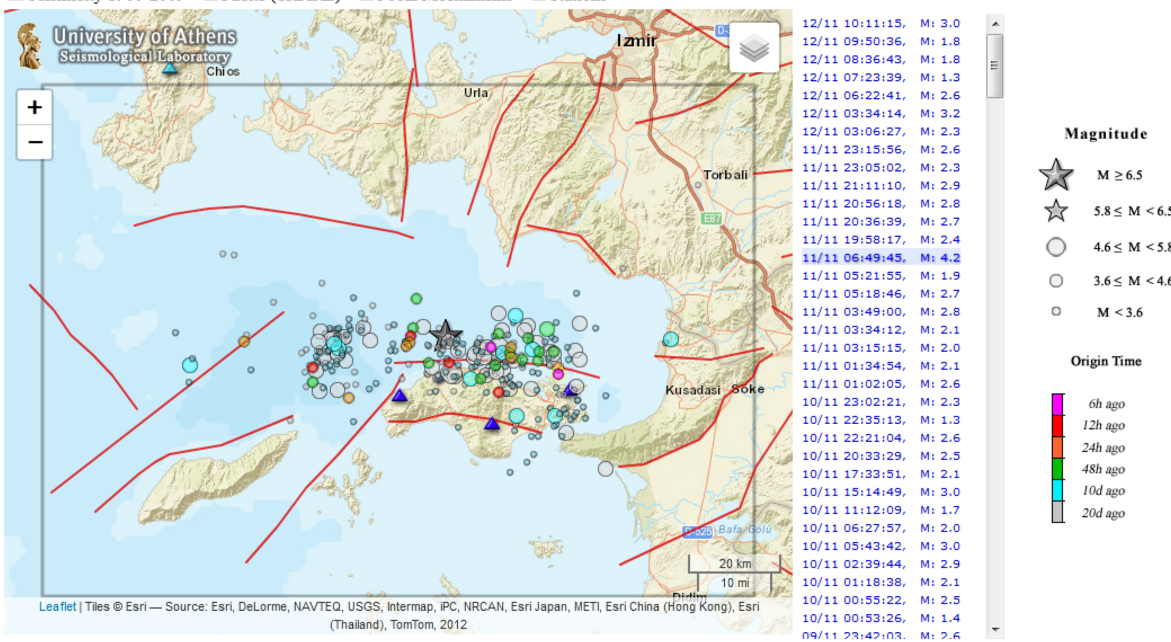
ISSN 2653-9454
Issue No. 21, November 2020 | 50

University of Athens
Faculty of Geology and Geoenvironment
Department of Geophysics-Geothermics

SL-NKUA SPECIAL WEB-PAGE
FOR MONITORING OF THE SEQUENCE

Earthquakes of the last 14 days in the area of Samos, Greece

☐ Seismicity 1900-2009 ☑ Faults (SHARE) ☐ Focal Mechanisms ☑ Stations



Click on headers to sort table

#	Sol. Type	Origin Time (GMT)	Epicentral Location	Latitude (°N)	Longitude (°E)	Depth (km)	Mag.
1	M	12/11/2020 10:11:15	5.0 km NNE of Samos	37.7983	26.9990	11.0	3.0
2	M	12/11/2020 09:50:36	16.3 km NW of Samos	37.8515	26.8350	16.0	1.8
3	M	12/11/2020 08:36:43	22.7 km WNW of Samos	37.8210	26.7312	8.0	1.8
4	M	12/11/2020 07:23:39	32.4 km WNW of Samos	37.8725	26.6383	12.0	1.3
5	M	12/11/2020 06:22:41	32.7 km NE of Ikaria	37.8112	26.4012	2.0	2.6
6	M	12/11/2020 03:34:14	10.9 km W of Samos	37.7648	26.8528	12.0	3.2

A special interactive web-page that presents the seismicity in the 2020 Samos aftershock zone, automatically detected and manually analyzed, has been developed at the SL-NKUA.

The data are updated as soon as an earthquake is automatically detected and located or manually analyzed.

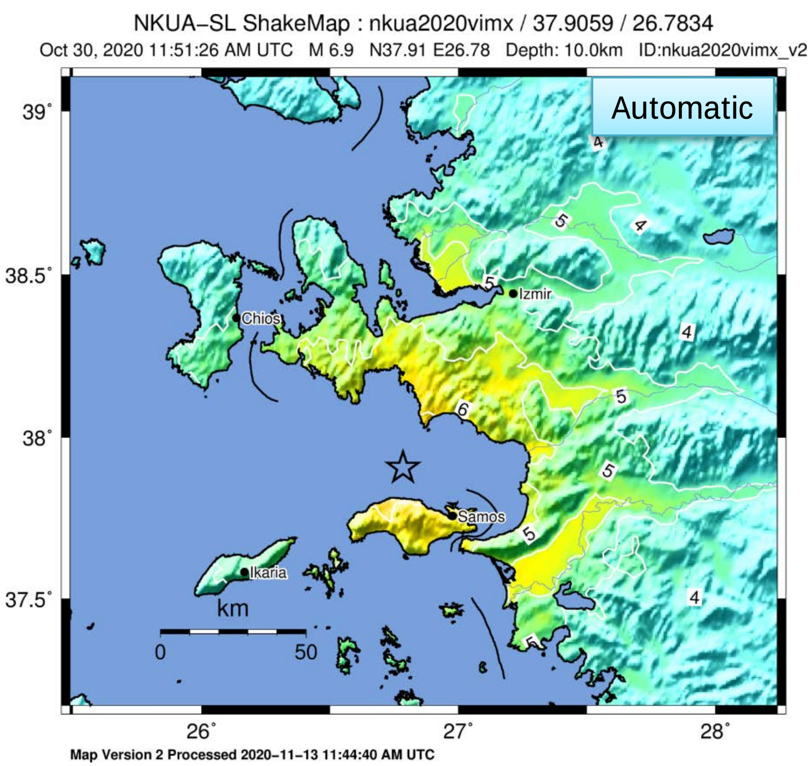
The user can also display fault sources from the European Database of Seismogenic Faults (EDSF, Basili et al., 2013), past seismicity (Makropoulos et al., 2012), focal mechanisms determined at SL-NKUA and view real-time waveforms of local and regional HUSN stations.

To access the interactive seismicity monitoring map, visit the web-page at:
http://www.geophysics.geol.uoa.gr/stations/gmaps3/samos_leaf.php?lng=en

ISSN 2653-9454
Issue No. 21, November 2020 | 51

University of Athens
Faculty of Geology and Geoenvironment
Department of Geophysics-Geothermics

SHAKEMAP (INTENSITY)

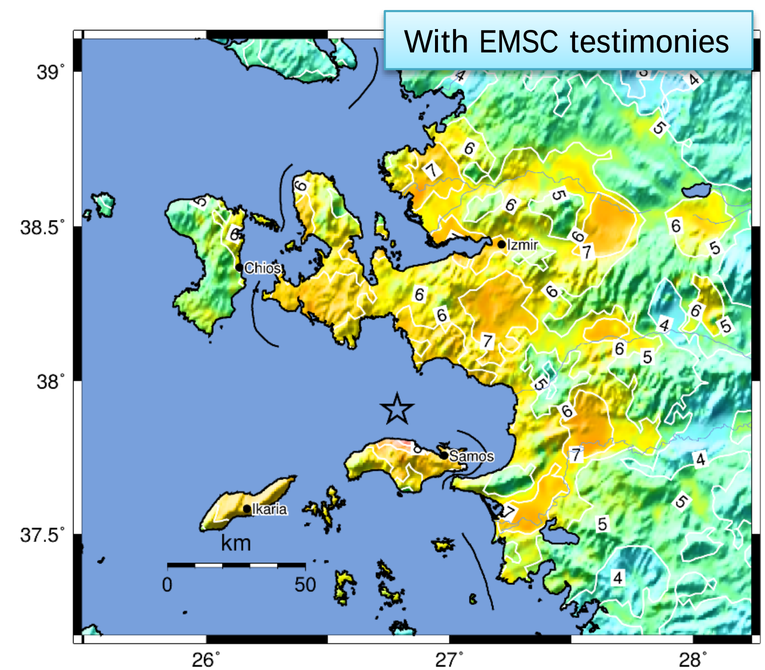


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

◀ Automatically generated ShakeMap (USGS, 2017) for the 2020 Samos M_w=6.9 mainshock. The maximum expected intensity values reach VII at the northern part of Samos Island and the opposite coast of Turkey.

▼ With additional information from the EMSC Did You Feel It (DYFI) reports, the resulting intensities mainly increase (see figure below)



For more information about the 2020 Samos mainshock, visit the event's web-page at SL-NKUA:
http://www.geophysics.geol.uoa.gr/stations/gmaps3/eventpage_leaf.php?scid=nkua2020vimx&lng=en

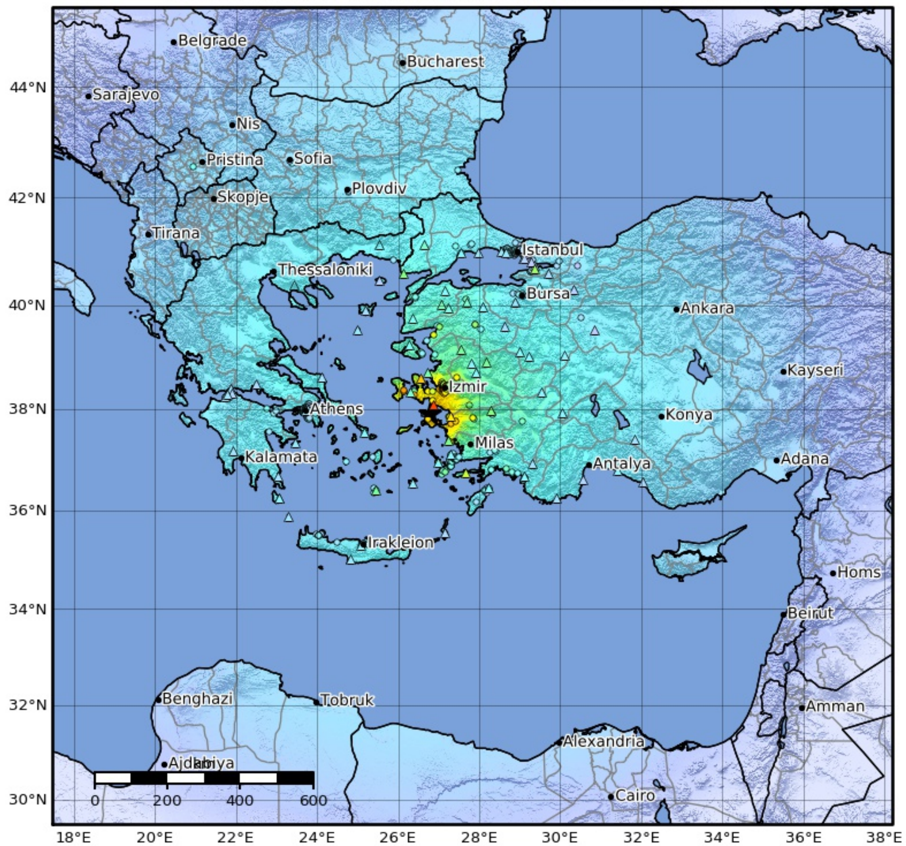
ISSN 2653-9454
Issue No. 21, November 2020

USGS science for a changing world

ITSAK

INTENSITY MAPS
FOR THE OCTOBER 30, 2020 EARTHQUAKE

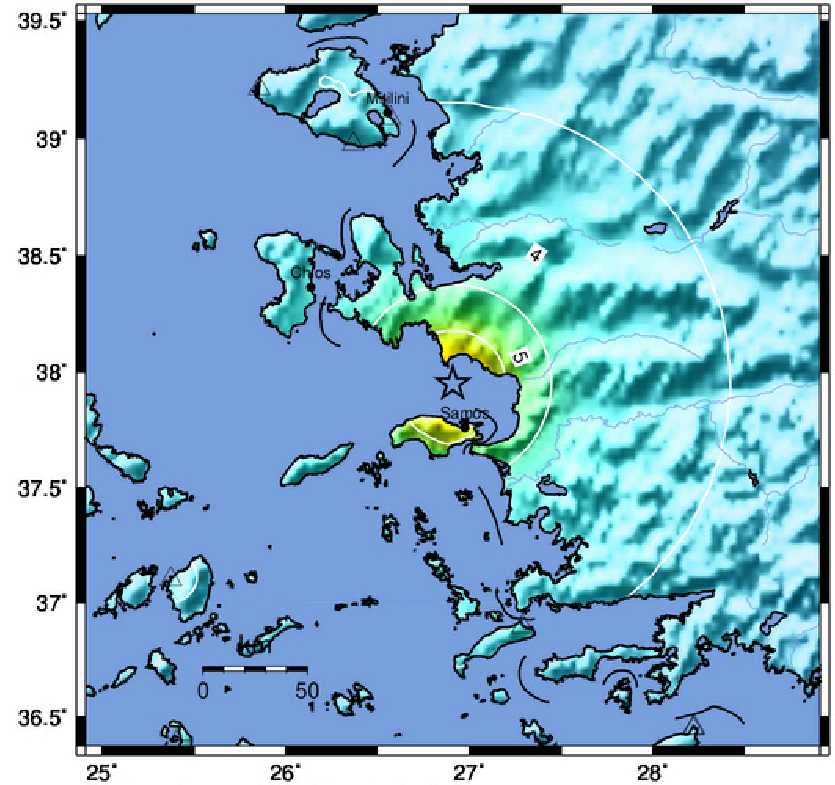
Macroseismic Intensity Map USGS
ShakeMap: 15 km NNE of Néon Karlovásion, North Aegean, GR
Oct 30, 2020 11:51:27 UTC M7.0 N37.92 E26.79 Depth: 21.0km ID:us7000c7y0



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Worden et al. (2012) Version 7: Processed 2020-10-31T11:52:26Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter ▭ Rupture

ITSAK ShakeMap : Northern coast of W. Turkey
Oct 30, 2020 11:51:25 UTC M 6.7 N37.95 E26.91 Depth: 3.0km ID:auth2020vimx



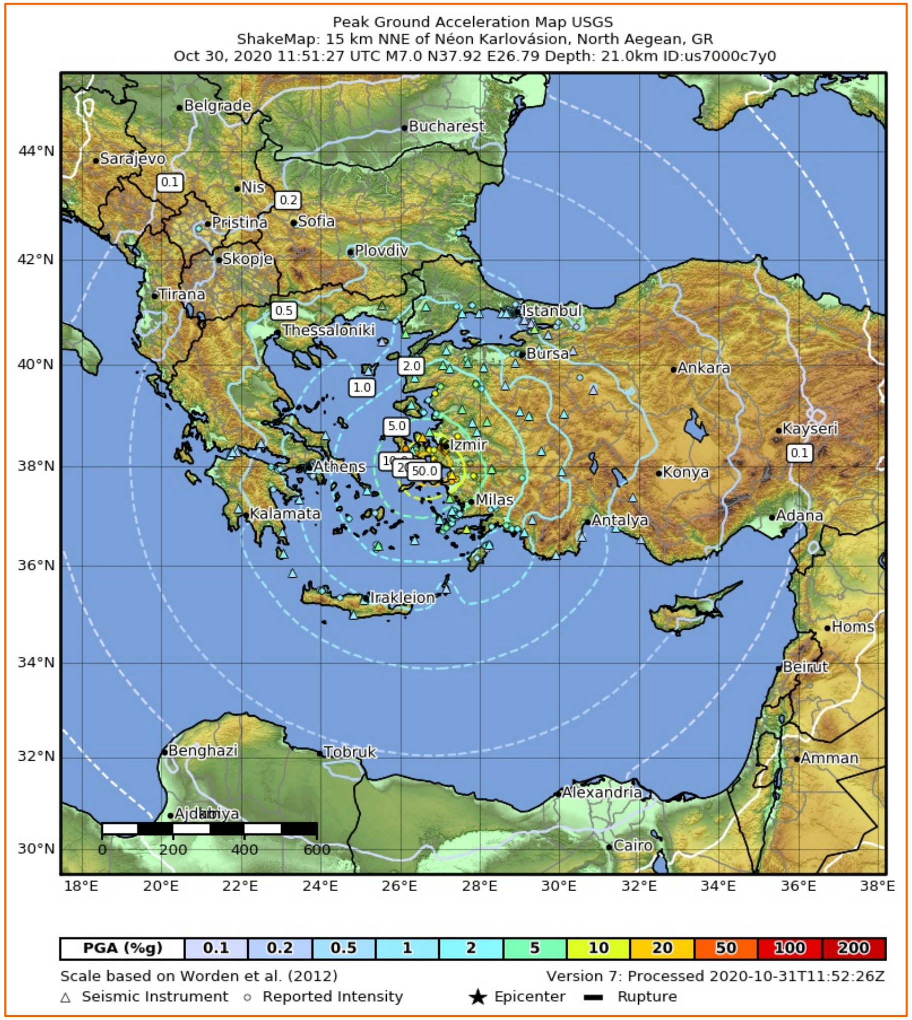
Map Version 2 Processed 2020-10-30 12:21:08 UTC

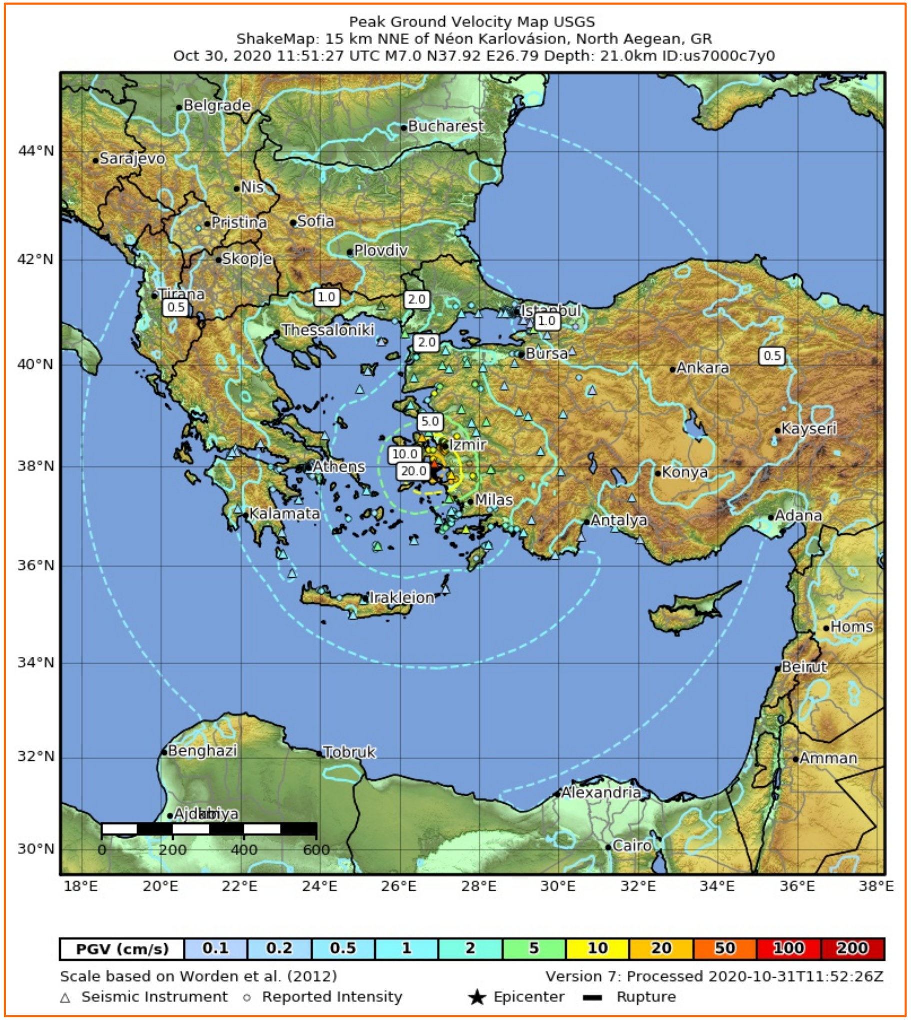
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

ISSN 2653-9454
Issue No. 21, November 2020 | **53**

PEAK GROUND ACCELERATION & PEAK GROUND VELOCITY MAPS
FOR THE OCTOBER 30, 2020, Mw 7.0 EARTHQUAKE



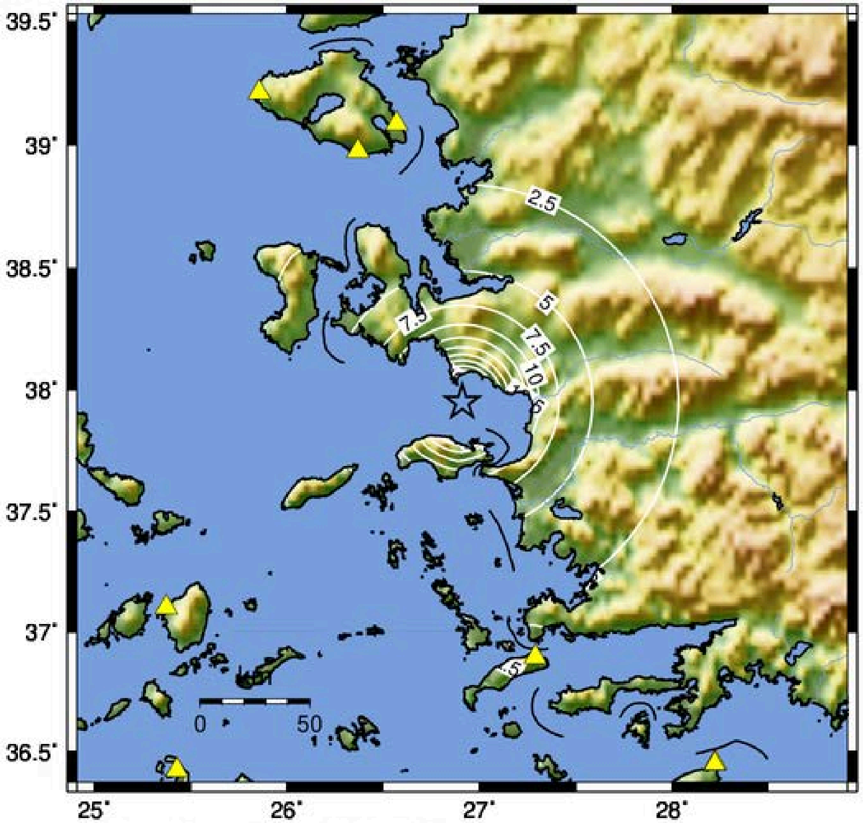


ISSN 2653-9454
Issue No. 21, November 2020

PEAK GROUND ACCELERATION & PEAK GROUND VELOCITY MAPS
FOR THE OCTOBER 30, 2020, Mw 7.0 EARTHQUAKE

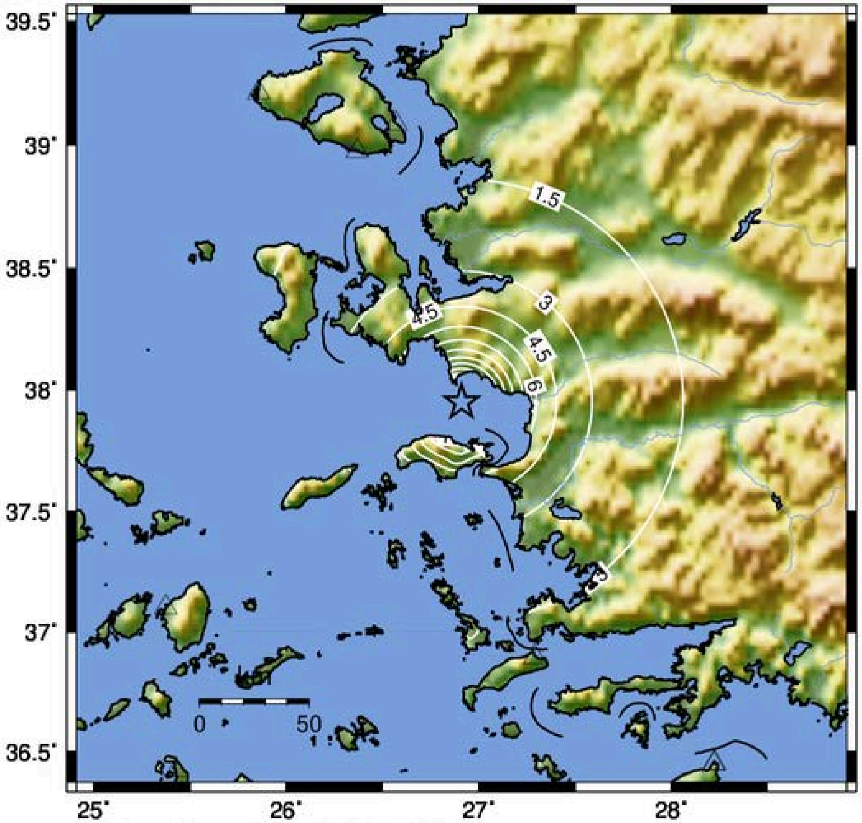
http://shakemaps. itsak.gr

ITSAK Peak Accel. Map (in %g) : Northern coast of W. Turkey
Oct 30, 2020 11:51:25 UTC M 6.7 N37.95 E26.91 Depth: 3.0km ID:auth2020vimx



Map Version 2 Processed 2020-10-30 12:21:08 UTC

ITSAK Peak Velocity Map (in cm/s) : Northern coast of W. Turkey
Oct 30, 2020 11:51:25 UTC M 6.7 N37.95 E26.91 Depth: 3.0km ID:auth2020vimx



Map Version 2 Processed 2020-10-30 12:21:08 UTC

ISSN 2653-9454
Issue No. 21, November 2020

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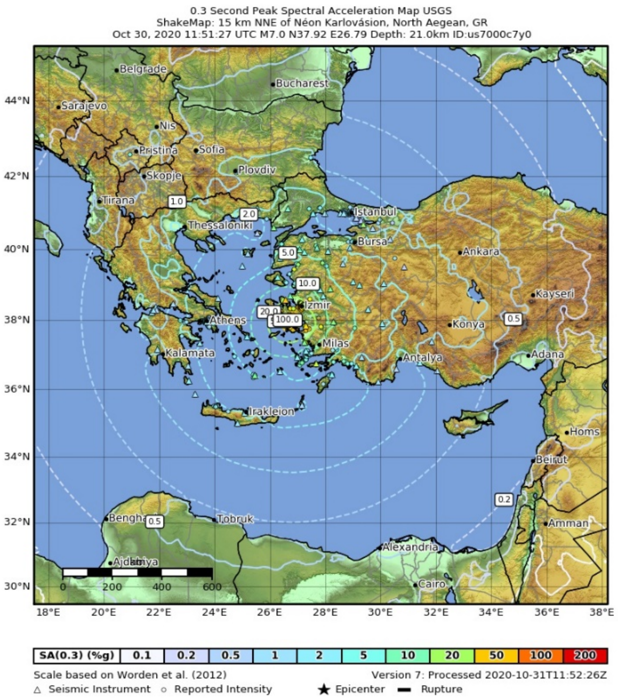
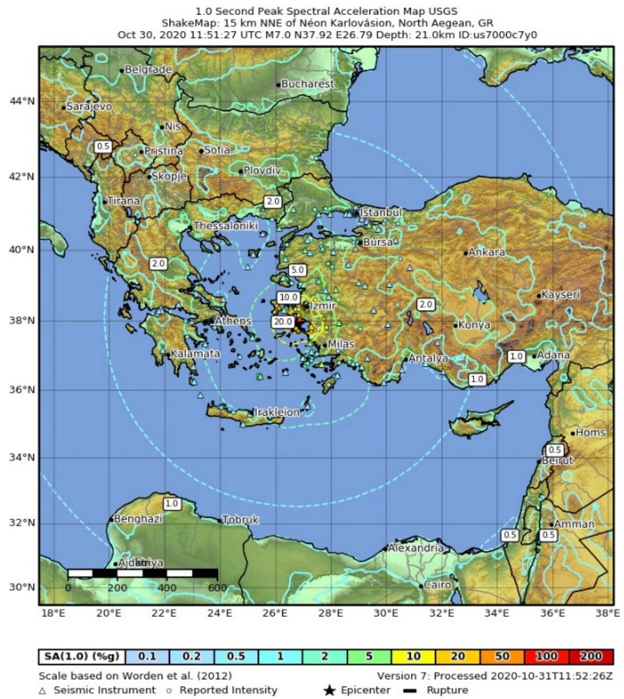
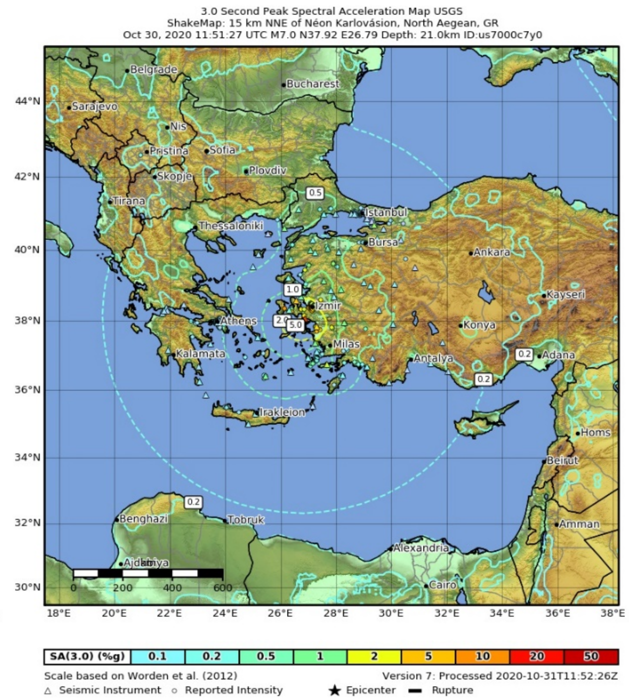
SPECTRAL RESPONSE
FOR THE OCTOBER 30, 2020, Mw 7.0 EARTHQUAKE







ISSN 2653-9454
Issue No. 21, November 2020

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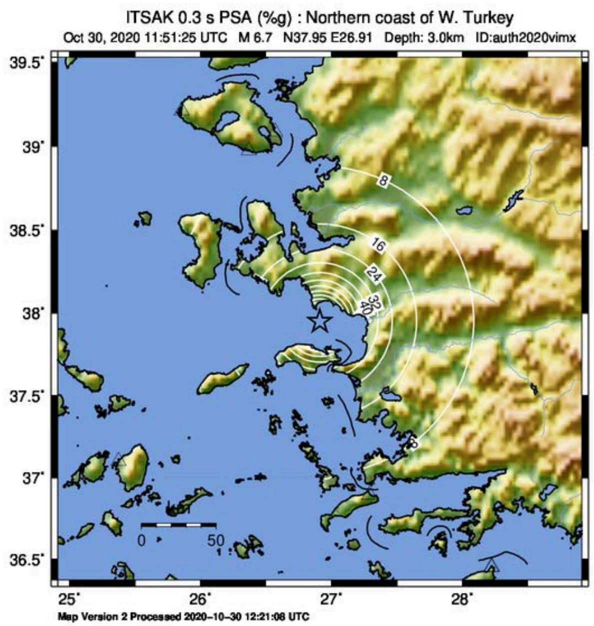
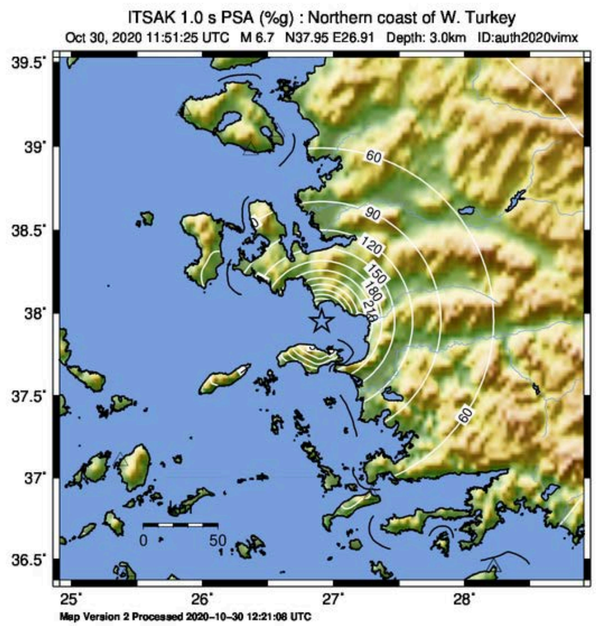
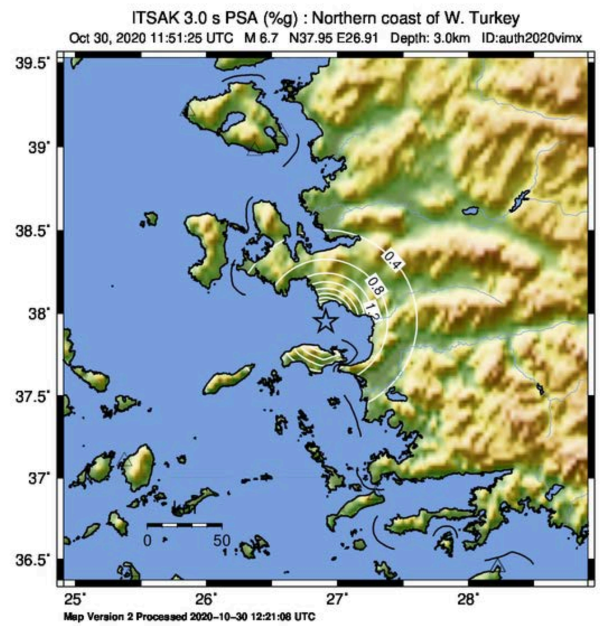
SPECTRAL RESPONSE
FOR THE OCTOBER 30, 2020, Mw 7.0 EARTHQUAKE



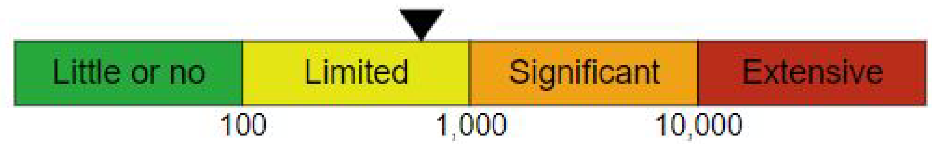




ISSN 2653-9454
Issue No. 21, November 2020

POPULATION EXPOSURE
FOR THE OCTOBER 30, 2020 EARTHQUAKE

Estimated Population Exposure



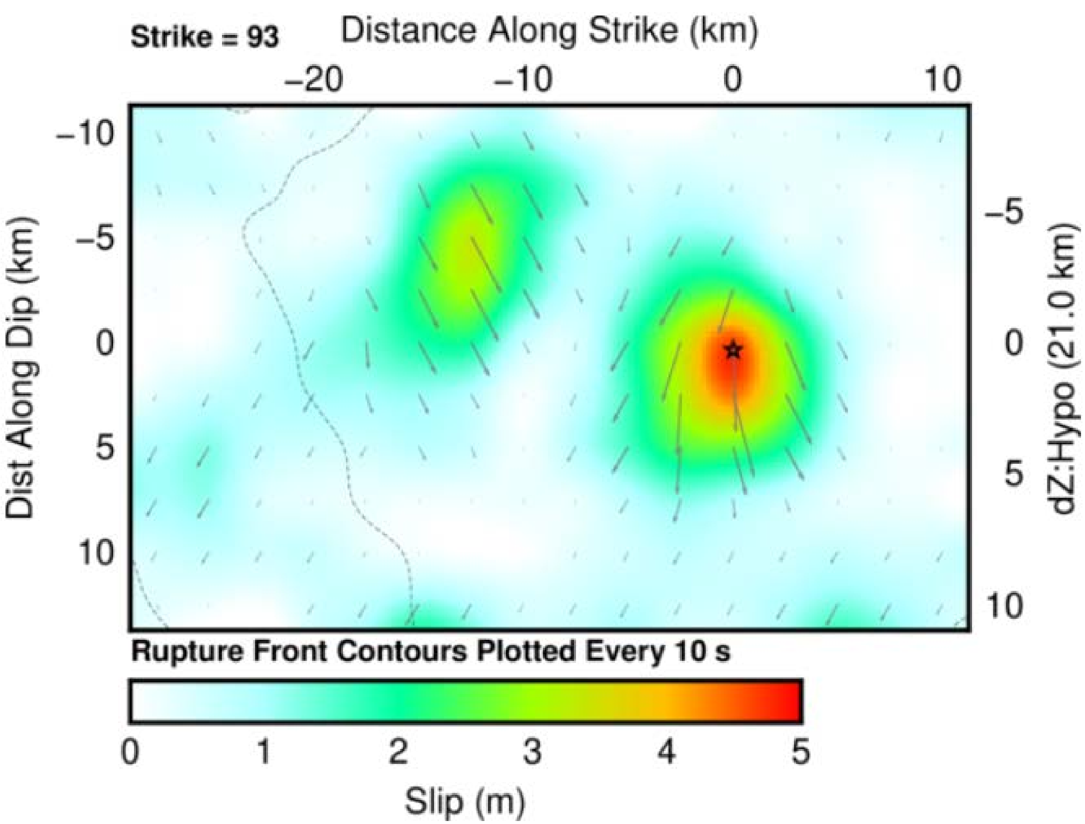
The number of people living near areas that could have produced landslides in this earthquake is limited. This is not a direct estimate of landslide fatalities or losses.

Estimated Population Exposure

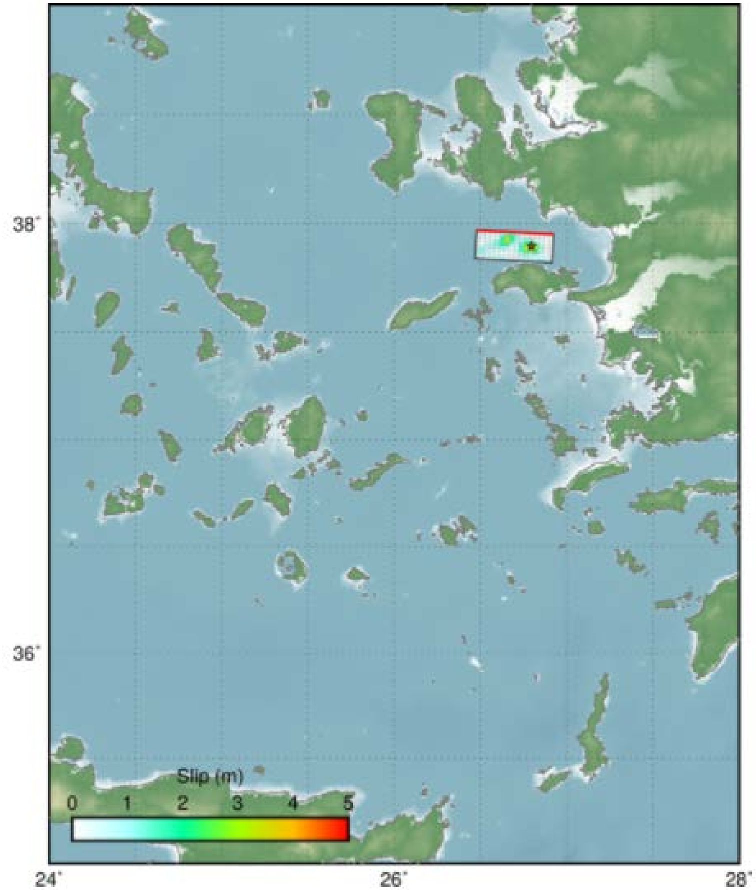
The number of people living near areas that could have produced liquefaction in this earthquake is significant. This is not a direct estimate of liquefaction fatalities or losses.

ISSN 2653-9454
Issue No. 21, November 2020 | 58

CROSS-SECTION AND SURFACE PROJECTION OF SLIP DISTRIBUTION



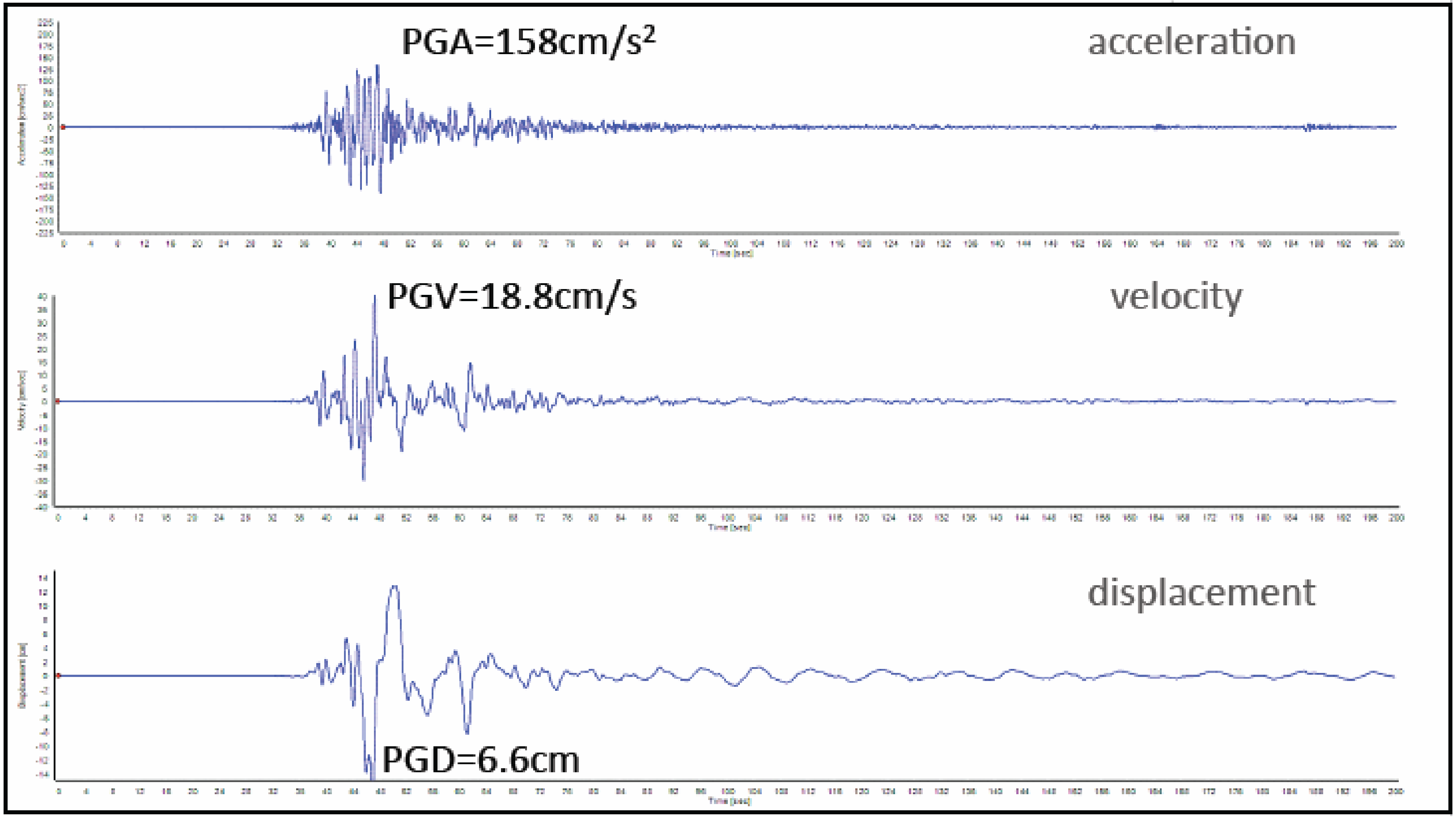
The strike direction is indicated above each fault plane and the hypocenter location is denoted by a star. Slip amplitude is shown in color and the motion direction of the hanging wall relative to the footwall is indicated with arrows. Contours show the rupture initiation time in seconds.



Surface projection of the slip distribution superimposed on GEBCO bathymetry.

Newsletter of
Environmental, Disaster, and Crises Management Strategies
ISSN 2653-9454
Issue No. 21, November 2020

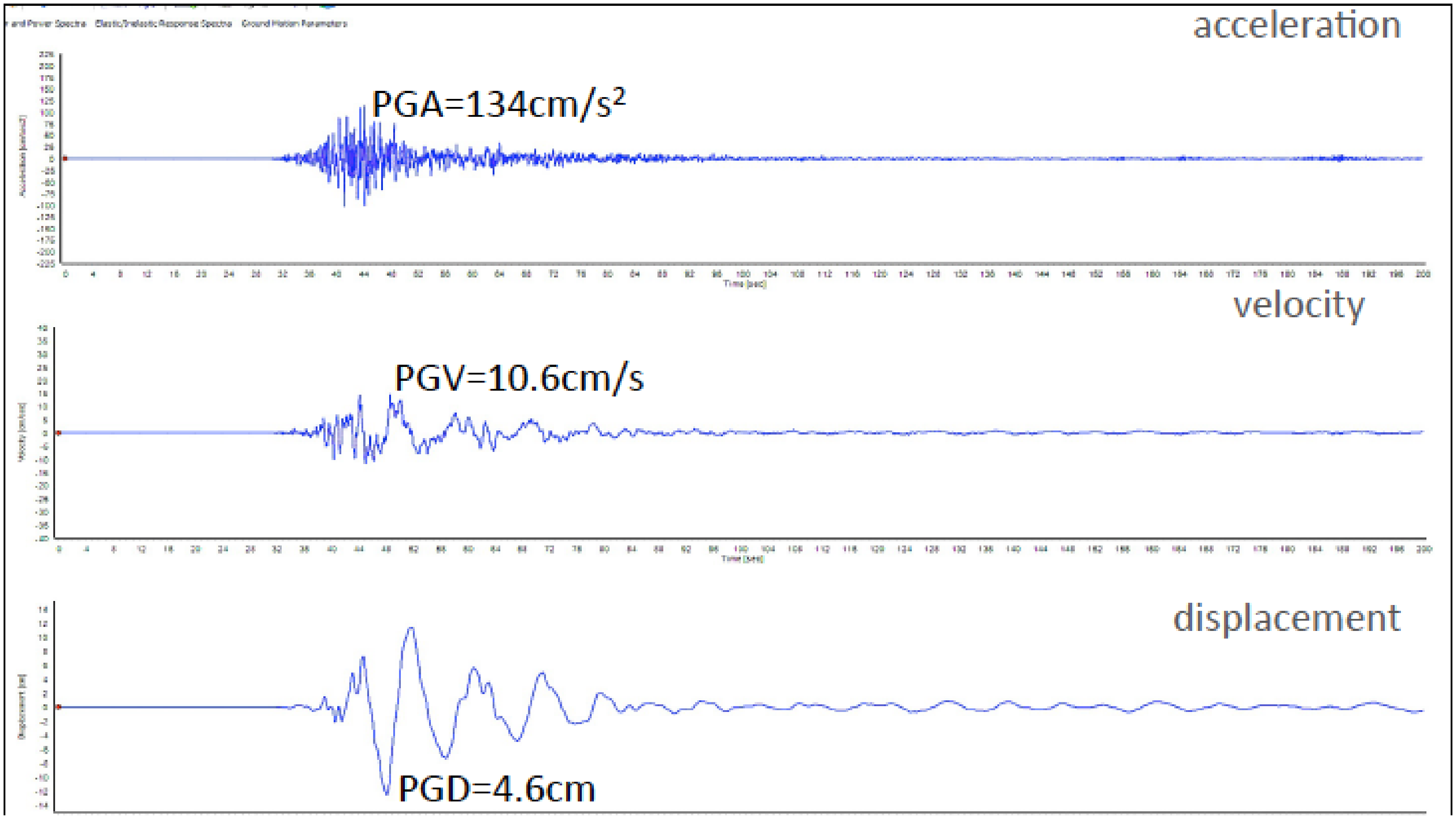
STRONG GROUND MOTION
RECORDED DURING THE OCTOBER 30, 2020, EARTHQUAKE



Time histories of the horizontal component (direction N48W). The accelerograph station of ITSAK-EPPO installed at the capital of Samos island with a station-to-epicenter distance R~15km.
http://www.itsak.gr/uploads/news/earthquake_reports/EQ_Samos_20201030_report_v2.pdf

ISSN 2653-9454
Issue No. 21, November 2020

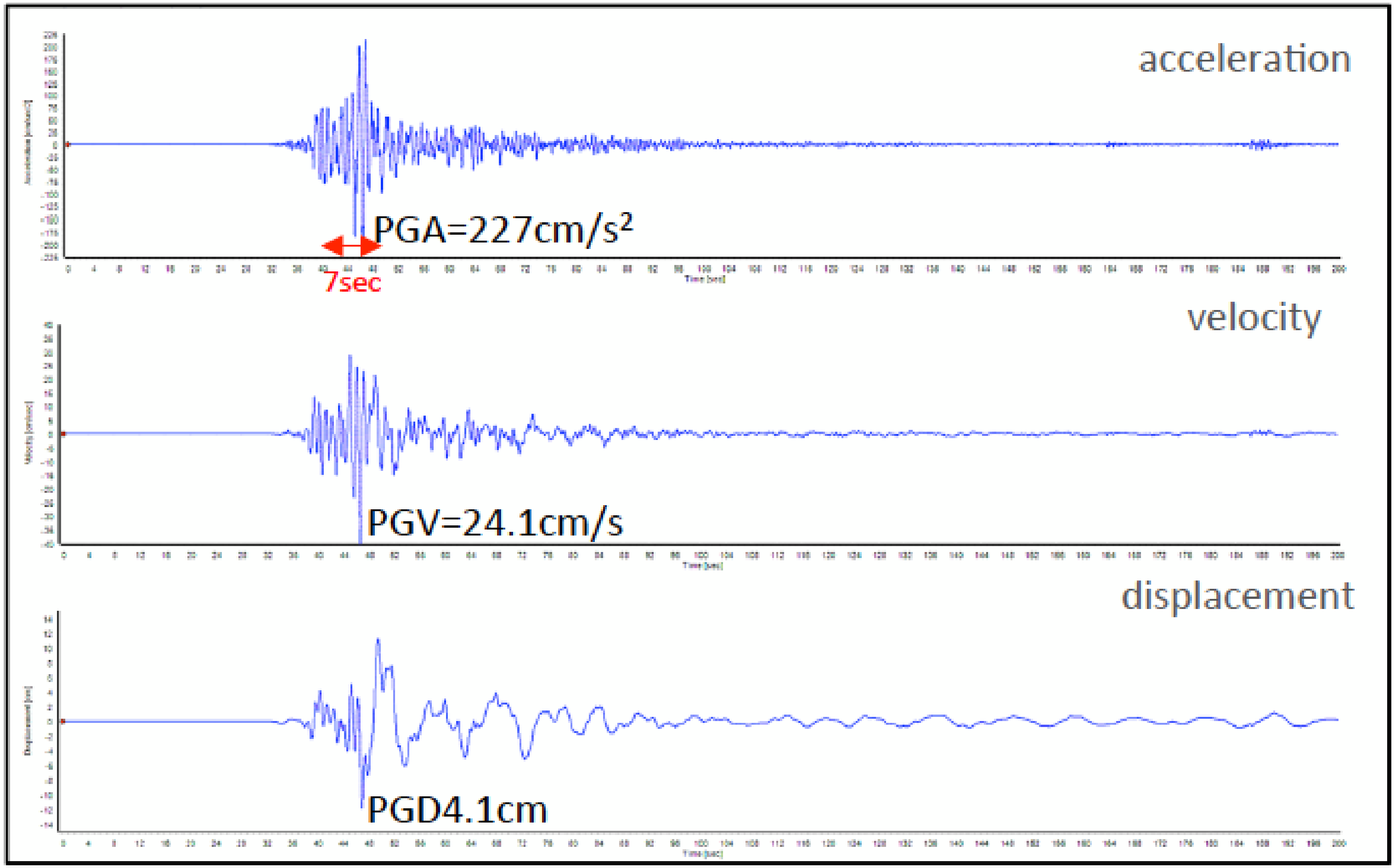
STRONG GROUND MOTION
RECORDED DURING THE OCTOBER 30, 2020, EARTHQUAKE



Time histories of the vertical component
http://www.itsak.gr/uploads/news/earthquake_reports/EQ_Samos_20201030_report_v2.pdf

ISSN 2653-9454
Issue No. 21, November 2020

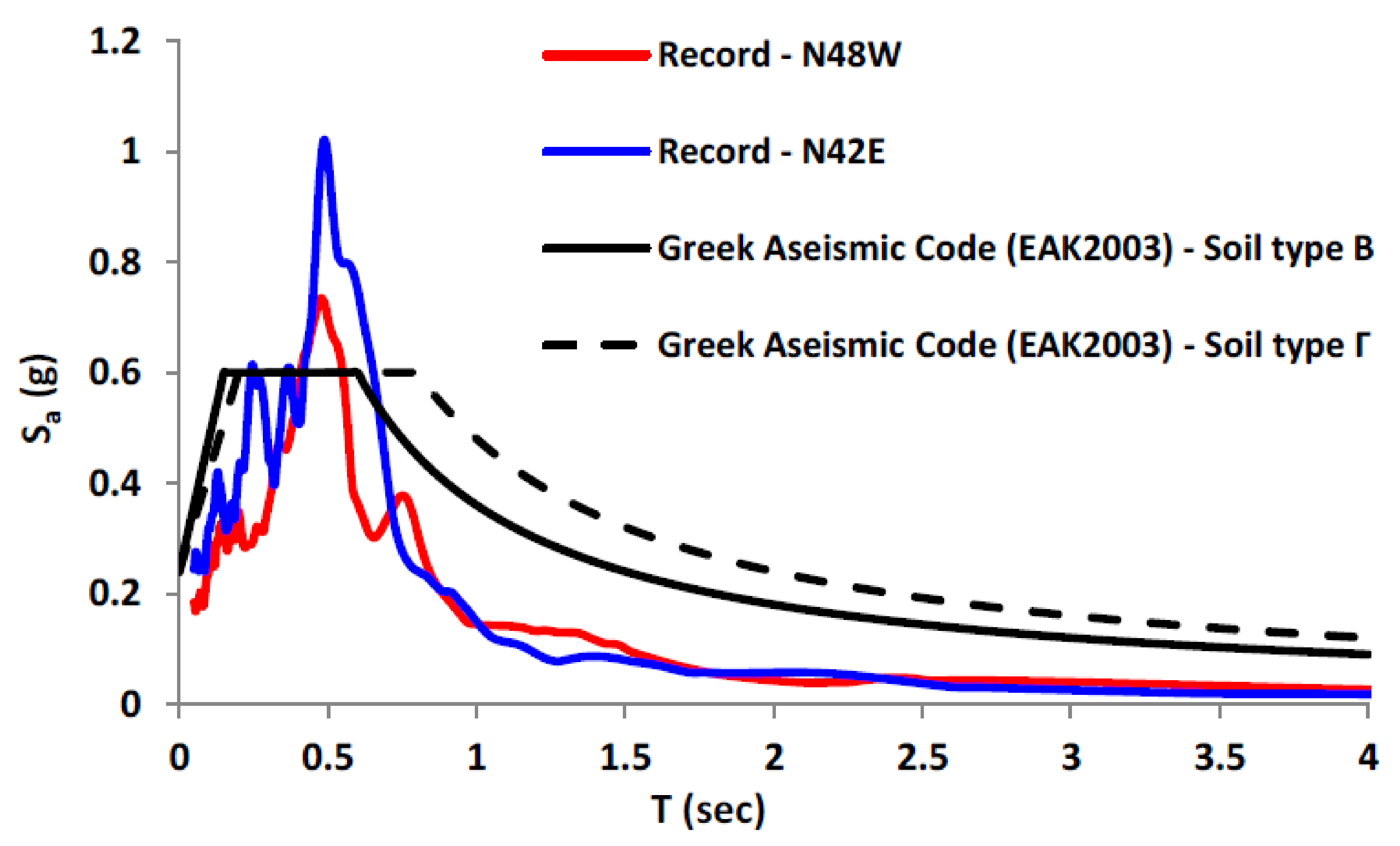
STRONG GROUND MOTION
RECORDED DURING THE OCTOBER 30, 2020, EARTHQUAKE



Time histories of the horizontal component (direction N42E)
http://www.itsak.gr/uploads/news/earthquake_reports/EQ_Samos_20201030_report_v2.pdf

ISSN 2653-9454
Issue No. 21, November 2020

RESPONSE SPECTRA
FOR THE OCTOBER 30, 2020 EARTHQUAKE

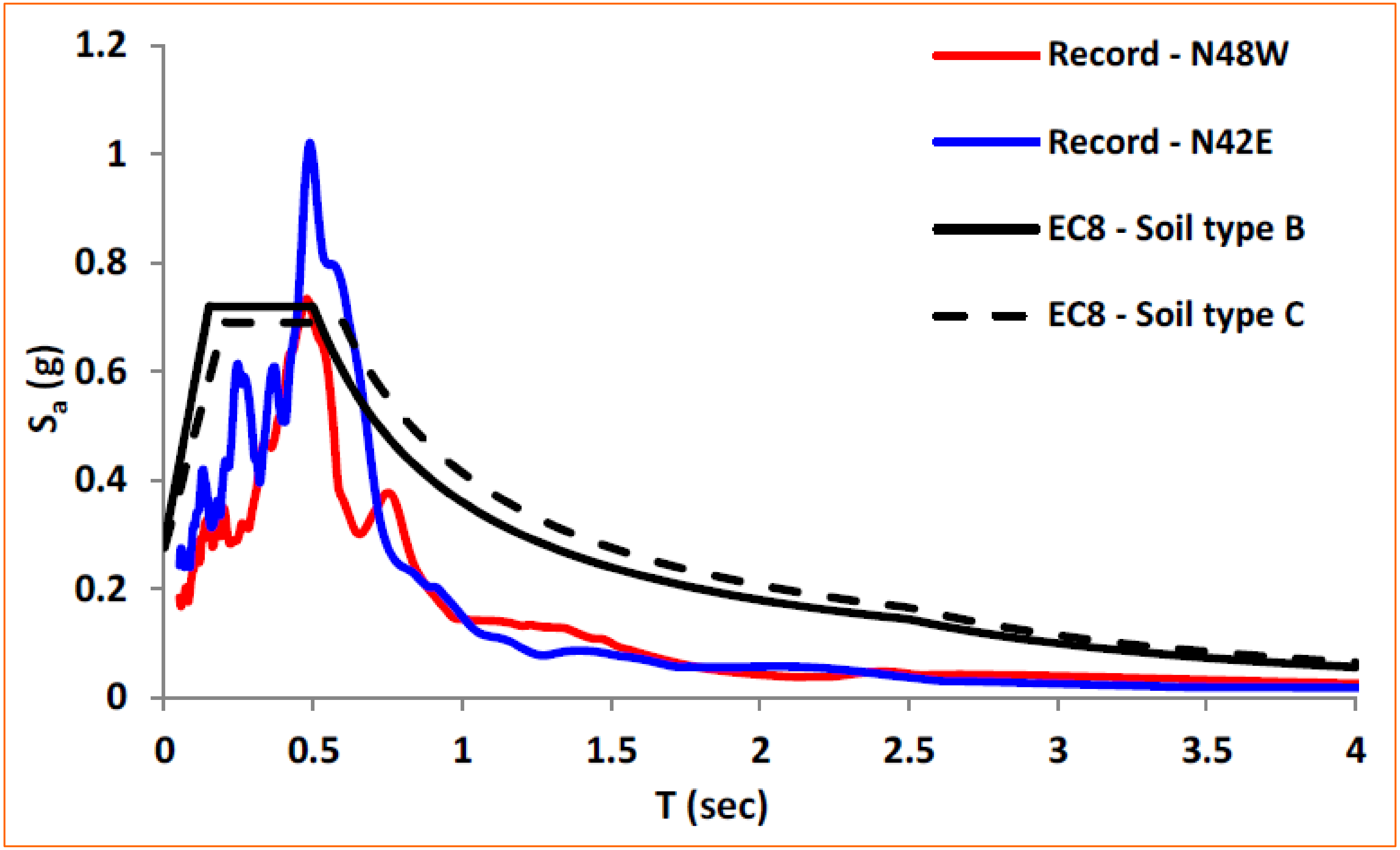


Comparison of the 5%-damped elastic acceleration response spectra between the earthquake record in Vathy, Samos and the Greek Aseismic Code: Horizontal components of seismic motion

ISSN 2653-9454
Issue No. 21, November 2020 | 63

ITSAK

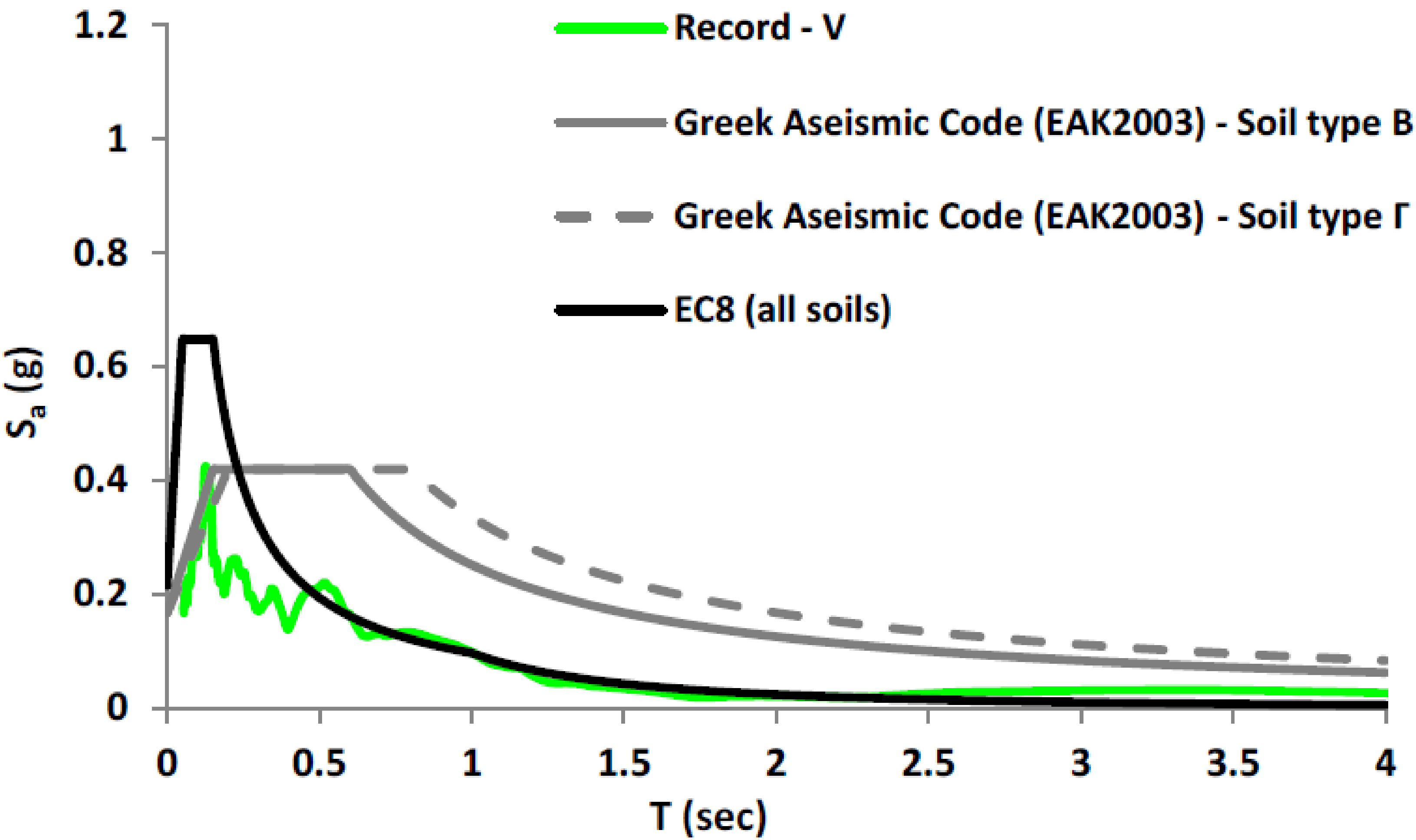
RESPONSE SPECTRA
FOR THE OCTOBER 30, 2020 EARTHQUAKE



Comparison of the 5%-damped elastic acceleration response spectra between the earthquake record in Vathy, Samos and the EC8 Code: Horizontal components of seismic motion. Due to the fact that the earthquake has magnitude Ms > 5.5, the response spectra correspond to an earthquake of type 1 (strong earthquake).

ISSN 2653-9454
Issue No. 21, November 2020

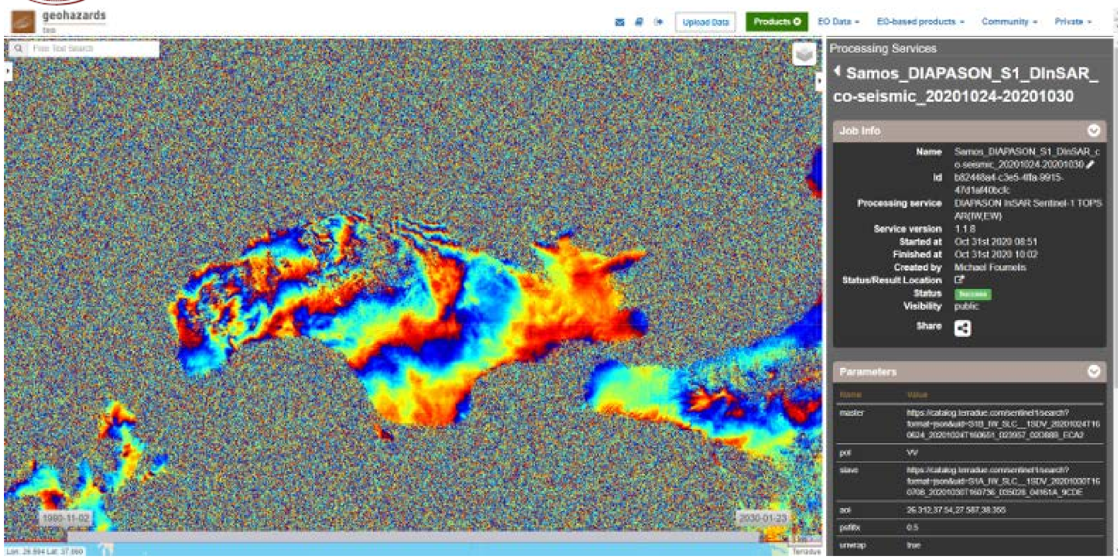
RESPONSE SPECTRA
FOR THE OCTOBER 30, 2020 EARTHQUAKE

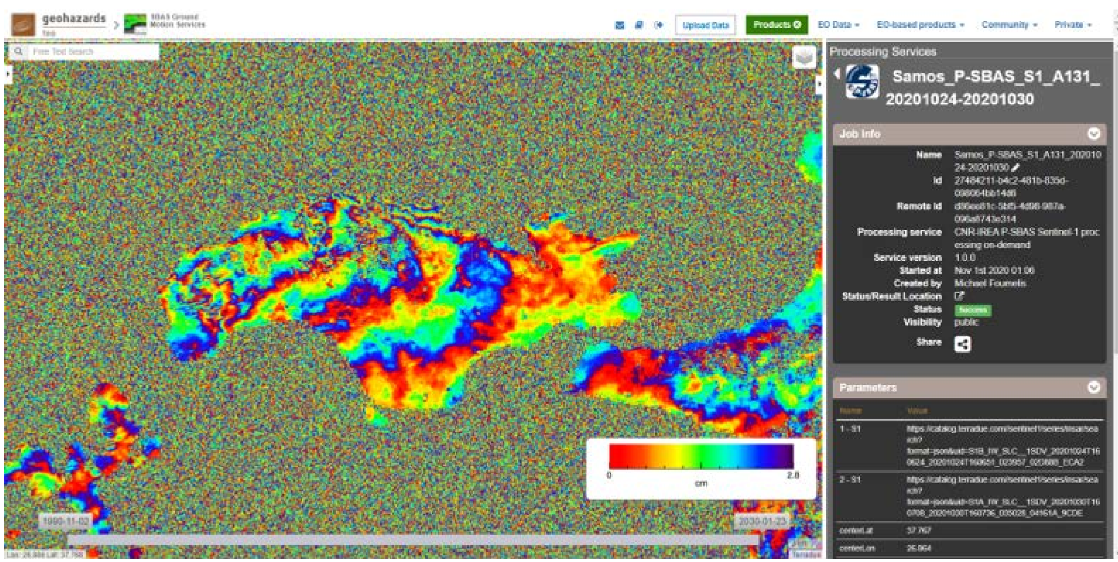


Comparison of the 5%-damped elastic acceleration response spectra between the earthquake record in Vathy, Samos and the Seismic codes (EAK2003 and EC8): Vertical component of seismic motion.

ISSN 2653-9454
Issue No. 21, November 2020

INTERFEROMETRIC ANALYSIS OF SYNTHETIC APERTURE RADAR (INSAR) DATA FOR THE OCTOBER 30, 2020 EARTHQUAKE





Co-seismic differential interferograms (wrapped phases) using Copernicus Sentinel-1 images acquired before (24/10/2020) and approximately four hours after the seismic event (30/10/2020 at 16:07 GMT); processed by CNES DIAPASON DInSAR (*up*) and CNR IREA P-SBAS (*down*) online services on the GEP. Contains modified Copernicus Sentinel data (2020), processed by AUTh on GEP.

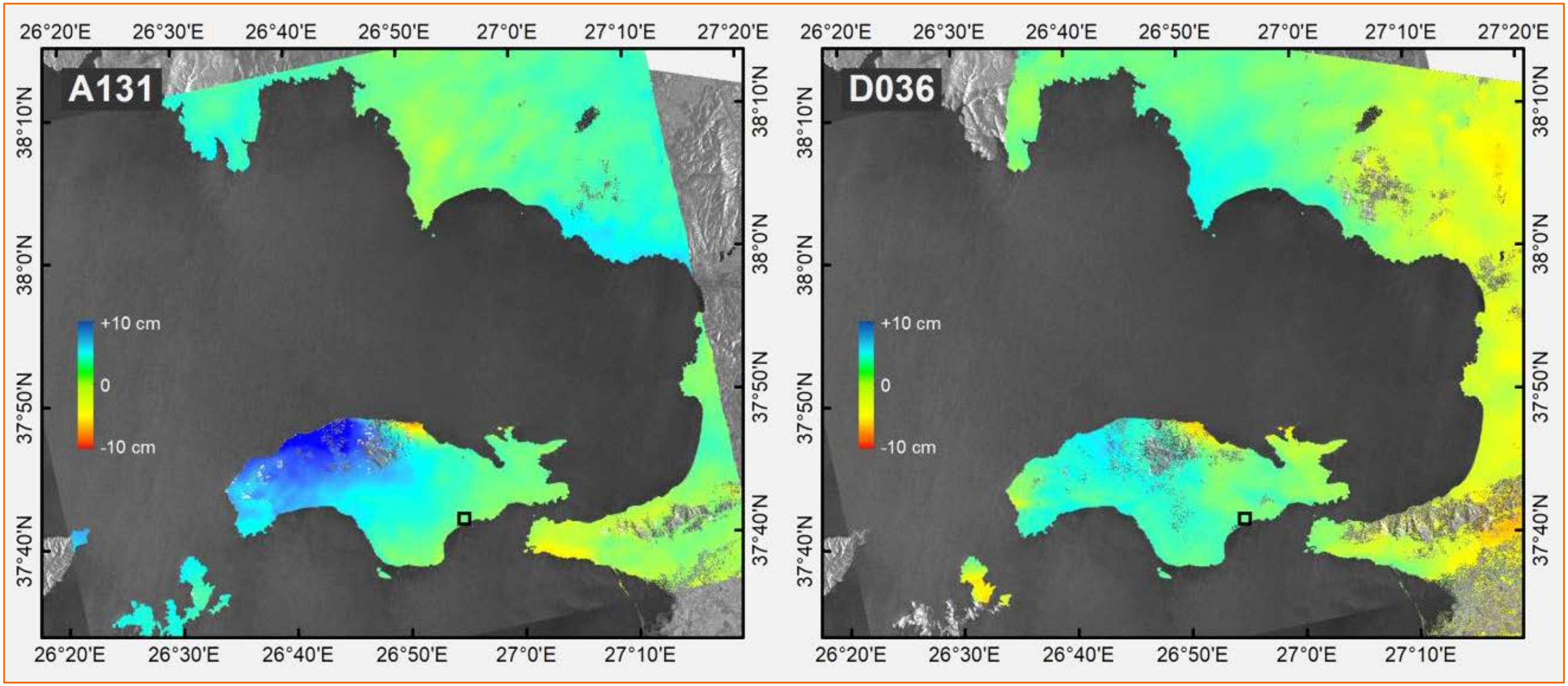
As illustrated, both interferometric measurements appear aligned showing a sinking pattern (up to 6-7 cm) concentrated along a narrow area at the northernmost part of Samos (Agios Konstantinos – Vourliotes region), whereas the W-NW part of Samos island shows significant uplift (locally exceeding 10 cm).

https://sentinel.esa.int/web/sentinel/news/-/article/copernicus-sentinel-1-supports-timely-interpretation-of-southern-europe-s-earthquake

Newsletter of
Environmental, Disaster, and Crises Management Strategies
ISSN 2653-9454
Issue No. 21, November 2020

INTERFEROMETRIC ANALYSIS OF SYNTHETIC APERTURE RADAR (INSAR) DATA

CO-SEISMIC DISPLACEMENT FIELD BASED ON SENTINEL-1 MISSION DATA

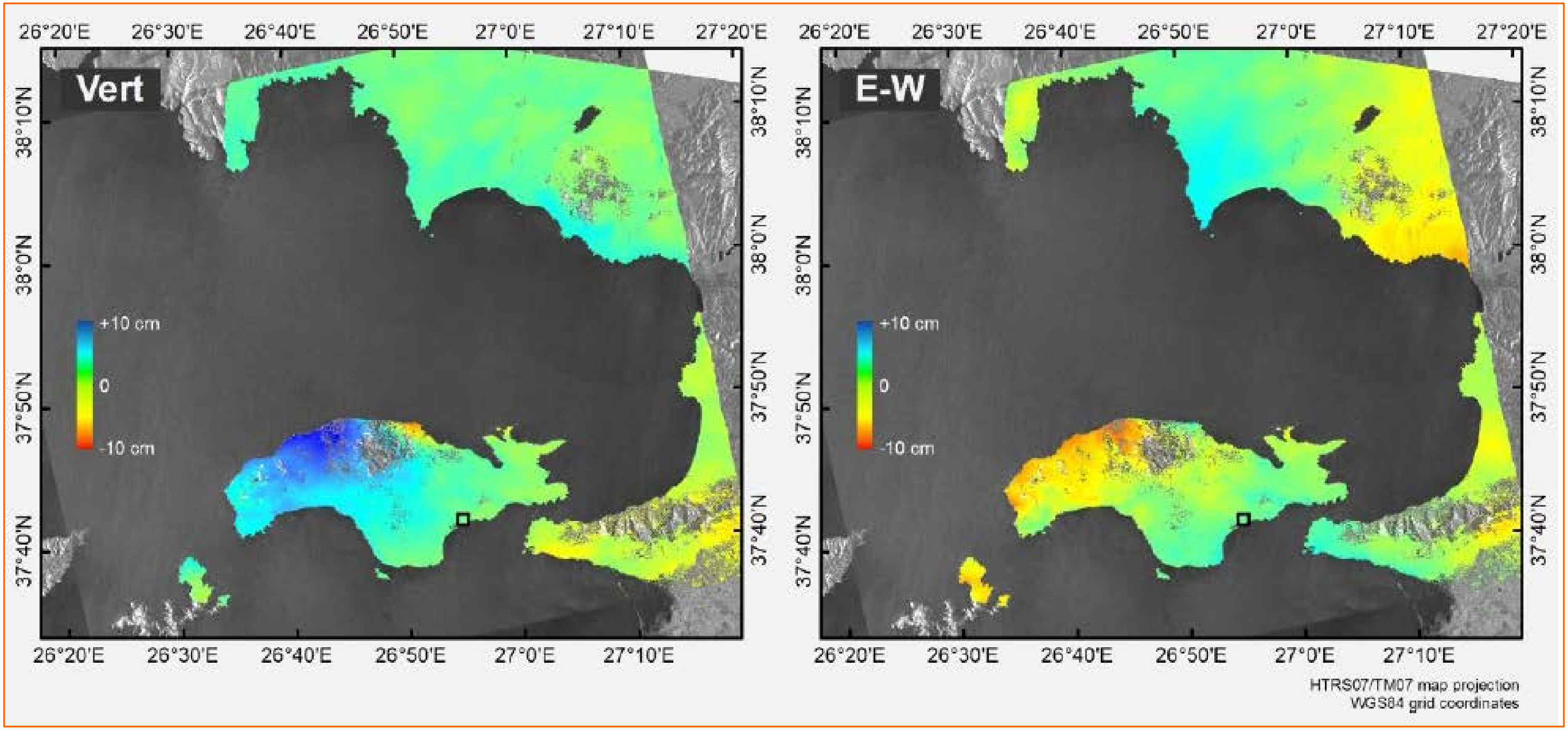


Sentinel-1 LoS ground displacement from various satellite orbits (A131, A029, D036). Positive values indicate motion towards the satellite, whereas negative values motion away from the satellite. Reference area indicated (black square).

ISSN 2653-9454
Issue No. 21, November 2020

INTERFEROMETRIC ANALYSIS OF SYNTHETIC APERTURE RADAR (INSAR) DATA

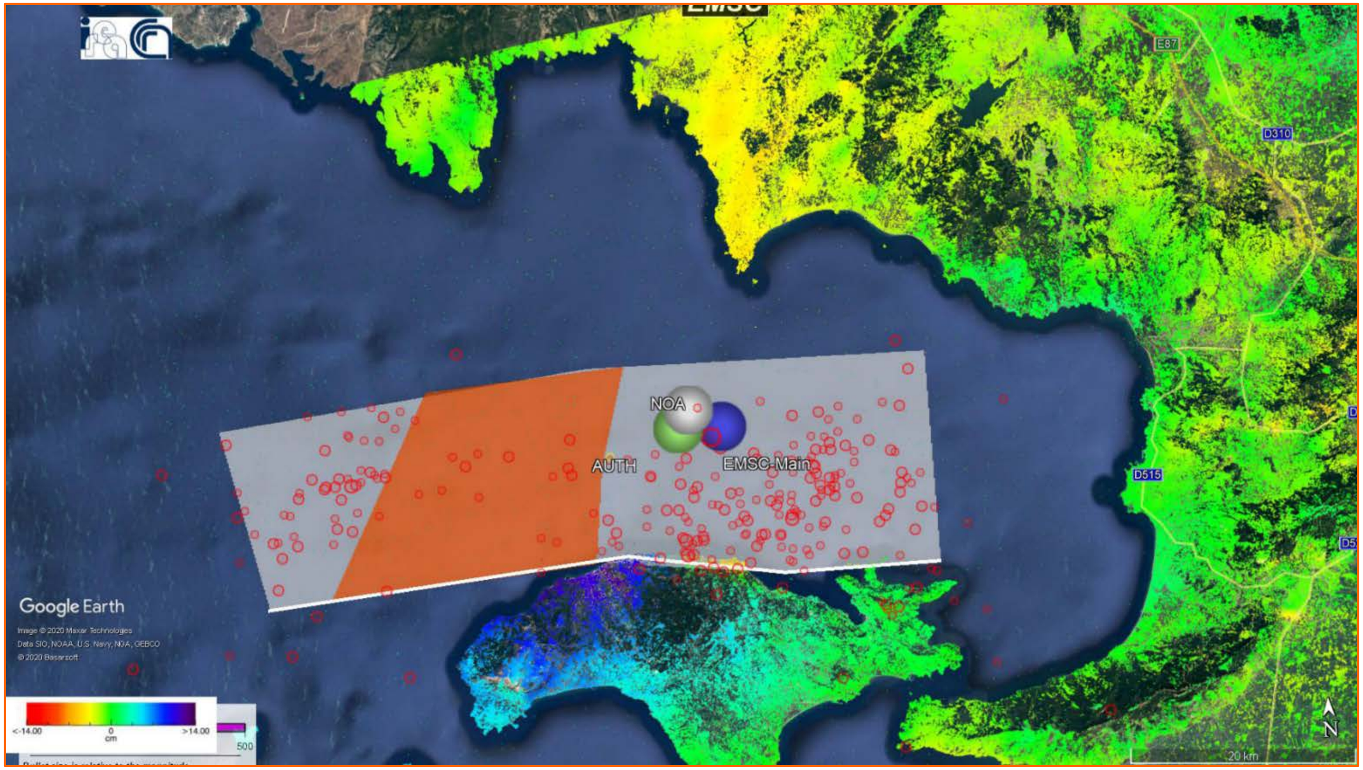
VERTICAL AND E-W COMPONENTS OF THE CO-SEISMIC DISPLACEMENT FIELD



Sentinel-1 co-seismic displacement field along the vertical and E-W directions based on the combination of independent LoS InSAR measurements. Positive values indicate uplift and/or motion towards East, whereas negative values downlift and/or motion towards West.

ISSN 2653-9454
Issue No. 21, November 2020

COMBINING SEISMOLOGICAL DATA AND SPACEBORNE OBSERVATIONS

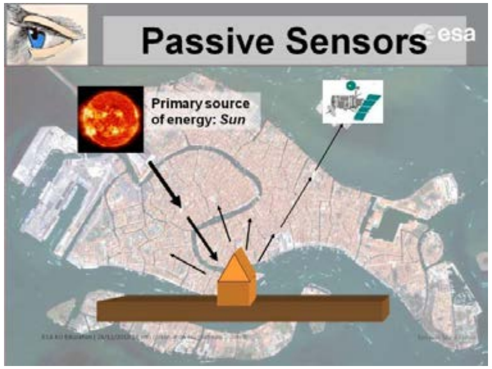


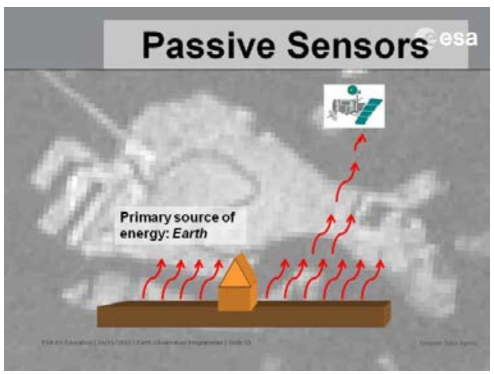
The rupture started from the hypocenter (relocated depth ~13 km), possibly expanded bilaterally in both directions (East and West), rupturing an area with a length of 55-60 kilometers and a width of 15 kilometers (the fault, white polygon). The large fault displacements possibly occurred along the western fault segment (orange area), where fault may have reached the surface, significantly shifting the sea bottom (though this can be done only by the static displacement) and generating the observed tsunami.

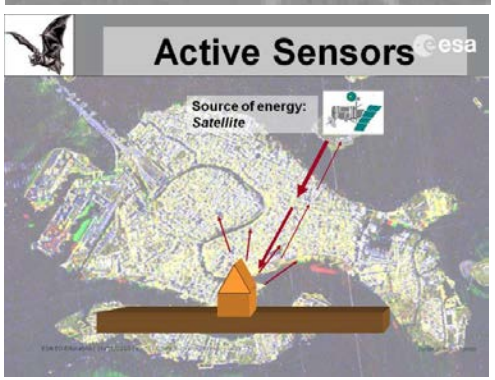
Initial interpretation by Professor Costas Papazachos (AUTH)

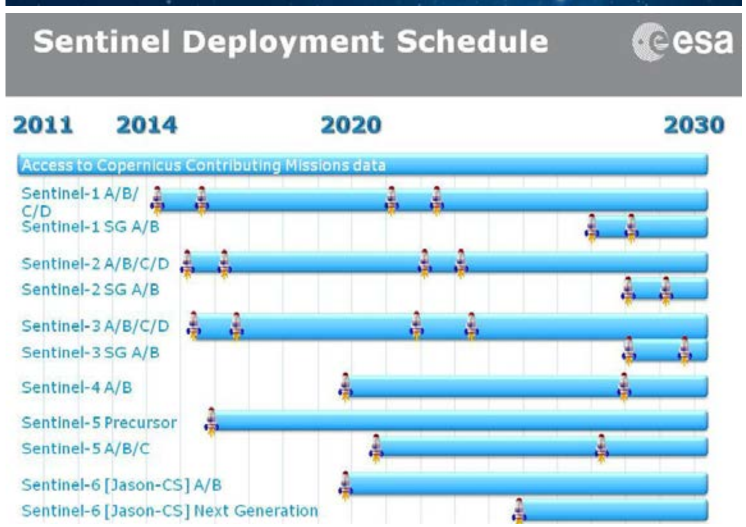
ISSN 2653-9454
Issue No. 21, November 2020

COPERNICUS EARTH OBSERVATION PRODUCTS
FOR MAPPING AND MONITORING THE SAMOS SEISMIC EVENT









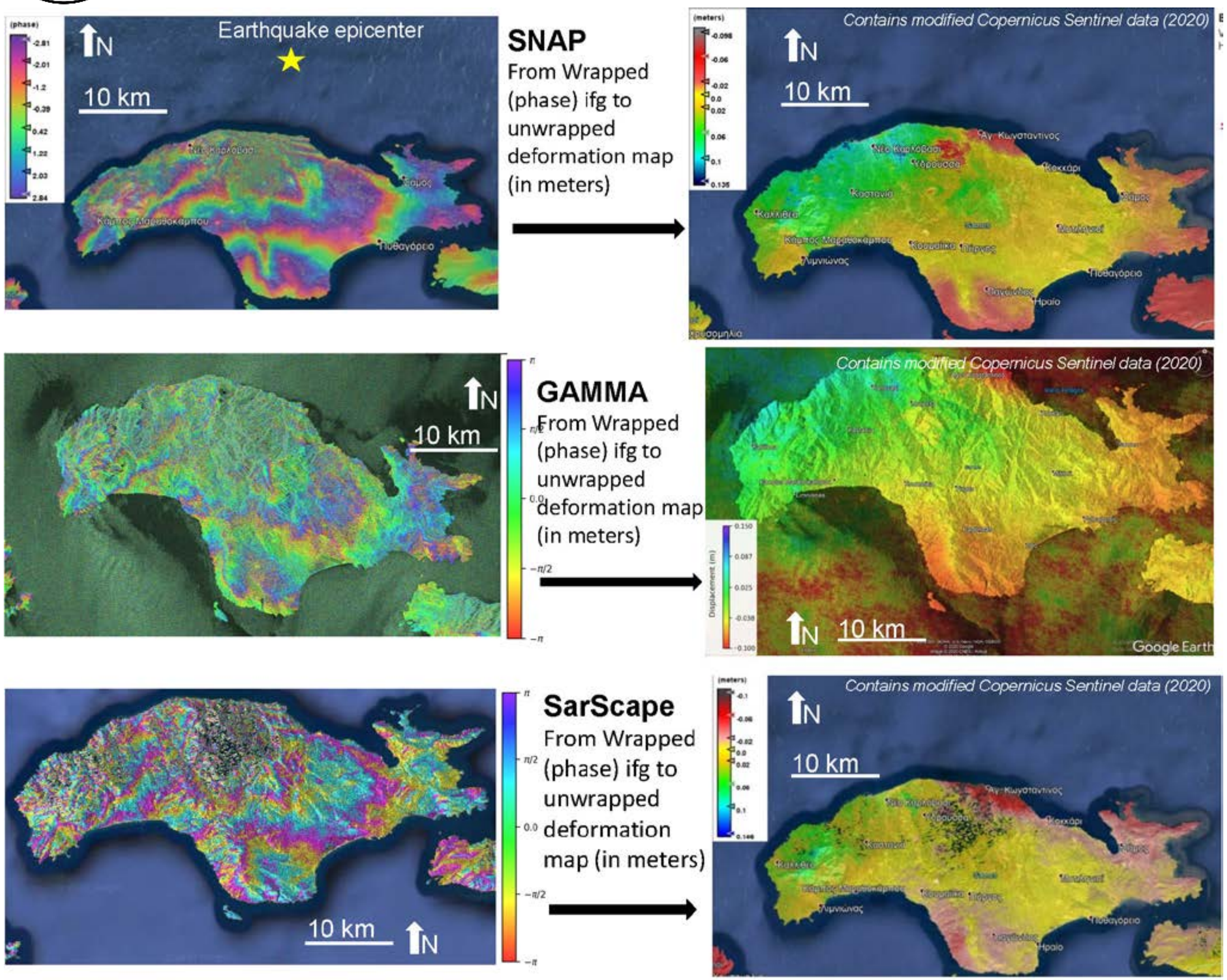
By using satellite data, alongside ground-based and other observations, we can monitor earthquakes and volcanoes across the globe, and apply what we learn in one location more widely.

Satellites such as Sentinels (free) help us to understand how the ground deforms around earthquake centers, faults and volcanoes. They can give very precise measurements of ground motion that we can combine with other techniques to create geophysical models of what is happening beneath the Earth's surface.

In this study Sentinel 1 & 3 are used in order to create deformation maps by SAR interferometry and based on thermal emissivity to create sea thermal images. Unfortunately due to cloud cover during the period of monitoring wasn't possible to use optical data (Sentinel 2).

ISSN 2653-9454
Issue No. 21, November 2020

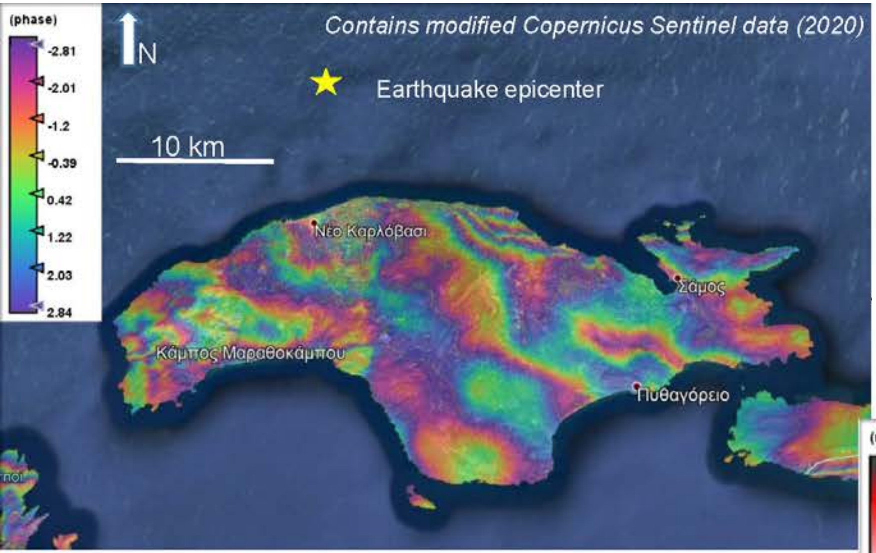
COPERNICUS EARTH OBSERVATION PRODUCTS
FOR MAPPING AND MONITORING THE SAMOS SEISMIC EVENT



An interferometric pair of Sentinel-1 ascending SLC scenes dated 6/10 and 30/10. All the results (regardless of the processing s/w) showed the same quality results, ie uplift of the NW area of the island and subsidence (in coastal areas in the north of the island) and quantitatively the results are similar: the uplift from 10 to 14 cm in LOS while in the case of subsidence the maximum value is 9 cm in LOS (Avlaki area). There is topo induced phase in the central part of the island

ISSN 2653-9454
Issue No. 21, November 2020 | **71**

COPERNICUS EARTH OBSERVATION PRODUCTS
FOR MAPPING AND MONITORING THE SAMOS SEISMIC EVENT



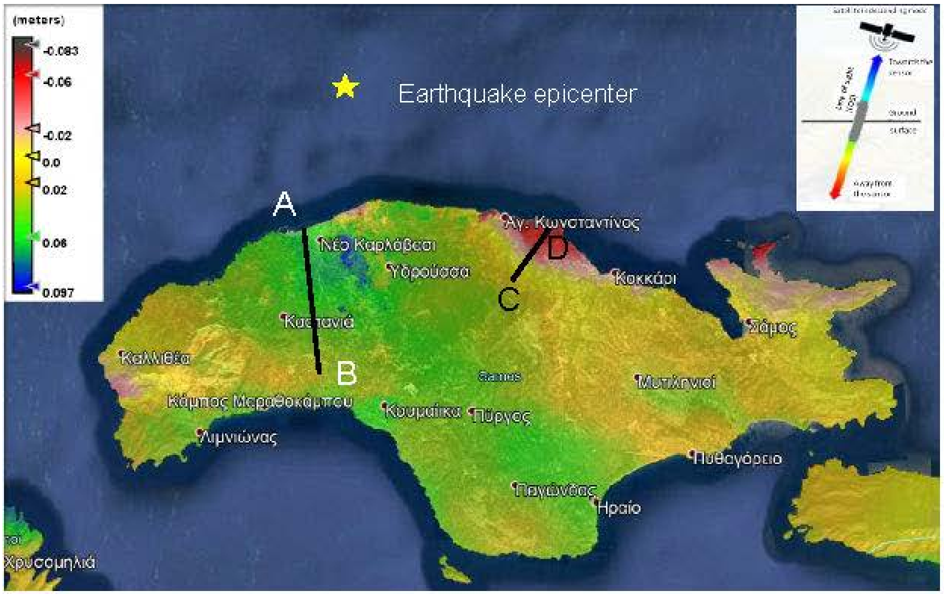
◀ Wrapped interferogram (phase)

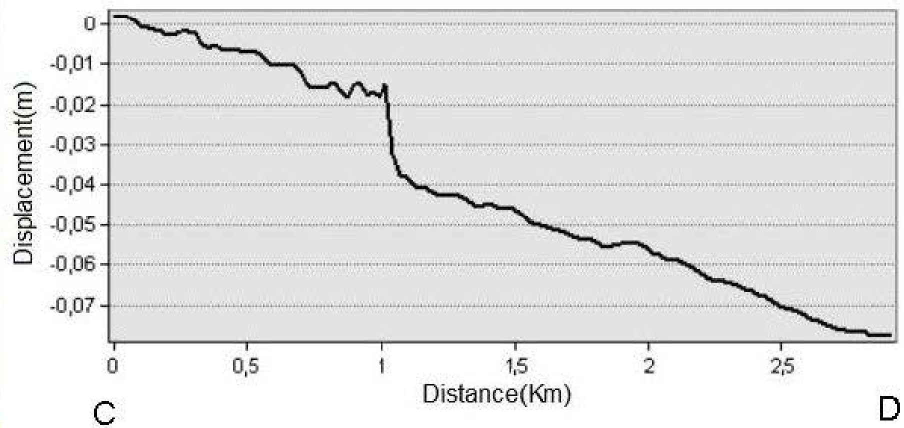
▶ Unwrapped interferogram
(Displacement Map in meters)

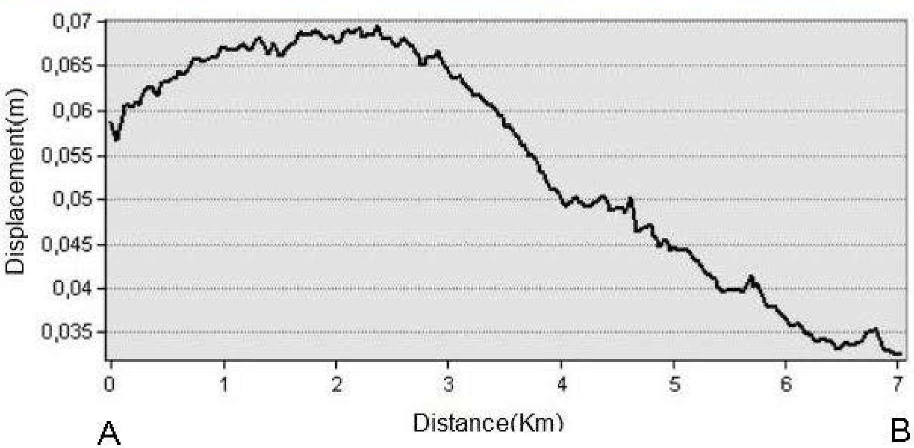
Interferometric pair formed by Sentinel 1 SLC scenes in descending geometry of acquisition dated 24/10 and 5/11. Processing was done using the ESA's free and open s/w SNAP in Linux environment. The wrapped interferogram (left) after unwrapping the displacement map has been produced (co-seismic deformation in meters)

ISSN 2653-9454
Issue No. 21, November 2020

COPERNICUS EARTH OBSERVATION PRODUCTS
FOR MAPPING AND MONITORING THE SAMOS SEISMIC EVENT



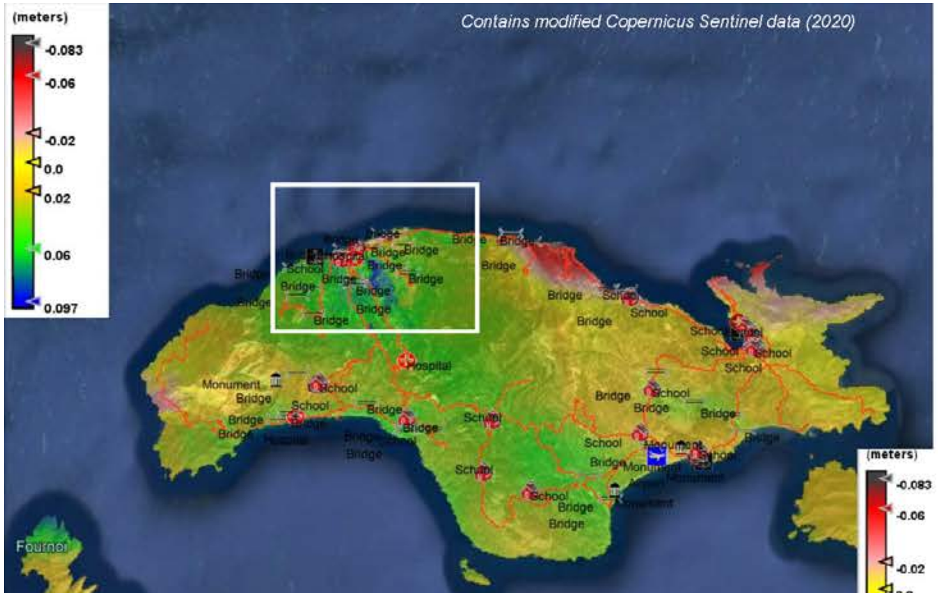




Deformation sections based on the co-seismic deformation map of the descending pair of Sentinel 1 SLC scenes.

ISSN 2653-9454
Issue No. 21, November 2020

COPERNICUS EARTH OBSERVATION PRODUCTS FOR MAPPING AND MONITORING THE SAMOS SEISMIC EVENT



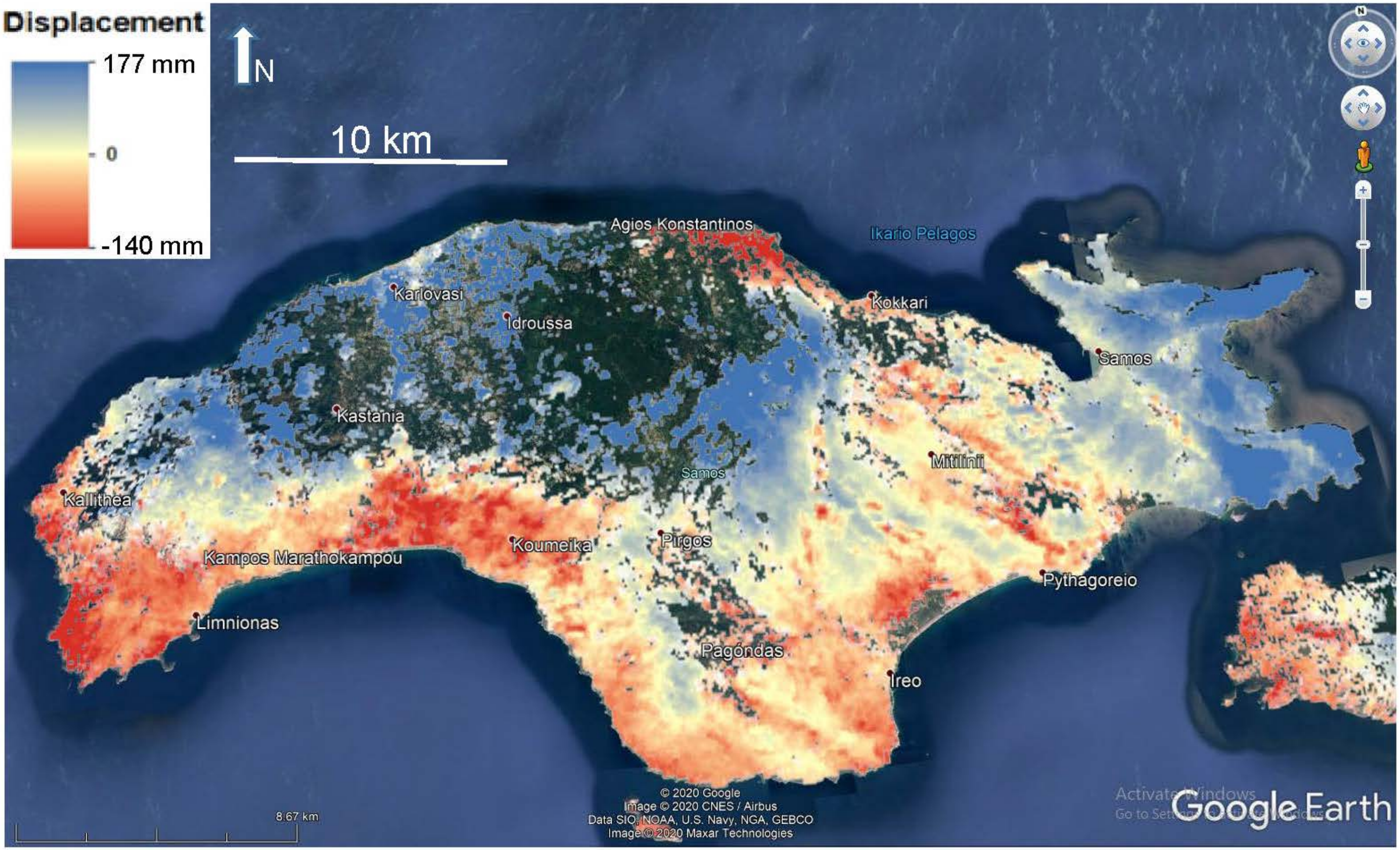
Displacement map produced by the descending Sentinel 1 SLC pair overlapped by local exposure (road network, hospitals, schools, cultural heritage sites and museums, bridges etc).

◀ The entire island of Samos
▼ The detailed of Karlovasi City

During this study a Google Earth based application for tablets and mobiles (with activation of GPS) was developed as an operational tool to use during post disaster inspections concerning structural health of local infrastructure.

ISSN 2653-9454
Issue No. 21, November 2020 | 74

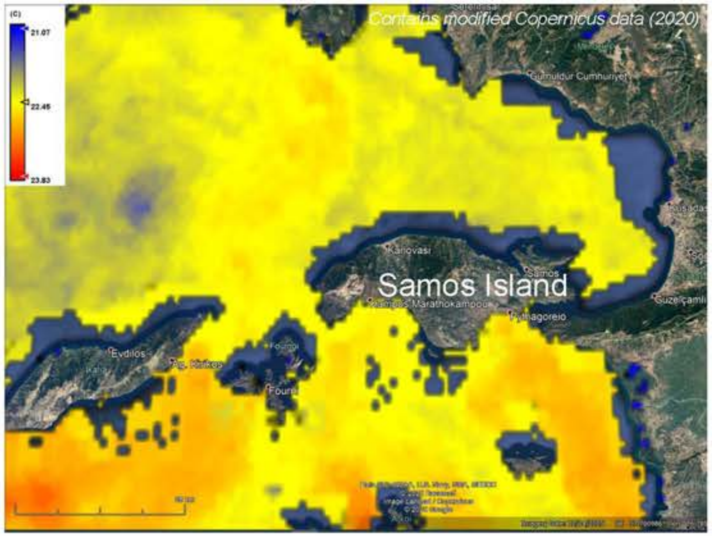
COPERNICUS EARTH OBSERVATION PRODUCTS
FOR MAPPING AND MONITORING THE SAMOS SEISMIC EVENT

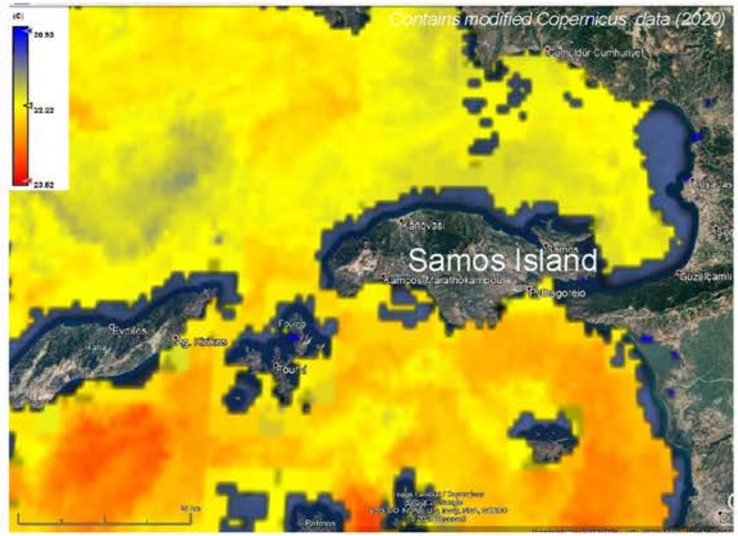


Multitemporal InSAR product using 15 SAR.SLC Sentinel -1 scenes in ascending geometry covering the period 5/2020 – early November/2020 following the SBAS algorithm of SARSCAPE

ISSN 2653-9454
Issue No. 21, November 2020

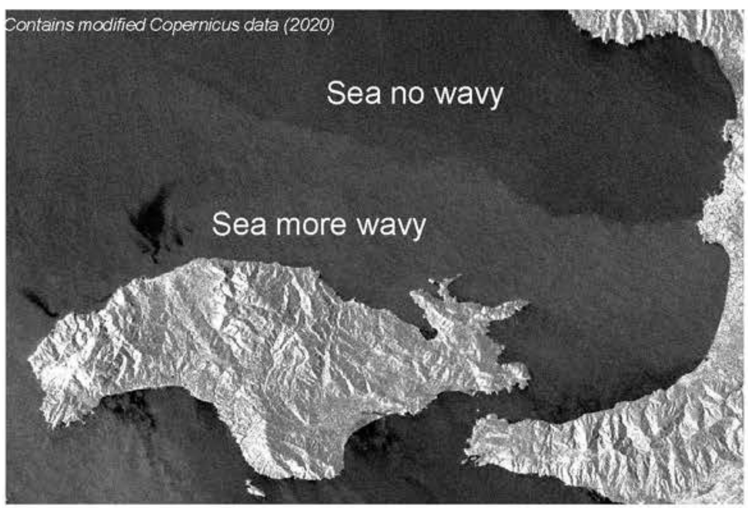
COPERNICUS EARTH OBSERVATION PRODUCTS
FOR MAPPING AND MONITORING THE SAMOS SEISMIC EVENT

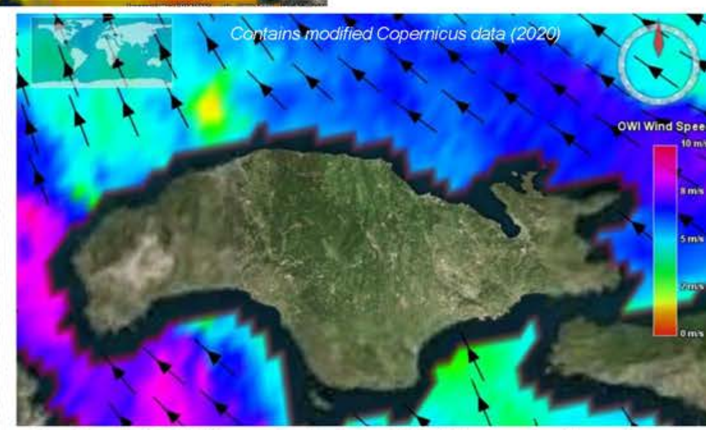




Sentinel-3 scenes were used for the assessment of Sea Surface Temperature (SST) using the SLSTR Instrument. The acquisition dates are 27/10/2020 (left) and 31/10/2020 (right) and pass direction is Ascending. The processing was conducted in ESA's SNAP Software. The final product is the Sea Surface Temperature (SST) in Celsius.

Sentinel 1 GRD scene dated 30/10 T:16.06 Z after orbit file updated, thermal noise removal, Calibration, speckle filtering, terrain correction, subset and finally conversion to dB. The image is very sensitive in micro-topography in land and sea.





Sentinel 1 OCN product dated 30/10 ascending showing wind speed and wind direction (arrows indicate the direction in which the wind is coming)

ISSN 2653-9454
Issue No. 21, November 2020

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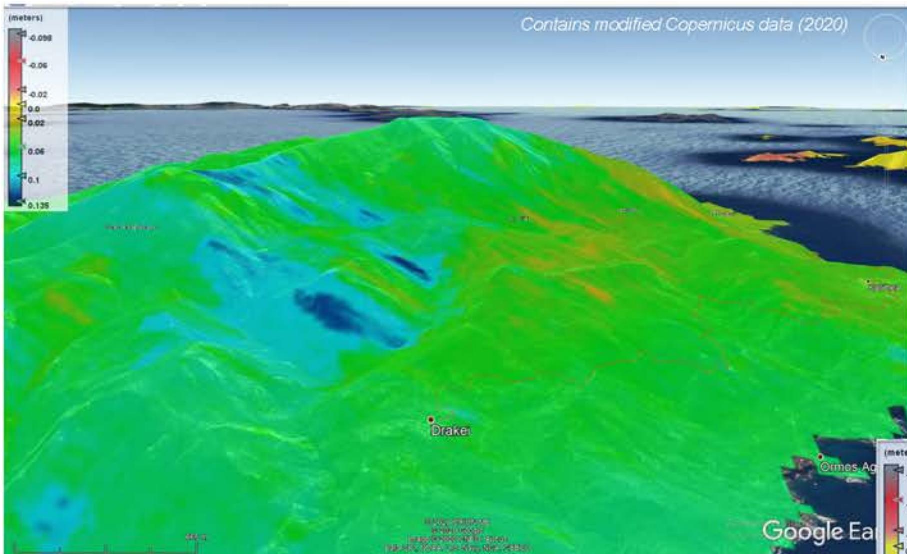
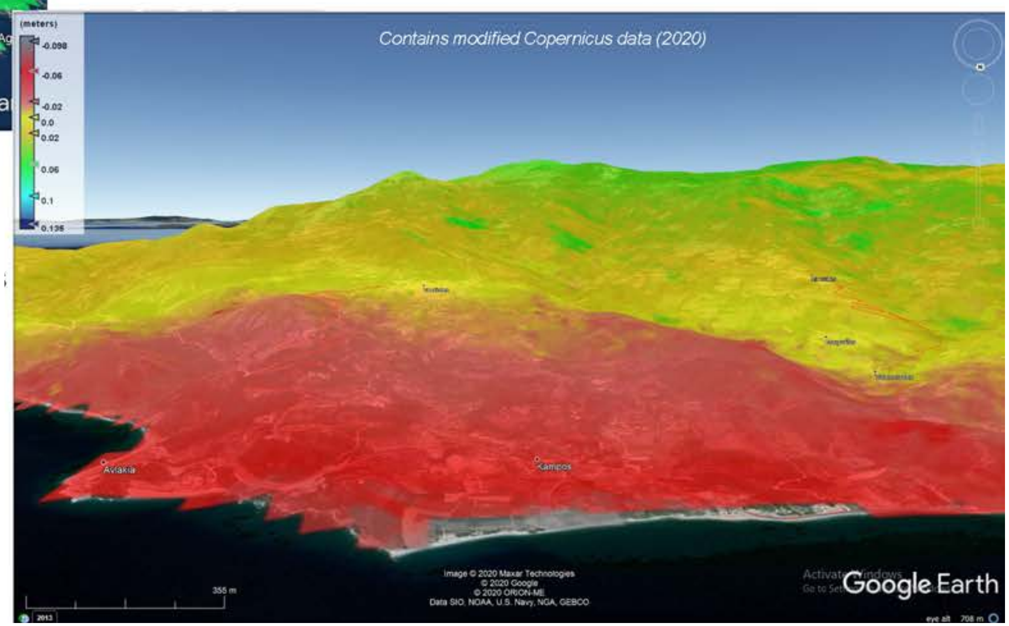


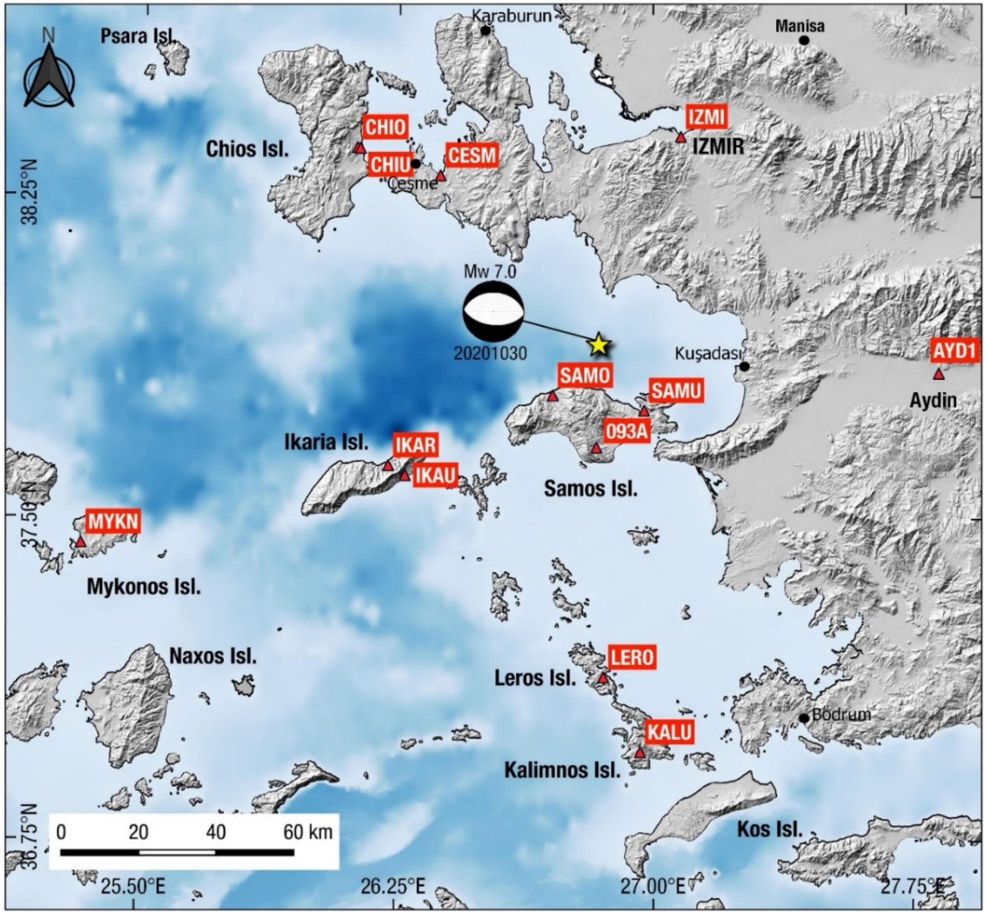
◀ Slope instabilities in NW part of the Samos Island based on the displacement map (subset)



▶ Subsided coastal area at the Northern part of the Samos Island based on the displacement map (subset)

ISSN 2653-9454
Issue No. 21, November 2020

RESULTS FROM SAR INTERFEROMETRY AND GNSS

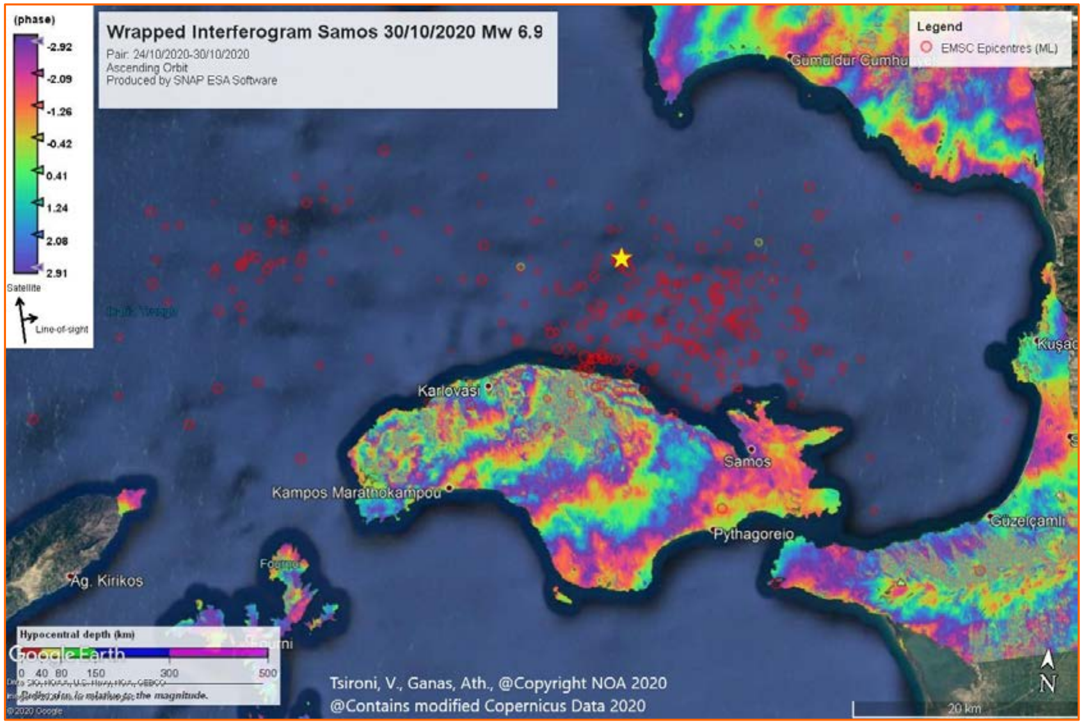


A first analysis of the geodetic data is presented by the NOA scientific team (Ganas, Tsironi, Karasante). They used a set of ascending SAR images acquired by the SENTINEL-1 satellites that are distributed routinely by the European Space Agency (ESA) free of charge. They also used GNSS data (at 30-s sampling interval) from permanent stations surrounding the epicenter that were provided by the Greek private GNSS networks (SmartNet and Uranus) and the Turkish CORS network. The NOA team preliminary inversion modeling indicates that the rupture occurred on a 37±5-kilometer-long north-dipping tensional ("normal") fault located off the northern shore of Samos (Ganas et al. 2020).

Location map showing shaded topography / bathymetry, the focal mechanism (beachball; GCMT solution) and the epicenter of the October 30, 2020 Samos earthquake (yellow triangle). Red triangles indicate permanent GPS (GNSS) station locations (with codes in red frames).

ISSN 2653-9454
Issue No. 21, November 2020

RESULTS FROM SAR INTERFEROMETRY AND GNSS

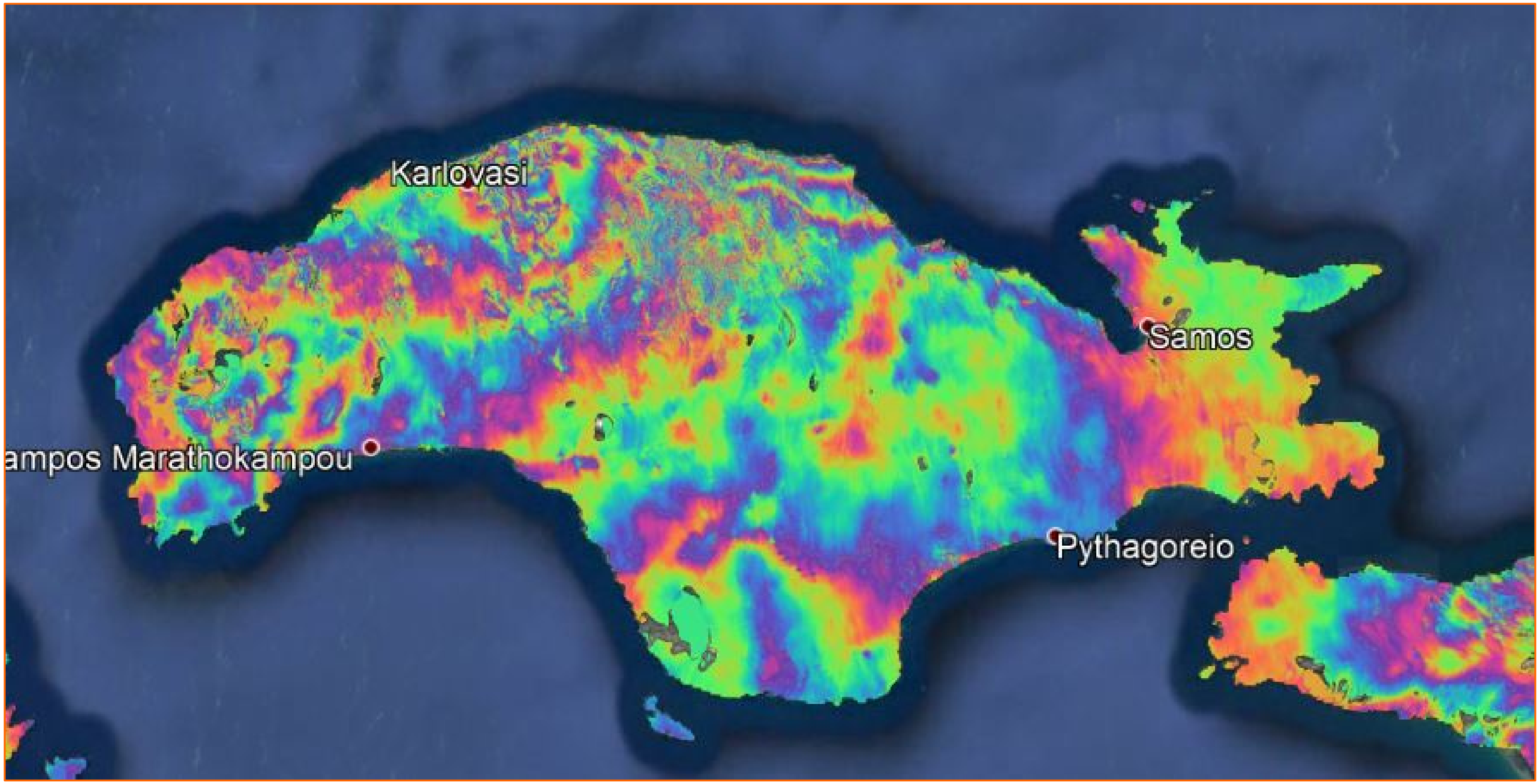


The NOA scientific team used the ascending images acquired by the European satellites Sentinel-1 (C-band data) on October 24 and October 30, 2020 and October 18-30, 2020 on the track 131. The interferograms were made on the Geohazards Exploitation Platform (https://geohazards-tep.eu) using the SNAP v5.0 software. The digital elevation model (DEM) used for the processing is the Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global (doi number: /10.5066/F7PR7TFT).

The quality of the interferogram is good, both in terms of coherence and tropospheric noise. The interferogram shows several fringes corresponding to ground deformation onshore Samos. The absolute value of the interferometric fringes is estimated by the tie to the GNSS stations SAMO (Karlovasi) and SAMU (Vathy) that recorded the co-seismic displacement. All fringes correspond to motion towards the satellite except the three northern one located by the coast (Agios Konstantinos – Kokkari) where the motion is away from the satellite. The uplift is interpreted a result of co-seismic motion along an offshore normal fault, running E-W and dipping to the North.

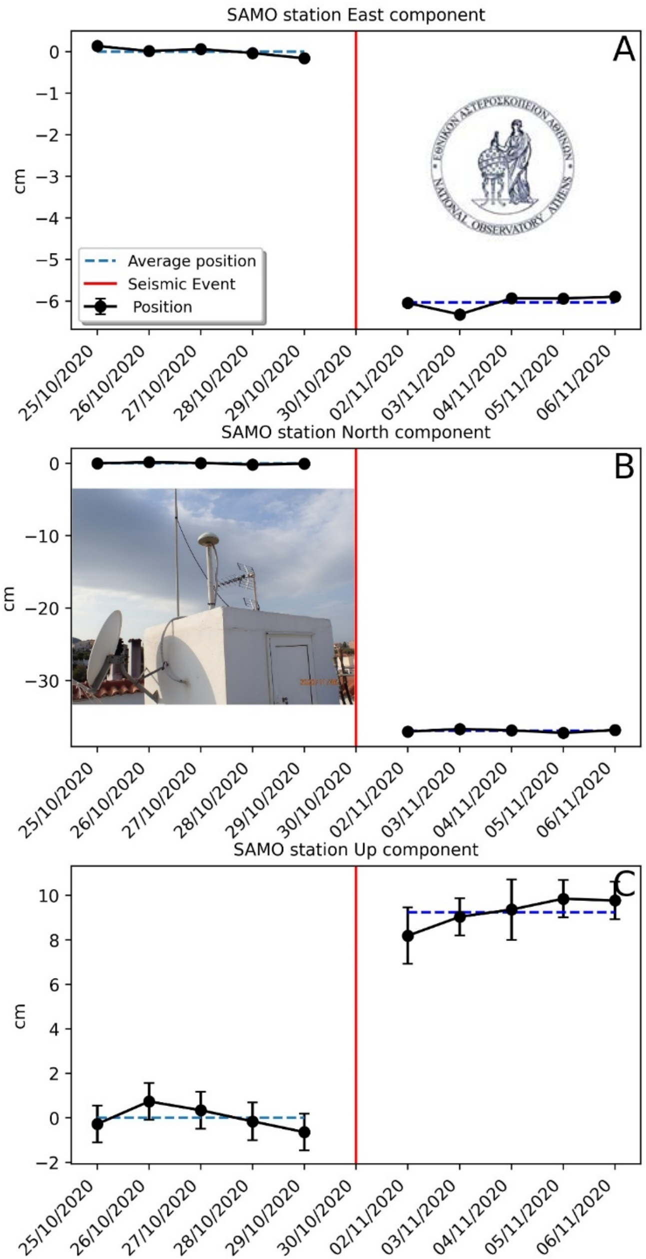
ISSN 2653-9454
Issue No. 21, November 2020

RESULTS FROM SAR INTERFEROMETRY AND GNSS



The co-seismic interferogram (wrapped phase; cropped swath) over Samos island. Top panel shows the image pair Oct. 24-Oct.30, 2020. Bottom panel: Oct. 18-Oct. 30, 2020. The ascending InSAR results show that most of Samos moved roughly upwards with the exception of a coastal strip from Agios Konstantinos to Kokkari that moved roughly downwards. The interferograms are draped over Google Earth imagery.

ISSN 2653-9454
Issue No. 21, November 2020



COSEISMIC MOTION OF THE GNSS STATIONS

COSEISMIC EFFECTS

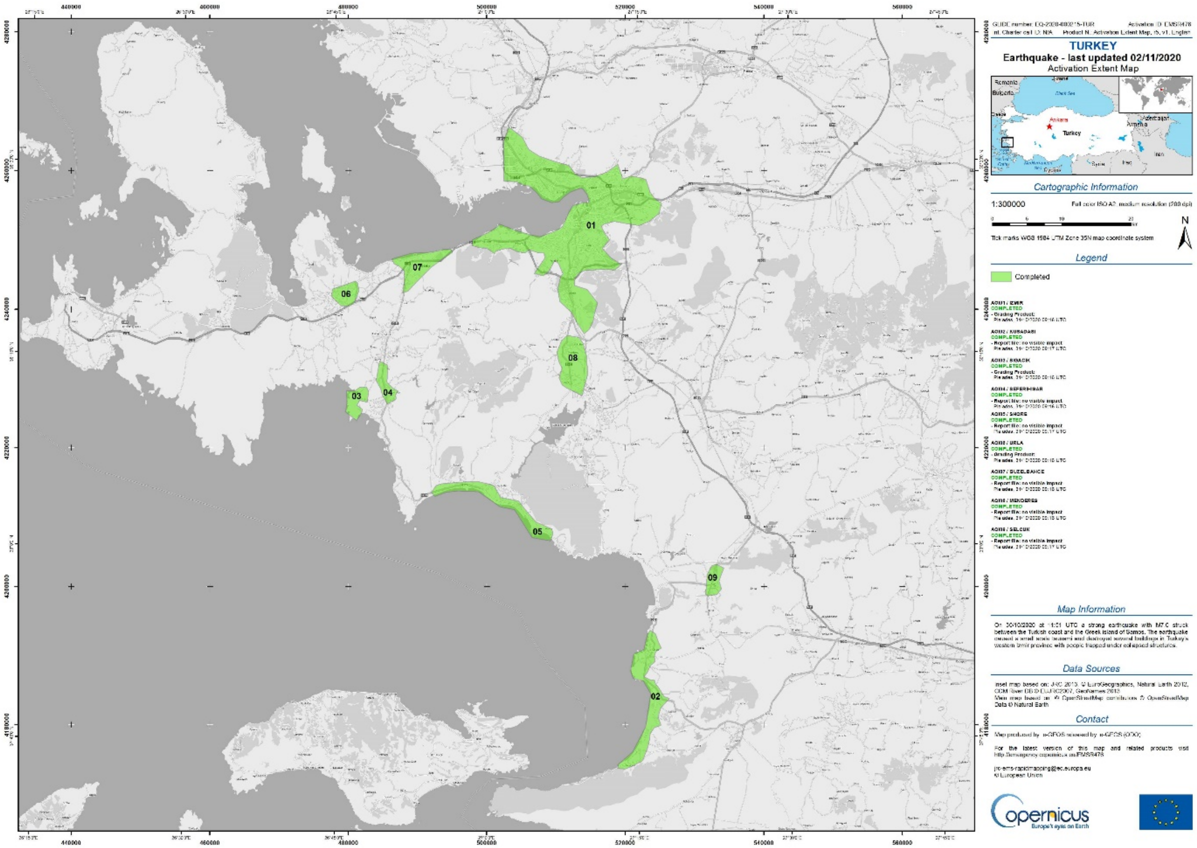
The NOA scientific team presented the co-seismic displacements, which were obtained from the difference between trend lines best fitting to time series of pre-seismic coordinates about 5 days before the mainshock and of post-seismic coordinates 5 days after. The horizontal displacement pattern is in full agreement with the normal-slip kinematics of the rupture. The **coseismic displacements** reached **37-cm of horizontal motion** towards south and **8-cm of uplift** (at Karlovasi town centre). In addition, coseismic displacements of the order of a few cm were measured at GNSS stations in Ikaria, Chios, and in Cesme and Izmir.

Position time series (E, N, Up) of station SAMO during the period 25 October – 6 November 2020. The co-seismic offsets (see dashed lines) are the following: dE = -6 cm, dN = -37 cm and dU = +8 cm. The red vertical lines indicate the timing of the main shock. Inset photo shows the SAMO antenna.

The antenna was inspected by A. Ganas on Friday 6 November 2020 and was found in excellent condition while the host-building suffered no damage or tilt due to the earthquake.

ISSN 2653-9454
Issue No. 21, November 2020

COPERNICUS
EMERGENCY MANAGEMENT SERVICE - MAPPING



Data and maps of the Copernicus Emergency Management Service/Mapping are freely available to all agencies and everyone competent to search and rescue operations and to the disaster management during the first crucial hours of the disaster response phase. Maps were produced for the affected areas in Turkey.

From
https://emergency.copernicus.eu/mapping/list-of-components/EMSR476/ALL/EMSR476_AOI01

ISSN 2653-9454
Issue No. 21, November 2020 | 82

EARTHQUAKE ENVIRONMENTAL EFFECTS
TRIGGERED BY THE OCTOBER 30, 2020, Mw 6.9 SAMOS EARTHQUAKE

The October 30, 2020, Mw 6.9 Samos earthquake triggered **primary and secondary environmental effects** in Samos Island. The primary environmental effects comprise permanent surface deformation of tectonic origin including uplift and subsidence, and coseismic surface ruptures.

The **permanent surface deformation** has been detected in the northwestern and southeastern parts of Samos. In the northwestern part of Samos, coastal uplift has been generated in the vessel shelter of Karlovassi as well as along the Potami beach, the Punta promontory and Agios Isidoros beach located west of the Karlovassi area. In the southeastern part of Samos, coastal uplift has been observed in the coastal areas of Potokokaki and Psili Ammos beaches and in Pythagorio port.

The **coseismic surface ruptures** has been also observed in the northwestern part of Samos and more specifically in the areas of Agios Nikolaos, Agios Elias and Kontakaeika villages. They were almost continuous, with a total length reaching almost 1 km. They ruptured roads, pavements, fields, slopes and they caused damage to adjacent buildings in the aforementioned buildings. They considered as the surface expression of the western termination of the seismic fault of the October 30, 2020 Mw 6.9 earthquake.

The secondary earthquake environmental effects included tsunami, slope failures and liquefaction phenomena.

Slope failures were also triggered in several sites in the earthquake-affected area. They were observed along the slopes of the road leading from Vathy located in the northeastern part Samos to Karlovassi located in the northwestern part of the island. Slope failures were also observed in Pyrhagorio area and more specifically in areas susceptible to the generation of earthquake environmental effects, characterized by steep and abrupt slopes and intensively faulted formations. Among the most impressive and characteristic examples are the landslides and rockfalls that have generated close to Avlakia area resulting in temporary traffic disruption.

ISSN 2653-9454
Issue No. 21, November 2020

EARTHQUAKE ENVIRONMENTAL EFFECTS TRIGGERED BY THE OCTOBER 30, 2020, Mw 6.9 SAMOS EARTHQUAKE

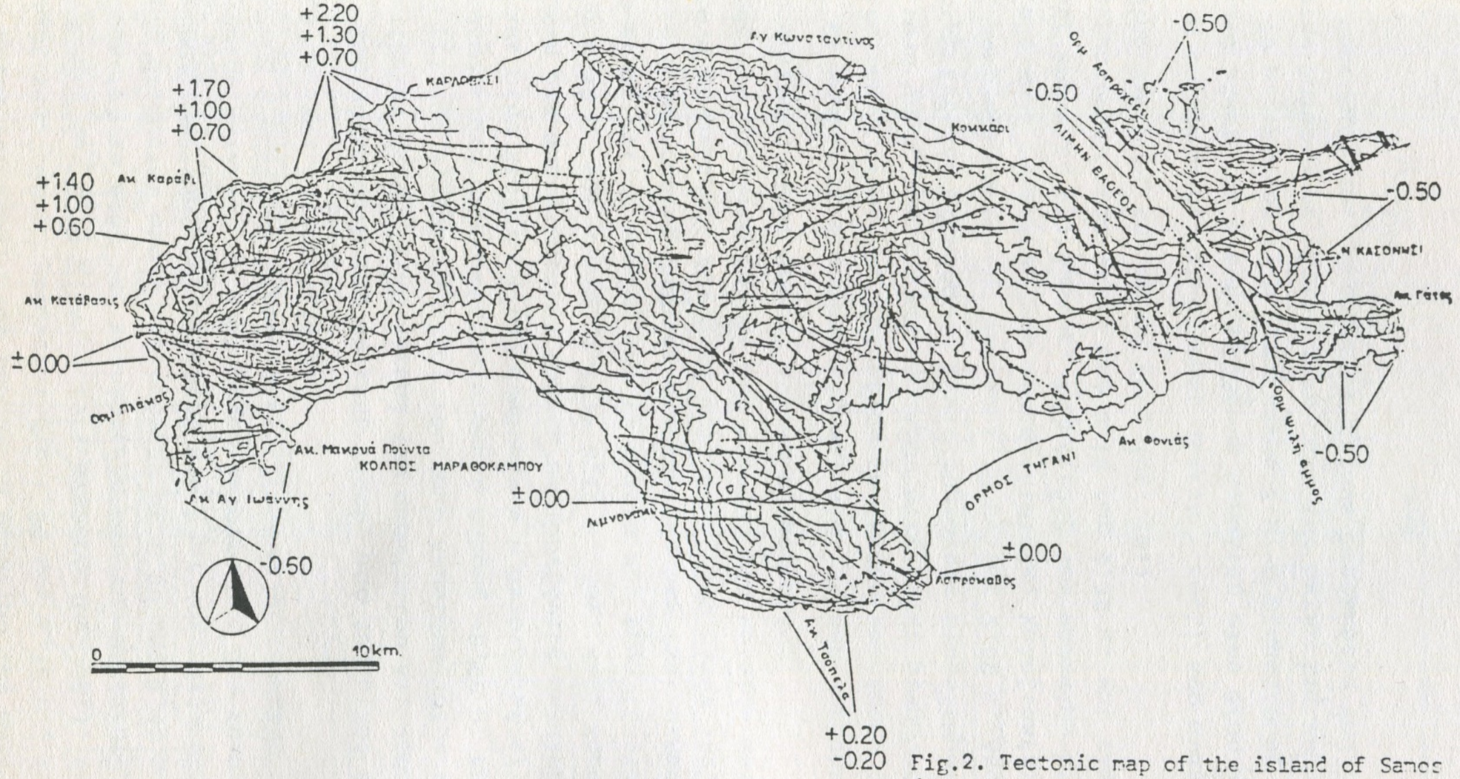
Liquefaction was also generated in coastal areas with effects on port facilities and phenomena in adjacent coastal areas. In particular, ground cracks and ejection of liquefied material were detected in the Malagari port and the adjacent beach and in the Vathy port. In ports, the triggered liquefaction phenomena caused damage to quay walls and jetties, but the ports remained operational.

As regards the **tsunami** impact on Samos Island, a post-event tsunami field survey was conducted by the scientific team of the Department of Dynamic Tectonic Applied Geology along with Dr. Gerassimos Papadopoulos shortly after the earthquake and the subsequent tsunami. They examined videos and interviewed with eyewitnesses and local authorities. The following conclusions were drawn:

- In Vathy, the first and second strong tsunami inundations started at about 12:04 and 12:24 am UTC, respectively.
- In Karlovassi, the first sea motion was retreat, then inundation happened ~12:00 am.
- Maximum run-up measured amsl was ~2 m and ~1.7 m in Vathy and Karlovasi at run-in distances of ~120 m and ~80 m, respectively.
- In Vathy, the water flow velocity inland ranged between 1.0 and 1.9 m/s.
- Material damage occurred in coastal shops, offices and other commercial stores as well as in cars and small vessels that drifted away by the tsunami.
- Run-up of ~1 m was reported from Komi, south Chios island, where small vessels crashed in the water break stones.
- Run-up of ~1 m but no damage was reported from Evdilos and Agios Kirikos ports of Ikaria island.
- Run-up less than 1 m was reported from Andros, Patmos and other islands.
- From 7 tide-gauge records they calculated tsunami magnitude Mt=6.8.

ISSN 2653-9454
Issue No. 21, November 2020

ANCIENT SHORELINES IN SAMOS ISLAND



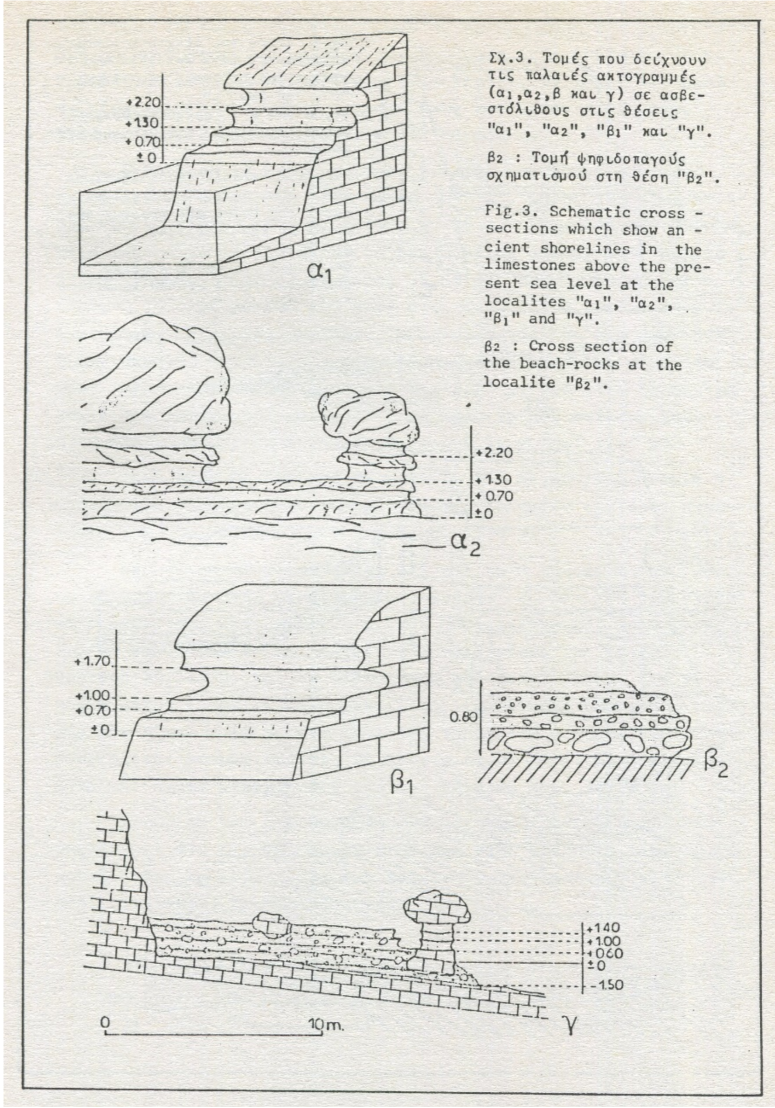
Σχ.2. Τεκτονικός χάρτης της νήσου Σάμου, (από το Γεωλογικό χάρτη της Ελλάδος. Νήσος Σάμος. (Θεοδωρόπουλος,Δ.1979. Φύλλα Νέον Καρλοβάσιον-Λιμήν Βαθέως), τροποποιημένος. Οι αριθμοί δίνουν τα υψόμετρα των παλαιών ακτογραμμών στις διάφορες θέσεις μετρήσεως.

Fig.2. Tectonic map of the island of Samos (from the Geological map of Greece. Samos island.(Theodoropoulos,D.1979, Neon Karlovassion-Limin Vatheos Sheet), modified. The numbers give the height of the ancient shorelines, at measurement sites.

From *Mourtzas and Stauropoulos (1989)*

ISSN 2653-9454
Issue No. 21, November 2020

ANCIENT SHORELINES IN SAMOS ISLAND

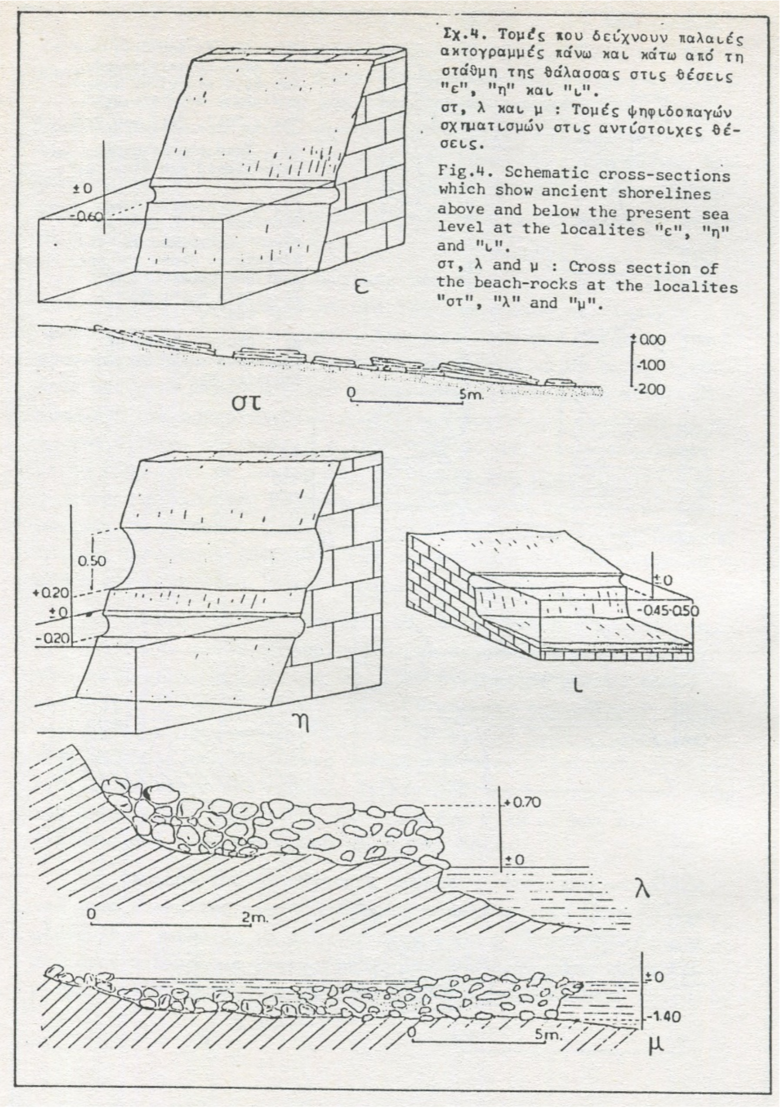


Σχ.3. Τομές που δείχνουν τις παλαιές ακτογραμμές (α1,α2,β και γ) σε ασβεστόλιθους στις θέσεις "α1", "α2", "β1" και "γ".

β2 : Τομή ψηφιδοπαγούς σχηματισμού στη θέση "β2".

Fig.3. Schematic cross - sections which show an - cient shorelines in the limestones above the present sea level at the localites "α1", "α2", "β1" and "γ".

β2 : Cross section of the beach-rocks at the localite "β2".



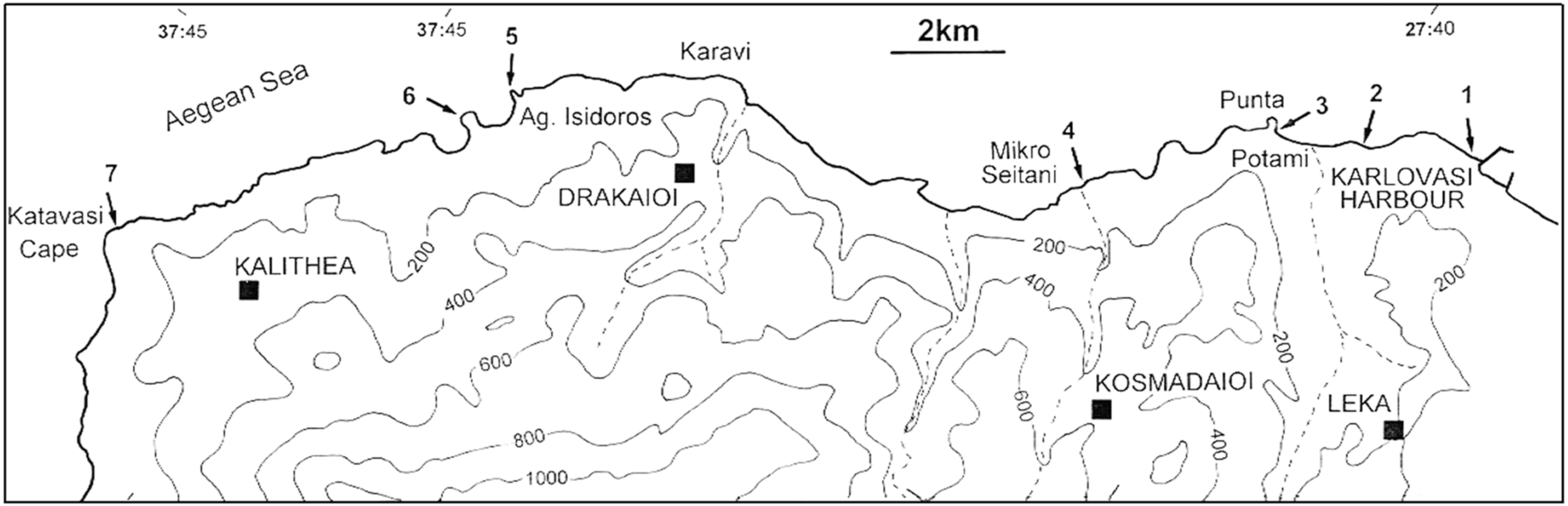
Σχ.4. Τομές που δείχνουν παλαιές ακτογραμμές πάνω και κάτω από τη στάθμη της θάλασσας στις θέσεις "ε", "η" και "ι".
στ, λ και μ : Τομές ψηφιδοπαγών σχηματισμών στις αντίστοιχες θέσεις.

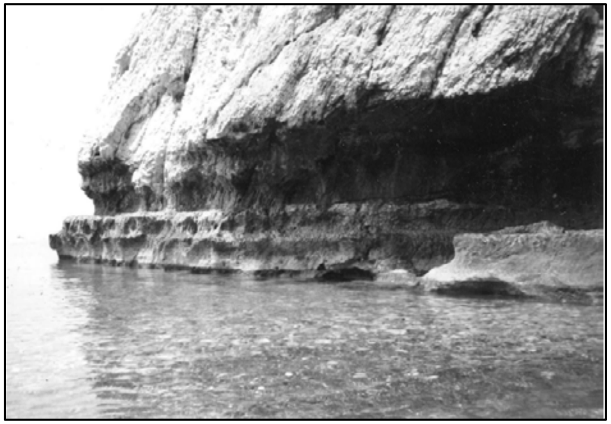
Fig.4. Schematic cross-sections which show ancient shorelines above and below the present sea level at the localites "ε", "η" and "ι".
στ, λ and μ : Cross section of the beach-rocks at the localites "στ", "λ" and "μ".

From *Mourtzas and Stauropoulos (1989)*

ISSN 2653-9454
Issue No. 21, November 2020 | 86

RAISED BEACHES AT NORTHWESTERN SAMOS





Mikro Seitani **Punta Promontory**

From *Stiros et al. (2000)*

ISSN 2653-9454
Issue No. 21, November 2020

PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS
PERMANENT SURFACE DEFORMATION AND COASTAL UPLIFT

Karlovassi

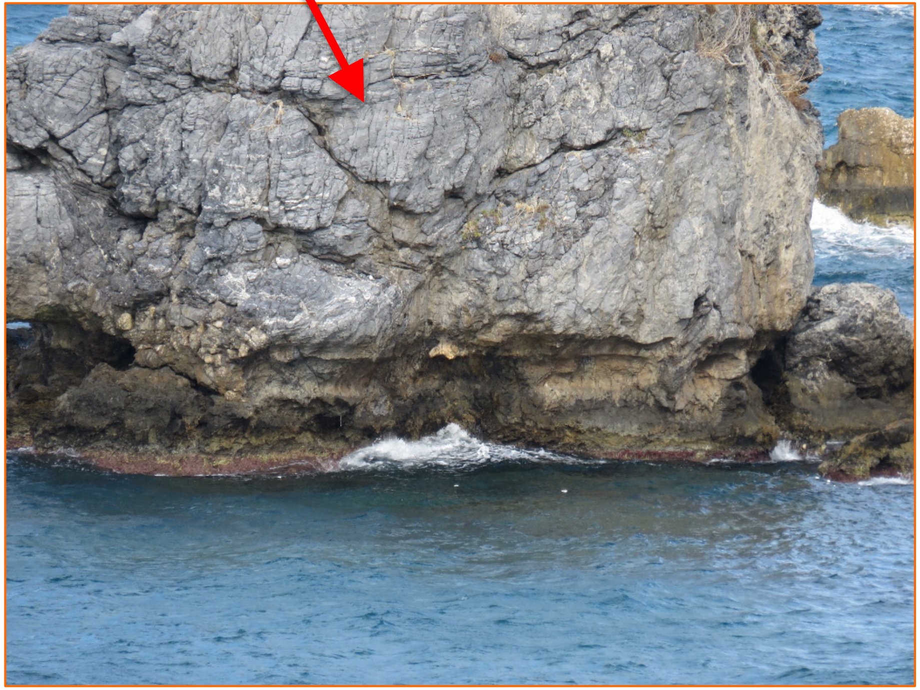
Permanent uplift in the Karlovassi coastal area. It has been observed in Karlovassi port. It has been imprinted not only on rocks for protection of the jetty, but also on the pier. Based on field measurements conducted by the scientific team of the NKUA, the uplift reached 24 cm.

ISSN 2653-9454
Issue No. 21, November 2020 | 88

PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS
PERMANENT SURFACE DEFORMATION AND COASTAL UPLIFT

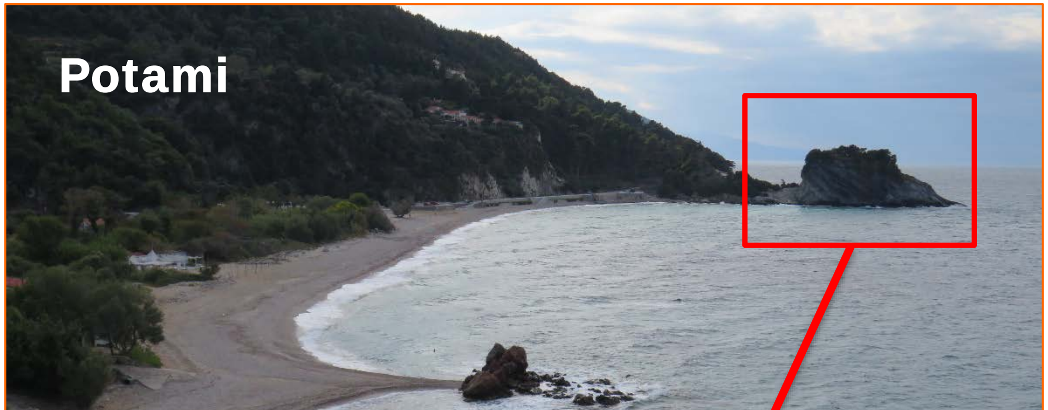
Potami

Permanent coseismic uplift in the area west of the Karlovassi port has been detected by the scientific team of NKUA. It has been imprinted on marbles of the Kerketeas nappe along the rocky coast of Potami (east of Agios Nikolaos church).

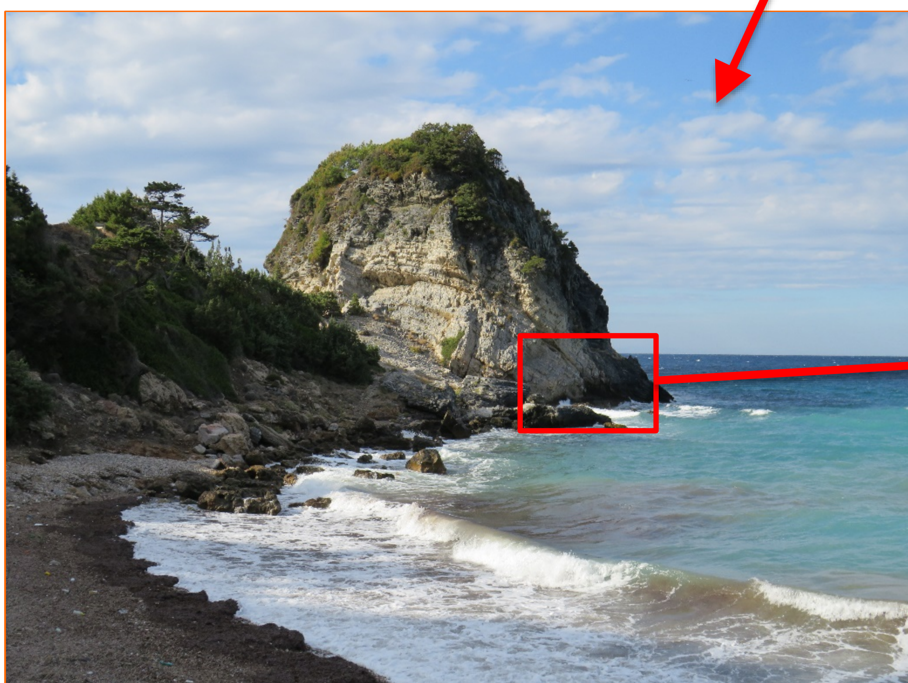


Newsletter of
Environmental, Disaster, and Crises Management Strategies
ISSN 2653-9454
Issue No. 21, November 2020

PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS
PERMANENT SURFACE DEFORMATION AND COASTAL UPLIFT



Permanent coseismic uplift in the area west of the Karlovassi port has been detected by the scientific team of NKUA. It has been imprinted on marbles of the Kerketeas nappe along Punta Promontory (west of Agios Nikolaos church).



ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Geography – Climatology

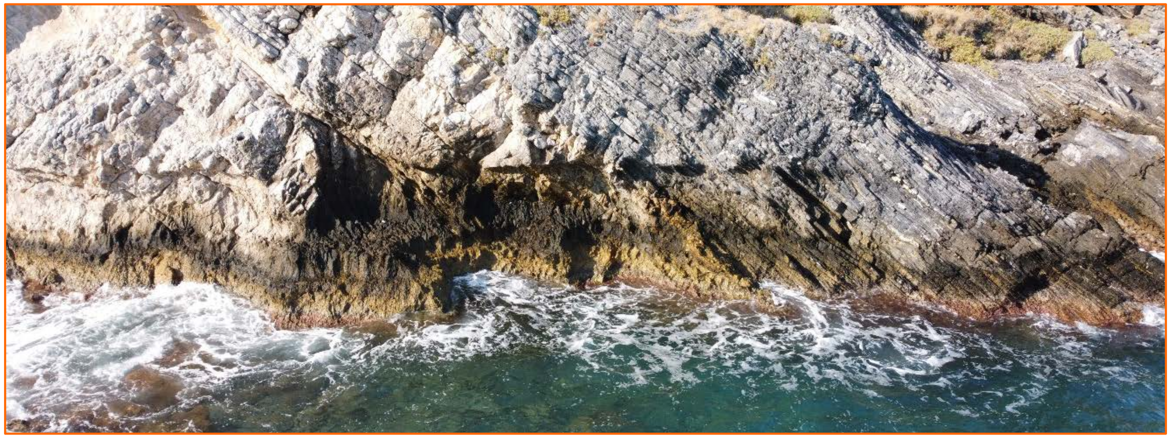
PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS

PERMANENT SURFACE DEFORMATION AND COASTAL UPLIFT

The scientific team mapped the coastline of Samos and reviewed the sea level indicators recorded in 2015, in order to compare them with their current post-earthquake position. Geological, geomorphological, and biological indicators were mapped, such as tidal, coastal benches, biogenic structures and karst geoforms and structures.

Agios Isidoros, uplift of 35 cm.
Comparison of current measurements with values from field work conducted in 2015.

Underwater tidal notch observed NE of **Mourtia** beach, which was uplifted by 8 cm. Comparison of current measurements with values from field work conducted in 2015.



Punta, uplift of 22 cm, comparison with values from Stiros et al. (2000)

Prof. N. Evelpidou
Dr. E. Karkani
MSc I. Kampolis

ISSN 2653-9454
Issue No. 21, November 2020

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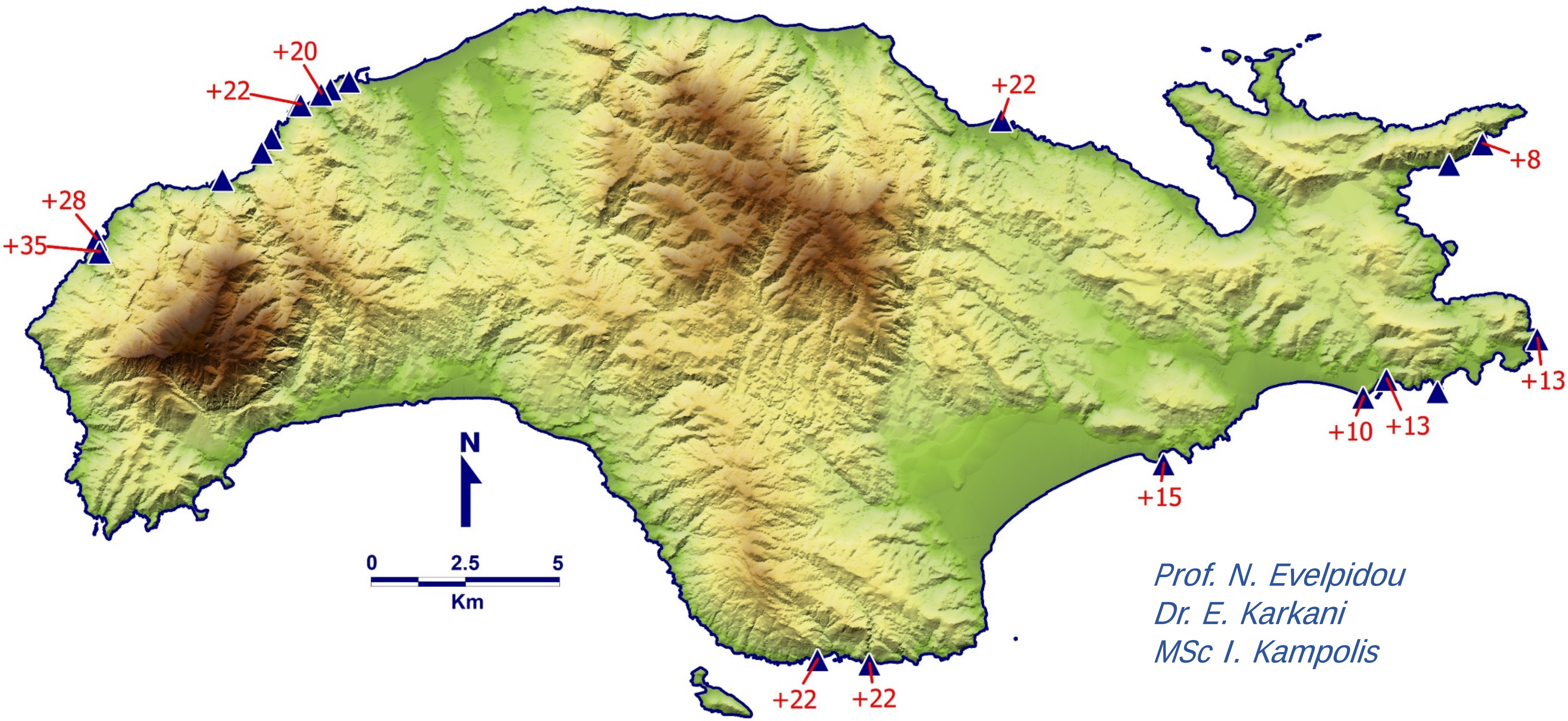
PERMANENT SURFACE DEFORMATION AND COASTAL UPLIFT



Prof. N. Evelpidou
Dr. E. Karkani
MSc I. Kampolis

Preliminary map with indicative measurement results, which illustrates the magnitude of the uplift along the coastal zone based on comparative measurements between 2015 and 2020, on new measurements and on a study on raised beaches at northwestern Samos conducted by Stiros et al. (2000). The blue triangles indicate sites with completed evaluation of comparative measurements. The red numbers correspond to the coseismic uplift induced by the October 30, 2020.

ISSN 2653-9454
Issue No. 21, November 2020

PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS
PERMANENT SURFACE DEFORMATION AND COASTAL UPLIFT IN SE SAMOS

According to eyewitnesses in Potokaki area, the sea receded permanently by 3 meters from its original position immediately after the earthquake, which indicates earthquake-induced uplift.

From https://twitter.com/GerasimosPapad2/status/1323949537954844672/photo/1

ISSN 2653-9454
Issue No. 21, November 2020

PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS
PERMANENT SURFACE DEFORMATION AND COASTAL UPLIFT IN SE SAMOS

Coseismic uplift detected in abandoned breakwater construction in Potokaki area
(From https://twitter.com/GerasimosPapad2/status/1323949537954844672)

ISSN 2653-9454
Issue No. 21, November 2020

PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS
PERMANENT SURFACE DEFORMATION AND COASTAL UPLIFT IN SE SAMOS

Coseismic uplift of about 20 cm detected in Pythagorio port

ISSN 2653-9454
Issue No. 21, November 2020

PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS

COSEISMIC SURFACE RUPTURES AND SURFACE EXPRESSION OF THE SEISMIC FAULT

Coseismic surface ruptures were observed in Agios Nikolaos area, at a distance of about 5 km east of Karlovasi port.

The coseismic surface ruptures were observed not only in fields and roads but also in adjacent slopes resulting in clear offsets of several cm, both horizontal and vertical.

ISSN 2653-9454
Issue No. 21, November 2020

PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS

COSEISMIC SURFACE RUPTURES AND SURFACE EXPRESSION OF THE SEISMIC FAULT

Coseismic surface ruptures and offsets south of Agios Nikolaos village (left) and in the coastal zone of Agios Nikolaos (middle).

Coseismic surface ruptures and offsets in olive fields located south of Agios Nikolaos.

ISSN 2653-9454
Issue No. 21, November 2020

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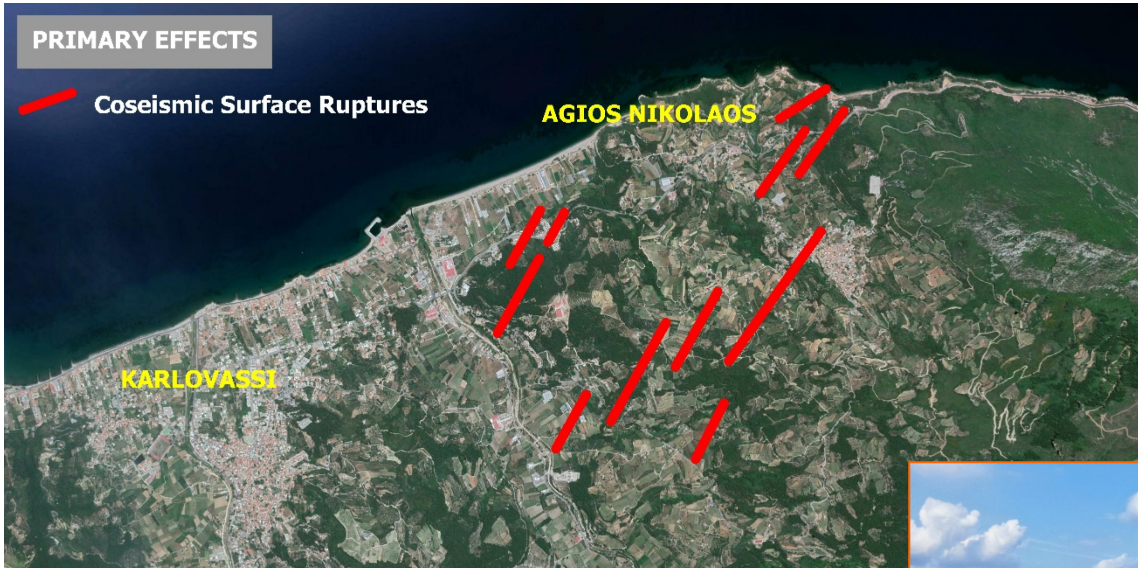
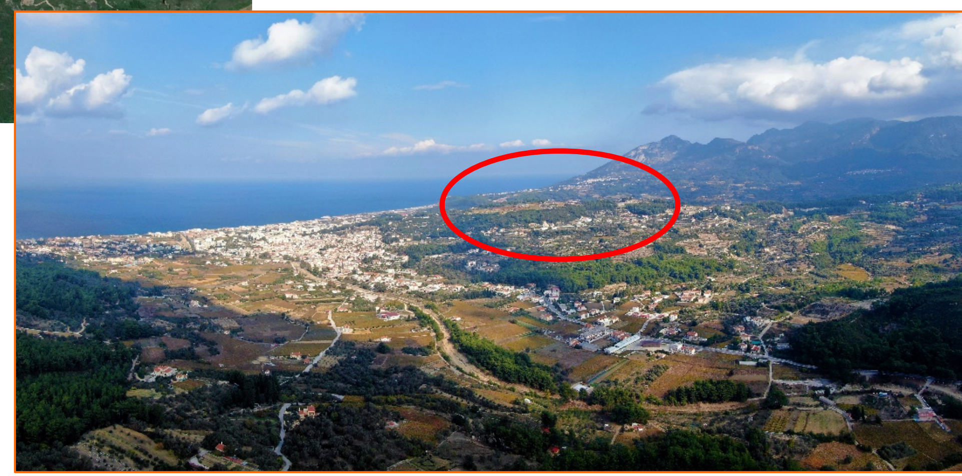
COSEISMIC SURFACE RUPTURES AND SURFACE EXPRESSION OF THE SEISMIC FAULT





Primary environmental effects were detected in the area of Agios Nikolaos, located in the northwestern part of the earthquake-affected island of Samos. More specifically, they were surface ruptures observed in fiels, roads and on the adjacent slopes. Their strike varied from N40 to N70 and their offset from 5 to 8 cm.

They caused deformation and damage to the asphalt pavement of the road leading from Vathy to Karlovassi. Based on the correlation of all aforementioned data, these coseismic surface ruptures can be considered as the western termination of the seismic fault that generated the October 30, 2020 Samos earthquake.

ISSN 2653-9454
Issue No. 21, November 2020

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Department of Dynamic Tectonic
Applied Geology

PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS

SURFACE RUPTURES AND SURFACE EXPRESSION OF THE SEISMIC FAULT

Coseismic surface ruptures were also observed in the area west of Kontakaeika village, located south of Agios Nikolaos area. They were observed continuously in the built environment of the village and they resulted damage to buildings, perimeter walls, pavements and roads.

ISSN 2653-9454
Issue No. 21, November 2020 | 99

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS

SURFACE RUPTURES AND SURFACE EXPRESSION OF THE SEISMIC FAULT

Coseismic surface ruptures were also observed in the area west and southwest of Kontakaeika village. They were observed continuously disrupting olive fields with vertical offset.

ISSN 2653-9454
Issue No. 21, November 2020

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Applied Geology

PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS

SURFACE RUPTURES AND SURFACE EXPRESSION OF THE SEISMIC FAULT

Coseismic surface ruptures observed in the area of Agios Nikolaos

ISSN 2653-9454
Issue No. 21, November 2020

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Department of Dynamic Tectonic
Applied Geology

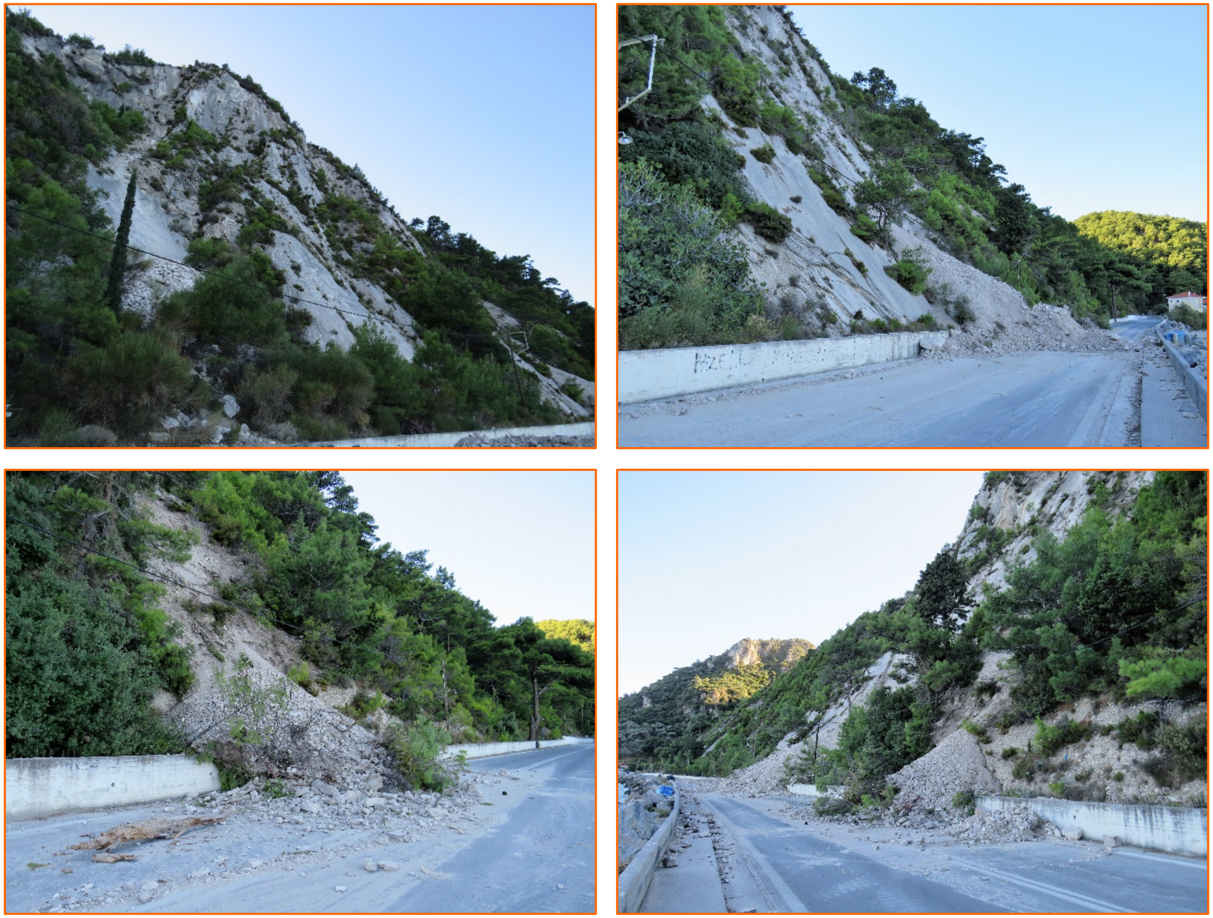
PRIMARY EARTHQUAKE ENVIRONMENTAL EFFECTS

DAMAGE INDUCED BY PRIMARY EFFECTS

Kontakaeika village, located south of Agios Nikolaos, suffered damage to its buildings. The buildings are located close to the coseismic surface ruptures observed not only to the adjacent fields, slopes and roads but also within the village. The observed damage included not only non-structural damage comprising extensive cracking of walls but also heavy structural damage in their columns.

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS

SLOPE MOVEMENTS ALONG THE NORTHERN COASTAL PART OF SAMOS



Slope failures were generated along coastal slopes in Avlakia area. The area has been strongly affected by NW-SE striking normal faults. Based on the neotectonic map of Samos Island, these normal faults have been considered as inactive. Taking into account the interferometric products of several scientific teams for assessing the surface deformation on Samos, they are observed in an area characterized by subsidence.

ISSN 2653-9454
Issue No. 21, November 2020

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
SLOPE MOVEMENTS AND PROTECTION MEASURES

Slope failures along coastal slopes in Avlakia site were reactivated for many days after the generation of the mainshock, during the aftershock sequence. A concrete barrier made of large concrete block has been created along the base of the affected slope in order to protect the road from further slope failures and surface deformation during the aftershock sequence. They help block the rocks and debris from reaching the road. The unstable landslide material is now accumulated behind the barrier.

ISSN 2653-9454
Issue No. 21, November 2020| **104**

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
SLOPE MOVEMENTS AND PROTECTION MEASURES

A similar measure was applied in Pescara del Tronto area (Central Italy), which was severely affected by slope failures triggered by the 2016 Amatrice and Norcia earthquakes.

The use of large and heavy items along the base of a slope affected by an earthquake is usually adopted worldwide as a measure for the safety of passing cars and the protection of the road from further slope failures and surface deformation. These items are usually large concrete blocks or containers for helping block the rocks and debris from reaching the road. The unstable landslide material is accumulated behind the barrier.

From *Mavroulis et al. (2017)*

Scientific Mission of the National and Kapodistrian University of Athens in the earthquake affected central Italy

ISSN 2653-9454
Issue No. 21, November 2020 | 105

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
SLOPE MOVEMENTS ALONG THE NORTHERN COASTAL PART OF SAMOS

Rockfalls and landslides were triggered by the October 30, 2020, Mw 7.0, Samos earthquake in several sites along the road from Vathy to Karlovassi, in the northern part of the island. This part is composed of Neogene deposits and alpine formations of Vourliotes nappe.

ISSN 2653-9454
Issue No. 21, November 2020 | 106

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS

SLOPE MOVEMENTS IN REMATAKI AREA

Remataki area is located at the western part of Pythagoreio. It is characterized by favorable conditions for the generation of slope movements including mainly rockfalls. This susceptibility is also certified by previous generation of such phenomena resulting in damage to vehicles. Nowadays, the road is blocked for implementation of technical works dealing with slope instabilities.

ISSN 2653-9454
Issue No. 21, November 2020

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
2017 SLOPE FAILURE IN REMATAKI AREA

Slope failure in Remataki site was also generated in January 2017 resulting in crash damage to cars

(From http://aegaio.blogspot.com/2017/01/blog-post_238.html)

ISSN 2653-9454
Issue No. 21, November 2020

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
SLOPE MOVEMENTS ALONG THE NORTHERN COASTAL PART OF SAMOS

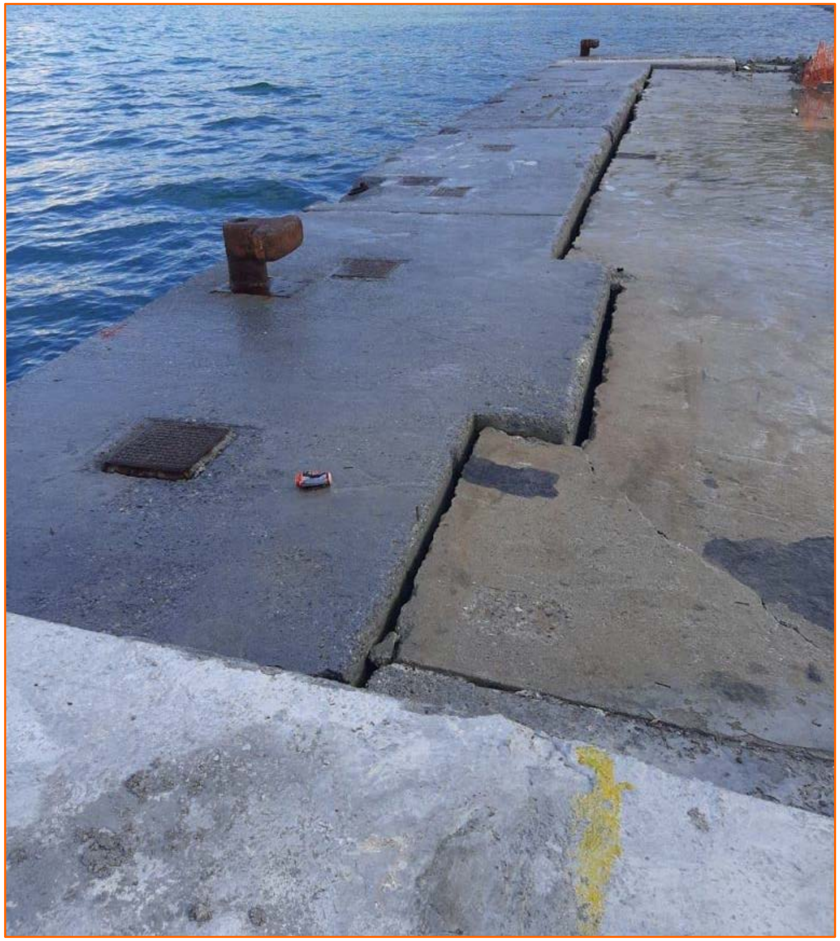
METEOLOGY

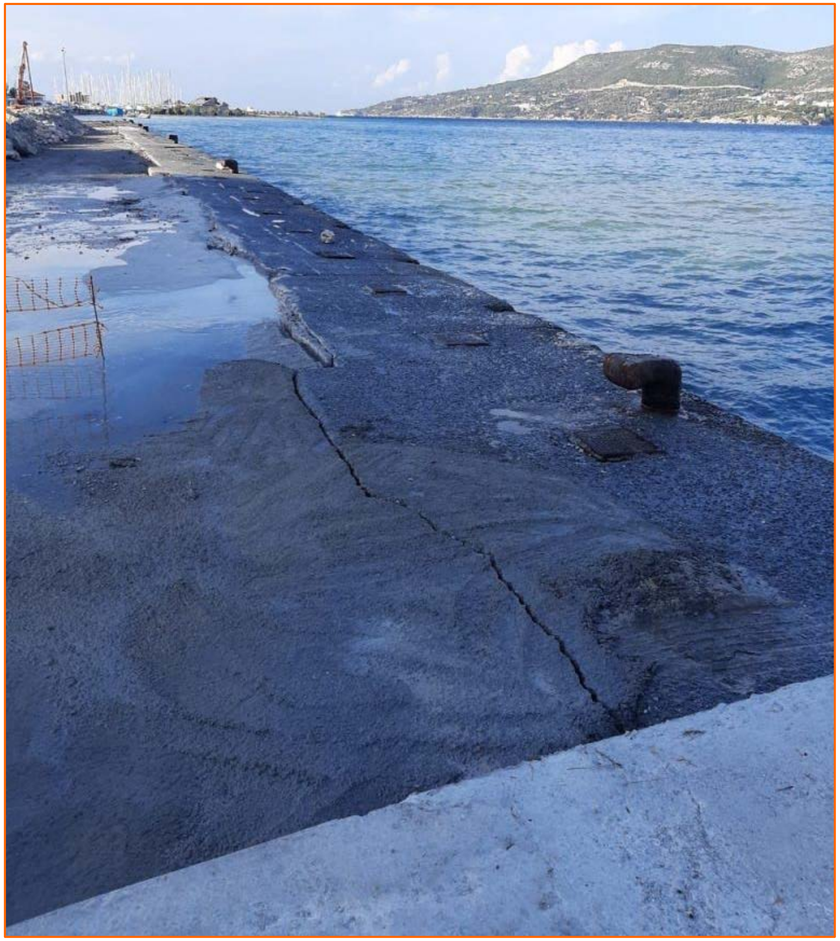
Rockfalls were also generated in Ikaria Island located westwards of Samos. More specifically, they were triggered in the provincial road leading from Evdilos to Akamatra settlements.

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
LIQUEFACTION PHENOMENA

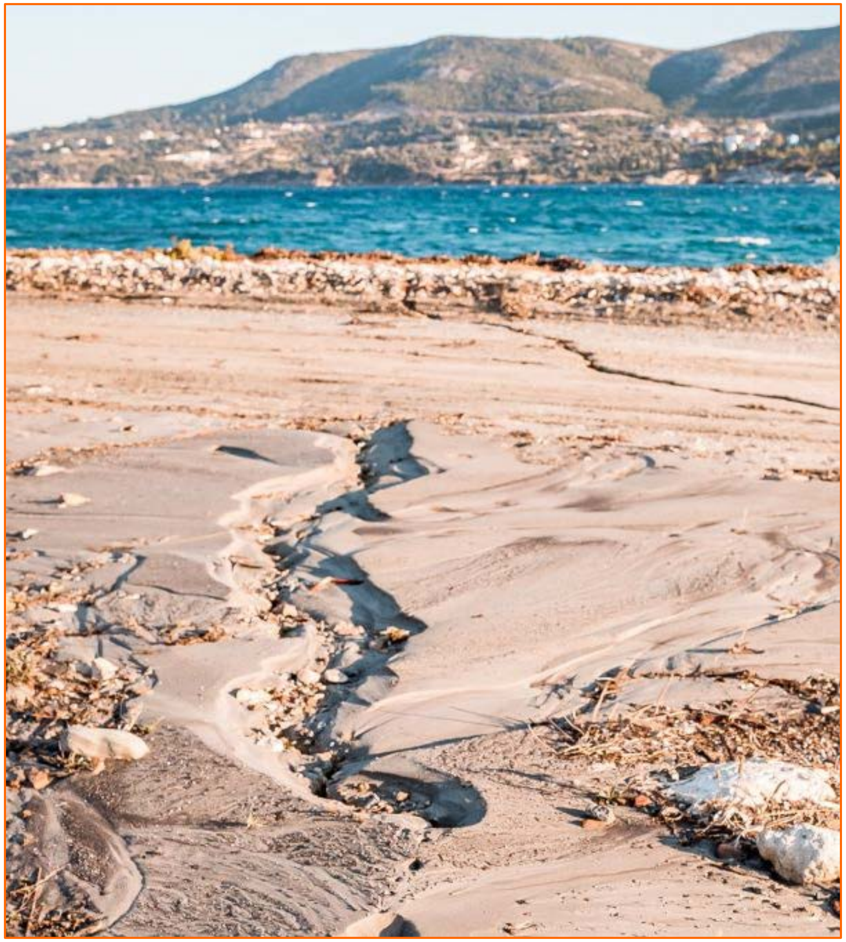




Interaction between concrete blocks that slightly settled and overturned and the dynamically compacted back - fill soil material. Ejection of liquefied sand material in the commercial port of Vathy (Malagari port). The observed liquefaction phenomena and the related damage were triggered by the main shock on October 30, 2020.

ISSN 2653-9454
Issue No. 21, November 2020

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
LIQUEFACTION PHENOMENA



Extensive cracks and ejection of liquefied sand material from the cracks were observed to the coast adjacent to the commercial port of Vathy (Malagari port). The observed liquefaction phenomena were triggered by the main shock on October 30, 2020.

ISSN 2653-9454
Issue No. 21, November 2020 | 111

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS

DAMAGE INDICATING NEAR-SURFACE LIQUEFACTION

Deformation of Vathy port was attributed to a combination of the dynamic consolidation of the back-fill soil material and the near-surface liquefaction induced by the October 30, 2020, Samos earthquake. Extensive cracking and subsidence resulted in tilting of the quay walls towards East.

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS

TSUNAMI INDUCED BY THE OCTOBER 30, 2020, SAMOS EARTHQUAKE

On 11:53:33 the maximum sea retreat of ~20 m occurs, while on 11:54:29 a small inundation happens.

On 11:55:18 inundation restarts, the room residents leave. On 11:55:35 the tsunami strike starts.

For more information on the triggered tsunami: ttps://edcm.edu.gr/images/docs/2020/Samos2020-TSUNAMI-REPORTv2.pdf

ISSN 2653-9454
Issue No. 21, November 2020 | 113

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS

TSUNAMI INDUCED BY THE OCTOBER 30, 2020, SAMOS EARTHQUAKE

On 11:55:42 inundation at h~2 m asl happens.

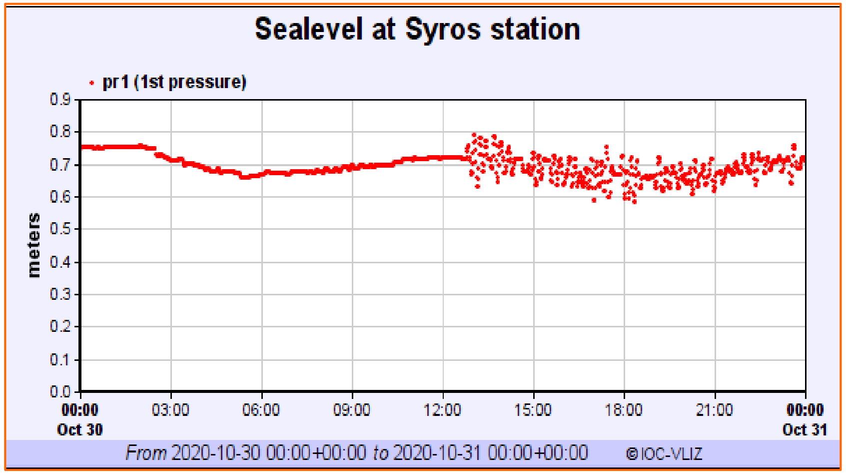
On 11:55:58 the wave retreat and on 14:31 the sea is completely calm.

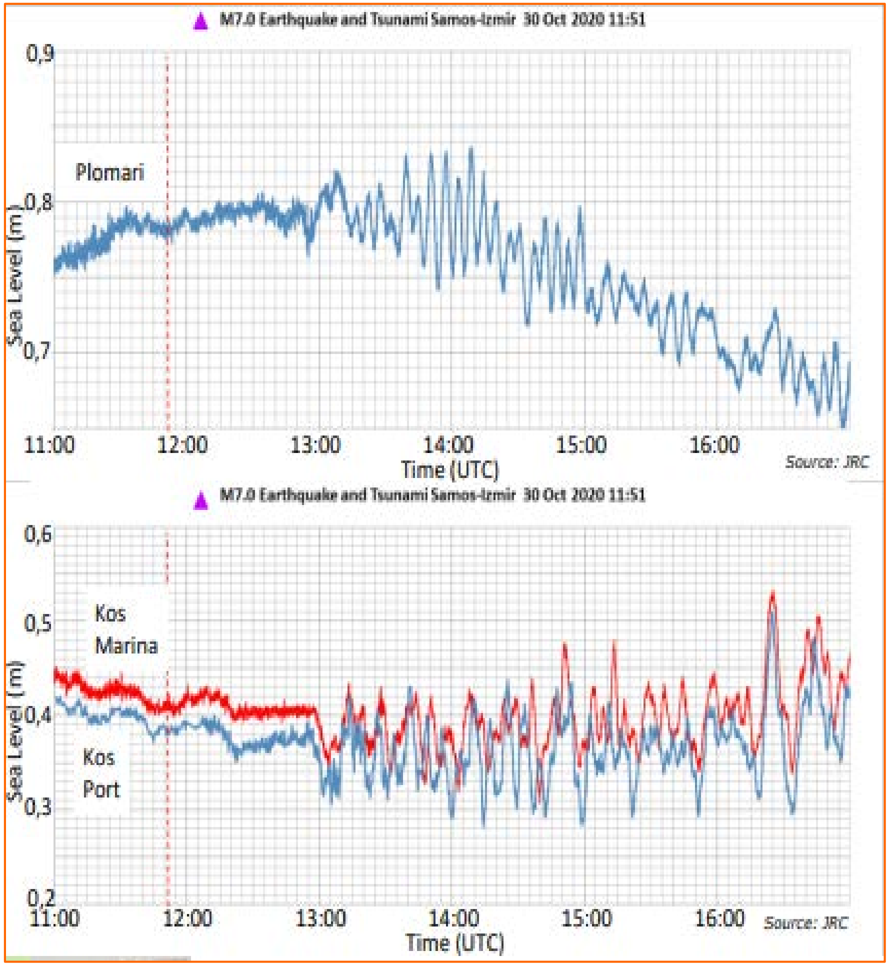
For more information on the triggered tsunami: ttps://edcm.edu.gr/images/docs/2020/Samos2020-TSUNAMI-REPORTv2.pdf

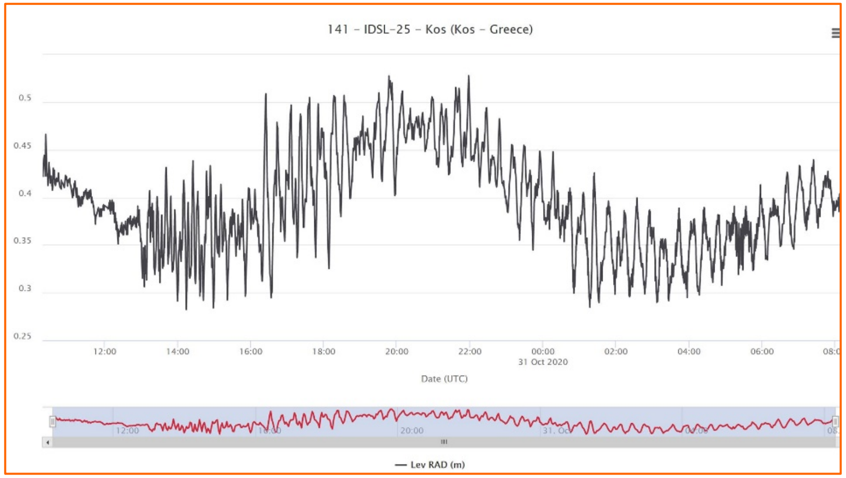
ISSN 2653-9454
Issue No. 21, November 2020

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS

TSUNAMI SEA LEVEL RECORDS BY TIDE GAUGES STATIONS







Tsunami sea level records are available at epicentral distances more than 110 km.

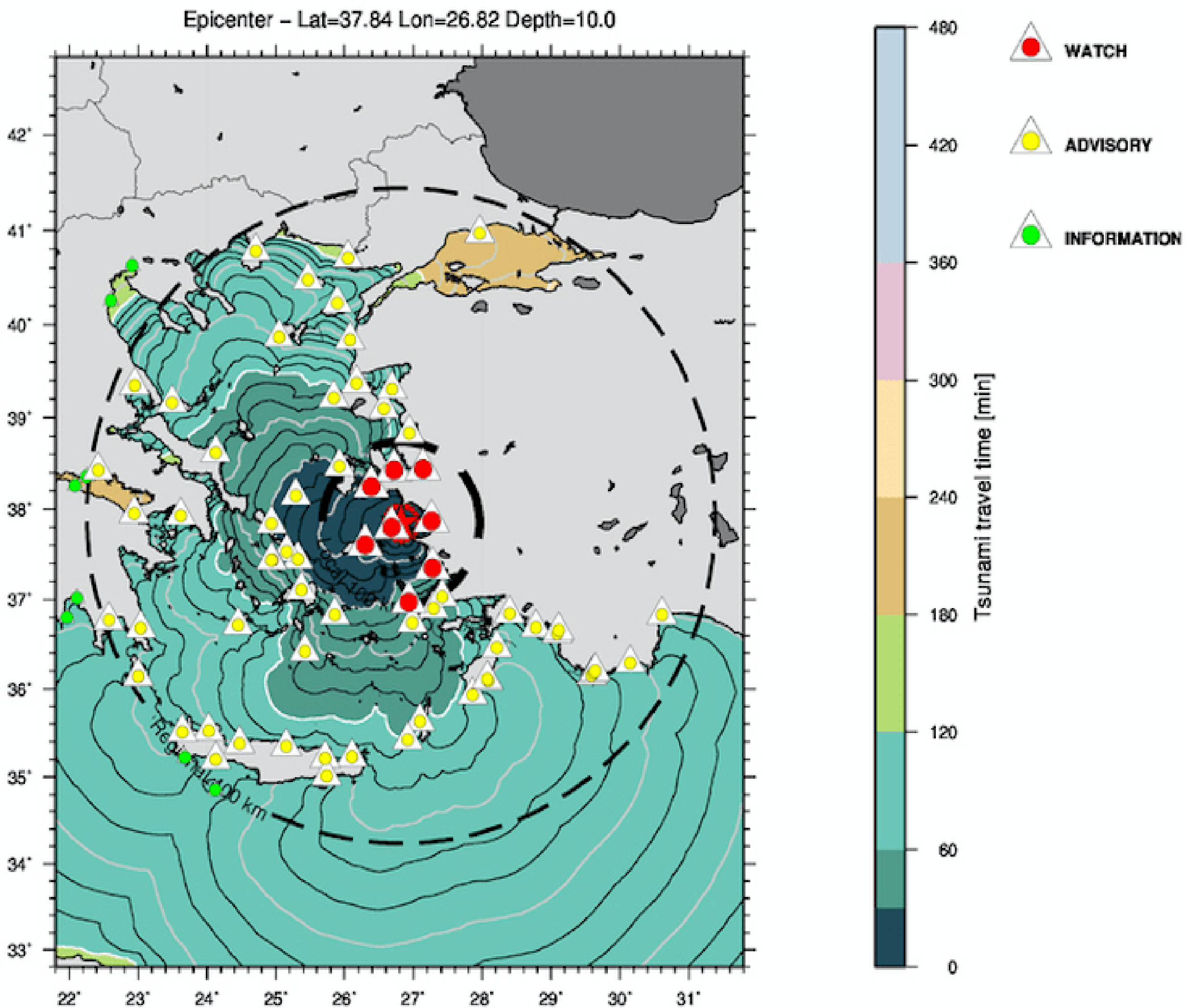
ISSN 2653-9454
Issue No. 21, November 2020 | 115

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
TSUNAMI SEA LEVEL RECORDS

NO.	TIDE STATION	Lat° N	Lon° E	Δ (km)	H (m)
1	**BORDUM**, IDSL-17	37.03217	27.423453	112	0.06
2	**KOS**, IDSL-25	36.898362	27.287792	118	0.19
3	**KOS-MARINA**, IDSL-33	36.891013	27.303632	120	0.18
4	**PLOMARI**, IDSL-41	38.97188	26.37055	122	0.10
5	**SYROS**, HNHS	37.438	24.9411	174	0.10
6	**KASOS**, NOA-03	35.4186	26.92184	274	0.12
7	**HERAKLION**, NOA-10	35.3484	25.15254	286	0.16

ISSN 2653-9454
Issue No. 21, November 2020

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
THEORETICAL ARRIVAL TIMES OF TSUNAMI WAVES



THEORETICAL ARRIVAL TIMES OF TSUNAMI WAVES

The triangles correspond to the tide graphs in the region and colors (red, yellow, green) to the associated alert level.

REAL ARRIVAL TIMES OF TSUNAMI WAVES

First wave at Vathy bay arrived only 5 min after the generation of the earthquake. Inundation at Vathy port initiated at 12:24 (UTC). This time represent the arrival time of the second and stronger wave.

CENTRO ALLERTA TSUNAMI
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

ISSN 2653-9454
Issue No. 21, November 2020

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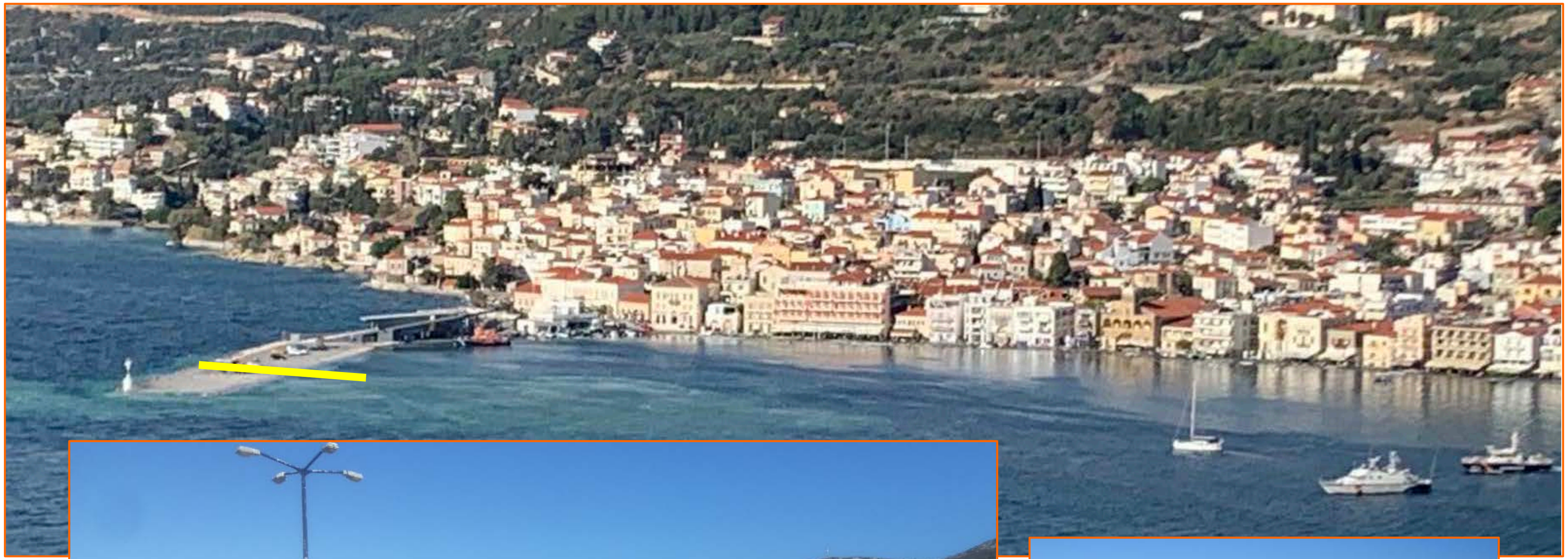
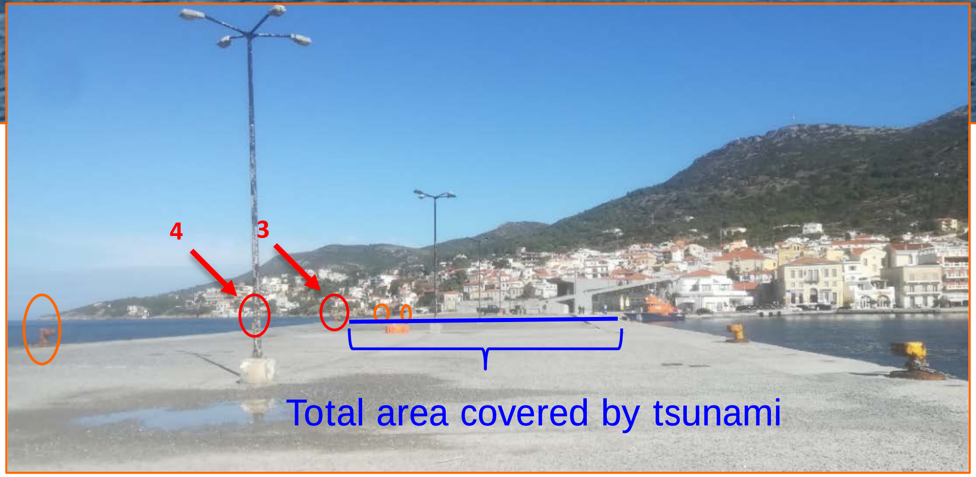
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS

TSUNAMI WAVE HEIGHT IN VATHY BAY





The height of the port jetty at point No3 is 2.07 m and at point No4 1.85 meters. Based on these measurements, on video recordings and information of the Hellenic Coast Guard, the height of the tsunami waves was at least 1.85 m at Vathy port.

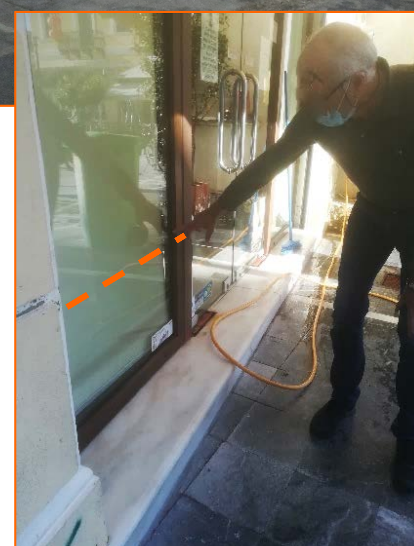
Newsletter of
Environmental, Disaster, and Crises Management Strategies

ISSN 2653-9454
Issue No. 21, November 2020 | **118**

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
TSUNAMI RUN UP IN VATHY BAY

Maximum tsunami run up of 1.69 m was measured in the field. Watermarks were found in every street around the coastal road and the second main road parallel to the shore.



ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS

TSUNAMI RUN-IN IN VATHY BAY

The run-in values derived from field survey shortly after the generation of tsunami and based on eyewitnesses in the eastern part of Vathy Bay

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

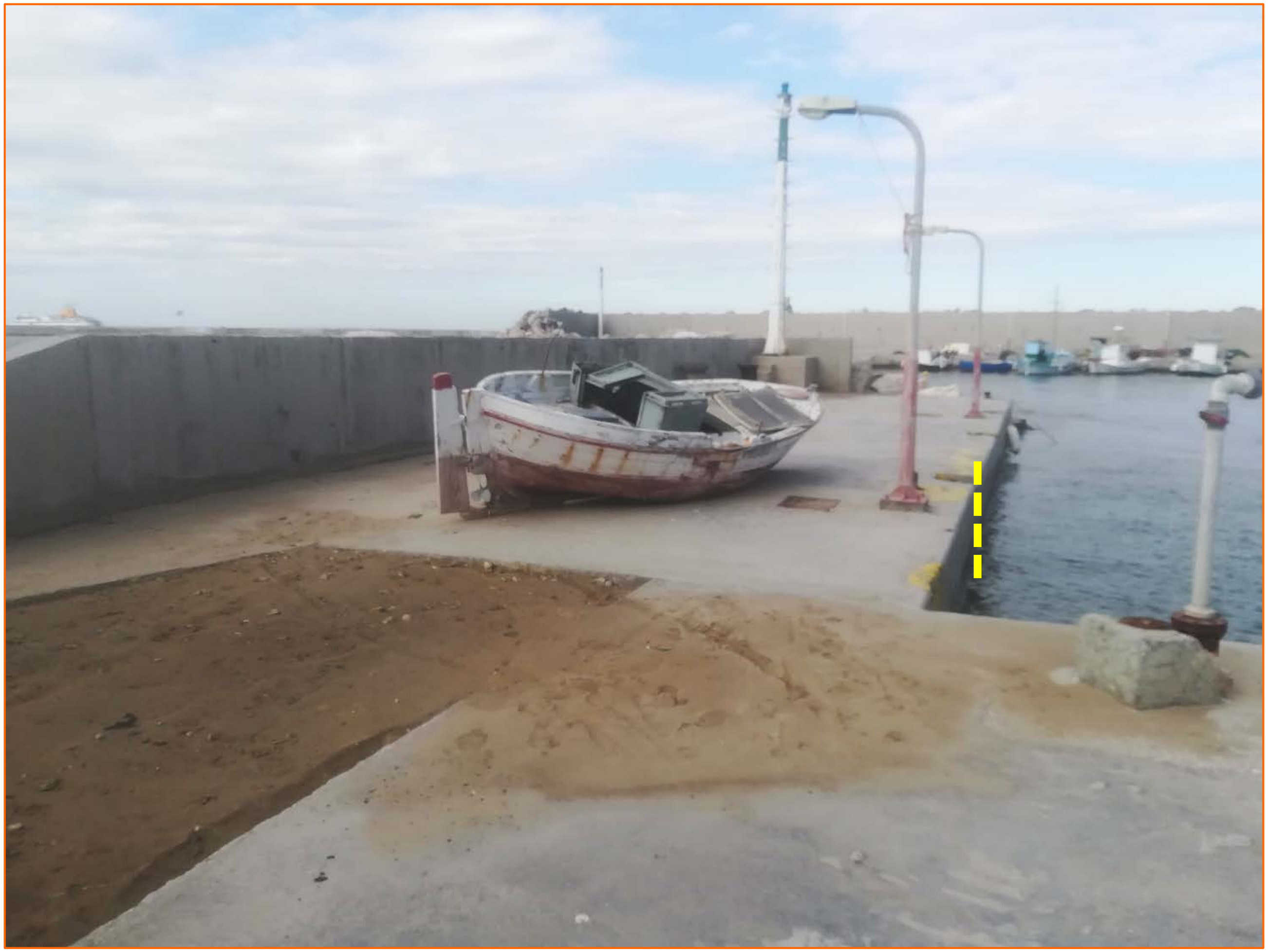
SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
TSUNAMI IN KARLOVASSI PORT

Based on the observed tsunami watermarks at the Karlovassi vessel shelter, at point [A] the inundation was 78m. At point [B], it reached 84 m.

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
TSUNAMI IN KARLOVASSI VESSEL SHELTER



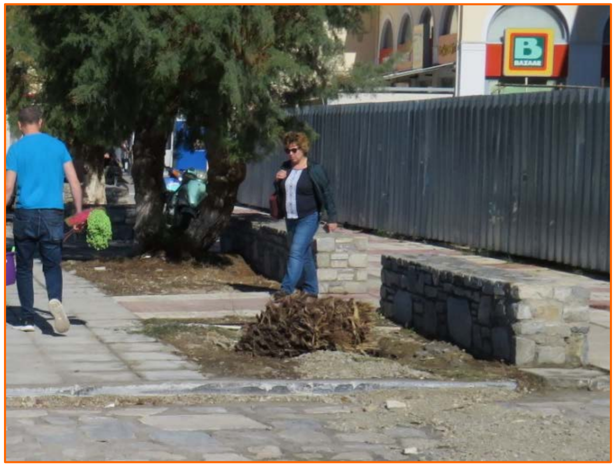
This wave overtopped the pier (h=0.7 m) and penetrated inland.
The small boat was washed ashore.

ISSN 2653-9454
Issue No. 21, November 2020 | **122**

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS

TSUNAMI IMPACT ON THE ENVIRONMENT



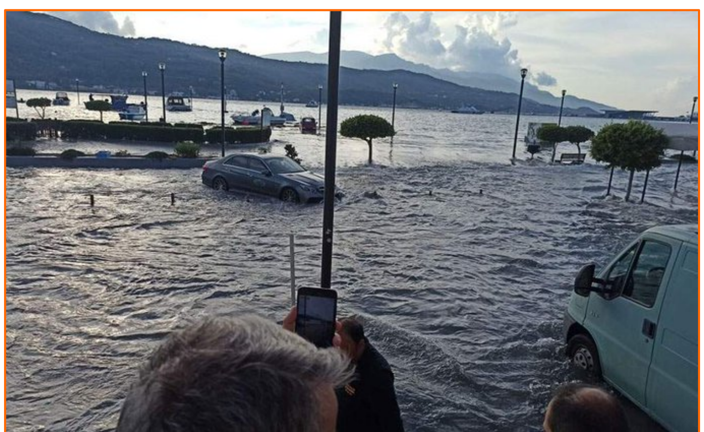
Debris were observed at several sites along the coast as well as in the Pythagoras square. Deposition of sand and pebbles was also observed. Palm trees were uprooted and fishes were found onshore at large distance from the shoreline (about 100 m).

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS

TSUNAMI IMPACT ON HUMAN

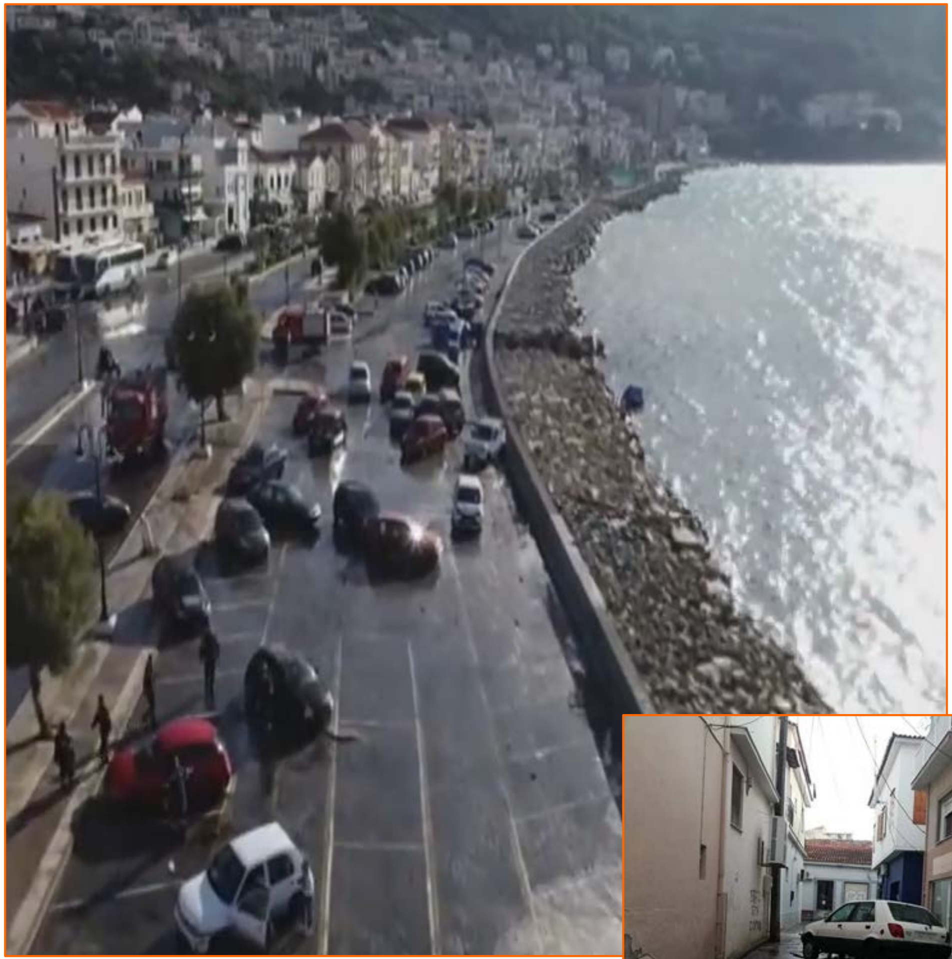


The tsunami was felt by all on board on big vessels and people along several coastal areas of Samos. Some people panicked and run for higher ground.

Newsletter of
Environmental, Disaster, and Crises Management Strategies
ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
TSUNAMI IMPACT ON MOBILE OBJECTS (VEHICLES)



A big container in Malagari port was drifted away. Many cars parked along the coastal road of Vathy town were carried by tsunami. Some of them were carried and found in the narrow streets of the town.

ISSN 2653-9454
Issue No. 21, November 2020 | 125

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
TSUNAMI IMPACT ON MOBILE OBJECTS





Vathy

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
TSUNAMI IMPACT ON MOBILE OBJECTS

Karlovassi

ISSN 2653-9454
Issue No. 21, November 2020 | 127

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS

TSUNAMI IMPACT ON INFRASTRUCTURES

Vathy

ISSN 2653-9454
Issue No. 21, November 2020 | **128**

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS
TSUNAMI IMPACT ON BUILDINGS



Vathy

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS

TSUNAMI DAMAGE ON WOODEN STRUCTURES

ISSN 2653-9454
Issue No. 21, November 2020 | 130

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

STRUCTURAL DAMAGE TO RC BUILDINGS
IN VATHY TOWN

Structural damage to columns of a building with RC frame. The concrete in the columns suffered cracking and disorganization resulting in heavy damage to the frame. The floor over the ground floor suffered heaviest damage, while the rest of the building remained almost intact by the earthquake. The floor act as pilotis, over which floors comprise infill walls.

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

NON-STRUCTURAL DAMAGE TO RC BUILDINGS
IN VATHY TOWN

Non-structural damage to building with reinforced concrete frame and infill walls. It comprised detachment of plaster from the infill walls and extensive cracking and collapse of brick walls. It is significant to note that the rigidity of the building along its height is almost uniform mainly due to the presence of infill walls, which proves their beneficial contribution to the antiseismic behavior of the building, when their are not interrupted (for example in pilotis).

ISSN 2653-9454
Issue No. 21, November 2020 | 132

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

NON-STRUCTURAL DAMAGE TO RC BUILDINGS
IN VATHY TOWN

Non-structural damage to building with reinforced concrete frame and infill walls. It comprised detachment of plaster from the infill walls and extensive cracking of brick walls. The entrance door has been deformed. It constitutes one more example of the beneficial contribution of the infill walls in the ground floor to the antiseismic behavior of the building.

ISSN 2653-9454
Issue No. 21, November 2020 | 133

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

DAMAGE TO RC BUILDINGS IN KARLOVASSI TOWN




The ground floor of this building has been heavily affected, while the upper floor remained almost intact by the earthquake. Structural and non-structural damage were observed. The first comprised heavy damage to columns of the ground floor, while the later included detachment of large pieces of plaster from the infill walls, extensive cracking of plaster and of brick walls, detachment of the walls from the surrounding RC frame and damage to the staircase.

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

DAMAGE TO RC BUILDINGS
IN KARLOVASSI TOWN

The ground floor of this building has been heavily affected, while the upper floor remained almost intact by the earthquake. Structural damage comprised heavy damage to the upper part of the columns of the ground floor, while non-structural damage included detachment of large pieces of plaster from the infill walls, extensive cracking of plaster and of brick walls, detachment of the walls from the surrounding RC frame and total collapse.

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

DAMAGE TO BUILDINS WITH LOAD-BEARING MASONRY WALLS IN VATHY TOWN

Vathy

Non-structural damage included cracking in plaster, detachment of large pieces of plaster from the walls, symmetrical cracks and displacement of collapse of the upper.

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

DAMAGE TO BUILDINS WITH MASONRY LOAD-BEARING WALLS

PARTIAL COLLAPSE OF THE BUILDING

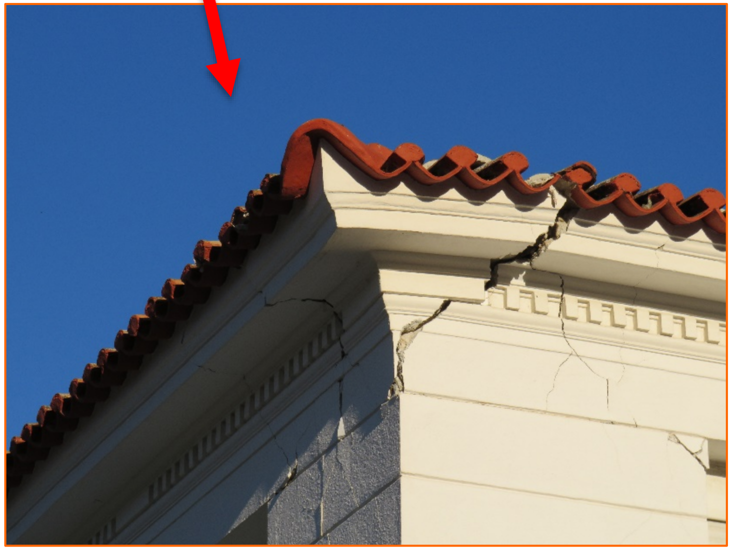
Heavy structural damage to building with load-bearing masonry walls. The building is on the verge of total collapse.

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

DAMAGE TO BUILDINS WITH LOAD-BEARING MASONRY WALLS

DAMAGE TO UPPER CORNERS



Symmetrical detachment of the corners edges of a building with masonry load-bearing walls is the trademark of the prevalence and the dominance of the vertical component of the earthquake ground motion over the horizontal. Collapse of the building cornices has been also observed.

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

DAMAGE TO BUILDINS WITH LOAD-BEARING MASONRY WALLS

DAMAGE TO UPPER CORNERS

Symmetrical detachment of the corners edges of a building with masonry load-bearing revealing the prevalence and the dominance of the vertical component of the earthquake ground motion over the horizontal. Collapse of the building cornices has been also observed. Impact between adjacent buildings is negligible.

ISSN 2653-9454
Issue No. 21, November 2020 | 139

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

DAMAGE TO BUILDINS WITH LOAD-BEARING WALLS
PARTIAL COLLAPSE OF THE LOAD-BEARING MASONRY WALLS

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

DAMAGE TO INFRASTRUCTURE
VATHY PORT

The jetty of the Vathy port has been affected by extensive longitudinal and transverse ground cracks resulting in subsidence and tilting due mainly to the dynamic compaction of the back-fill material.

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

DAMAGE TO MONUMENTS AND SPECIAL STRUCTURES

Churches in Samos suffered damage to the load-bearing masonry walls, arches, roofs, plasters and their bell tower. Characteristic damage in the Cathedral of Agios Spyridon in Vathy town.

ISSN 2653-9454
Issue No. 21, November 2020

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

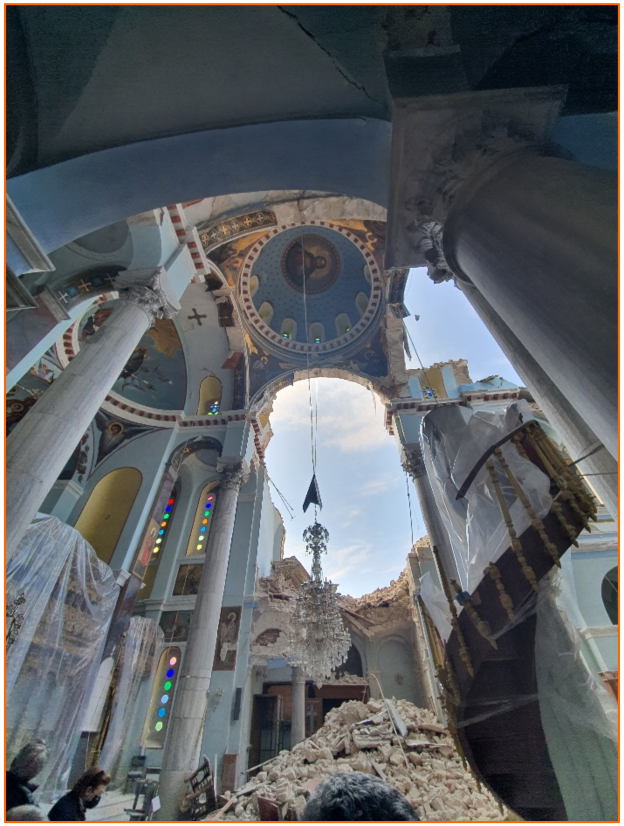
DAMAGE TO MONUMENTS AND SPECIAL STRUCTURES

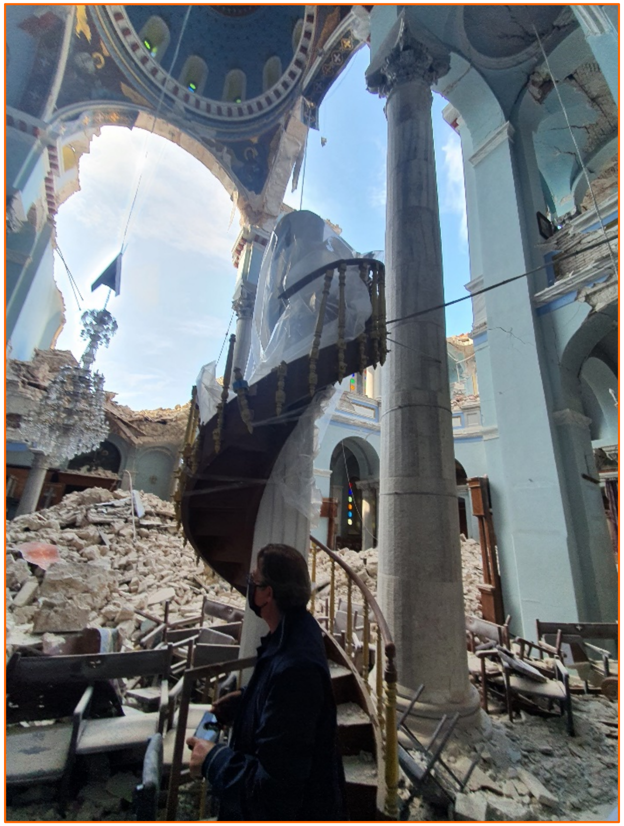
Characteristic example is Holy Church of the Assumption of the Virgin Mary in Karlovassi town, located at the northwestern part of Samos. It is the largest church in the Balkan peninsula. It suffered partial collapse of the roof and of their adjacent perimetric walls. The collapse occurred within the foundation plan of the building, while the remaining exterior walls were still standing indicating the prevalence of the vertical component of the earthquake ground motion.

ISSN 2653-9454
Issue No. 21, November 2020 | 143

University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

DAMAGE TO MONUMENTS AND SPECIAL STRUCTURES





Characteristic views of the damage induced to the Holy Church of the Assumption of the Virgin Mary in Karlovassi town from the interior of the structure. It suffered partial collapse of the roof and of their adjacent perimetric walls. The collapse occurred within the foundation plan of the building.

ISSN 2653-9454
Issue No. 21, November 2020

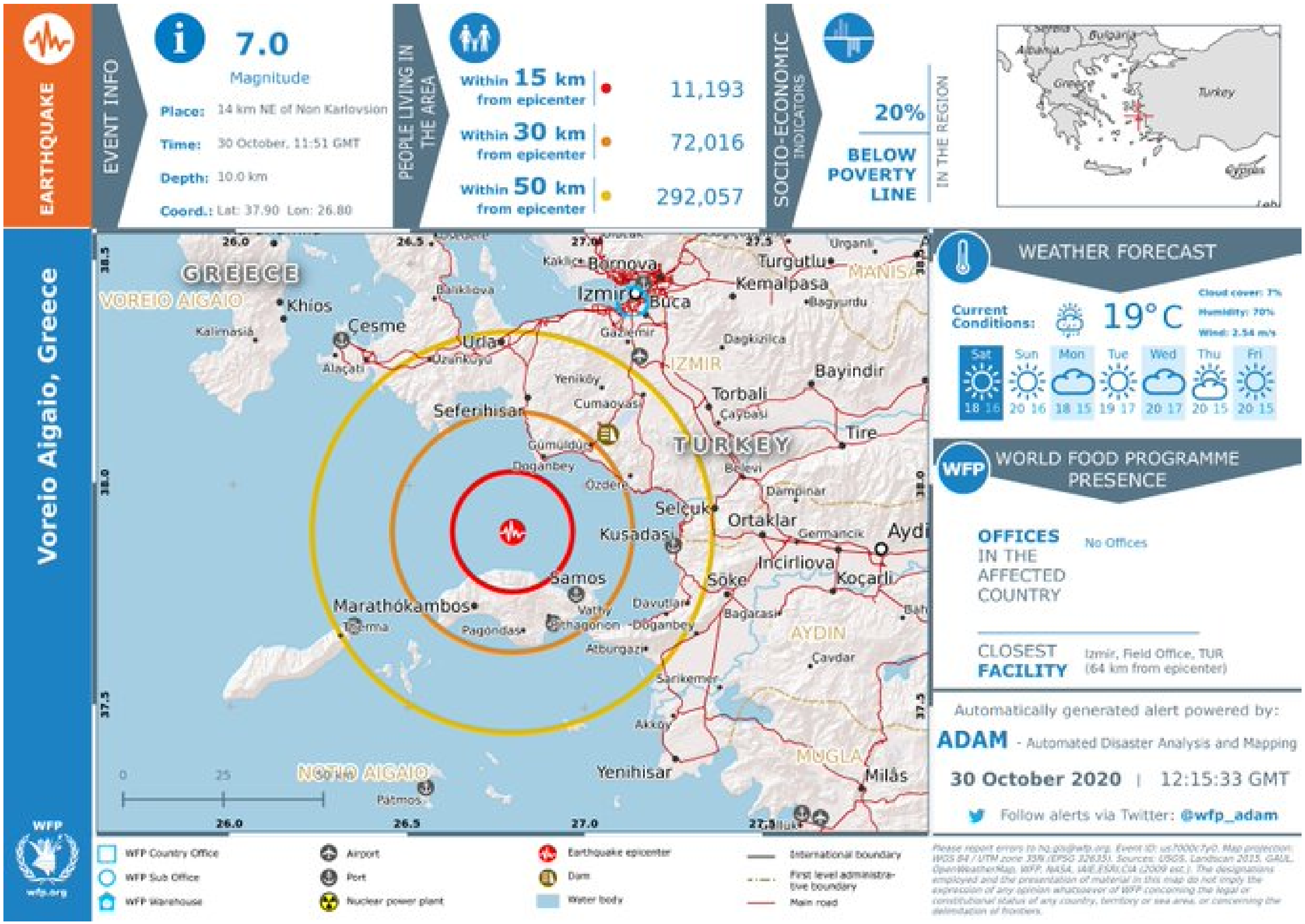
University of Athens
Faculty of Geology and Geoenvironment
Department of Dynamic Tectonic
Applied Geology

DAMAGE TO MONUMENTS AND SPECIAL STRUCTURES

The Catholic Church located at the coastal area in Vathy town suffered damage to masonry walls, the bell tower and the arches. It was also affected by the subsequent tsunami and the coastal inundation.

ISSN 2653-9454
Issue No. 21, November 2020 | 145

DISASTER ALERT AND EMERGENCY RESPONSE
AUTOMATICALLY GENERATED DISASTER ALERT



Automatic Disaster Analysis and Mapping (ADAM) Disaster Alerts: https://twitter.com/WFP_ADAM

ISSN 2653-9454
Issue No. 21, November 2020 | **146**

DISASTER ALERT AND EMERGENCY RESPONSE
AUTOMATICALLY GENERATED SHAKE MAP

EARTHQUAKE

EVENT INFO

7.0
Magnitude

Place: 14 km NE of Non Karlovsion
Time: 30 October, 11:51 GMT
Depth: 10.0 km
Coord.: Lat: 37.90 Lon: 26.80
Populat.: 72,016 within 30 Km

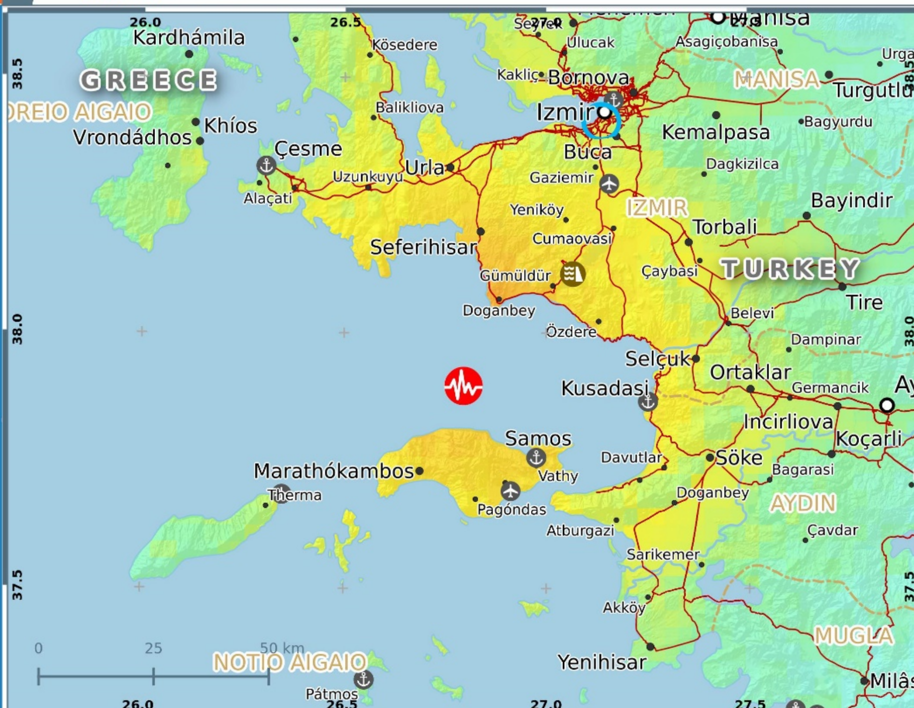
Automatically generated **SHAKE MAP** powered by:
ADAM - Automated Disaster Analysis and Mapping

30 October 2020 14:10:33 GMT

USGS ShakeMap

Instrumental Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X+
Potential Shaking	Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Moderate/ Heavy	Heavy	Very Heavy

Voreio Aigaio, Greece



WFP Country Office
WFP Sub Office
WFP Warehouse
Airport
Port
Nuclear power plant
Earthquake epicenter
Dam
Water body
International boundary
First level administrative boundary
Main road

MODIFIED MERCALLI INTENSITY SCALE:
7.6/10

Intensity class VII:
People have difficulty standing. Drivers on the road feel their cars shaking. Furniture may be overturned and broken. Loose bricks fall from buildings and masonry walls and cracks in plaster and masonry may appear. Weak chimneys may break at the roofline. Damage is slight to moderate in well-built structures; considerable in poorly constructed buildings and facilities.

Concepts and definitions

Shake Map combines instrumental measurements of shaking with information about local geology and earthquake location and magnitude to estimate potential impacts throughout a geographic area.

The estimated intensity map is derived from ground motions recorded by seismographs and represents Modified Mercalli Intensities (MMI's) that are likely to have been associated with the ground motions.

Magnitude and Intensity measure different characteristics of earthquakes. Magnitude measures the energy released at the source of the earthquake. Magnitude is determined from measurements on seismographs. Intensity measures the strength of shaking produced by the earthquake at a certain location. Intensity is determined from effects on people, human structures, and the natural environment. (Source: USGS)

Please report errors to hq.gis@wfp.org. Event ID: us7000c7y0. Map projection: WGS 84 / UTM zone 35N (EPSG 32635). Sources: USGS (ShakeMap layer, earthquake info), GAUL, WFP, NASA, ESRI. The designations employed and the presentation of material in this map do not imply the expression of any opinion whatsoever of WFP concerning the legal or constitutional status of any country, territory or sea area, or concerning the delimitation of frontiers.

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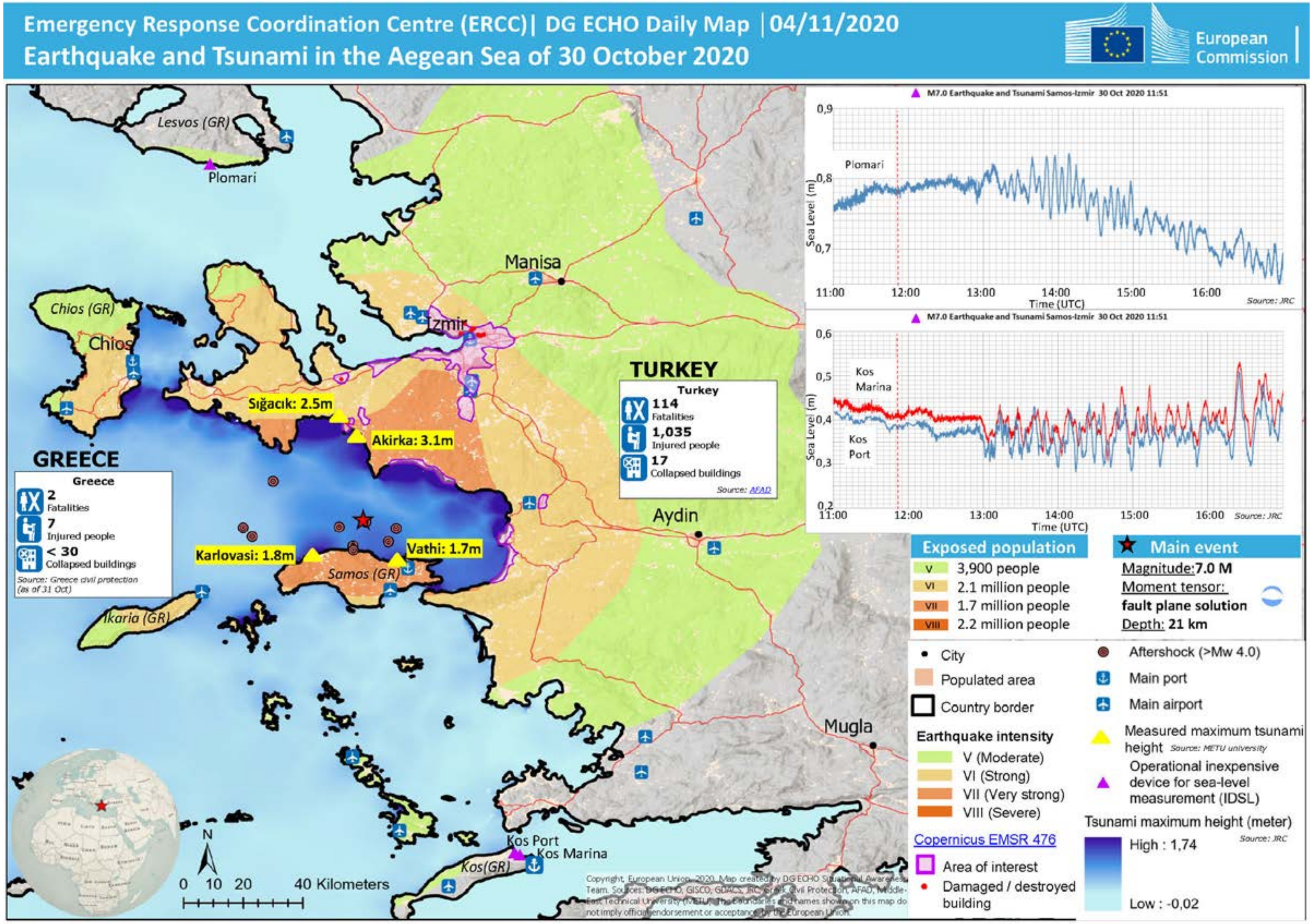
EMERGENCY RESPONSE COORDINATION CENTER - DG ECHO DAILY MAP
NOVEMBER 4, 2020



https://erccportal.jrc.ec.europa.eu/getdailymap/docId/3527

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Issue No. 21, November 2020

DISASTER MANAGEMENT

The Prime Minister and government officials arrived during the first moments of the emergency response in the affected area in order to assess the situation. Officials from Samos municipalities, the North Aegean Region and the Ministry of Infrastructure conducted primary level controls to all affected buildings in order to assess damage. In the town hall of Eastern Samos, an open air office was established, where residents reported earthquake-induced damage to their properties. Moreover, Units of the Hellenic Armed Forces constantly provided food and water to affected people in need.

ISSN 2653-9454
Issue No. 21, November 2020

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ISSN 2653-9454
Issue No. 21, November 2020

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ISSN 2653-9454
Issue No. 21, November 2020

DISASTER MANAGEMENT

Emergency shelters were established based on the existed open spaces. They were mostly military tents in open air spaces including stadiums, school yards and open municipal spaces. The authorities competent to the earthquake disaster management provided the earthquake-affected homeless or frightened population with emergency supplies during their staying in shelters.

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Issue No. 21, November 2020

DISASTER MANAGEMENT

The president and the staff of the Earthquake Planning and Protection Organization (EPPO) visited the earthquake affected island of Samos in order to assess the impact of the earthquake in various sectors. Among other activities of disaster management, the staff of EPPO visited schools in Vathy and Karlovassi and provided information concerning earthquake protection issues to teachers.

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Ο.Α.Σ.Π.

EARTHQUAKE AND EMERGENCY PREPAREDNESS
EARTHQUAKE DRILL "EUPALINOS 2017" IN SAMOS

The Earthquake Drill "Eupalinos 2017" was implemented on March 15, 2017, on Samos Island by the Earthquake Planning and Protection Organization in collaboration with the Regional Unit of Samos. All local authorities competent to the prevention and management of an earthquake disaster and to the Civil Protection participated in the drill: the Regional Unit of Samos (Department of Civil Protection), the Municipality of Samos, the 79th Senior National Guard Battalions Command, the Police Directorate, the Fire Department, the Port Authority, the National Center For Emergency Assistance, the General Hospital, the Hellenic Electricity Distribution Network Operator, the Samos Amateur Radio Association, volunteer organizations and teams of the island as well as a 4-member Special Team for Special Missions from Ikaria.

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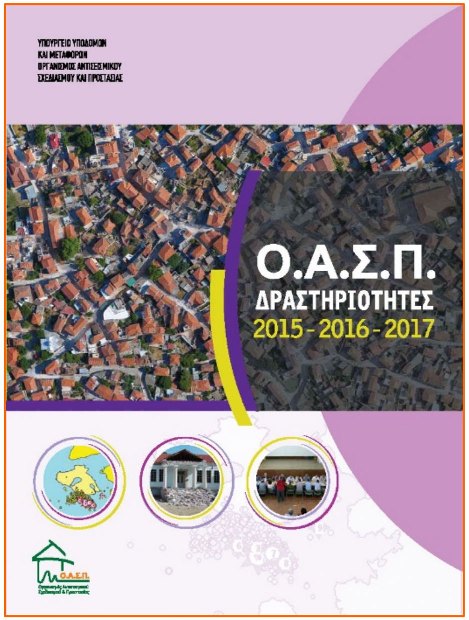

The level of the drill was characterized as
“excellent” and “very good” by the majority of the participants

CONCLUSIONS

The October 30, 2020 Mw 6.9 earthquake in Eastern Aegean has been generated by the rupture of a E-W striking normal fault. Based on the geological setting of the affected area, the causative fault is the E-W normal fault offshore northern Samos. The main part of the aftershock sequence spans ~50 km in an approximate E-W direction. Certain isolated clusters are located further west, north of Ikaria Island, and at the eastern edge of Samos Island.

The affected area experienced similar earthquakes in its historical past. The 1904 earthquake is very similar to the October 30, 2020 event. This earthquake caused damage to the villages of Ano Vathy, Chora, Pyrgos, Koumaeika, Skouraeika, Kontaeika and Agia Triada, which are built on recent deposits.

The 2020 Samos earthquake induced primary and secondary environmental effects. The primary effects included permanent surface deformation and coseismic surface ruptures, while the secondary effects tsunami, slope failures and liquefaction phenomena.

The permanent surface deformation has been detected by field survey shortly after the earthquake. The field survey results on the surface deformation are confirmed by spaceborne observations and in particular by the interferometric analysis of SAR and GNSS data.

As regards damage on built environment, the old structures with load-bearing masonry walls built on the beginning of the previous century suffered the most by the earthquake. Most damage was observed along the margins and within the basins of the affected area. Structural damage varied from heavy cracking to partial or total collapse of the structure. Non-structural damage included small cracks and detachment of plasters from the masonry walls.

Newsletter of
Environmental, Disaster, and Crises Management Strategies
ISSN 2653-9454
Issue No. 21, November 2020 | 156

The October 30, 2020, Mw 6.9 Samos (Greece) earthquake

E. **Lekkas**, S. **Mavroulis**, M. **Gogou**, G.A. **Papadopoulos**, I. **Triantafyllou**, K.-N. **Katsetsiadou**, H. **Kranis**, E. **Skourtsos**, P. **Carydis**

N. **Voulgaris**, P. **Papadimitriou**, V. **Kapetanidis**, A. **Karakonstantis**, . Spingos, V. **Kouskouna**, I. **Kassaras**, G. **Kaviris**, K. **Pavlou**, V. **Sakkas**

N. **Evelpidou**, E. **Karkani**, I. **Kampolis**

P. **Nomikou**, D. **Lambridou**, P. **Krassakis**

M. **Foumelis**, C. **Papazachos**

A. **Karavias**, D. **Bafi**, T. **Gatsios**, O. **Markogiannaki**, I. **Parcharidis**

A. **Ganas**, V. **Tsironi**, I. **Karasante**

D. **Galanakis**, K. **Kontodimos**

D. **Sakellariou**

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A. **Kourou**, M. **Manousaki**, T. **Thoma**, N. **Karveleas**

Samos, 2020