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The March 21, 2020, Mw 5.7 Epirus (Greece) Earthquake

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About

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Scientific Mission

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

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THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE

On March 21, 2020 (02:49:50) an earthquake struck Epirus. Based on various seismological observatories and institutes including KOERI, USGS, INGV, GCMT, CPPT, ERD, GFZ and EMSC, the magnitude has been assessed as Mw 5.5 or 5.7. Its epicenter was located at a distance of 15 km east of Parga city. Its focal depth ranged from 5 to 16 km. Based on the provided focal plane solutions, the mainshock was generated by the activation of a NW-SE striking reverse fault along the eastern margin of the Acheron River basin.

The main shock was felt in Epirus, the Ionian Islands, the western part of the mainland Greece and Northwestern Peloponnese. It was also felt in the neighboring southern Albania. Fortunately, the earthquake resulted in only injuries. Three people were slightly injured in Kanallaki village due to falling items and debris, while about 20 residents were staying in hotels due to heavy structural damage in their homes.

The earthquake affected area comprises villages and towns along the eastern margin of the Acheron River Basin and within the lower Acheron River alluvial valley. More specifically, building damage was observed and reported in several villages of Parga, Souli and Dodoni municipalities of Epirus Perfecture. The worst affected areas in terms of building damage were Kanallaki, Gliki, Potamia, Kipseli, Skafidoti and Skoteino villages. Heavy structural damage was observed in masonry buildings, while reinforced concrete buildings was slightly affected.

As regards the earthquake impact on the infrastructure and lifelines, slope failures were generated along the road network resulting in temporary traffic disruption. Moreover, the earthquake caused temporary electric power shutdowns in the affected area (Skoteino – Skafidoti).

As regards the earthquake environmental effects, slope failures and hydrological anomalies were induced. The slope failures included rockfalls and the hydrological anomalies comprise water turbidity in Acheron River.

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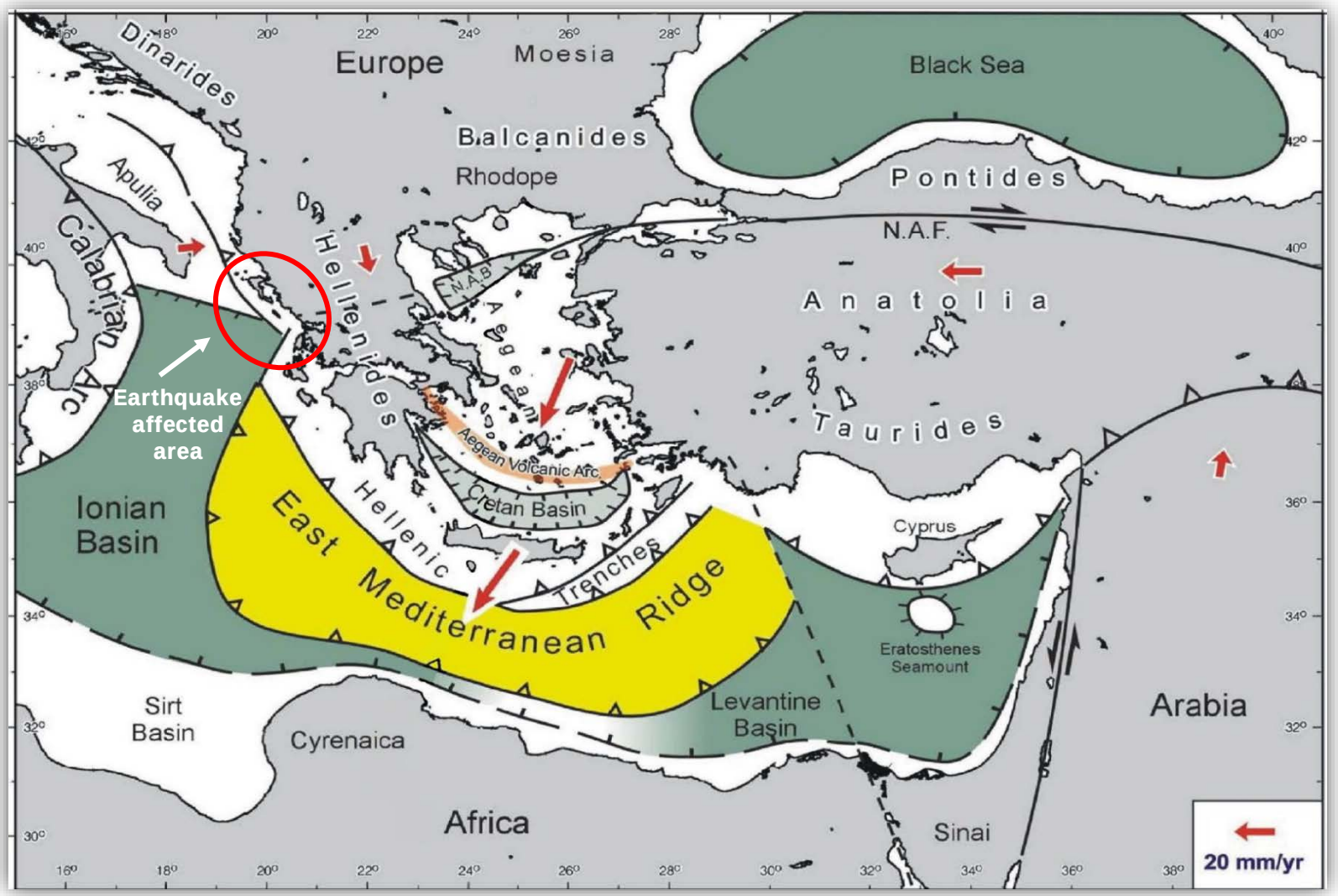
MAIN TECTONIC ELEMENTS IN THE EASTERN MEDITERRANEAN REGION
THE HELLENIC ARC & TRENCH SYSTEM



From *Papanikolaou et al. (2004)*

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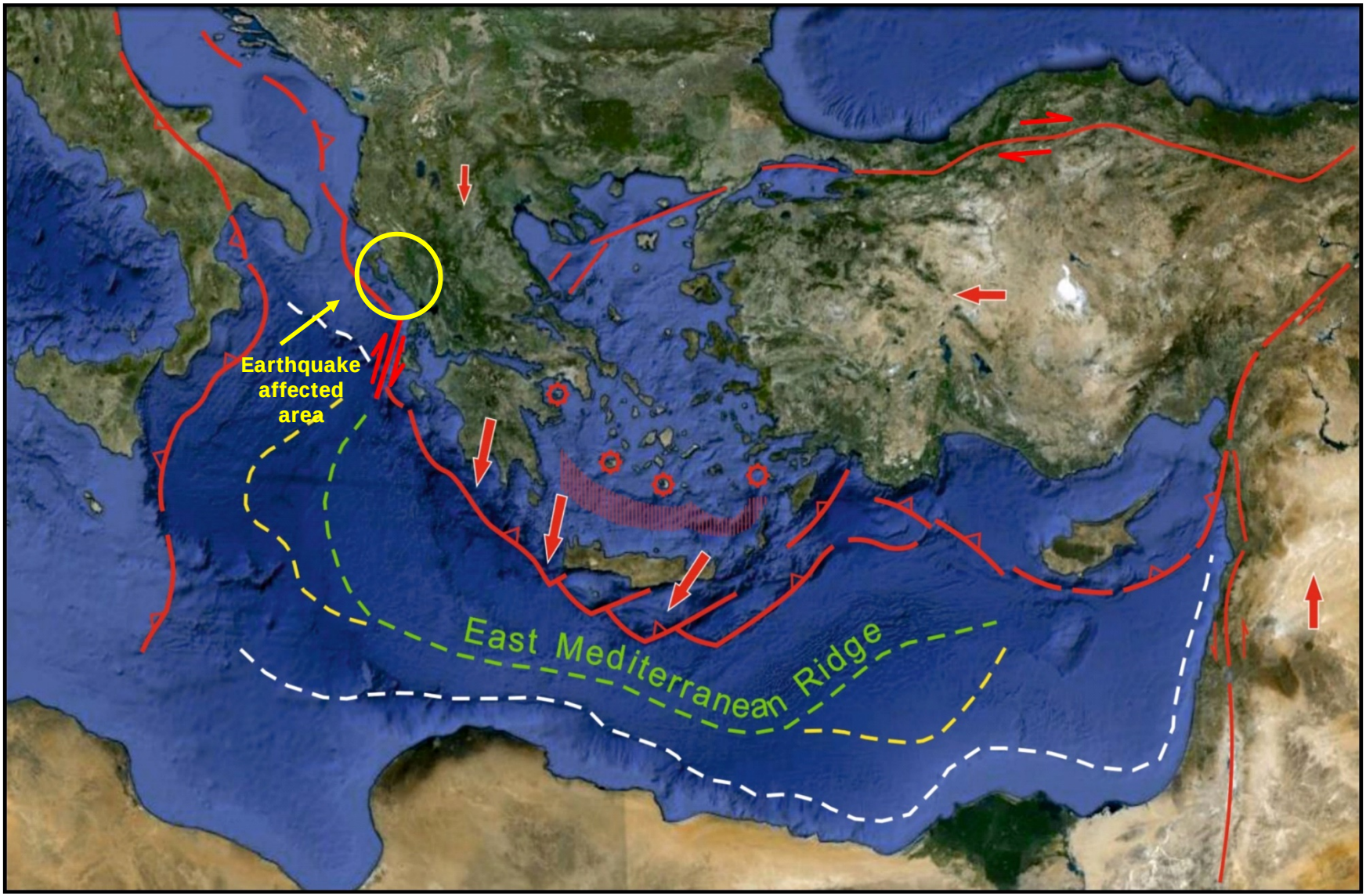
MAIN TECTONIC ELEMENTS IN THE EASTERN MEDITERRANEAN REGION

THE HELLENIC ARC & TRENCH SYSTEM



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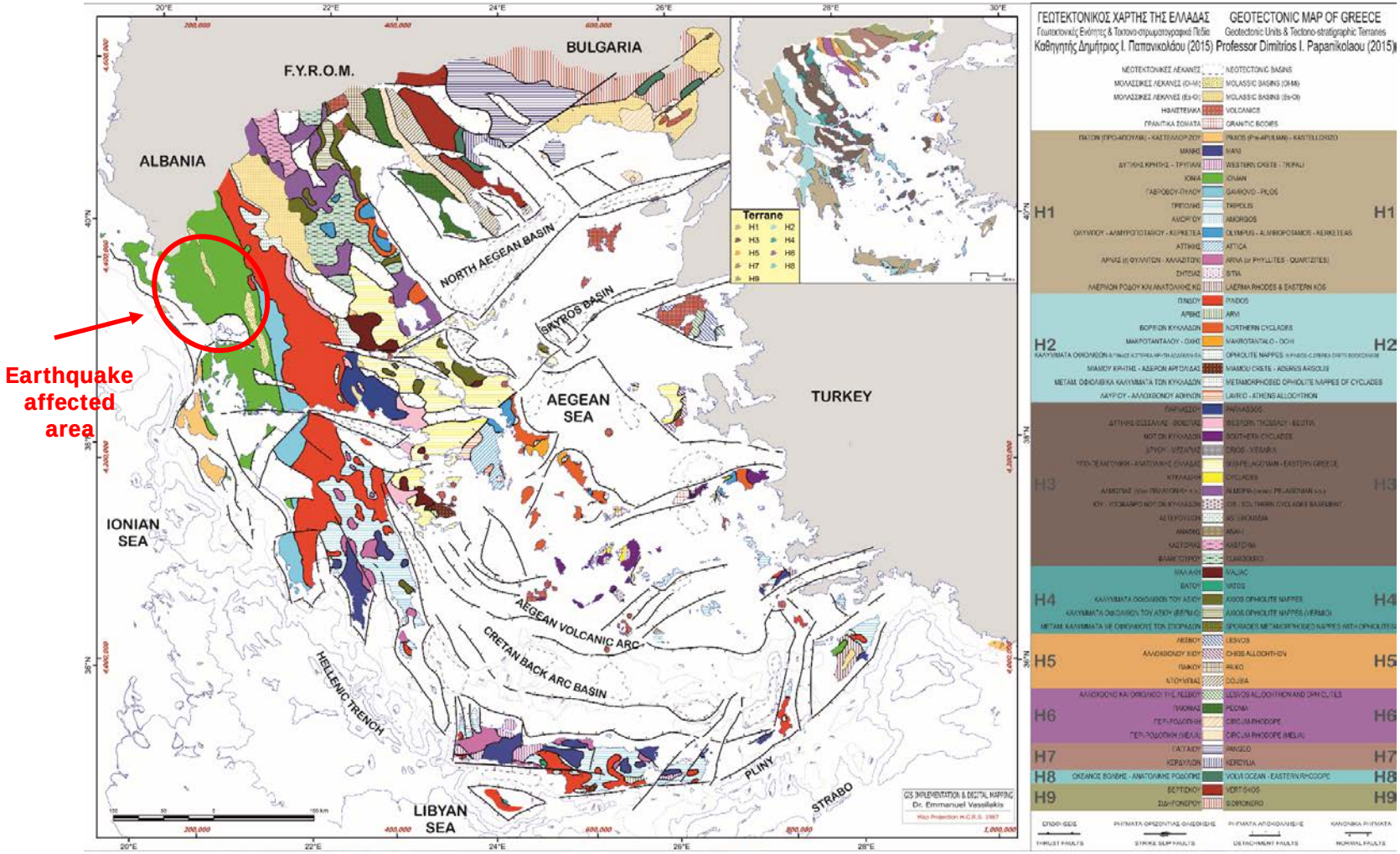
GEOTECTONIC MAP OF GREECE
GEOTECTONIC UNITS & TECTONOSTRATIGRAPHIC TERRANES



The earthquake affected area belongs to the tectonostratigraphic terrane H1 and it is composed of alpine geological formations of the Ionian geotectonic unit and post-alpine deposits (From *Papanikolaou, 2015*)

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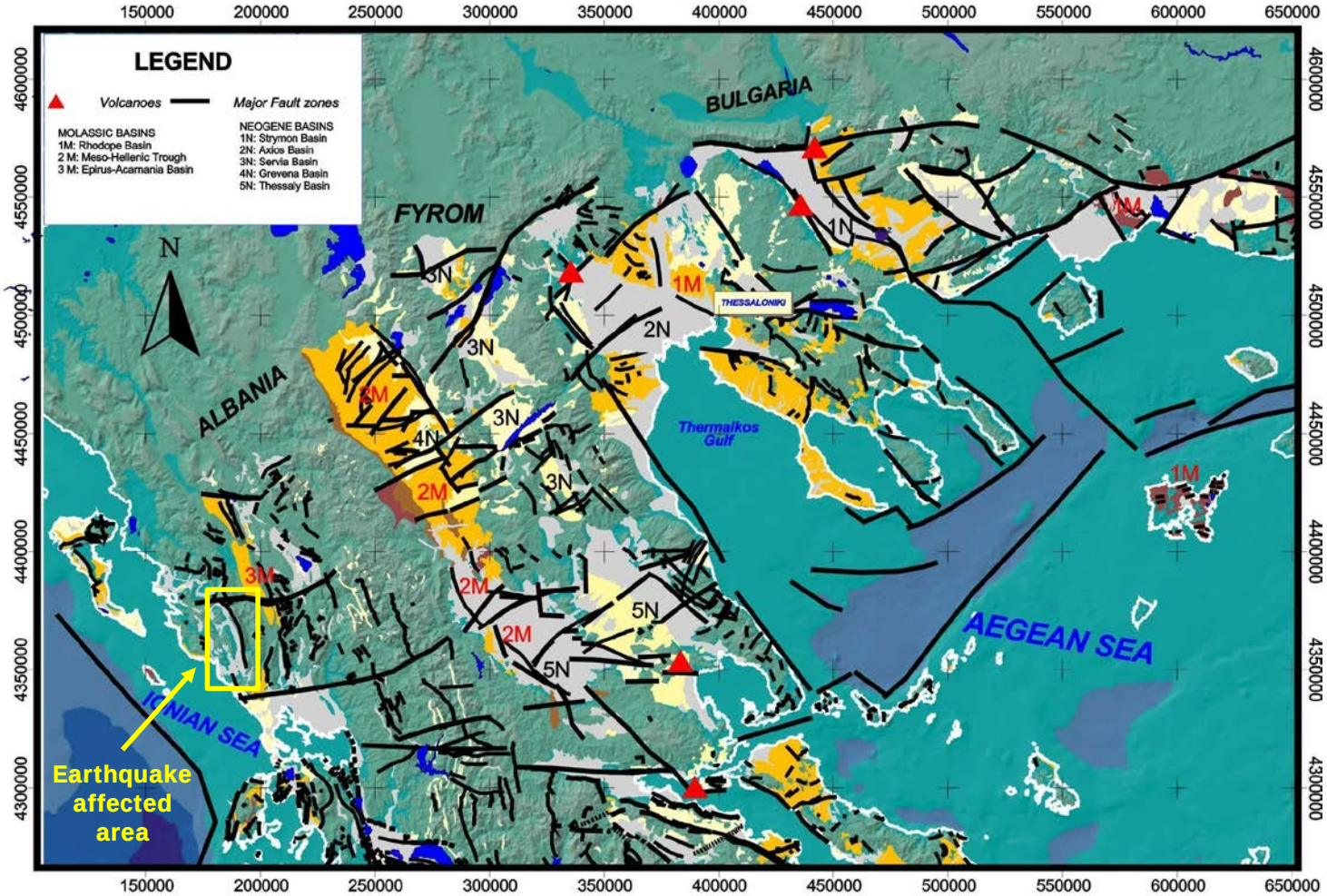
POST-ALPINE BASINS & FAULT ZONES IN NORTHERN GREECE



The post-alpine basins and fault zones in Northern Greece. The earthquake affected area is marked with the yellow frame and comprises settlements along the Paramythia thrust, which constitutes the eastern margin of the Acheron Basin (From *Mariolakos, et al., 2004*).

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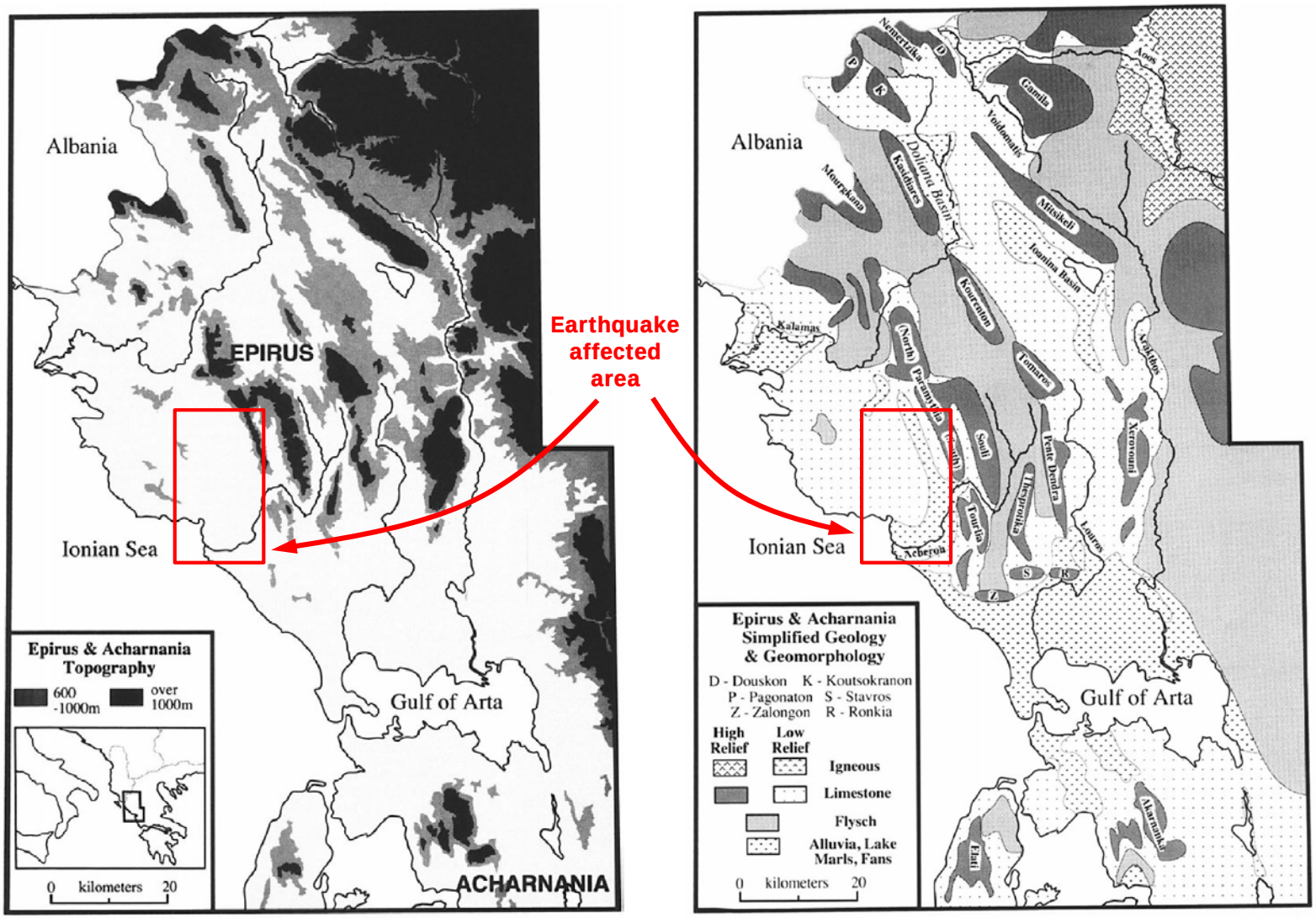
GEOMORPHOLOGY & SIMPLIFIED GEOLOGY OF NORTHWESTERN GREECE



From *King et al. (1993)*

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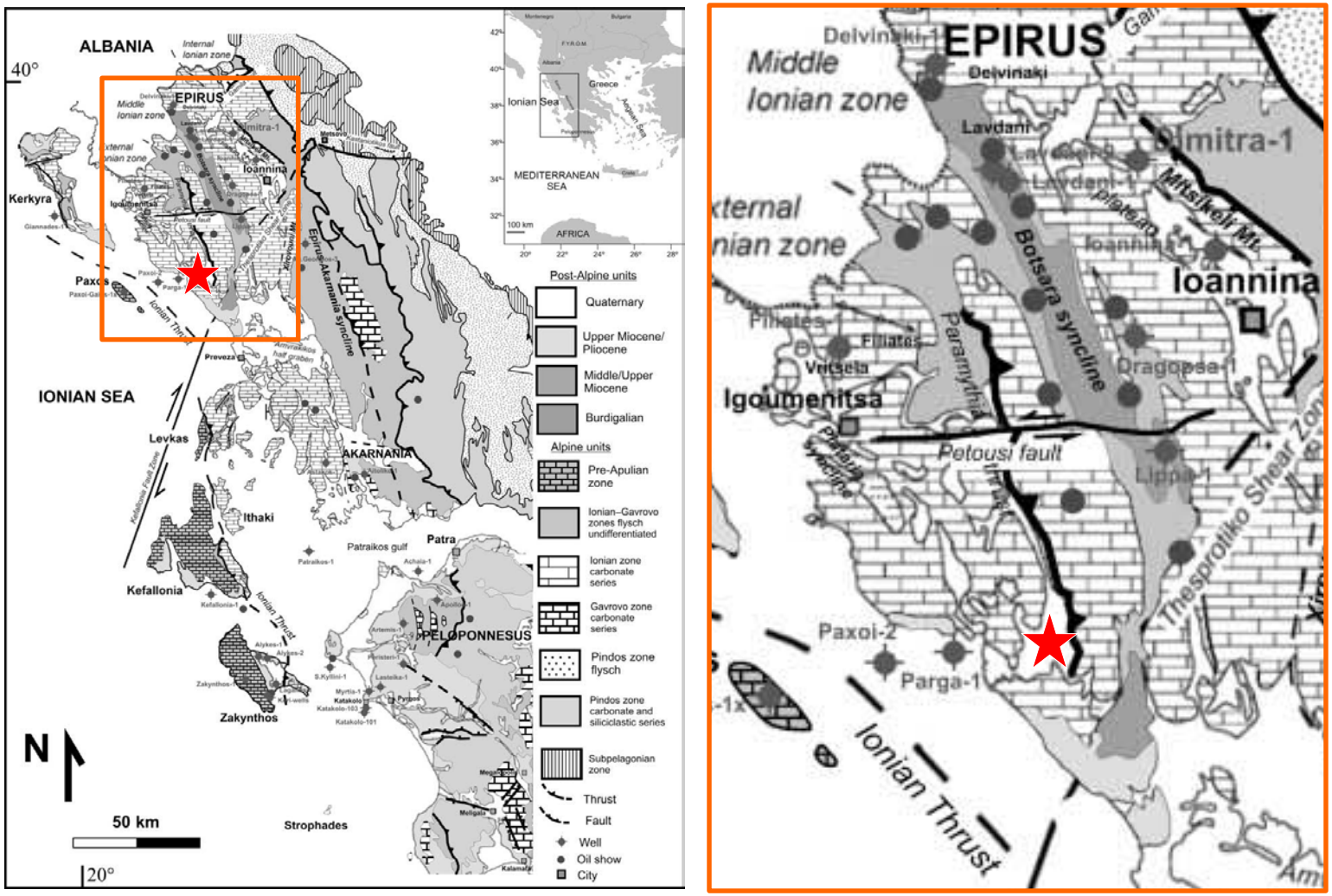
GEOLOGIC & TECTONIC STRUCTURES OF THE EARTHQUAKE AFFECTED AREA



Geologic map of western Greece, indicating the alpine geotectonic units and the post-alpine deposits (From *Karakitsios, 2013*). The location of the March 21, 2020, Mw 5.7 earthquake is also presented along with the main tectonic structures including Paramythia thrust and Petousi fault.

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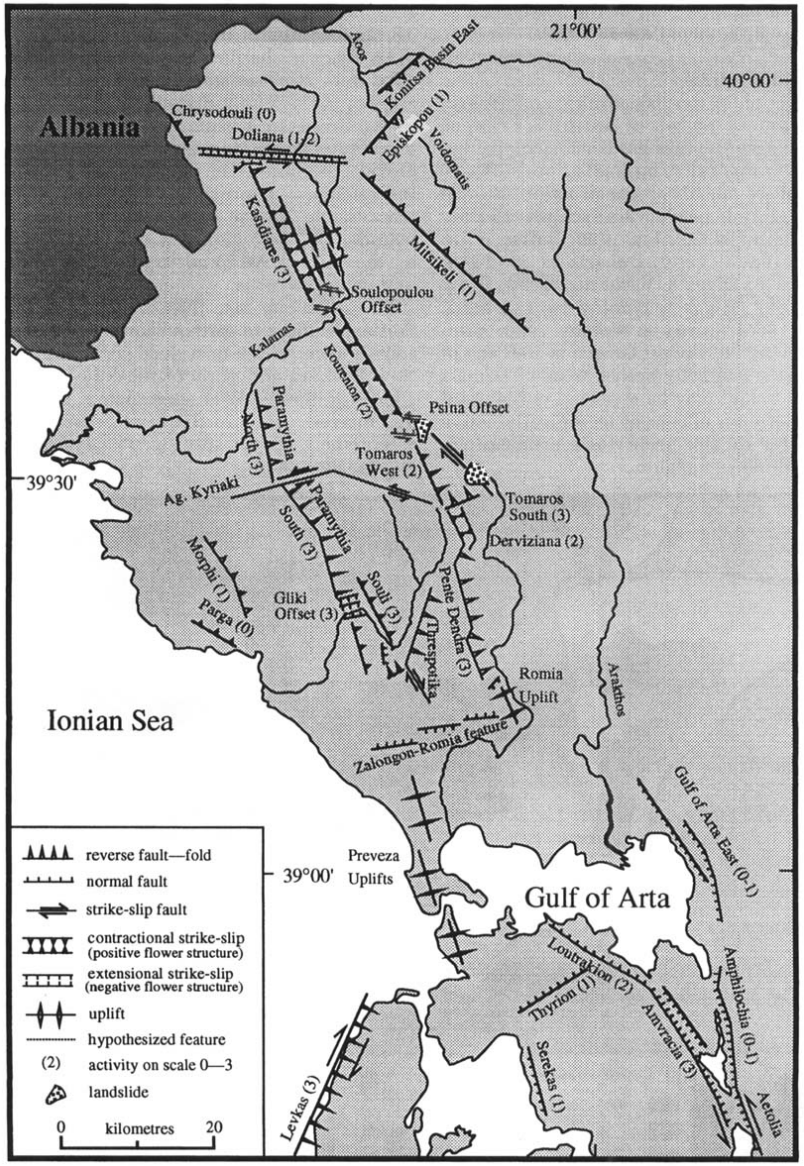
MAJOR ACTIVE STRUCTURES OF NORTHWESTERN GREECE



The **Paramythia thrust** is divided to two parts: the north thrust and the south thrust. These thusts are separated by the **Gliki offset**. Based on *Bailey et al. (1993)*, the north and south Paramythia thrusts and the **Souli fault** are considered active, but less active than **Petoussi** and **Acheron faults**.

Based on seismicity data, *Bailey et al. (1993)* and *King et al. (1993)* supported that Epirus is subject to earthquakes with a rate of activity comparable to regions such as Japan, New Zealand and parts of the Middle East, where uplift rates of between meters and tens of metres per millennium are well established. Both studies of earthquake mechanisms and the geology indicate a region subject to compression, and its broad features can be understood in such a context. However, strike-slip motion also plays significant role to the evolution of this area.

From *Bailey et al. (1993)* and *King et al. (1993)*

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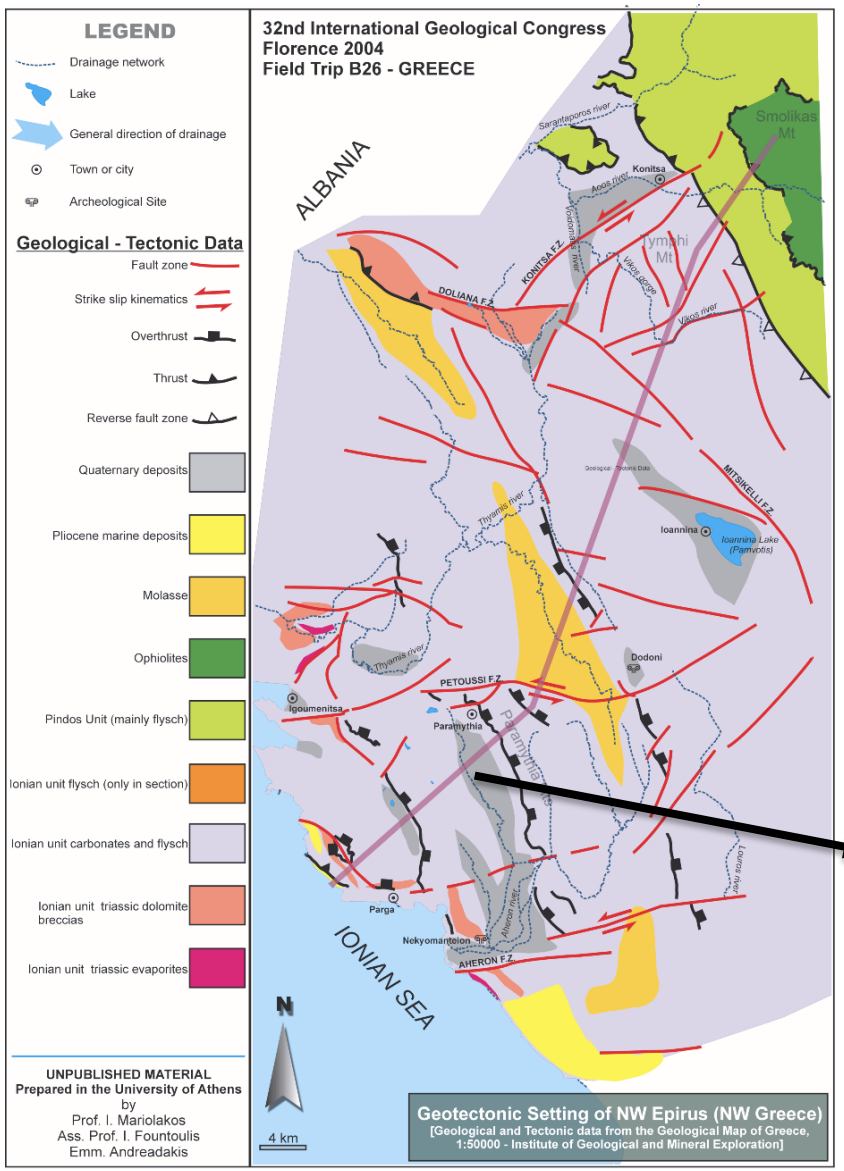
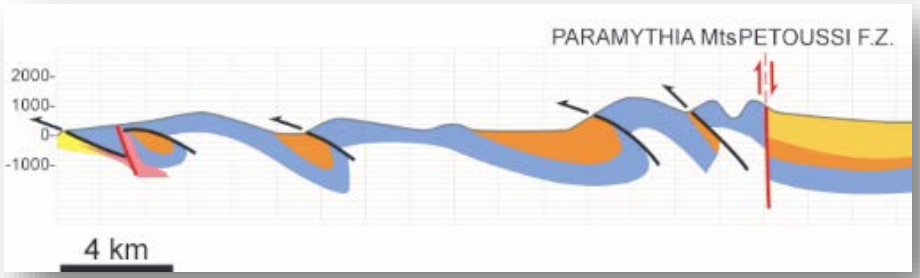
GEOTECTONIC SETTING OF NW EPIRUS



The earthquake affected area is composed of alpine formations of the Ionian geotectonic unit in its eastern part, where Paramythia Mts occur, and Quaternary deposits in its westen part, where the Acheron River valley is located.

The earthquake affected area includes the western part of the Acheron drainage basin comprising the eastern part of the Acheron alluvial valley and the western part of Paramythia Mts. This part is bounded to the north by the E-W striking active **Petoussi fault zone**, to the south by the almost E-W **Acheron fault zone**, to the east by the NW-SE striking **Paramythia and Souli thrusts** and to the west by a NW-SE thrust.



From *Mariolakos et al. (2004)*

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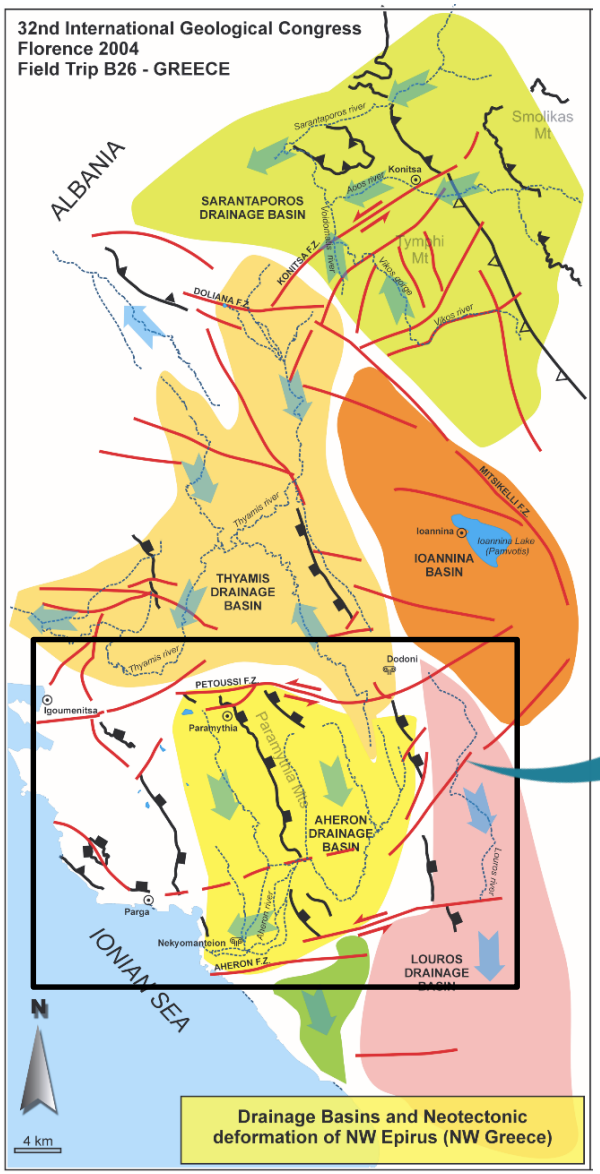
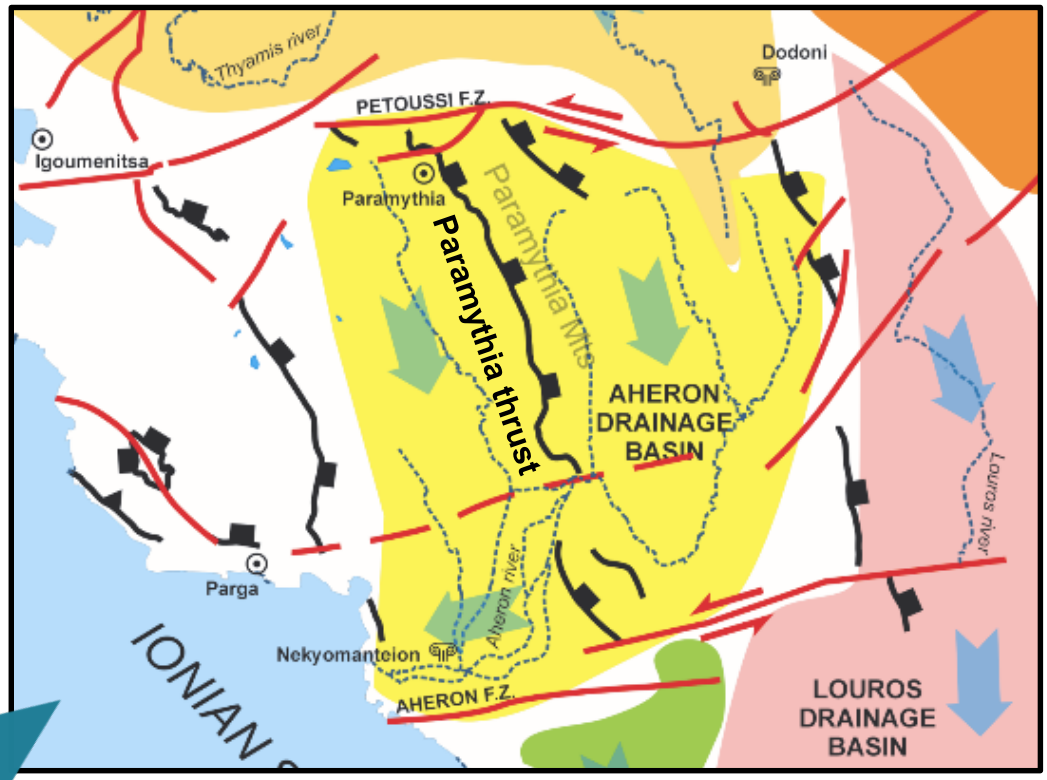
MORPHOTECTONIC MAP OF EPIRUS





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From *Mariolakos et al. (2004)*

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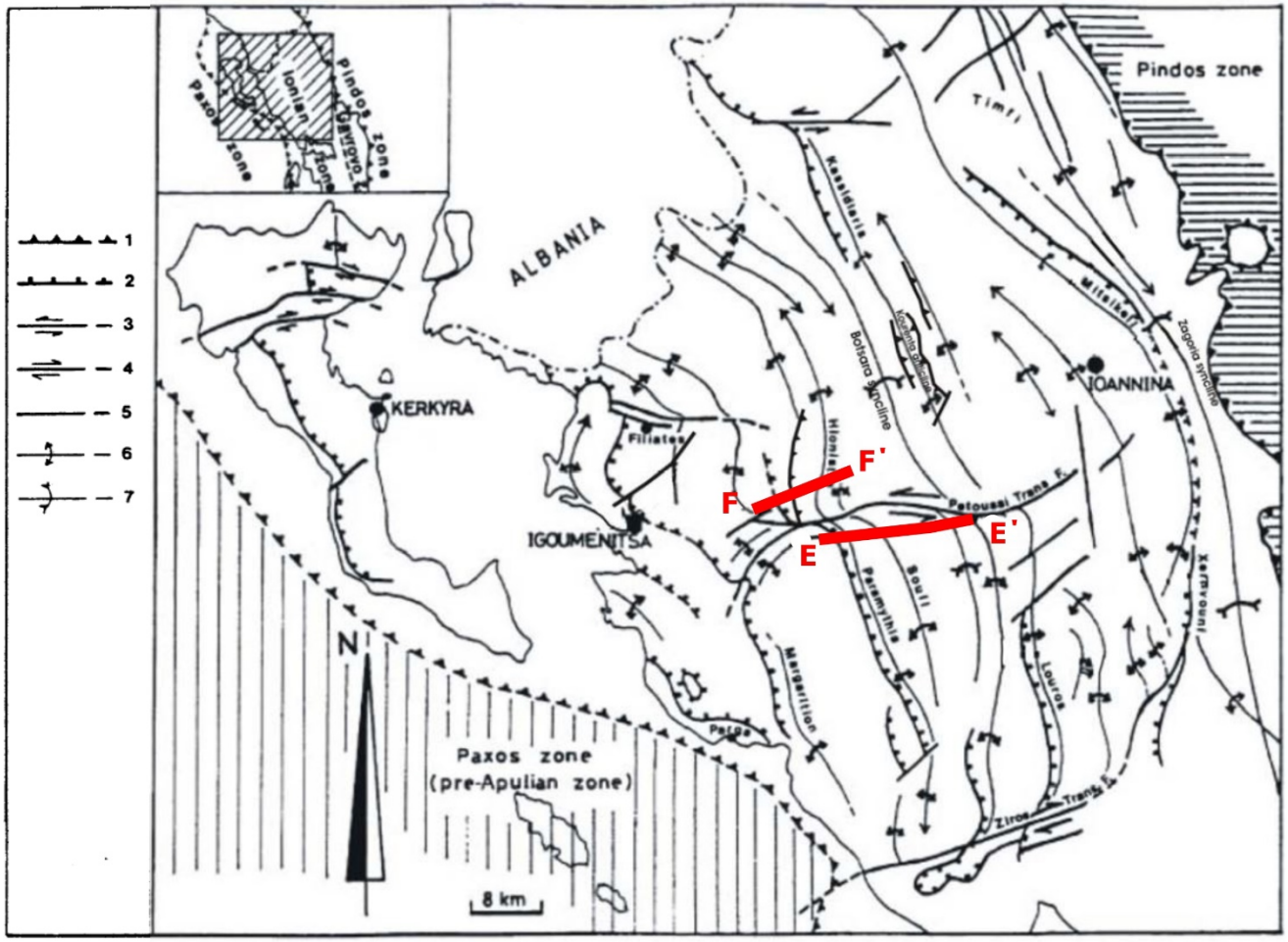
MAJOR STRUCTURES OF NORTHWESTERN GREECE



Structural map of the Epirus region
(after IGRS-IFP 1966, modified)

1: Pindos overthrust
2: Thrust or reverse fault
3: Sinistral transcurrent fault
4: Dextral transcurrent fault
5: Fault
6: Anticlinal axis
7: Synclinal axis

Sections E-E' and F-F' in the next page

From *Karakitsios (1995)*

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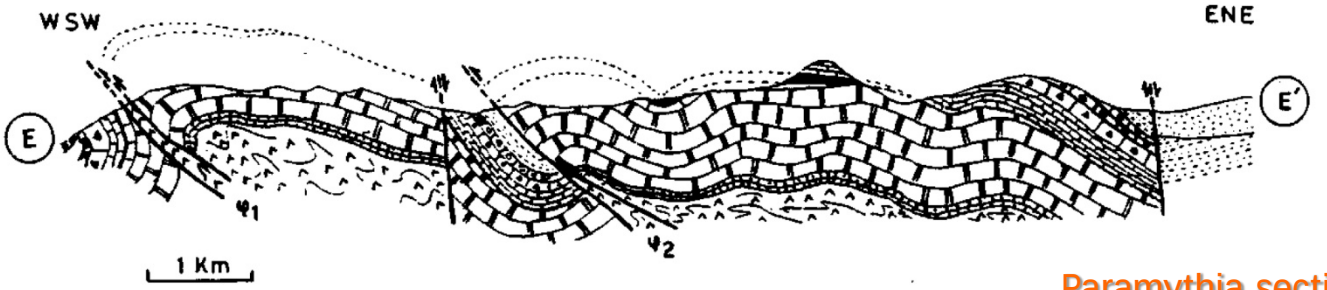
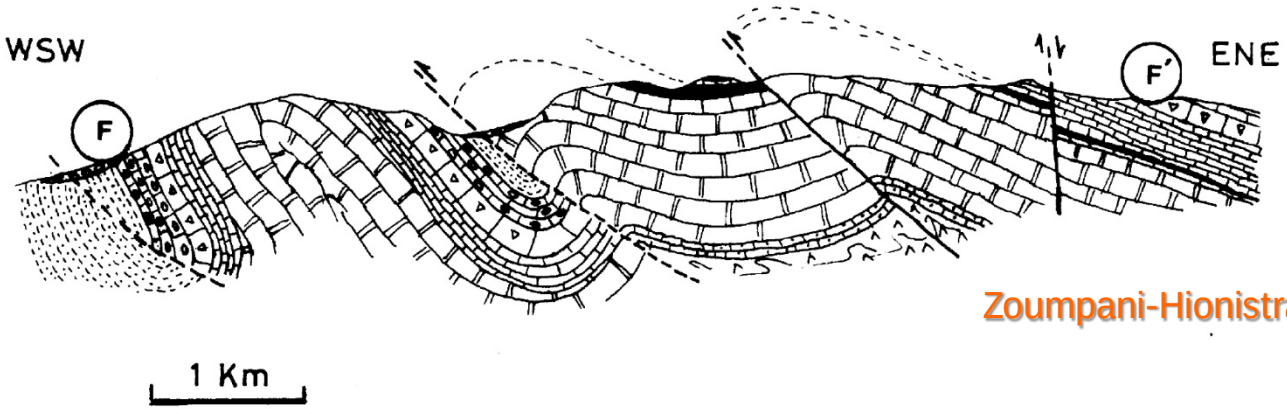
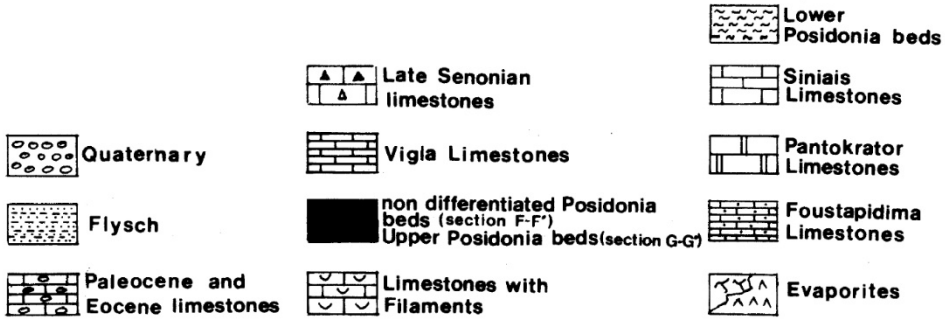
GEOLOGICAL SECTIONS OF THE ALPINE FORMATIONS
IN THE EARTHQUAKE-AFFECTED AREA



Paramythia section E-E'



Zoumpani-Hionistra section F-F'



From *Karakitsios (1995)*

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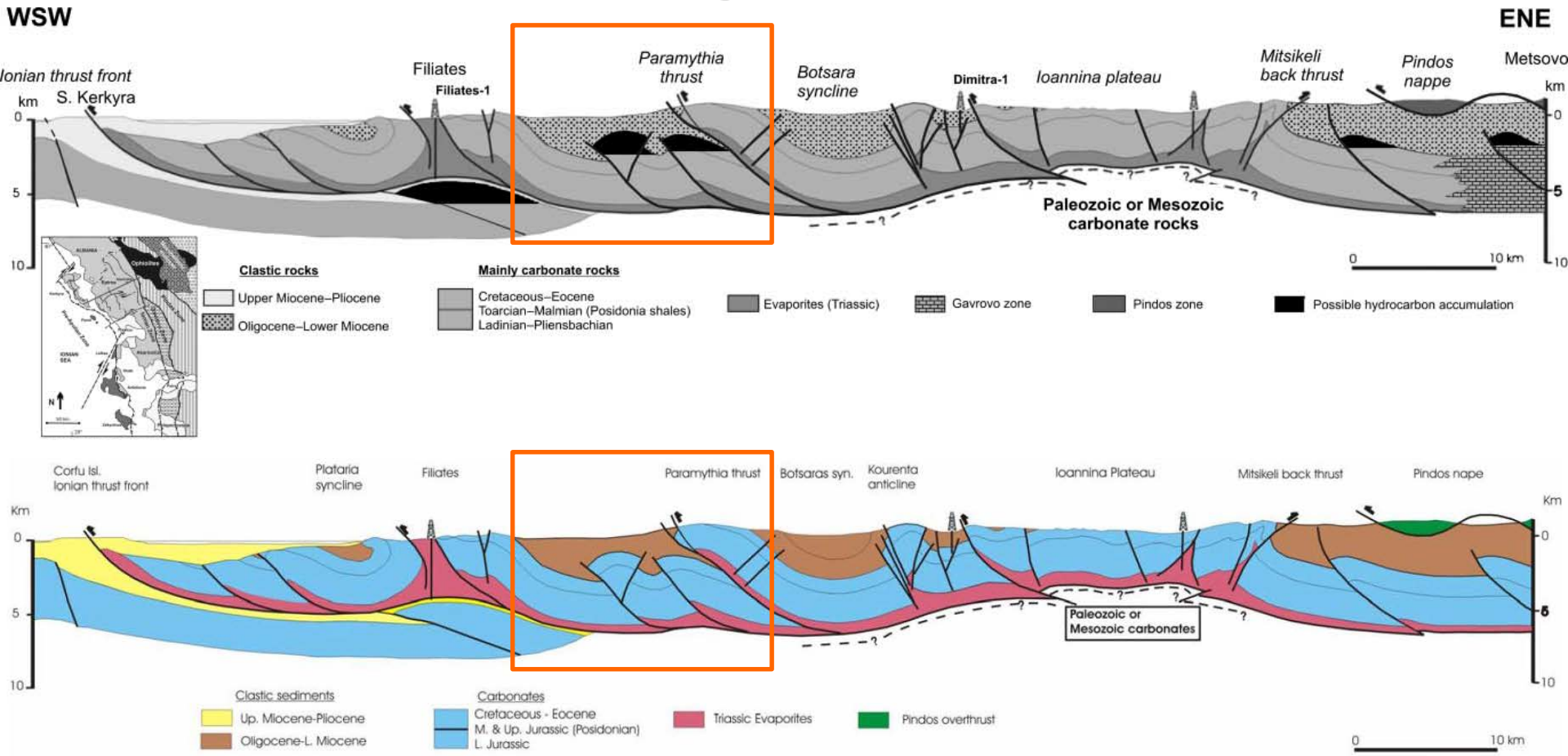
GEOLOGICAL SECTION OF THE NORTHWESTERN GREECE & THE EARTHQUAKE AFFECTED AREA



The Kerkyra Island to Metsovo geologic section resulted from a combination of surface, well, and seismic reflection data (From *Marnelis et al., 2007; Karakitsios, 2013*). The bold line in the inset map shows the approximate location of the section. The geological structure of the earthquake affected area is presented in the orange frame. It comprises alpine formations (flysch, carbonates, evaporites) of the **Ionian geotectonic unit**.

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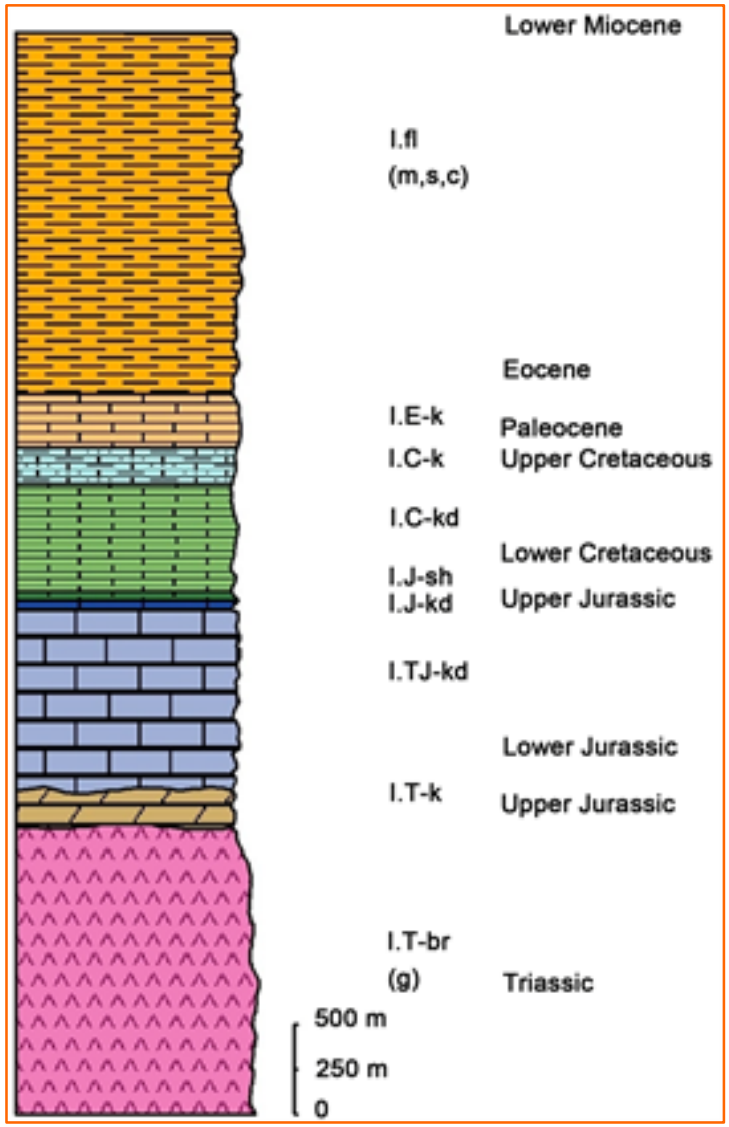
LITHOSTRATIGRAPHIC COLUMN OF THE IONIAN UNIT
IN THE EARTHQUAKE-AFFECTED AREA



I.Fl	Flysch
I.fl-m	Flysch-mainly Marls
I.fl-c	Flysch-mainly Conglomerates
I.fl-s	Flysch mainly Sandstones
I.E-k	Paleocene-Eocene Limestones
I.C-k	Upper Sennonian Limestones
I.C-kd	Vigla Limestones
I.J-kd	Limestones with Filaments
I.J-sh	Upper/Siliceous Shales with Posidonia
I.TJ-kd	Pantokratoras Limestones
I.T-k	Upper Triassic Limestones
I.T-br	Triassic Breccias
I.T-g	Gypsum

From *Ntokos (2017, 2018)*

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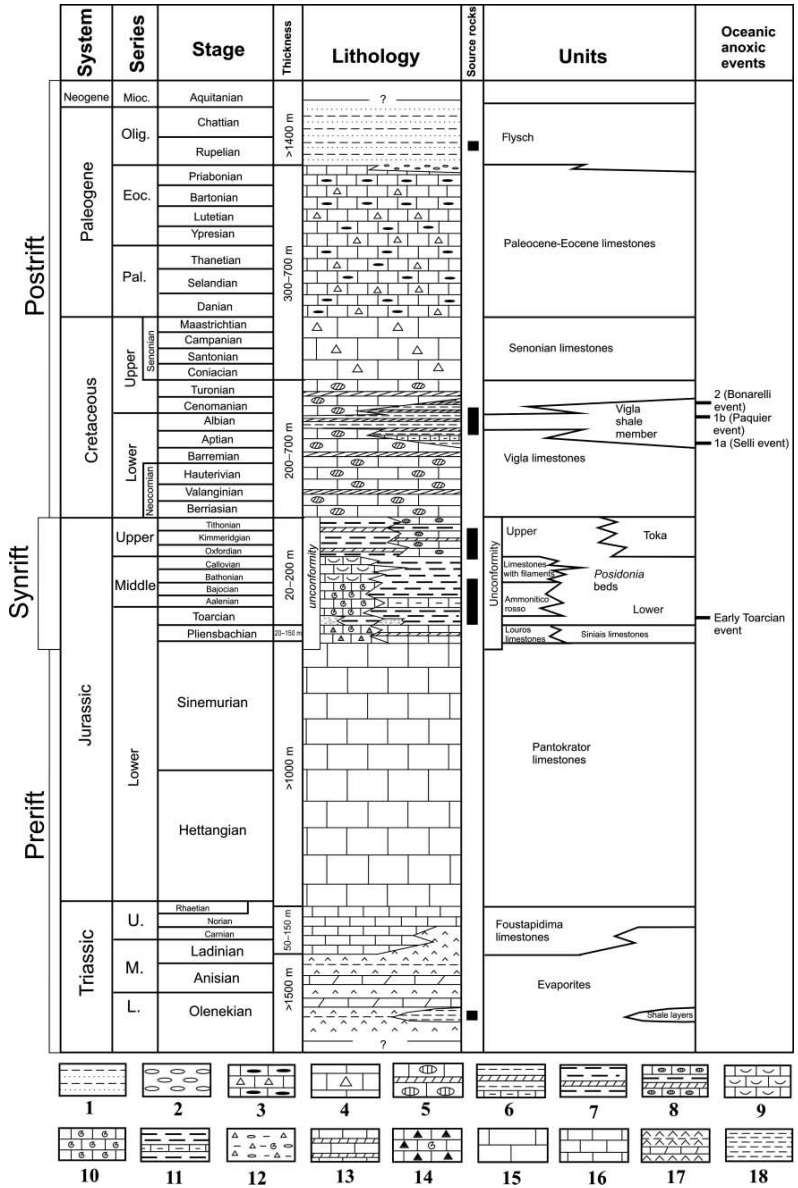
SYNTHETIC LITHOSTRATIGRAPHIC COLUMN OF THE IONIAN UNIT



(1) Pelites and sandstones
(2) Conglomerate
(3) Limestones with rare cherty intercalations, occasionally brecciated
(4) Pelagic limestones with calciturbidite intercalations
(5) Pelagic limestones with cherts
(6) Cherty beds with shale and marl intercalations
(7) Alternating cherty and shale bends
(8) Pelagic limestones with cherty nodules and marls
(9) Pelagic limestones with lamellibranches
(10) Pelagic, nodular red limestones with ammonites
(11) Marly limestones and laminated marls
(12) Conglomerates-breccias and marls with ammonites
(13) Pelagic limestones with rare cherty intercalations
(14) External platform limestones with brachiopods and small ammonites in the upper part
(15) Platform limestones
(16) Thin-bedded black limestones
(17) Evaporites
(18) Shale horizons

From *Karakitsios (2013)*

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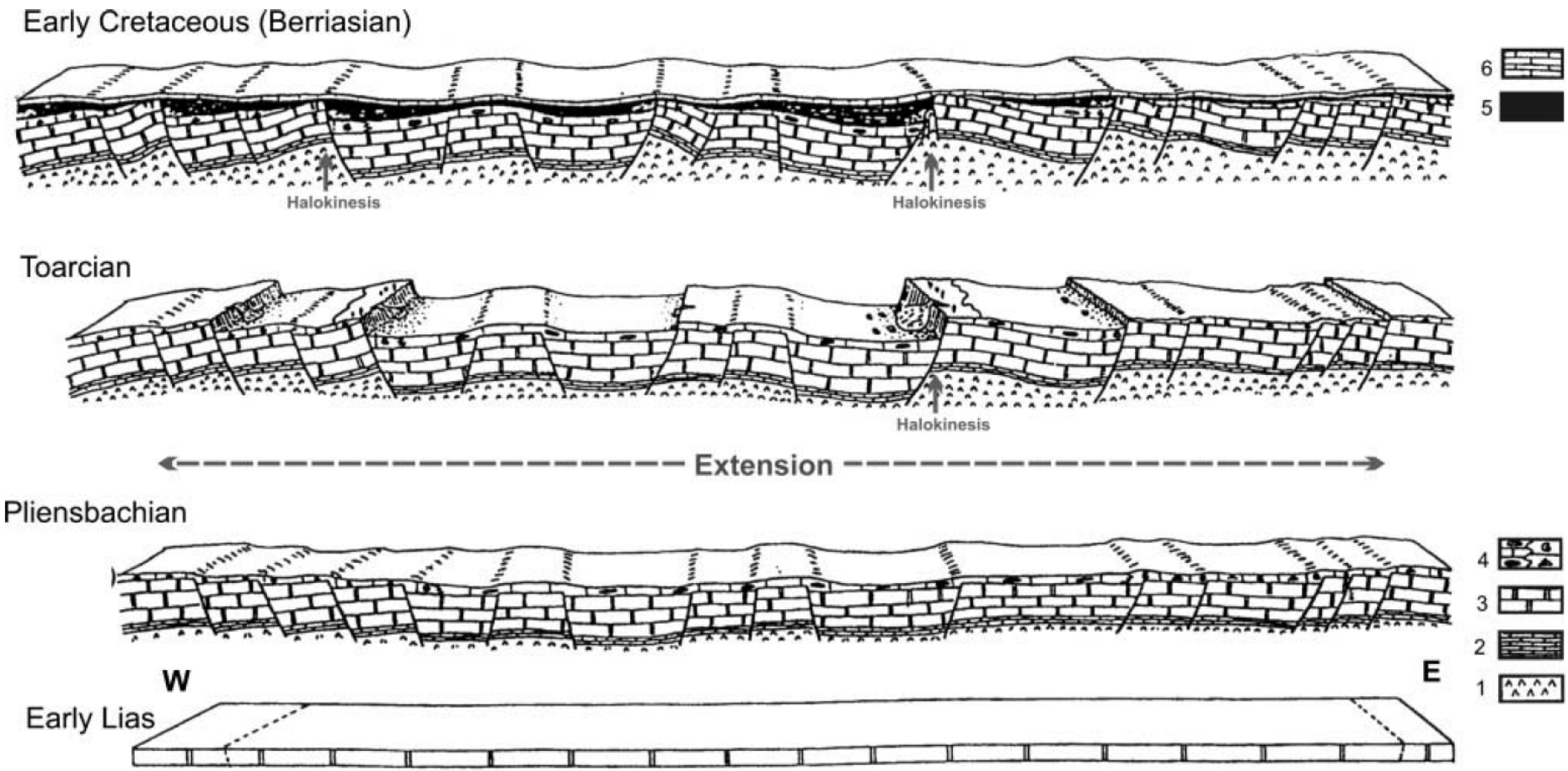
PALAEOGEOGRAPHIC EVOLUTION OF THE IONIAN ZONE



Palaeogeographic evolution of the Ionian zone, from the Early Jurassic to the Early Cretaceous (Berriasian). (1) Evaporites. (2) Foustapidima limestones. (3) Pantokrator limestones. (4) Siniais and Louros limestones. (5) Synrift formations. (6) Vigla limestones (From *Karakitsios, 1992, 2013*).

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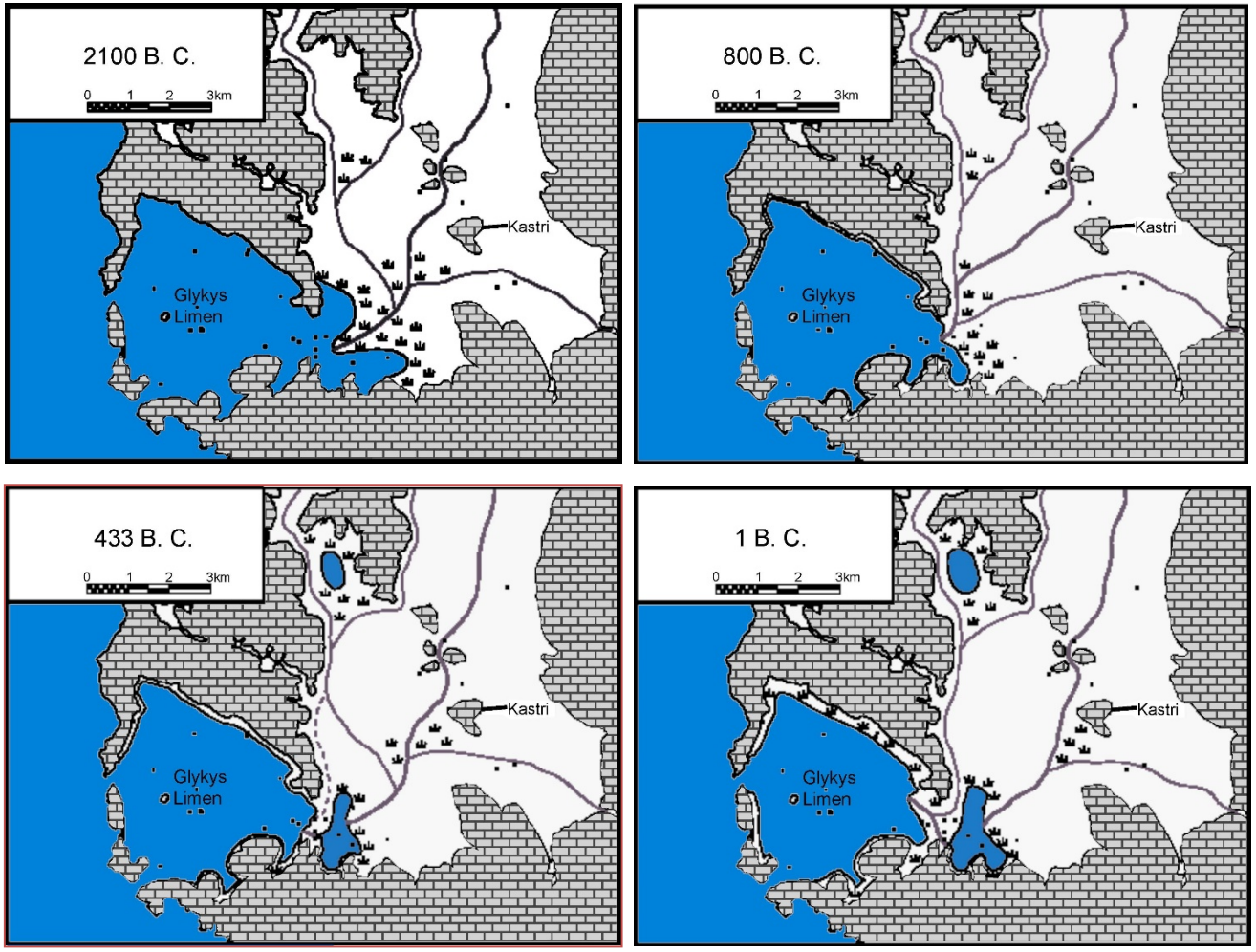
PALAEOGEOGRAPHY OF THE LOWER ACHERON VALLEY



The lower part of the Acheron River alluvial valley is a dynamic terrain subjected to ongoing changes and processes that affect not only the geomorphological properties of the area, but also the built environment comprising its buildings, infrastructures and lifelines (From *Besonen et al., 2003,* modified from *Fountoulis, 2007*).

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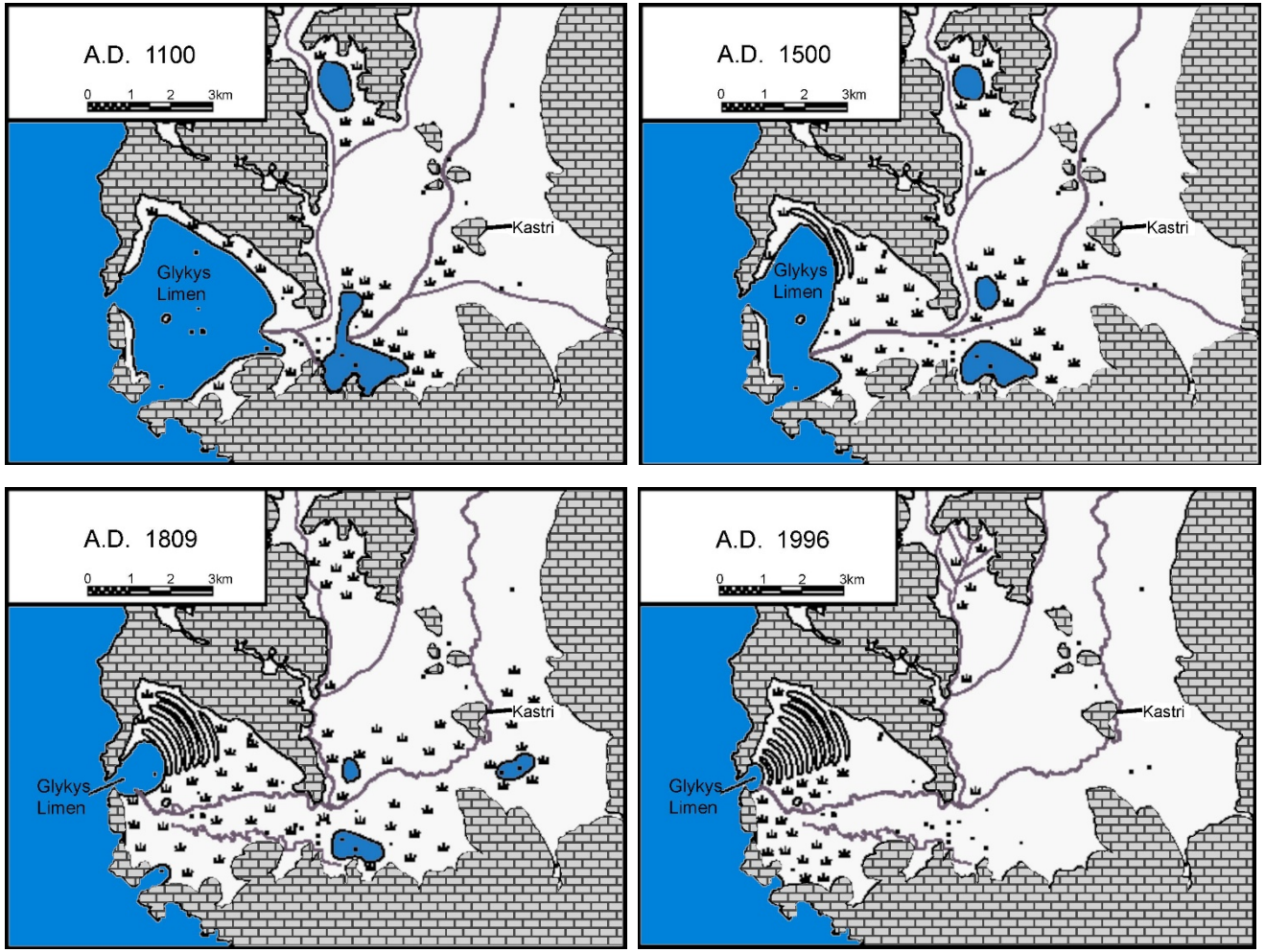
PALAEOGEOGRAPHY OF THE LOWER ACHERON VALLEY



Coastline displacement of 3.5 km and reduction of Glykys Limen surface of 11 km^2 during the last 900 years (1100-1996 AD)
(From *Besonen et al., 2003,* modified from *Fountoulis, 2007*)

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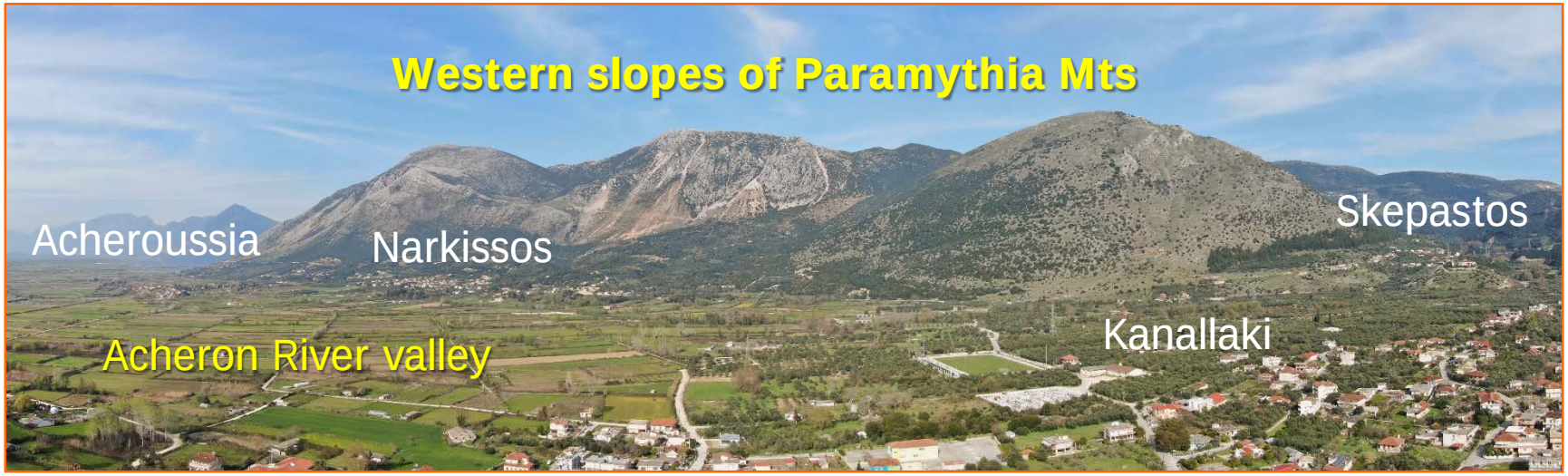
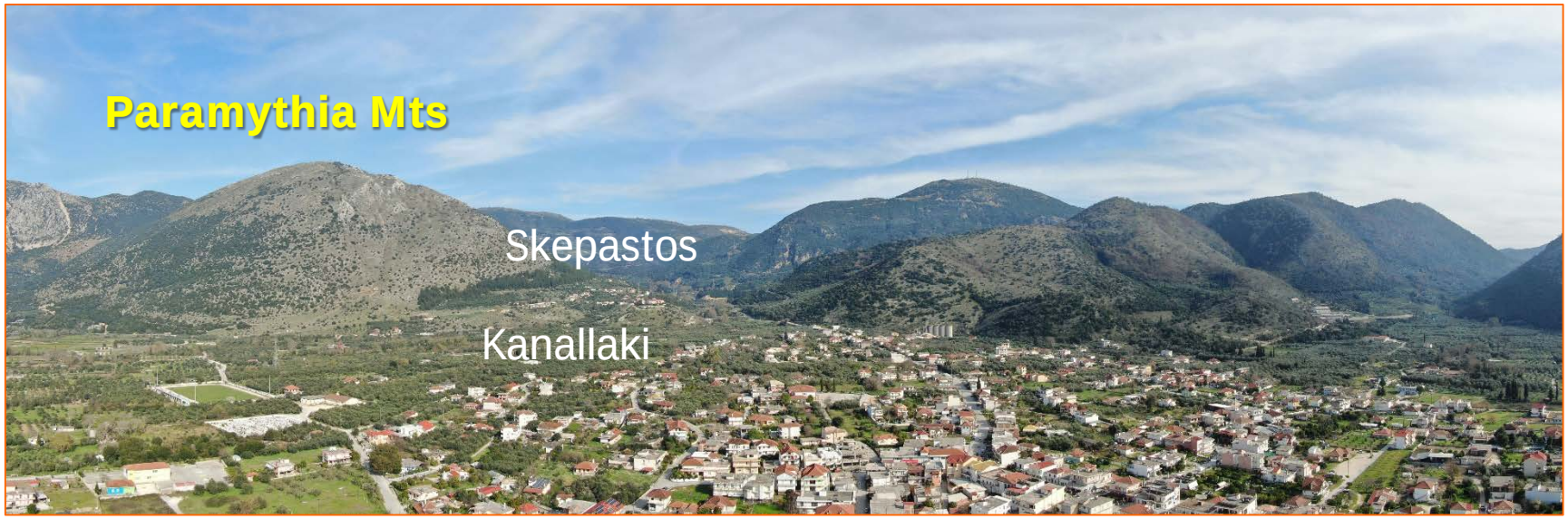
PANORAMIC DRONE VIEW OF THE 2020 EARTHQUAKE AFFECTED AREA





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PANORAMIC DRONE VIEW OF THE 2020 EARTHQUAKE AFFECTED AREA

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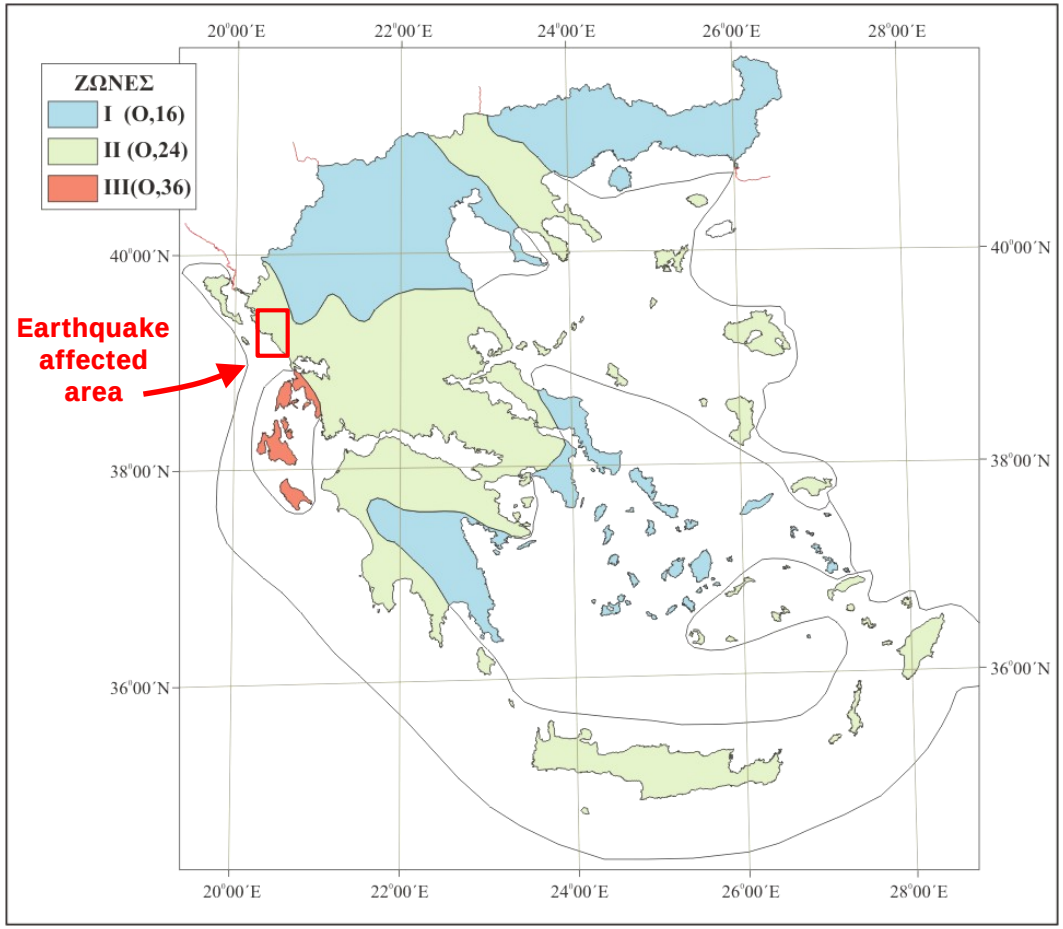
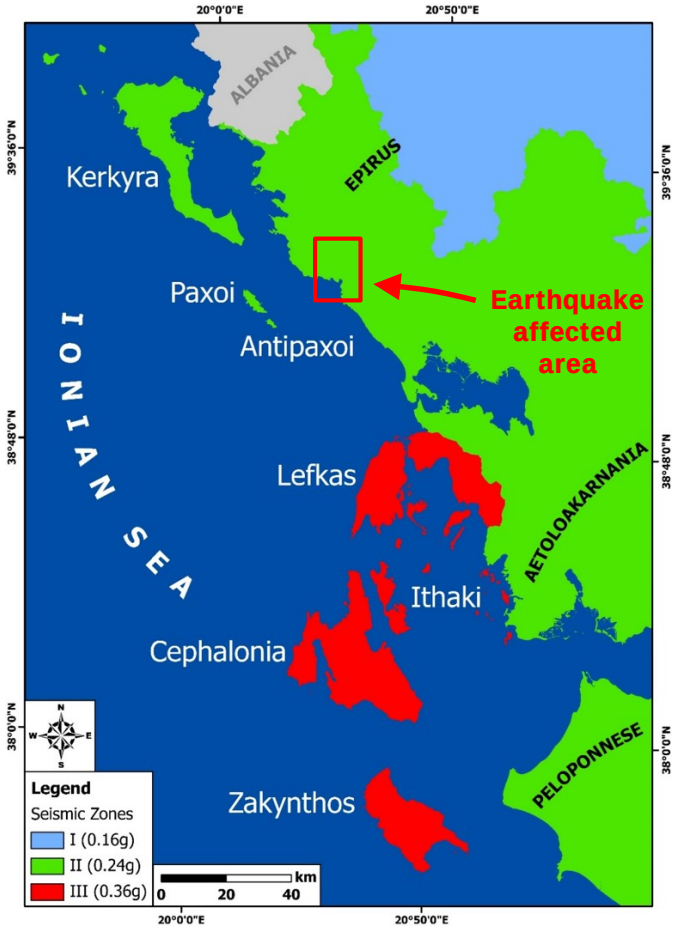
SEISMIC ZONES IN WESTERN GREECE

The area affected by the March 21, 2020, Mw 5.7 earthquake falls in the second seismic zone of Greece, which is characterized by a ground acceleration coefficient of 0.24 g corresponding to the greatest seismic strength demand according to the Greek Code for Seismic Resistant Structures.



From *Earthquake Planning and Protection Organization (2003)*



From *Mavroulis et al. (2017)*

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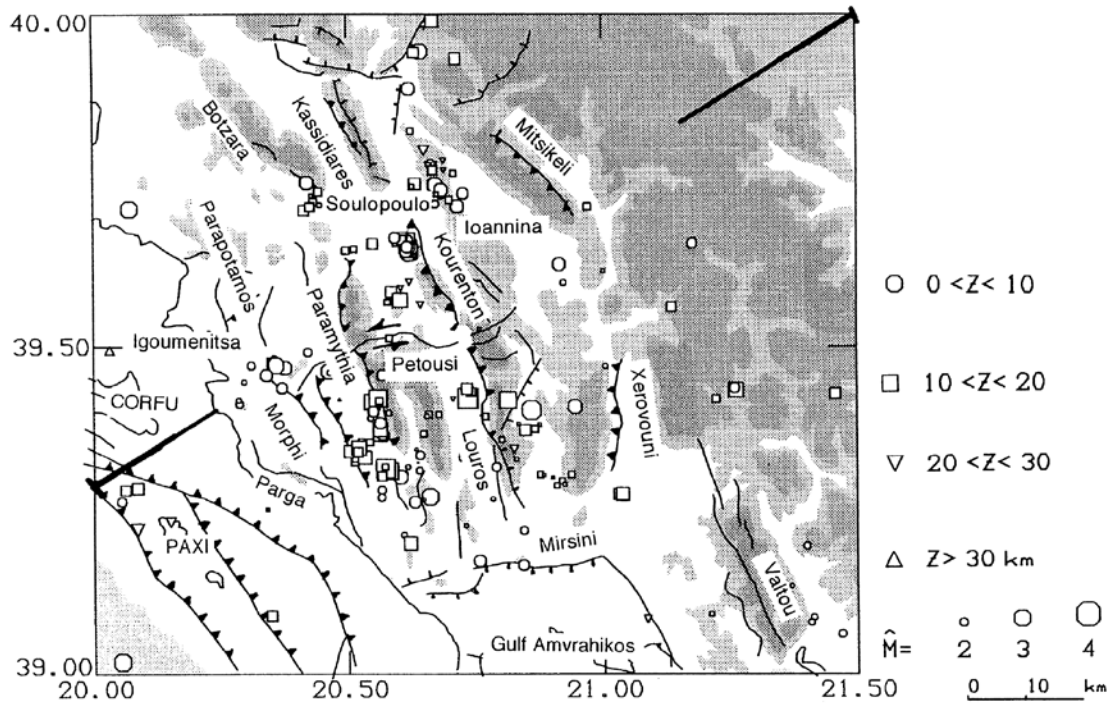
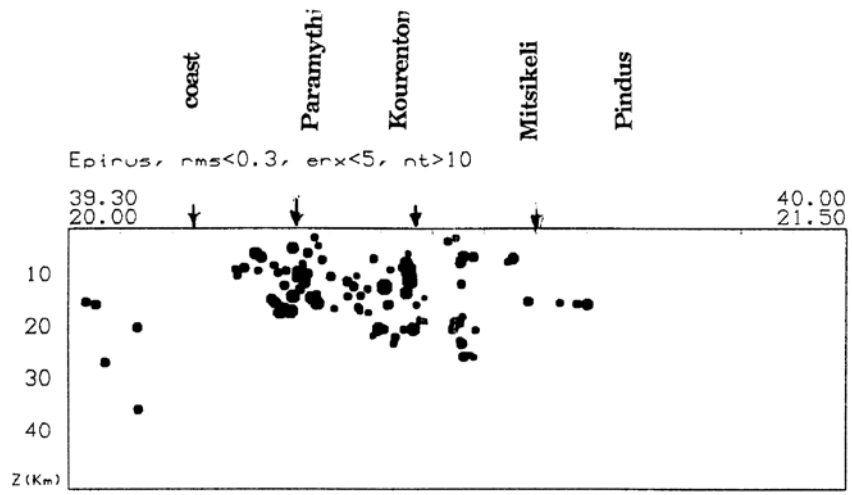
SEISMICITY IN EPIRUS





In Epirus, seismicity is restricted to the fold and thrust belt located west of the Pindos mountain range (Botzara, Kassidiares, Paramythia, Kourenton and Louros Mts).

The Pindos Mts as well as the regions of low topography, such as the Parga and Parapotamos, are of low seismic activity.

South of Petoussi fault, seismicity with depths ranging from 9 to 14 km seems concetrated around Paramythia and Morphi mountains, which are bounded by reverse faults dipping east (*IGRS-IFP, 1966*) and inferred to be active (*King et al., 1993; Waters, 1993*).

From *Hatzfeld et al. (1995)*

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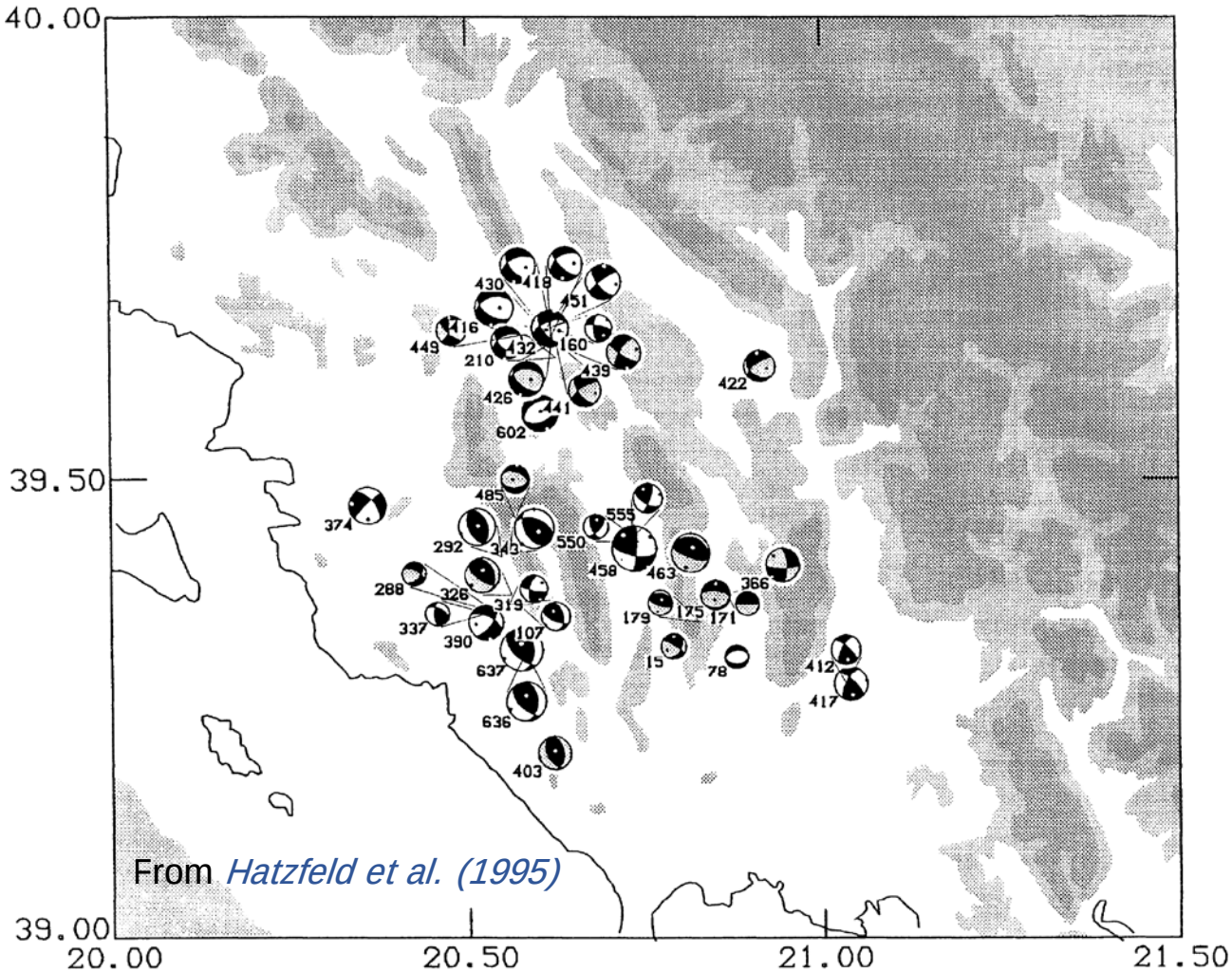
FOCAL MECHANISMS IN EPIRUS



Most mechanisms in Epirus show reverse faulting with P axes trending NE (#107, 292, 326, 337, 343, 403, 636), but there are also some with a large component of N-S extension or strike-slip faulting (#288, 319, 390, 485).

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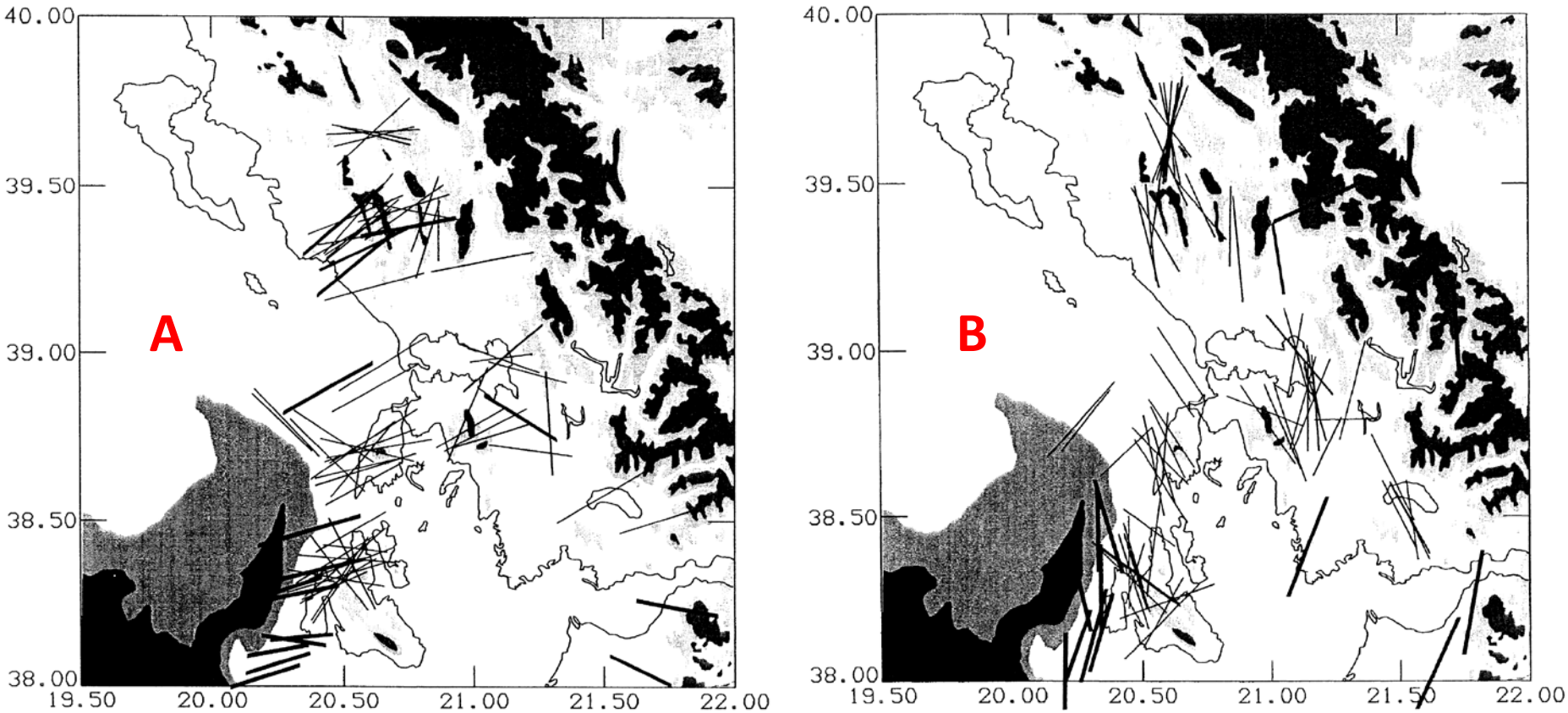
PRINCIPAL AXES OF DEFORMATION IN EPIRUS



Maps of the principal axes of deformation deduced from the focal mechanisms of *Hatzfeld et al. (1995)*. Thin lines are from *Hatzfeld et al. (1995)* and thick lines are either from body wave modelling of earthquakes *(Baker et al., 1994)* or CMT solutions. (**A**) P axes, (**B**) T axes.

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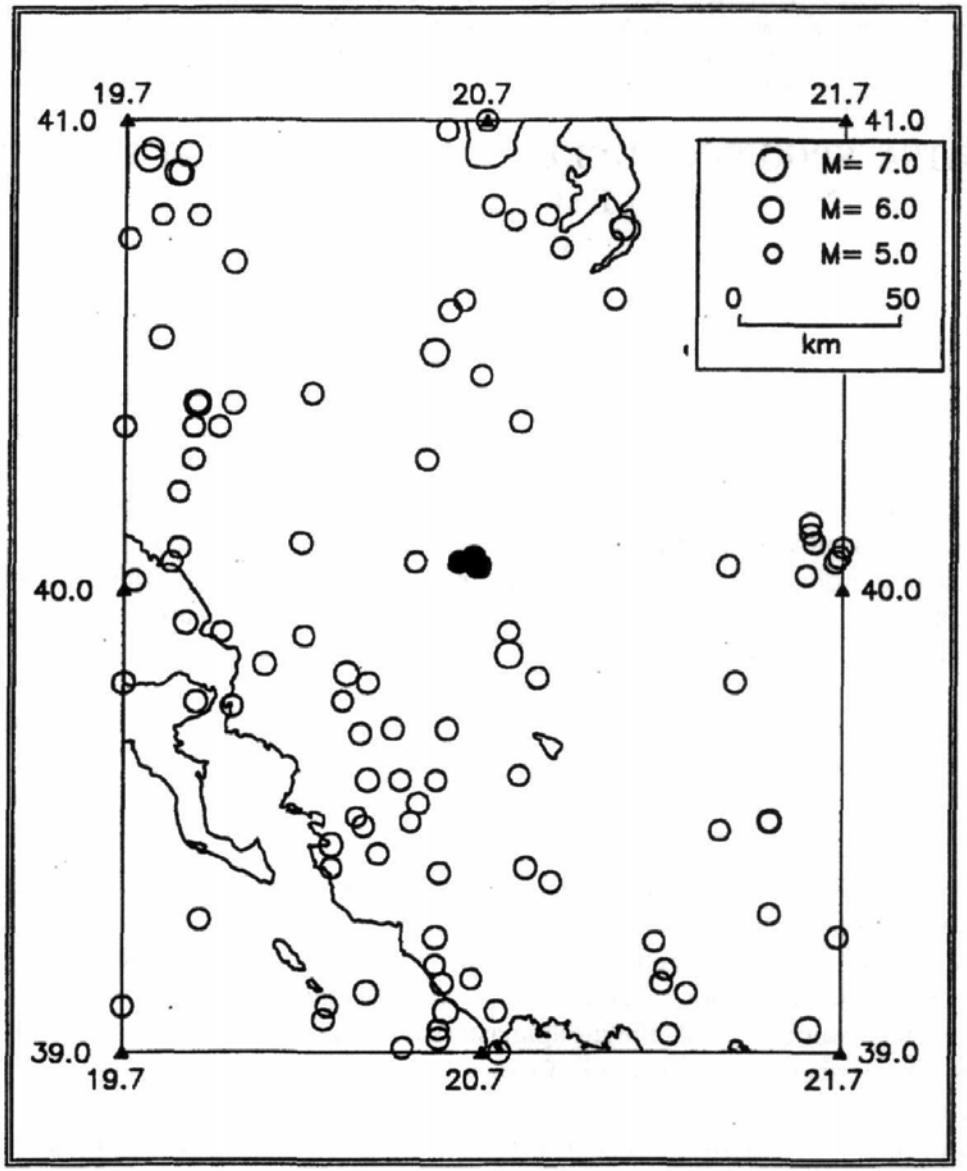
SEISMICITY IN EPIRUS



Northwestern Greece displays a complex tectonic pattern because it is a transitional zone between the Inner Aegean extensional region and the outer compressional zone (*King et al., 1983*, *Papadopoulos et al., 1986*).

Instrumental seismic records show the occurrence of a large number of earthquakes of low magnitude (*Hatzfeld et al., 1995*) and a very limited number of earthquakes of high magnitude (*Papazachos and Comninakis, 1978; Voidomatis, 1989*).

There is also evidence for historical seismic events in the broader area (*Papazachos and Papazachou, 1989, 1997, 2003*) such as those of 1740 (I_{MM}=VIII), 1813 (I_{MM}=IX), 1823 (I_{MM}=IX) and 1895 (I_{MM}=VIII). Both historical and instrumental records show that the spatial distribution of the epicenters is scattered, there being no clear seismotectonic correlation between specific faults and seismic activity.

◀ Background seismicity of the broader area of Epirus for the period 1900-2000
(From *Papanastasiou, 2001*)

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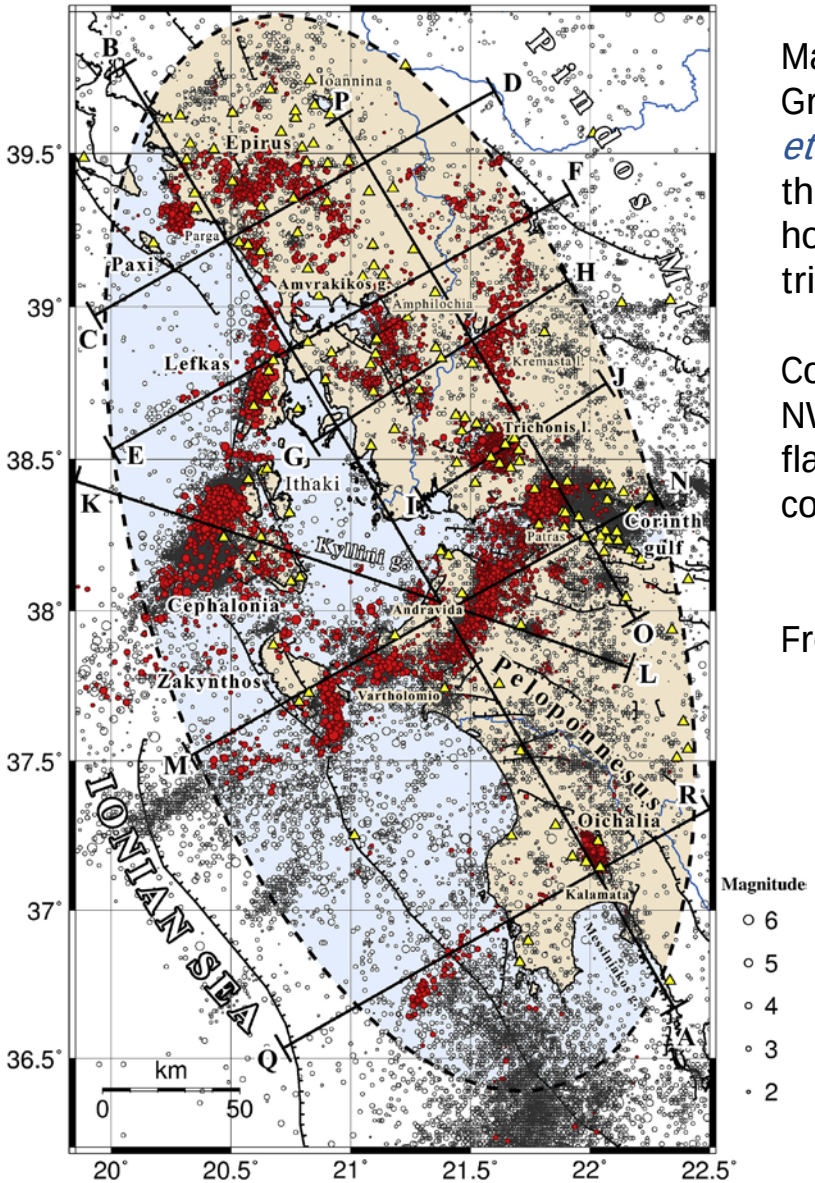
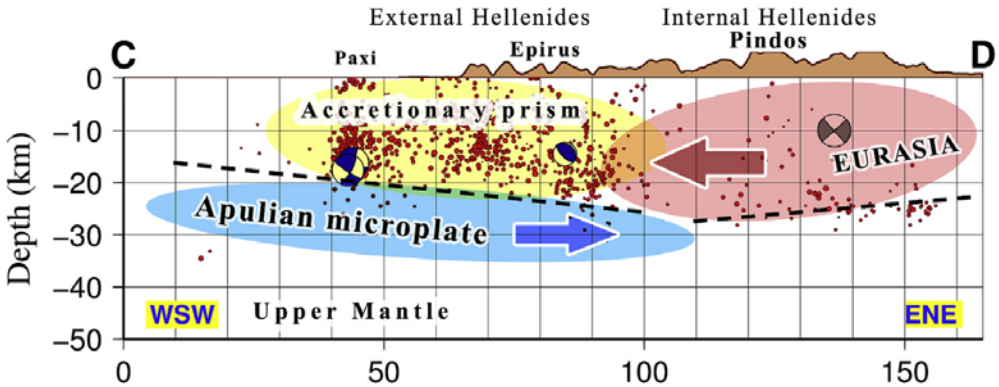
SEISMICITY IN EPIRUS



Map of relocated seismicity (red solid circles) in the Western Greece on top of seismicity from the catalogue of *Makropoulos et al. (2012)* for the period 1987-2007 and routine locations of the National Observatory of Athens during 2008-2014 (gray hollow circles). Seismological stations are represented by triangles.

Compressional and strike-slip tectonics apparently dominate in NW Greece. An aseismic area between Epirus and the western flanks of Pindos Mt. bounds the latter regime which gradually converts to extension easterly, beneath Pindos.

From *Kassaras et al. (2016)*



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HISTORICAL EARTHQUAKES WITHIN THE 2020 EARTHQUAKE AFFECTED AREA

1895, May 14, 39.42° N, 20.61° E, h=n, M=6.3
Epirus (X, Dragoumi)

The earthquake destroyed the village **Dragoumi** where 96 houses, the school and five churches collapsed, while 75 people were killed and 46 injured. It was also destructive in the village **Karvounari**, where 183 houses were entirely destroyed. The rest 14 houses remained uninhabitable and 7 people were killed. In other 8 nearby villages several houses collapsed. Many people were injured and one was killed. In **Gardiki** some houses collapsed. The village **Kourtesi** near Margariti suffered much. In **Paramythia**, most of the houses, the Catholic Church and the upper part of the mosque in the market were fissured and some derelict walls collapsed. Some damage also occurred in **Filiates** and in the **Ioannina** plain. The earthquake was felt in Zante. It was preceded by a foreshock, which occurred some hours earlier and followed by aftershocks, which continued for a long time.

From *Papazachos and Papazachou (1989, 1997, 2003)*

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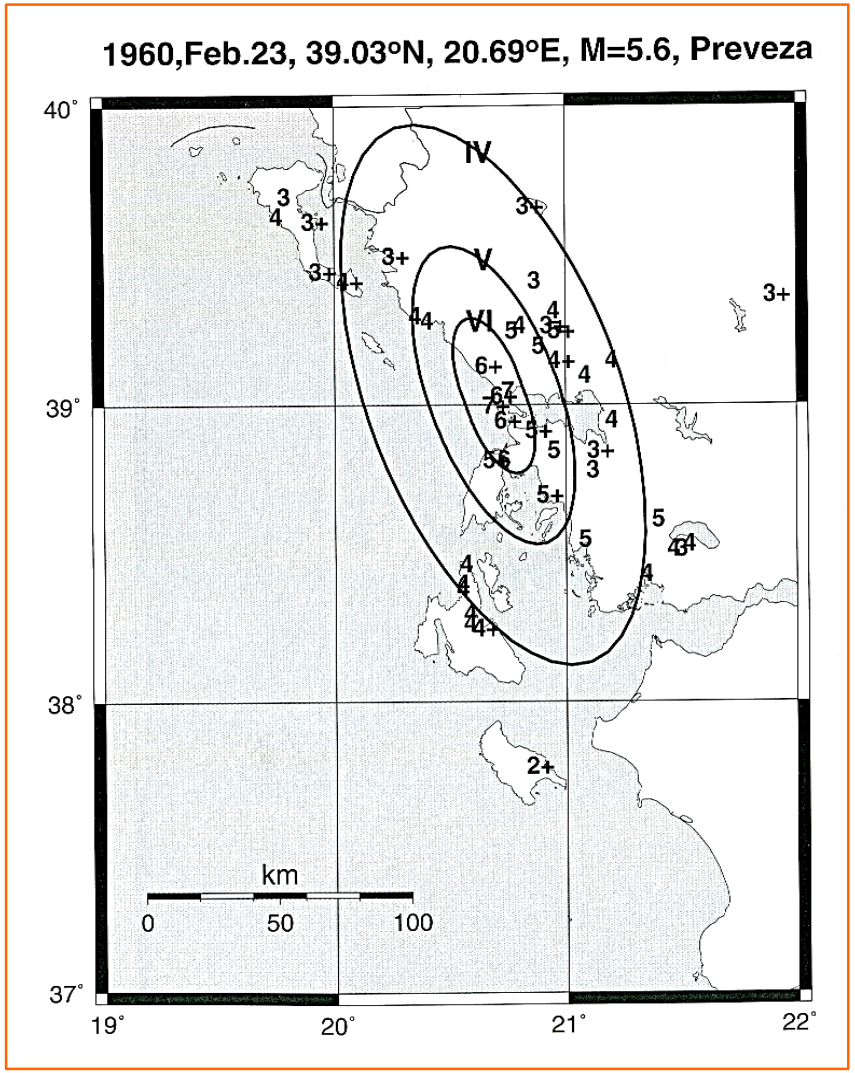
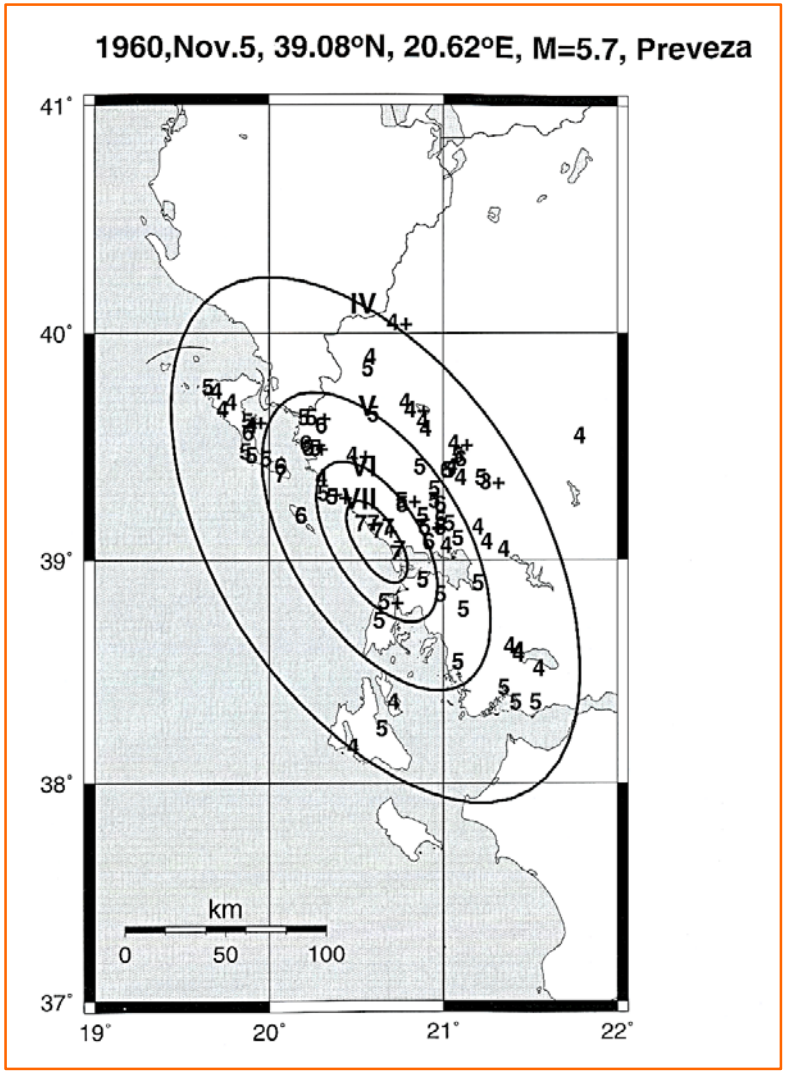
ISOSEISMAL MAPS OF PREVIOUS EVENTS
WITH IMPACT ON THE 2020 EARTHQUAKE AFFECTED AREA





From *Papazachos et al. (1997)*

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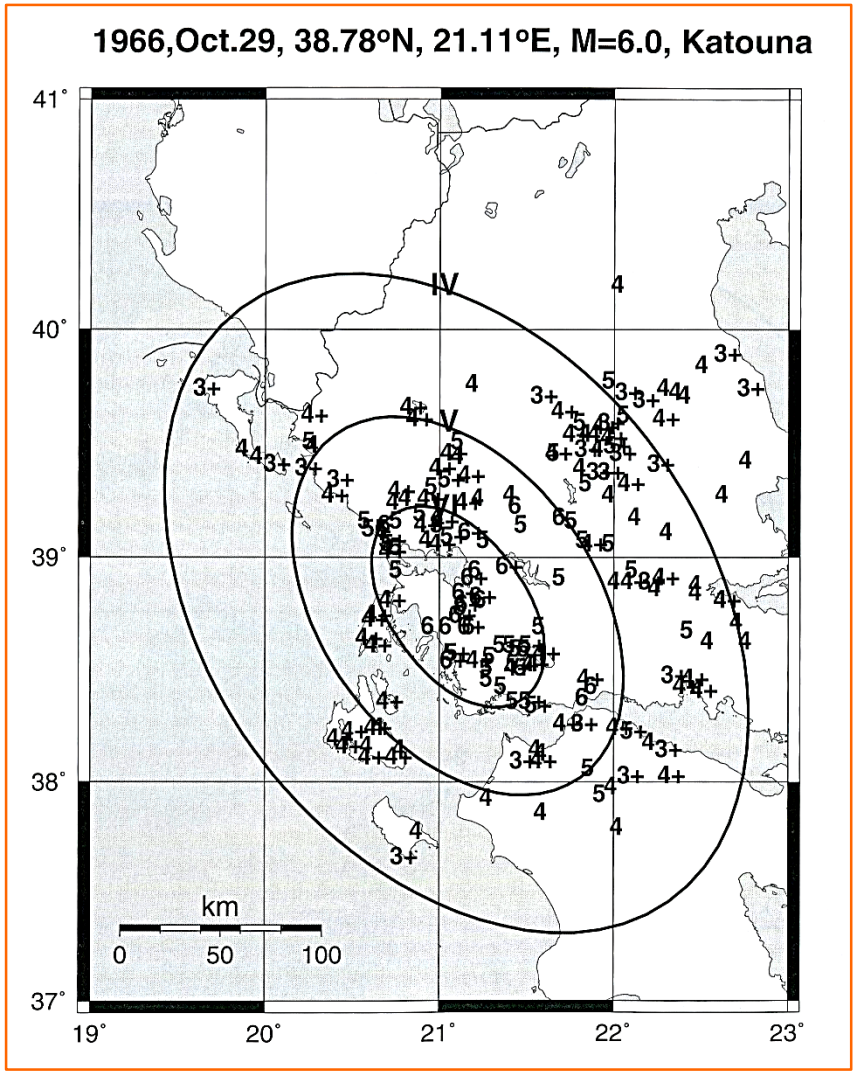
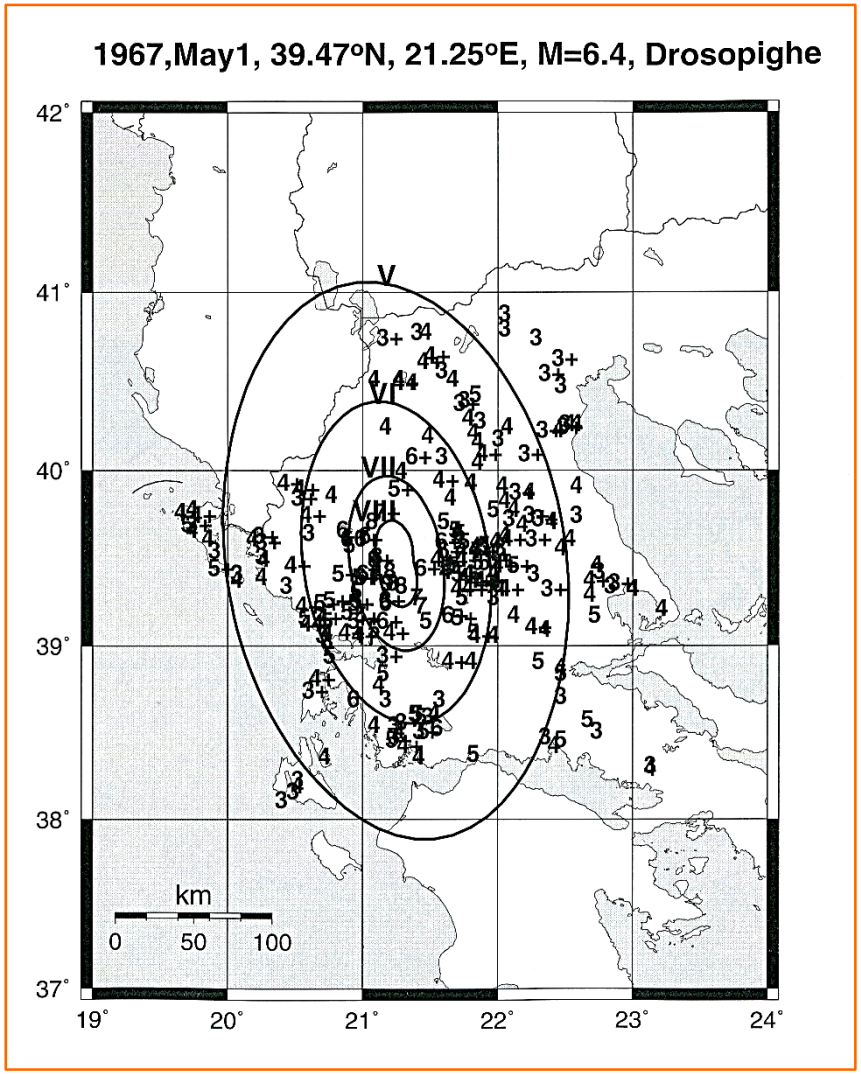
ISOSEISMAL MAPS OF PREVIOUS EVENTS
WITH IMPACT ON THE 2020 EARTHQUAKE AFFECTED AREA





From *Papazachos et al. (1997)*

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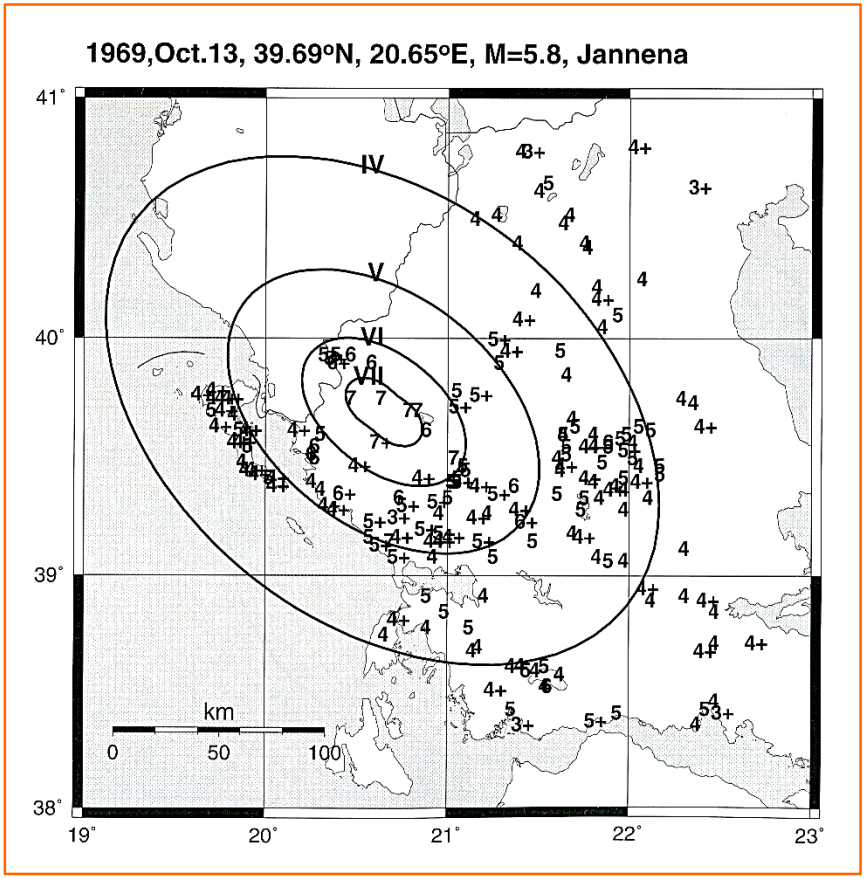
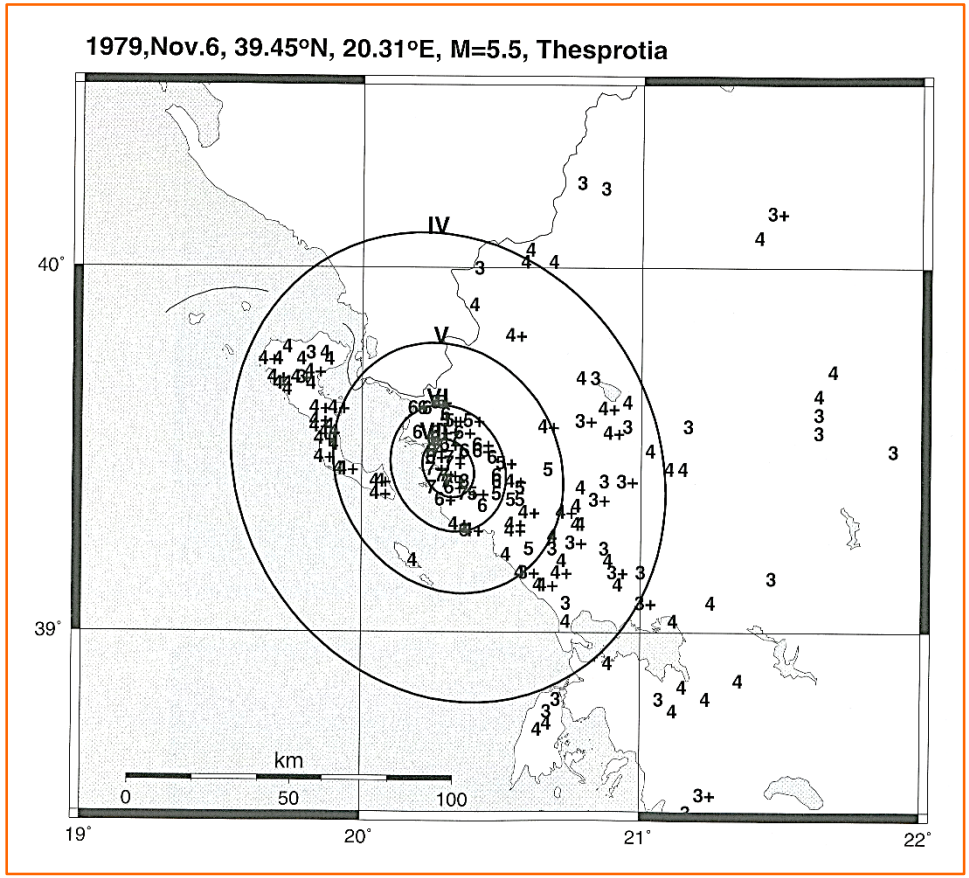
ISOSEISMAL MAPS OF PREVIOUS EVENTS
WITH IMPACT ON THE 2020 EARTHQUAKE AFFECTED AREA





From *Papazachos et al. (1997)*

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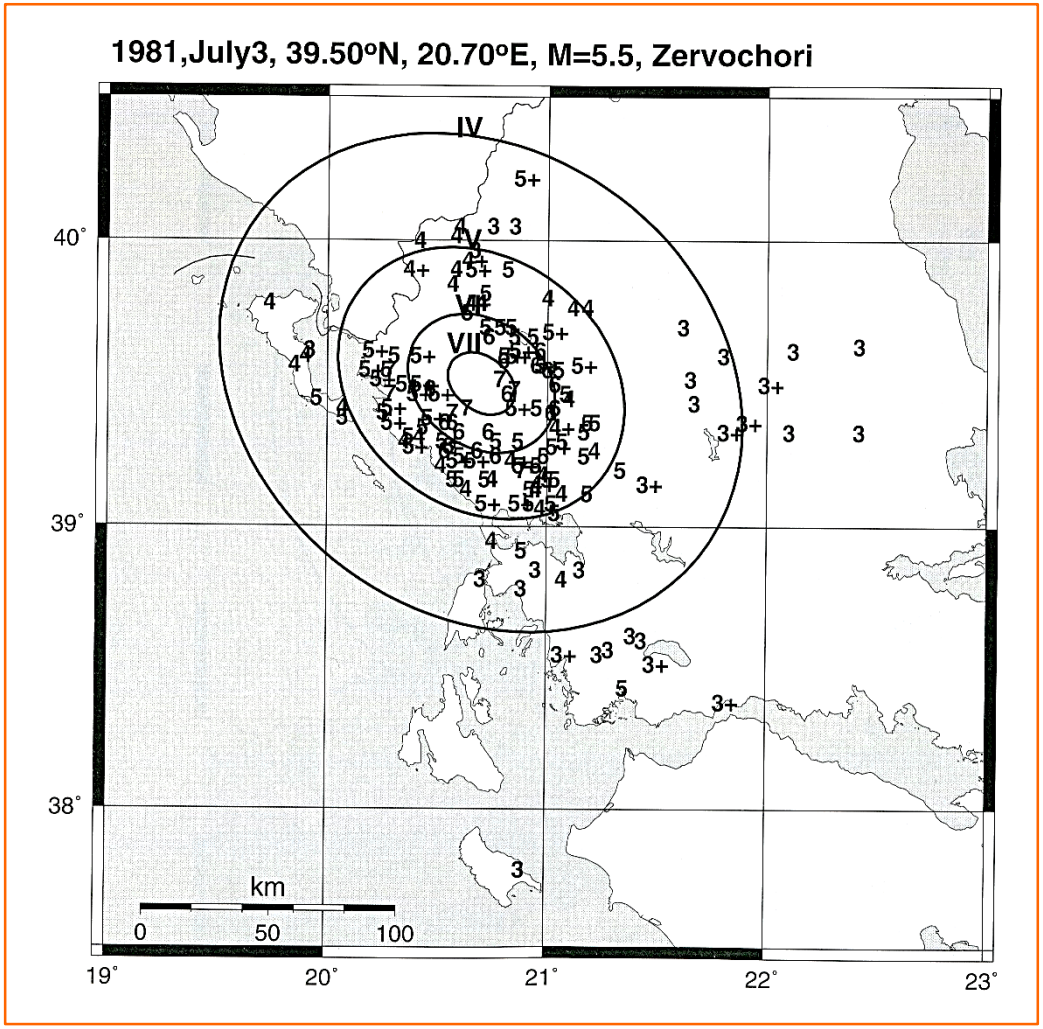
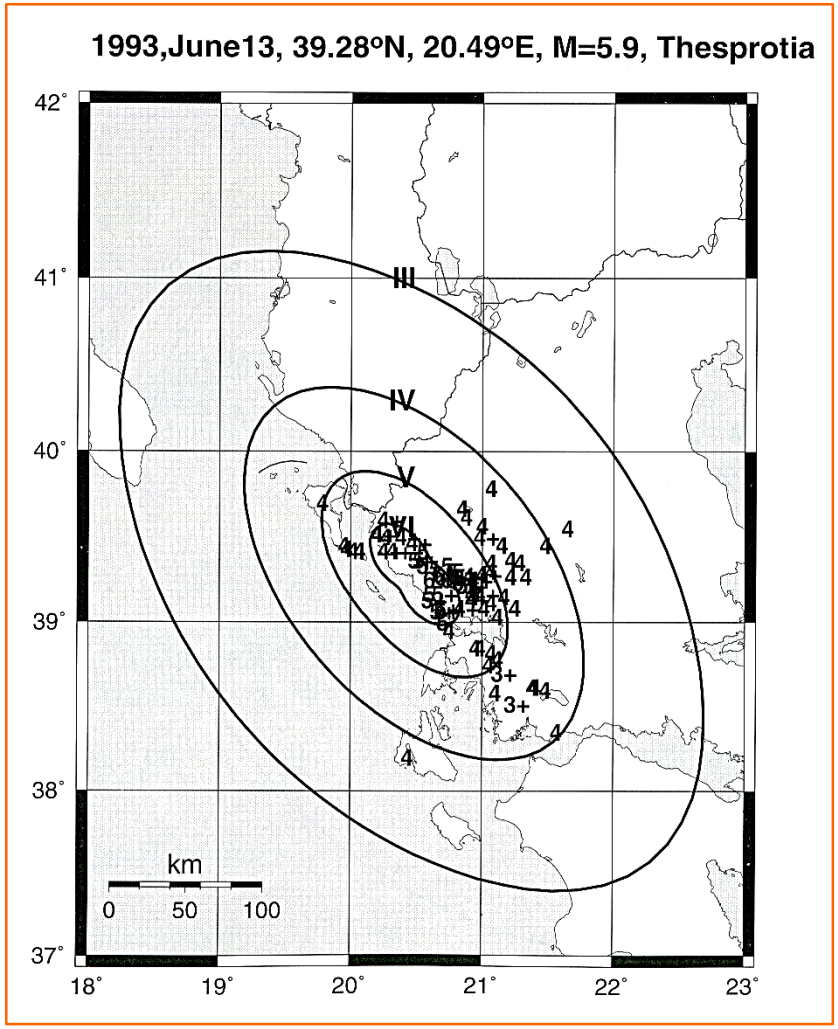
ISOSEISMAL MAPS OF PREVIOUS EVENTS
WITH IMPACT ON THE 2020 EARTHQUAKE AFFECTED AREA





From *Papazachos et al. (1997)*

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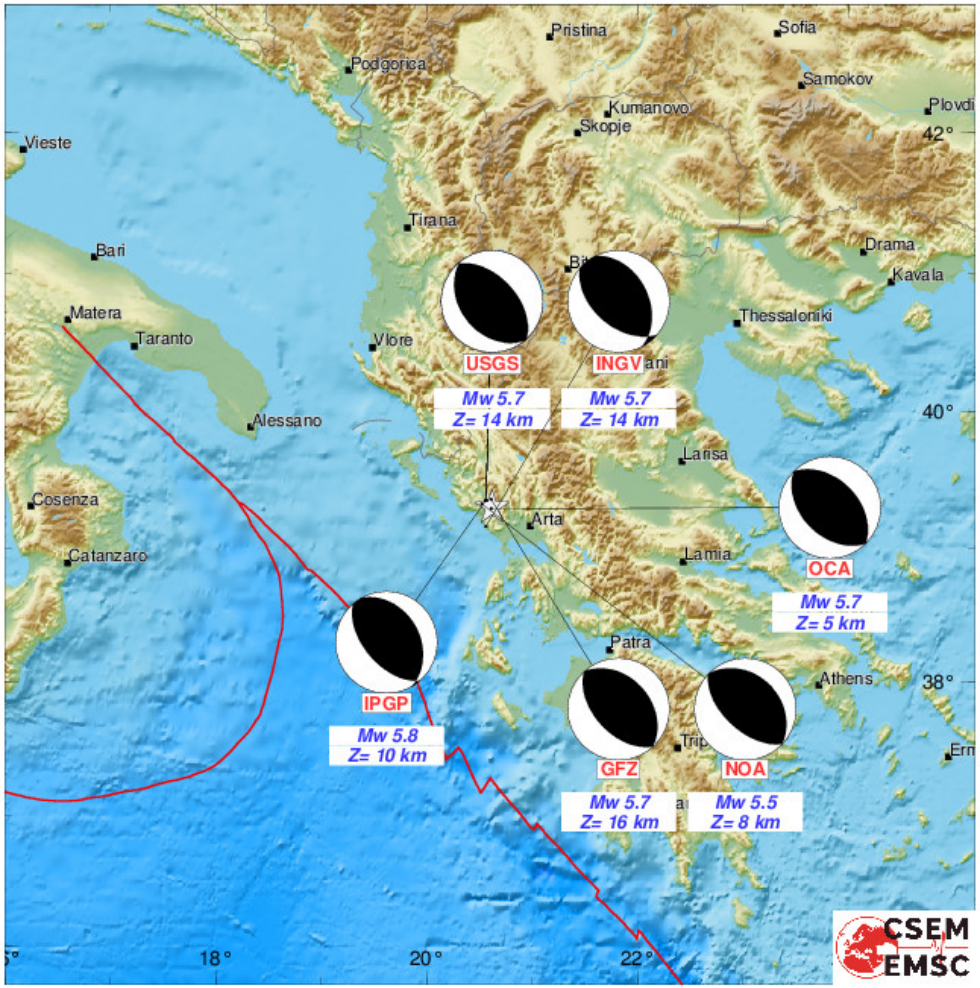
QUICK SOLUTIONS & REGIONAL MOMENT TENSORS
FOR THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE



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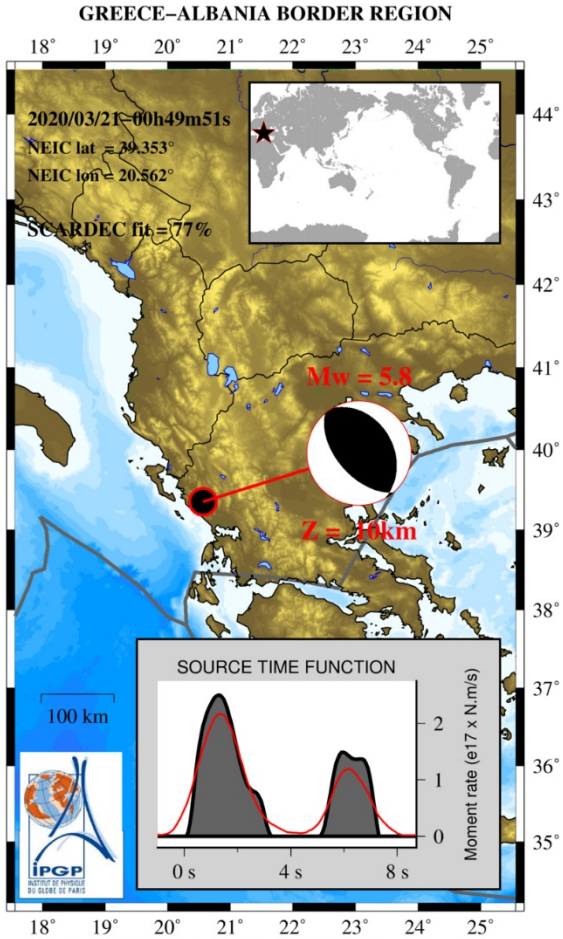
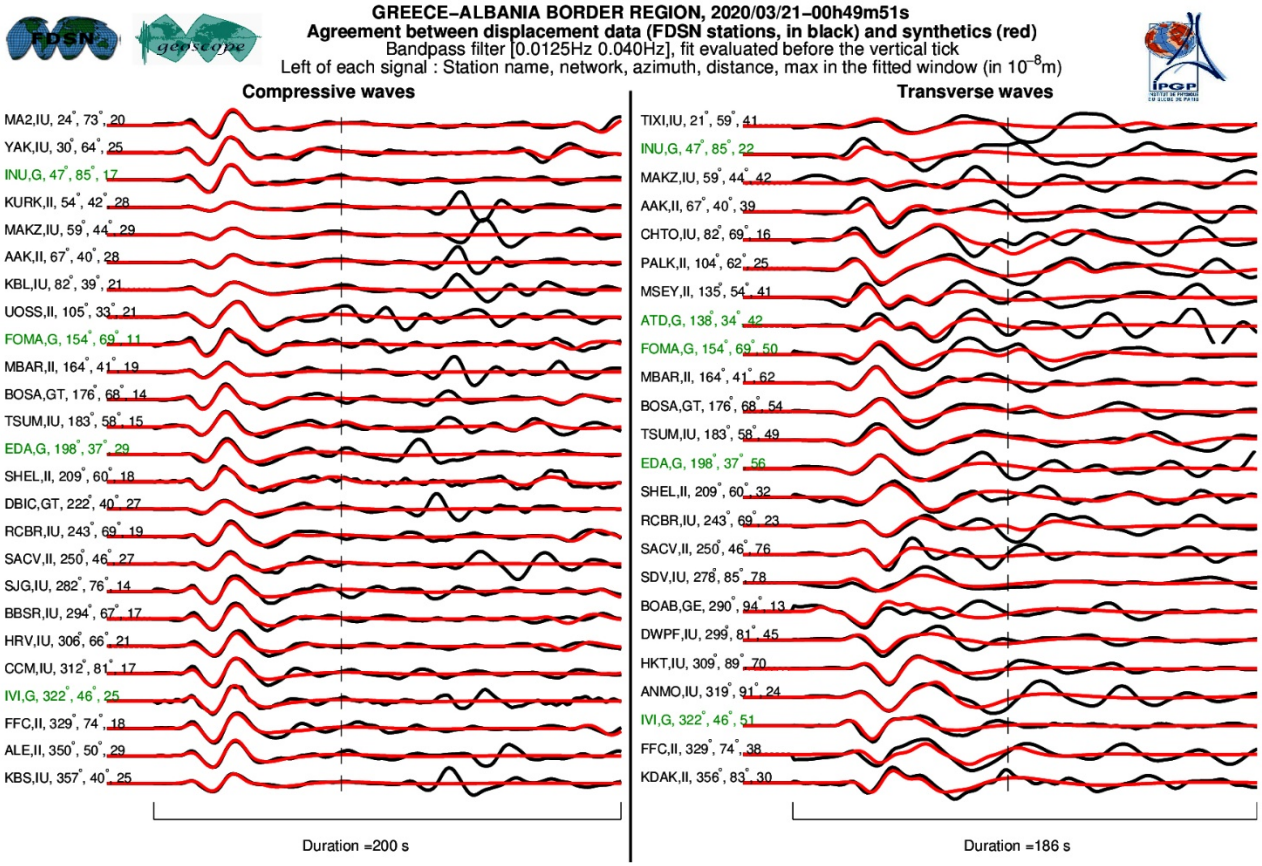
QUICK SOLUTION FOR THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE



(Strike, Dip, Rake) = (331°, 35°, 100°) / (139°, 56°, 83°)

M0 = 6.61E+17Nm (Mw = 5.81)



http://geoscope.ipgp.fr/index.php/en/catalog/earthquake-description?seis=us70008db1

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EPICENTER LOCATION
FOR THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE

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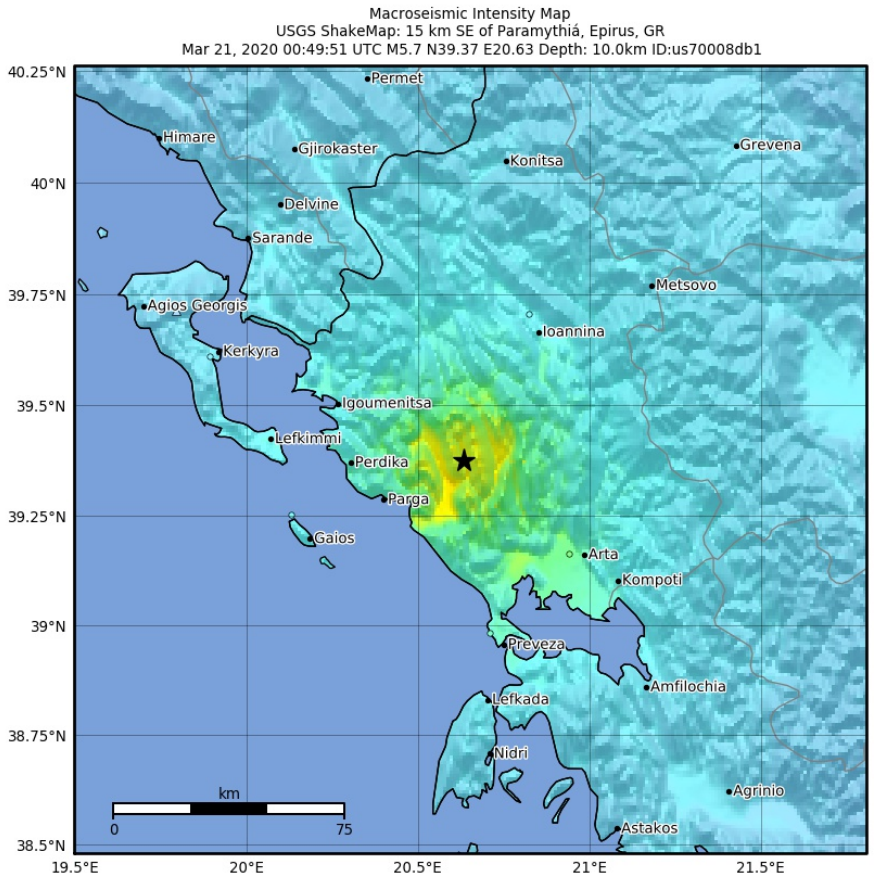
INTENSITY MAP
FOR THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE



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)	<0.05	0.3	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.02	0.13	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 6: Processed 2020-03-21T03:39:17Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

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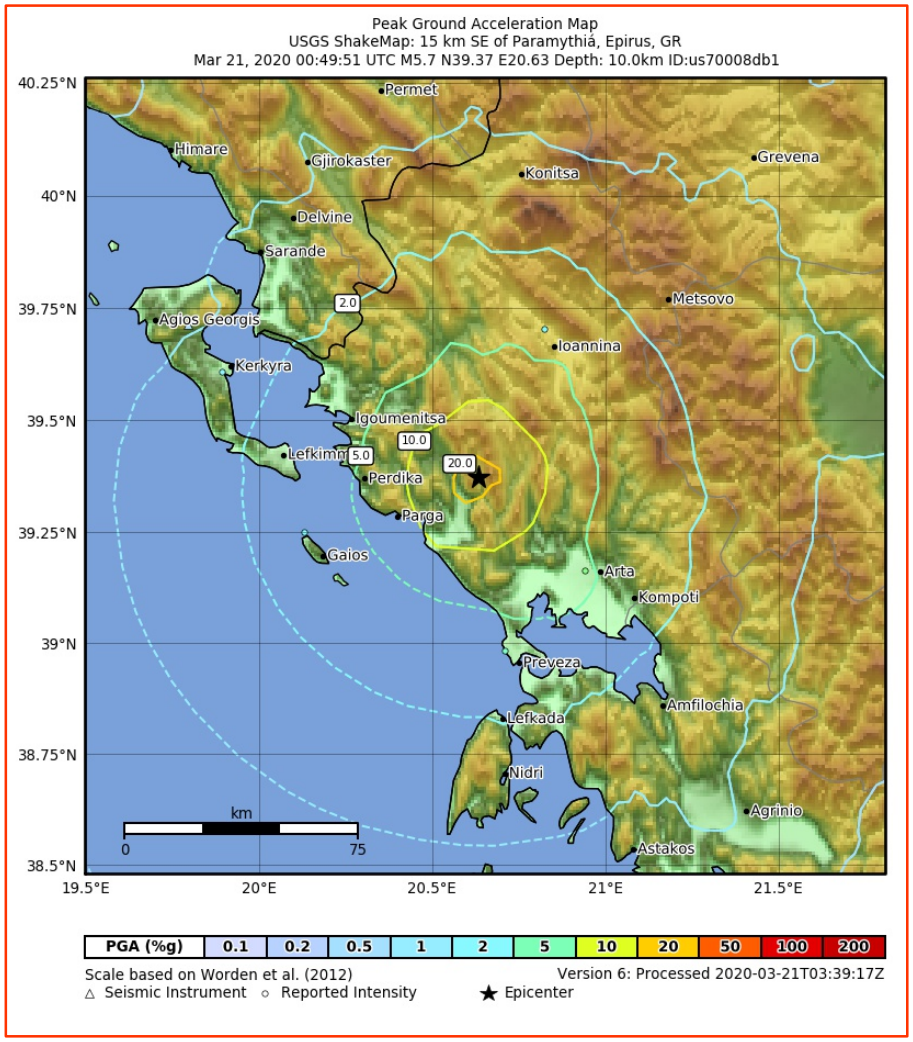
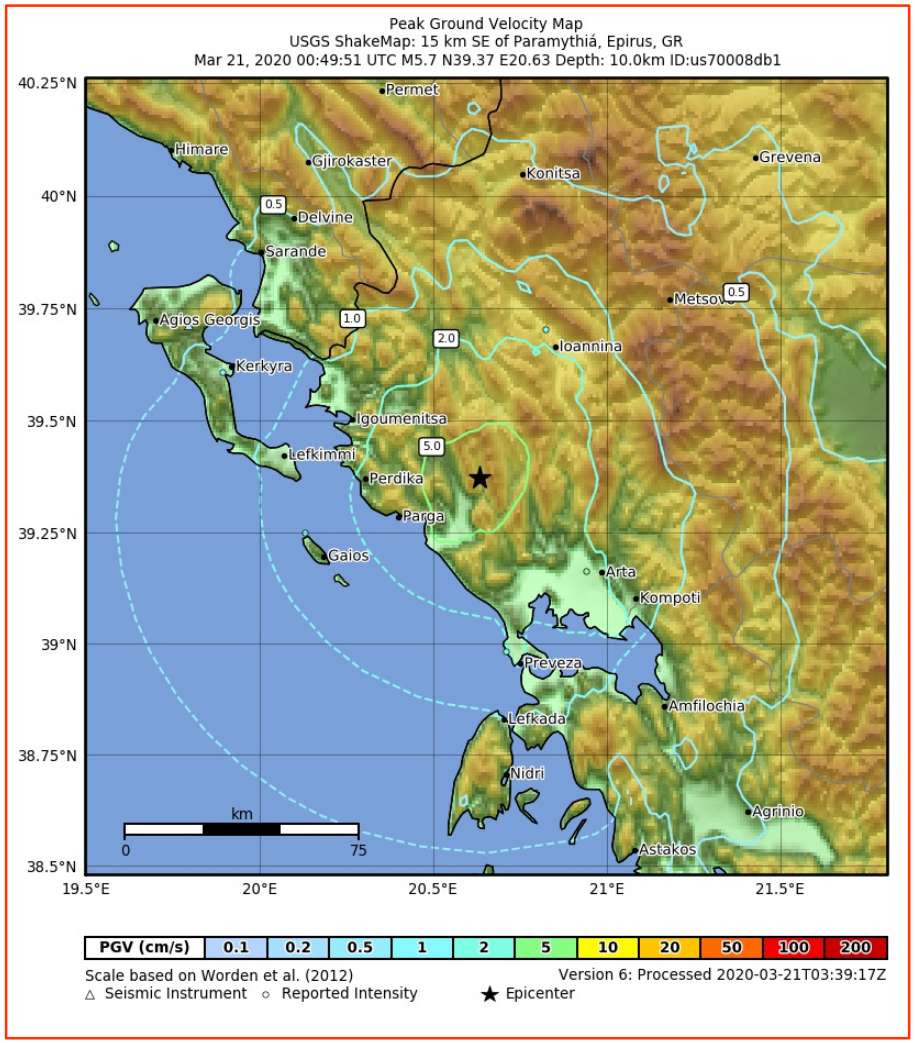
PEAK GROUND ACCELERATION & PEAK GROUND VELOCITY MAPS
FOR THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE





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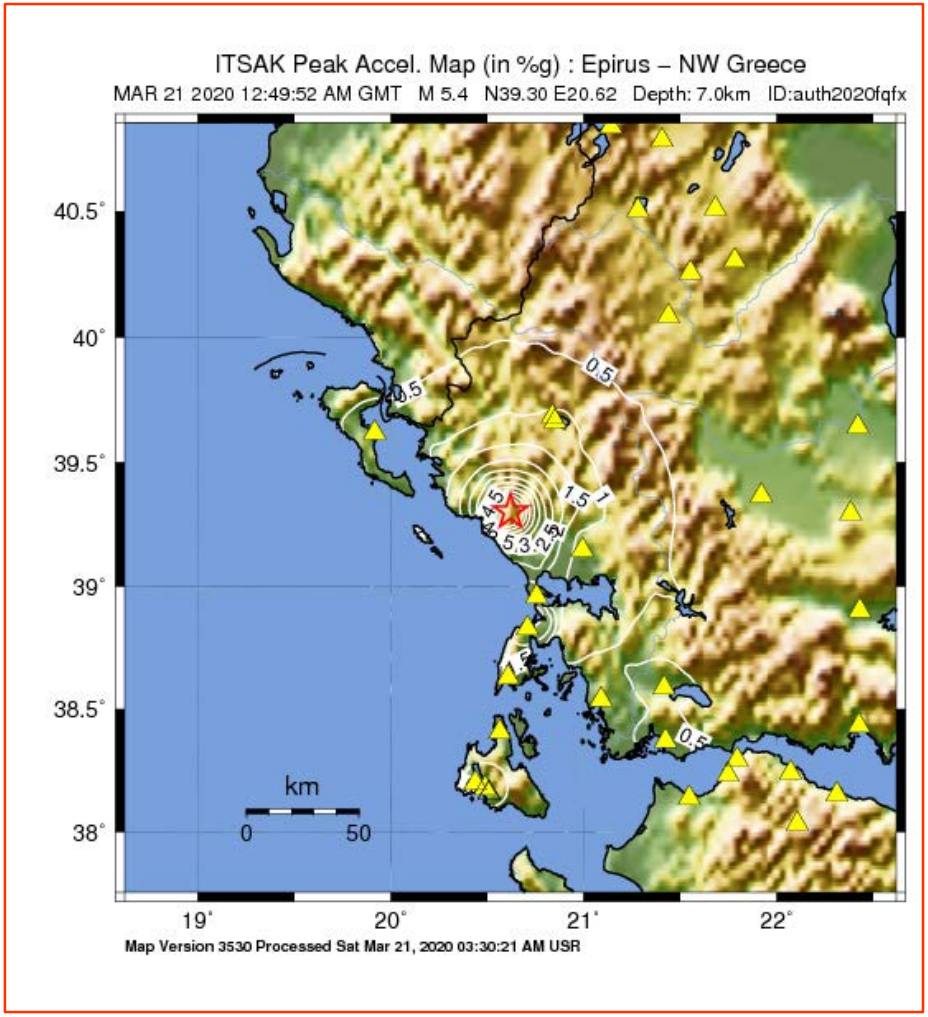
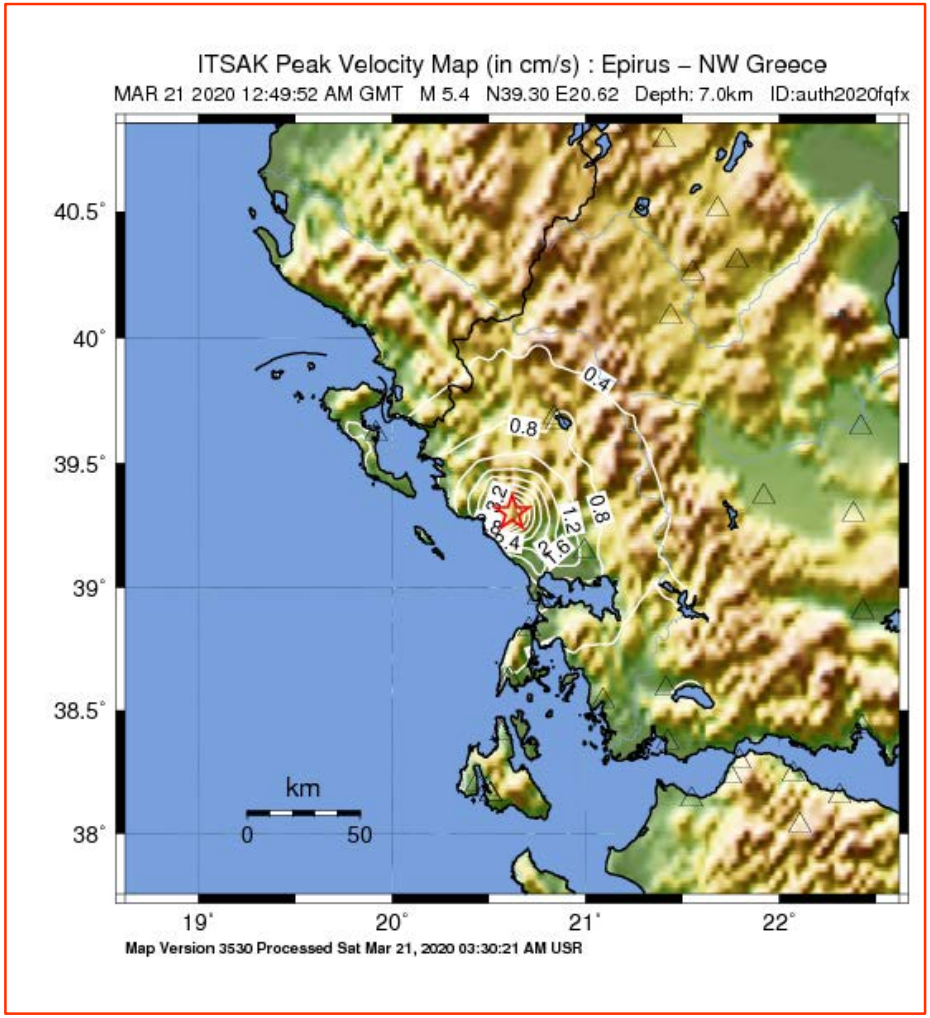
PEAK GROUND ACCELERATION & PEAK GROUND VELOCITY MAPS
FOR THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE

http://shakemaps. itsak.gr





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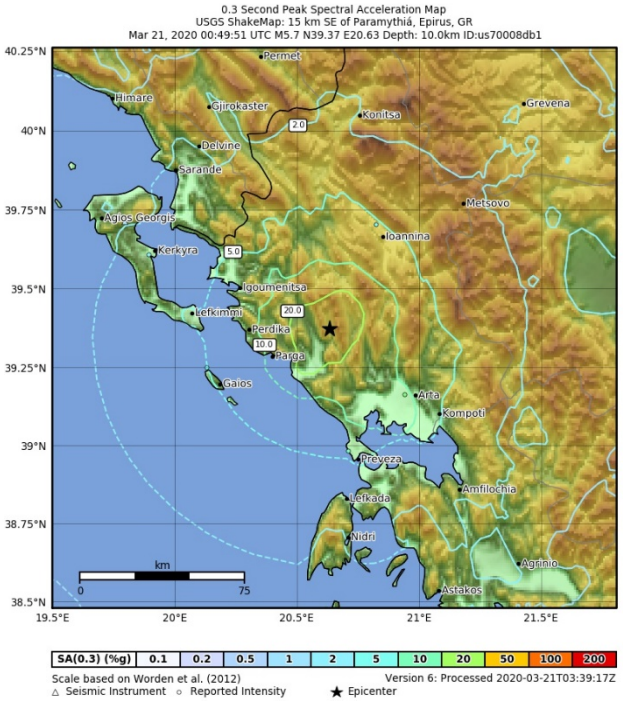
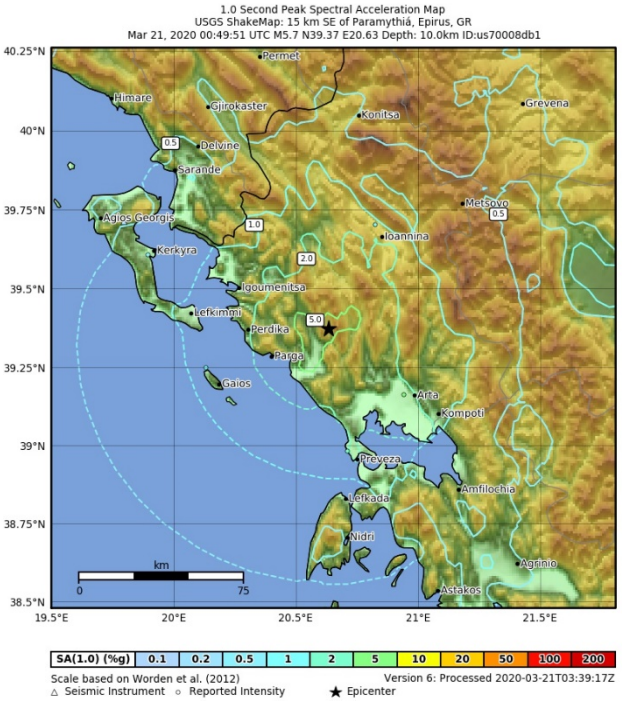
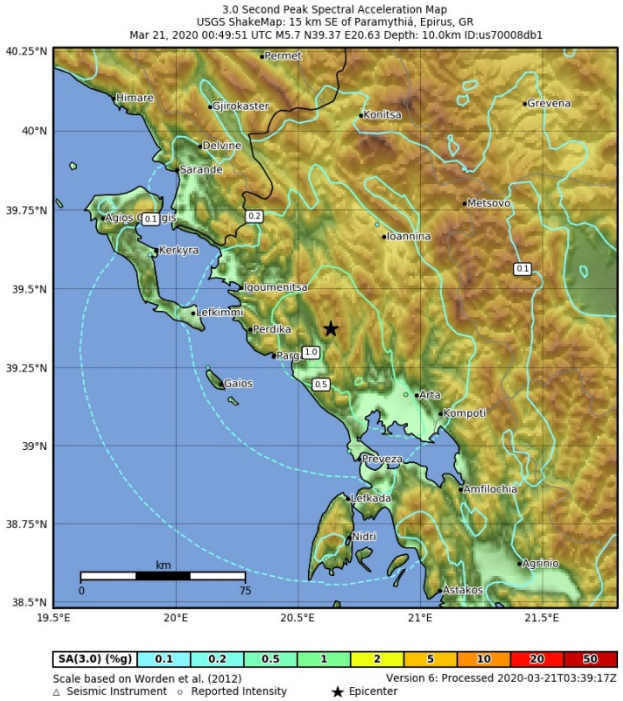
SPECTRAL RESPONSE
FOR THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE







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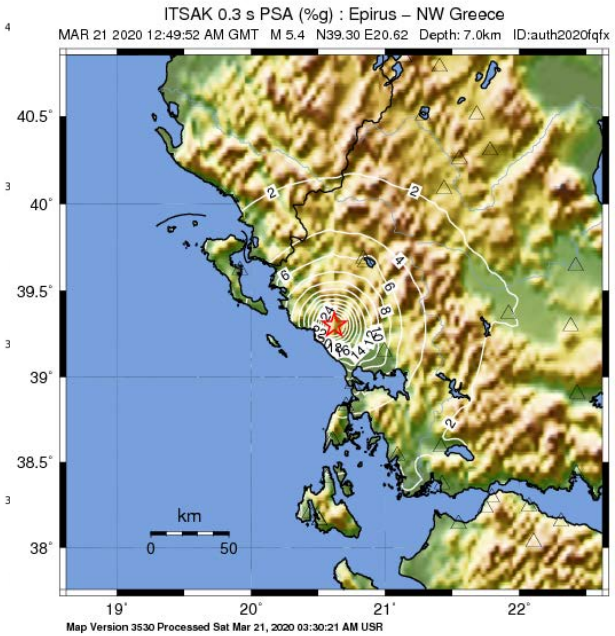
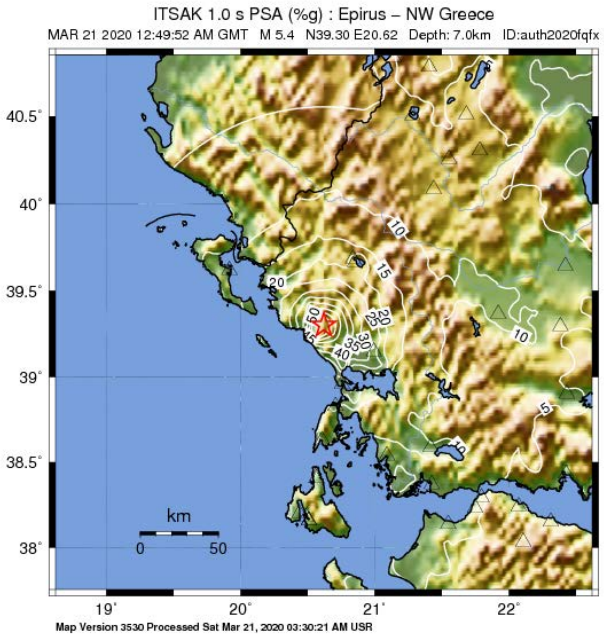
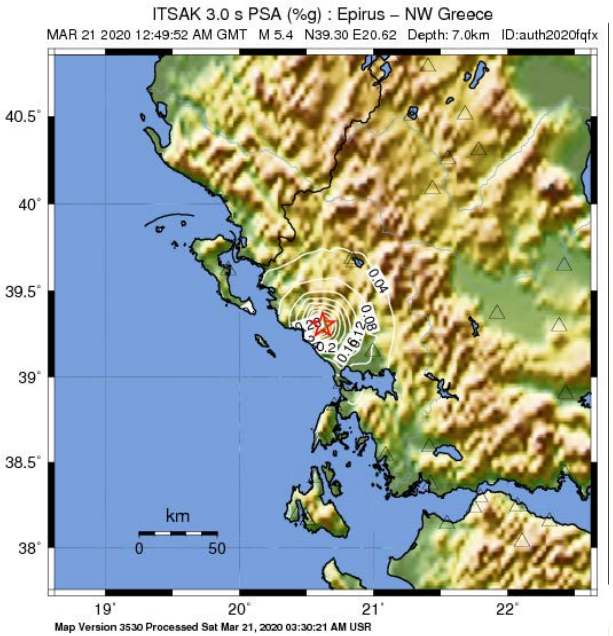
SPECTRAL RESPONSE
FOR THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE







http://shakemaps. itsak.gr

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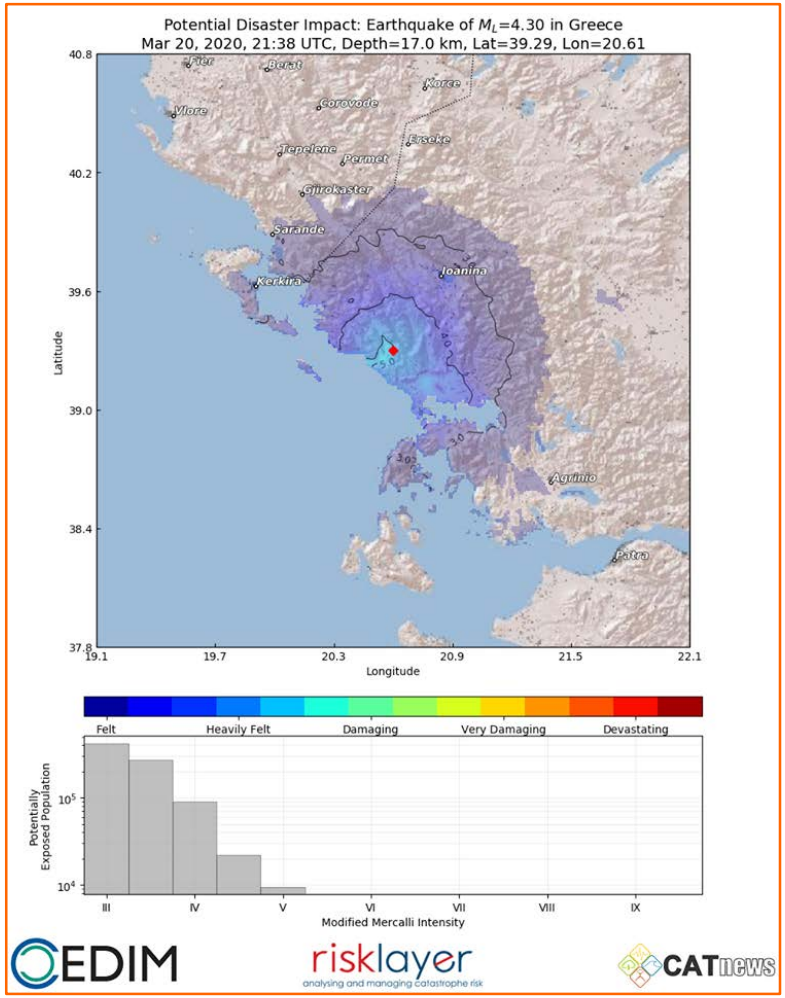
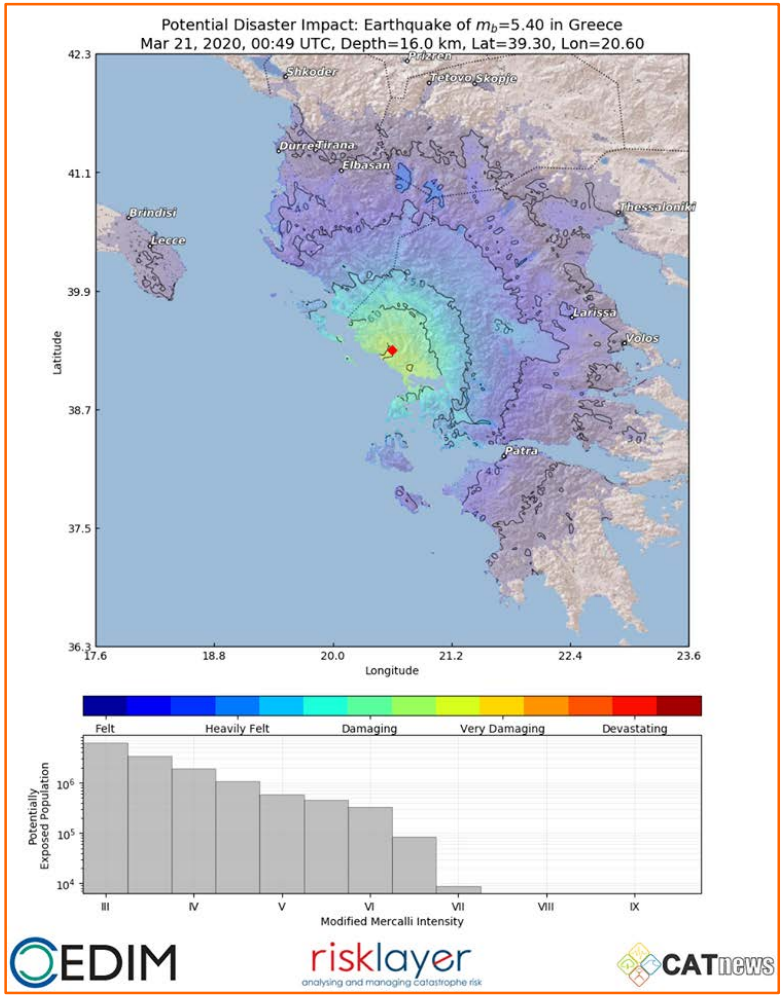
POTENTIAL DISASTER IMPACT & POTENTIAL AFTERSHOCK IMPACT MAPS
FOR THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE





https://www.facebook.com/catnewsde/photos/a.335140110019648/1322877901245859/?type=3&theater

https://www.facebook.com/catnewsde/photos/a.335140110019648/1323215947878721/?type=3&theater

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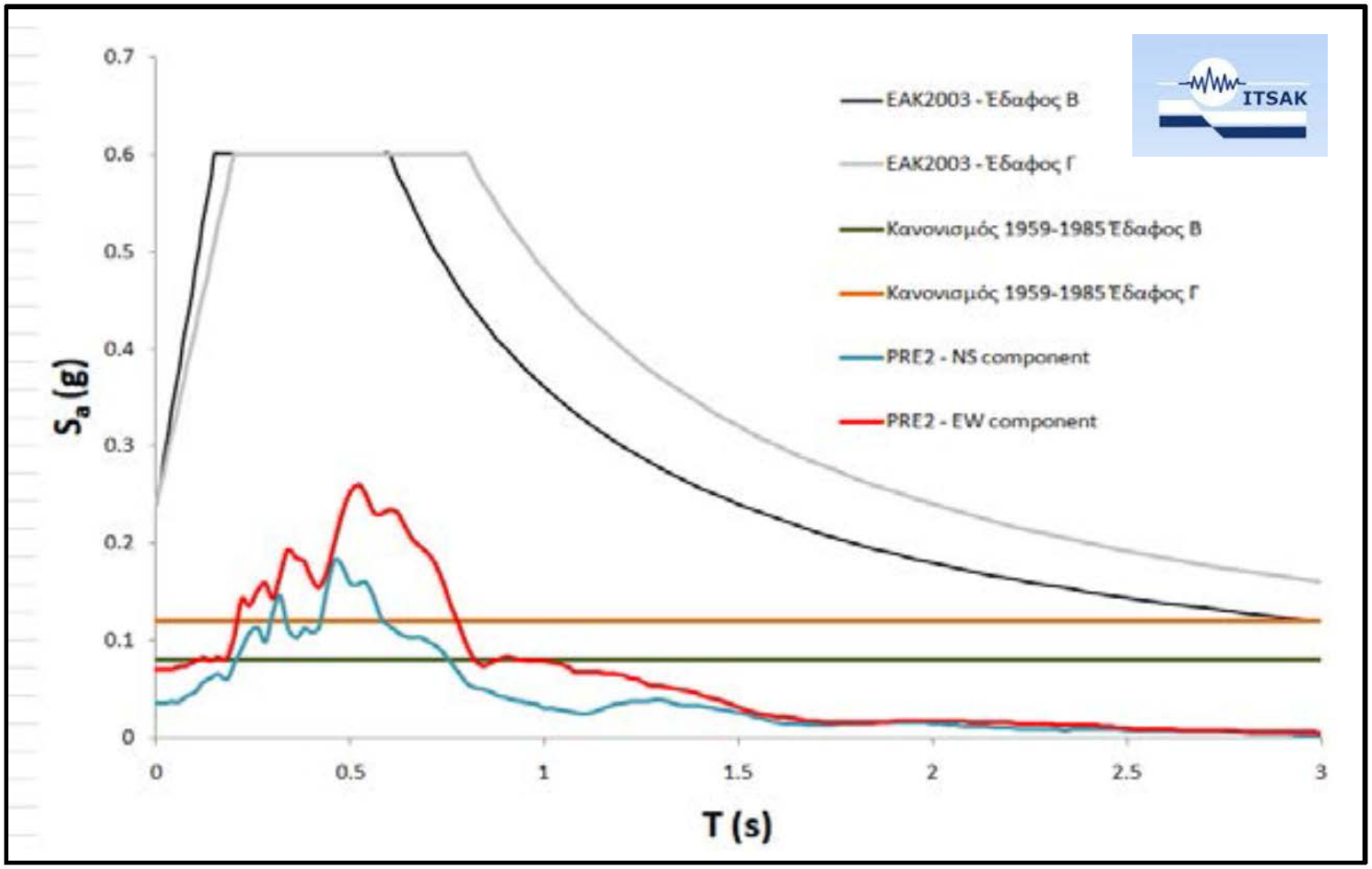
RESPONSE SPECTRA
FOR THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE



Comparison between the elastic response spectra of horizontal component (N-S and E-W component) in PRE2 site and response spectra of antiseismic codes of 1959-1985 and 2003 for soil types B and Γ (attenuation 5%) (From *ITSAK, 2020*).

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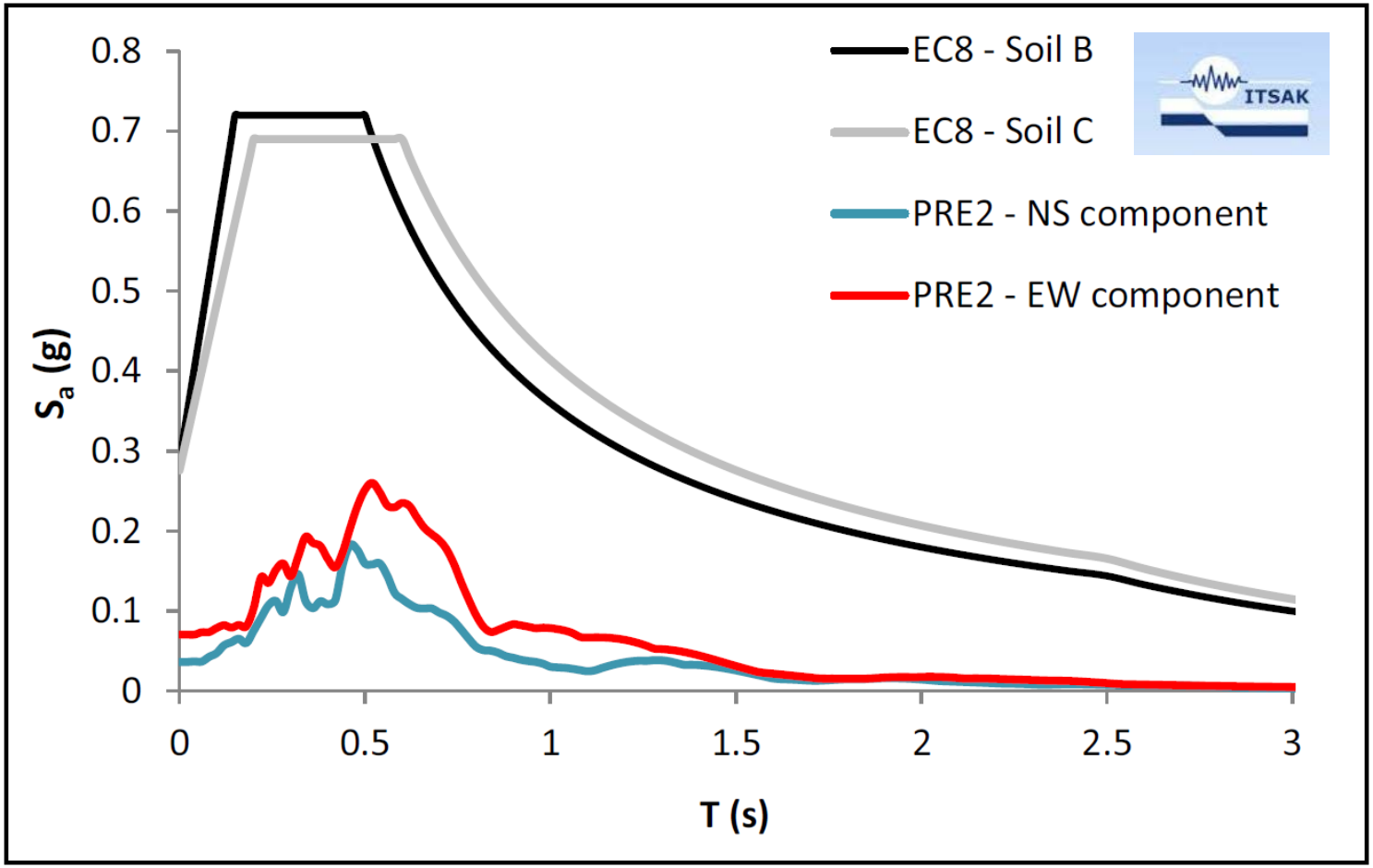
RESPONSE SPECTRA
FOR THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE



Comparison between the elastic response spectra of horizontal component (N-S and E-W component) in PRE2 site and response spectra of EC8 for soil types B and C (attenuation 5%) (From *ITSAK, 2020*). These EC8 spectra are of type 1, for larger earthquakes (M > 5.5).

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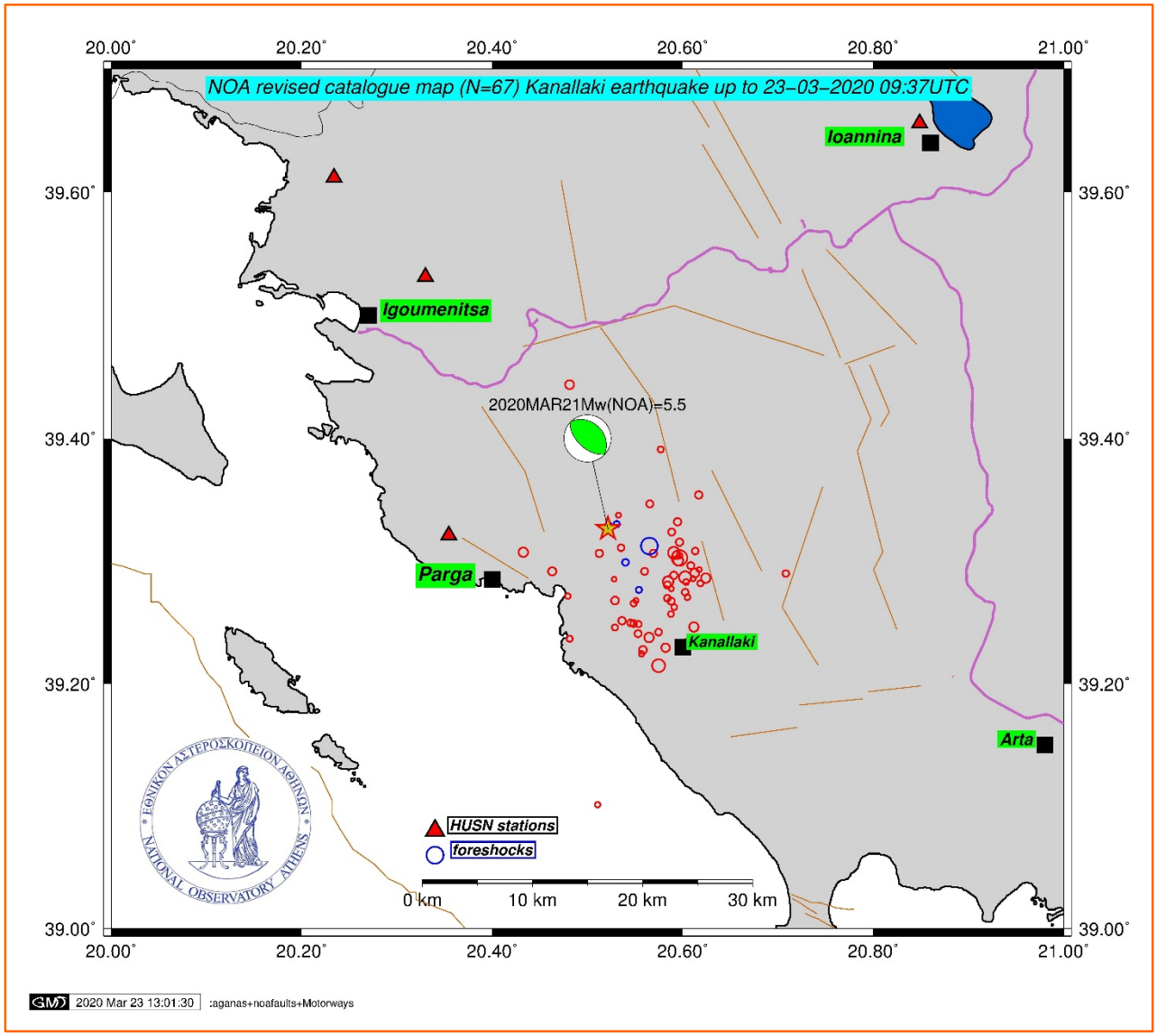
EPICENTER, FAULT PLANE SOLUTION & AFTERSHOCK SEISMICITY MAP
BY THE GEODYNAMIC INSTITUTE OF THE NATIONAL OBSERVATORY OF ATHENS



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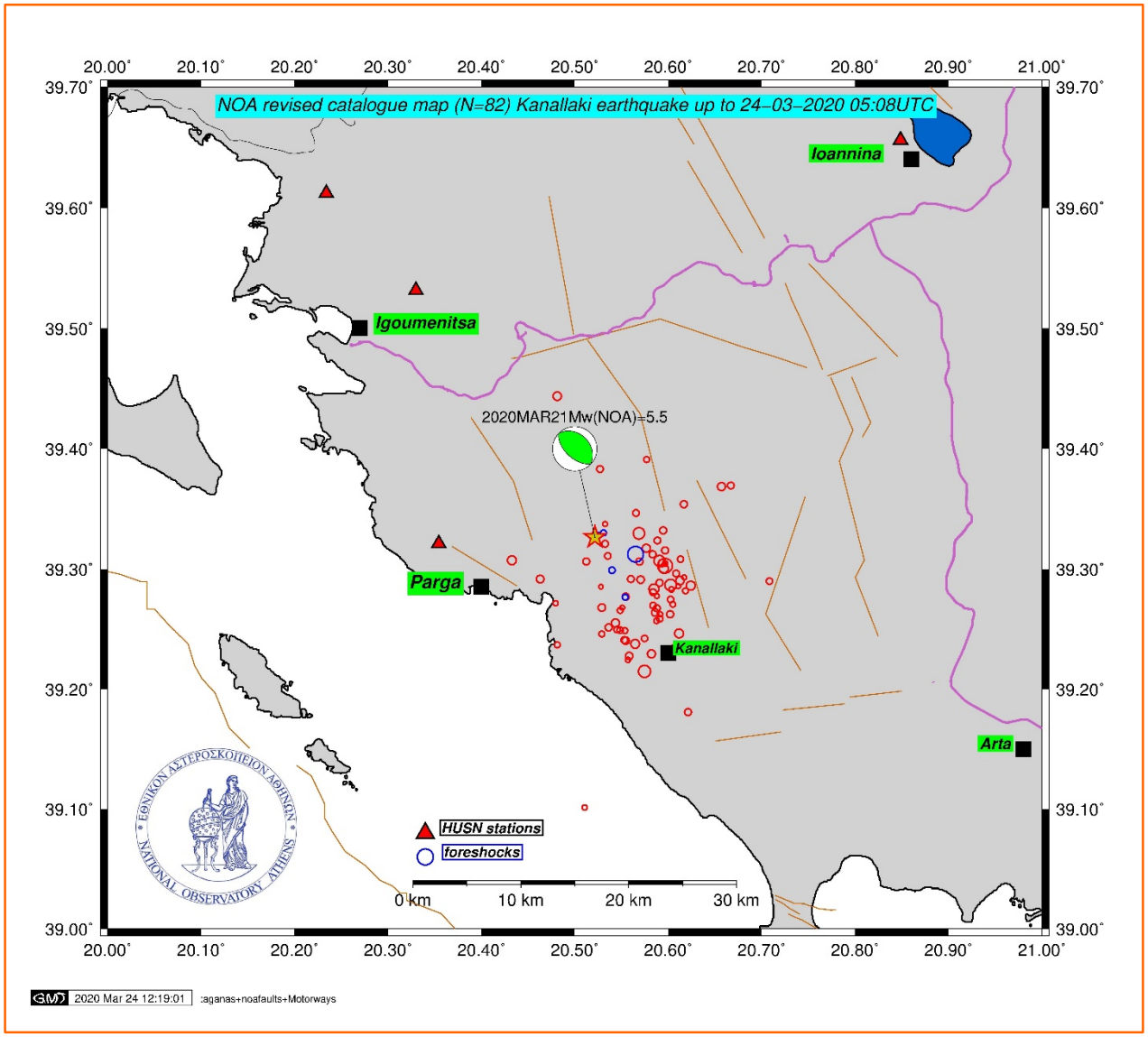
EPICENTER, FAULT PLANE SOLUTION & AFTERSHOCK SEISMICITY MAP
BY THE GEODYNAMIC INSTITUTE OF THE NATIONAL OBSERVATORY OF ATHENS



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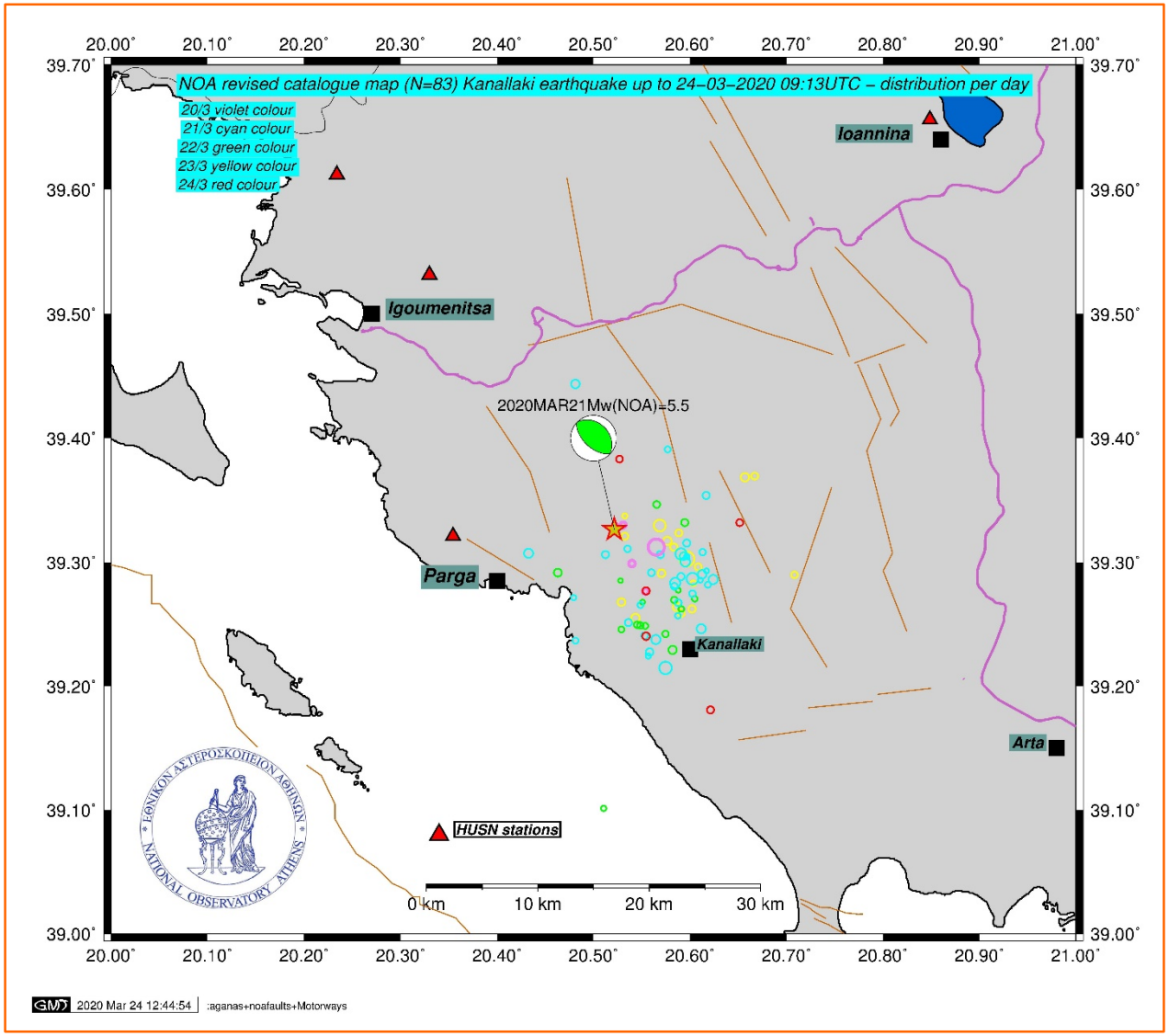
EPICENTER, FAULT PLANE SOLUTION & AFTERSHOCK SEISMICITY MAP
BY THE GEODYNAMIC INSTITUTE OF THE NATIONAL OBSERVATORY OF ATHENS



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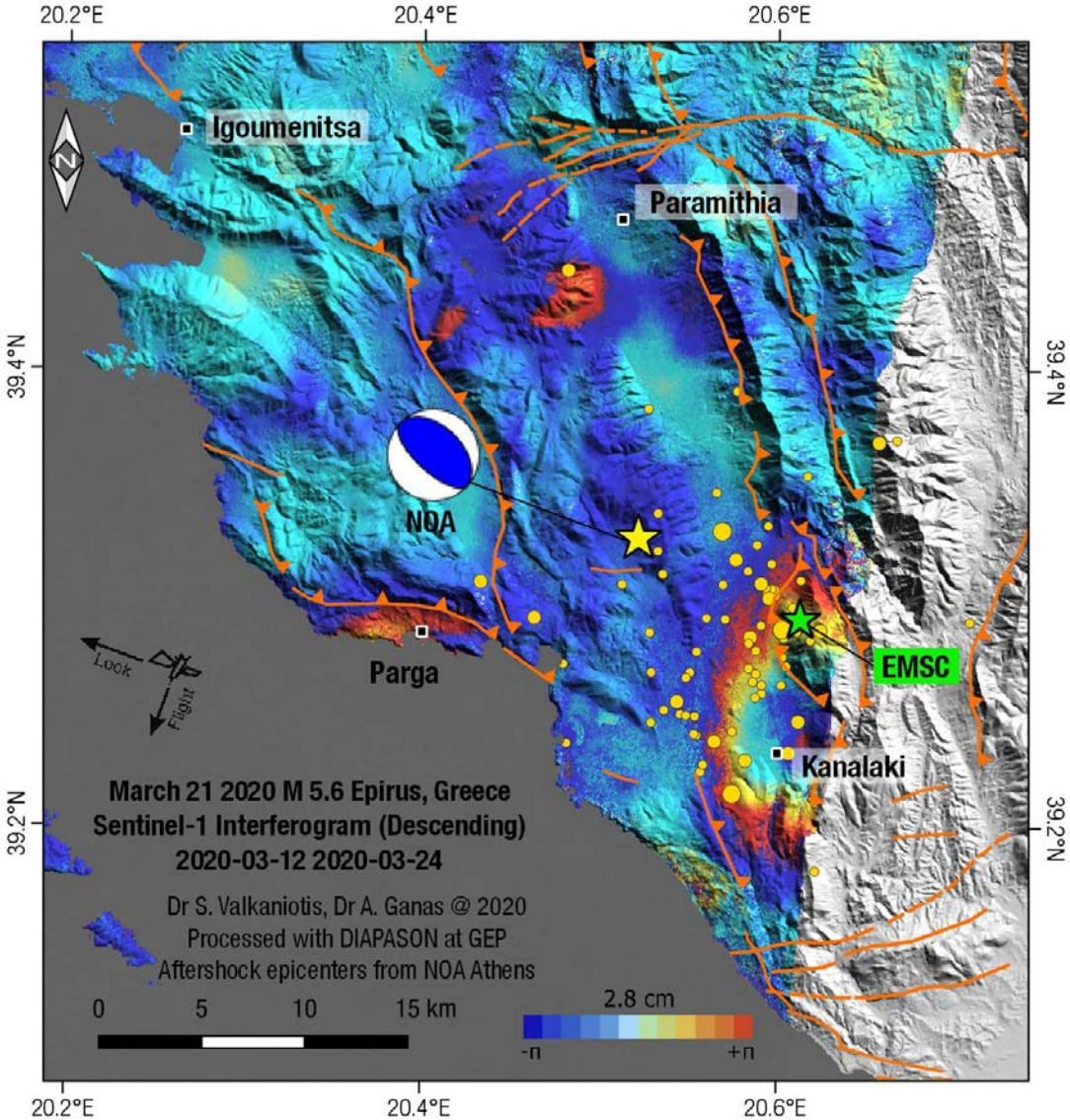
INTERFEROMETRIC ANALYSIS OF SYNTHETIC APERTURE RADAR (INSAR) DATA
FOR THE MARCH, 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE



Sentinel-1 wrapped interferogram (descending orbit) for the March, 21, 2020 Mw 5.7 Epirus earthquake along with its aftershock sequence by NOA (yellow solid circles), the NOA fault plane solution, the EMSC epicentre location and the main tectonic structures of the earthquake affected area.

Color scale (2π) shows one cycle of phase difference between a pair of images relative to the satellite (line-of-sight).

A displacement fringe of at least 2.8 cm along the satellite line of sight is observed in the wider Kanallaki-Acheron springs area.

From *Valkaniotis and Ganas (2020)*

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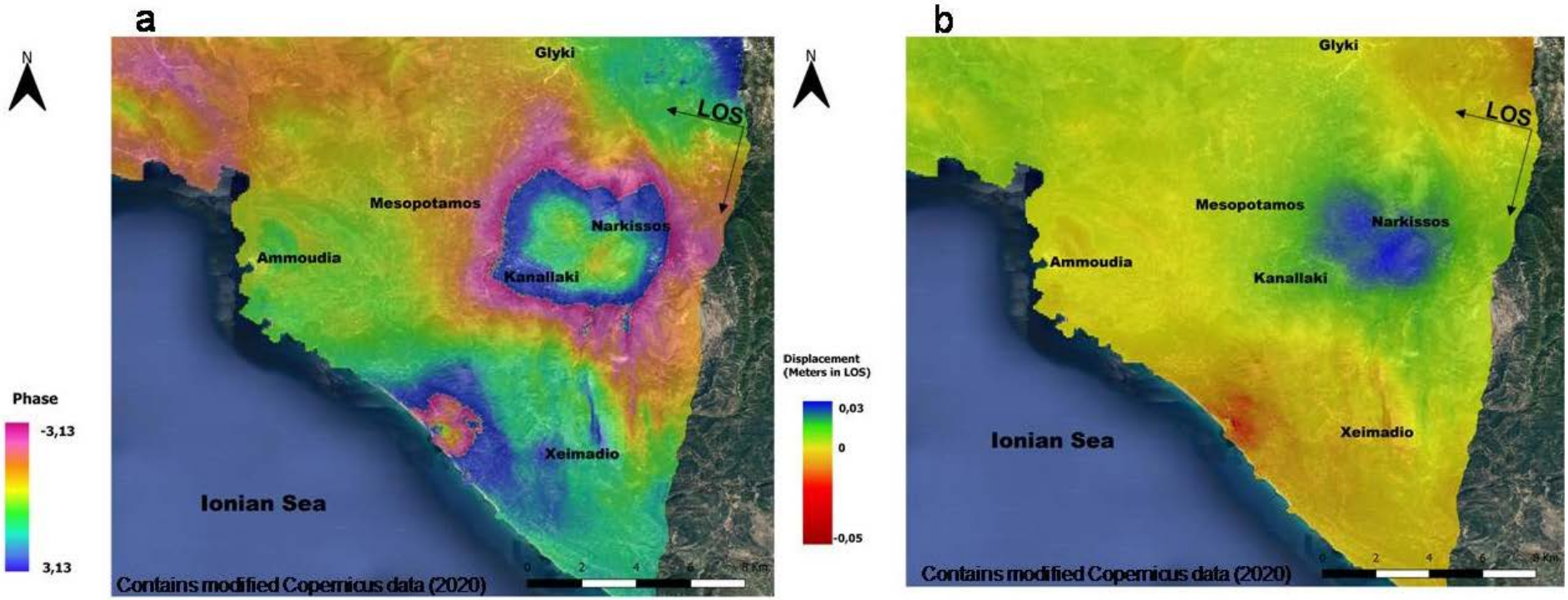
COSEISMIC DEFORMATION
INDUCED BY THE MARCH, 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE

ΧΑΡΟΚΟΠΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ
HAROKOPIO UNIVERSITY

UNIVERSITY OF WESTERN MACEDONIA

HELLENIC REPUBLIC
National and Kapodistrian University of Athens
EST. 1837

Ο.Α.Σ.Π.



(a) Wrapped interferogram (wrapped phase) after processing Sentinel 1 descending pair SAR images.

(b) Deformation map (meters in LOS) after unwrapping, Sentinel 1 descending pair SAR images.

From *Gatsios et al. (2020)*

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POST-DISASTER INSPECTIONS BASED ON LOCAL EXPOSURE & ON COSEISMIC DINSAR RESULTS

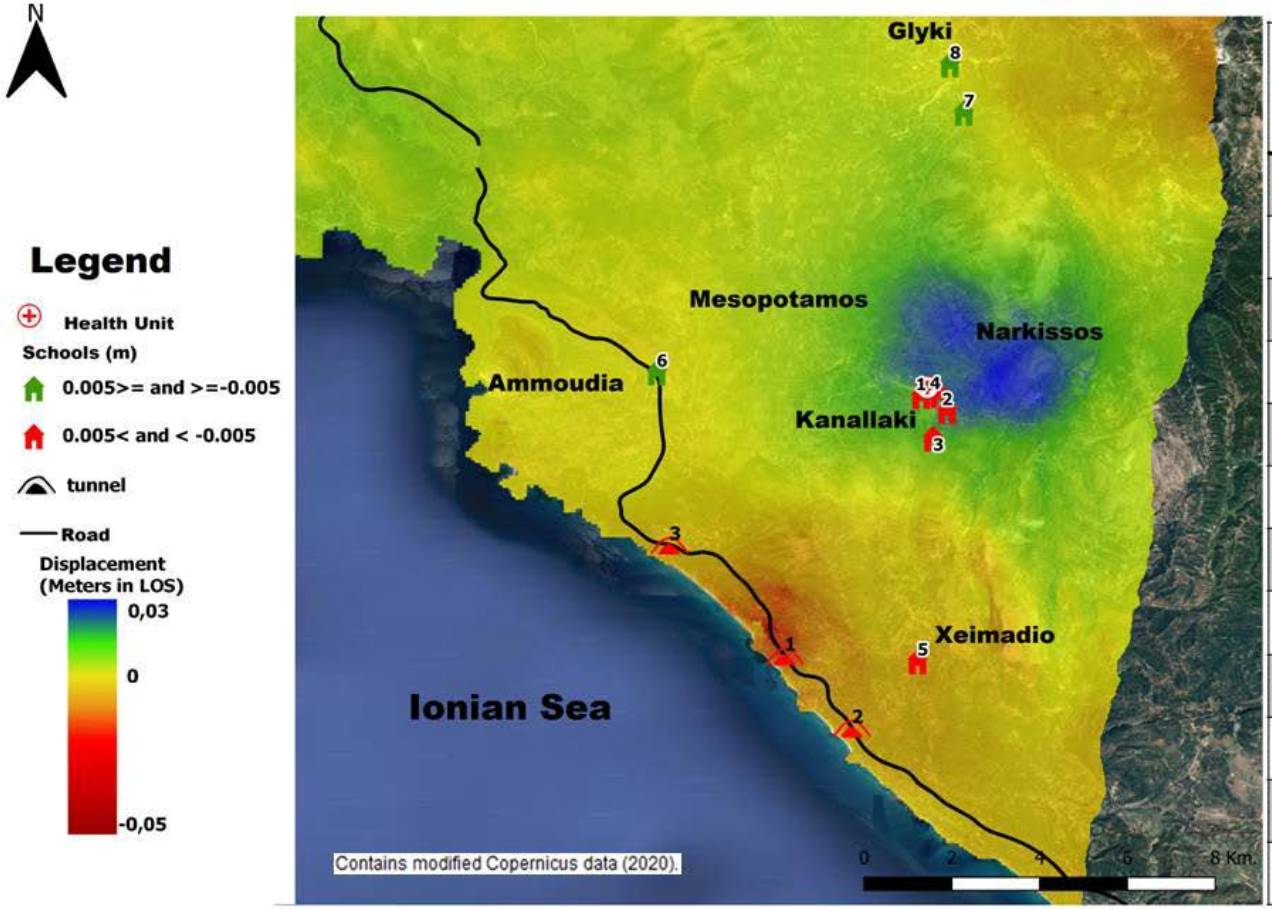
POINT-LIKE INFRASTRUCTURES & COSEISMIC DEFORMATION

ΧΑΡΟΚΟΠΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ
HAROKOPIO UNIVERSITY

UNIVERSITY OF WESTERN MACEDONIA

HELLENIC REPUBLIC
National and Kapodistrian University of Athens
EST. 1837

O.A.Σ.Π.



Infrastructures	Displacement (Meters in LOS)
School 1	0,0172
School 2	0,0208
School 3	0,0145
School 4	0,0223
School 5	-0,0110
School 6	-0,0009
School 7	0,0035
School 8	0,0010
Tunnel 1	-0.02051
Tunnel 2	-0.0081
Tunnel 3	-0.00642
Health Unit	0,0188

From *Gatsios et al. (2020)*

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POST-DISASTER INSPECTIONS BASED ON LOCAL EXPOSURE & ON COSEISMIC DINSAR RESULTS

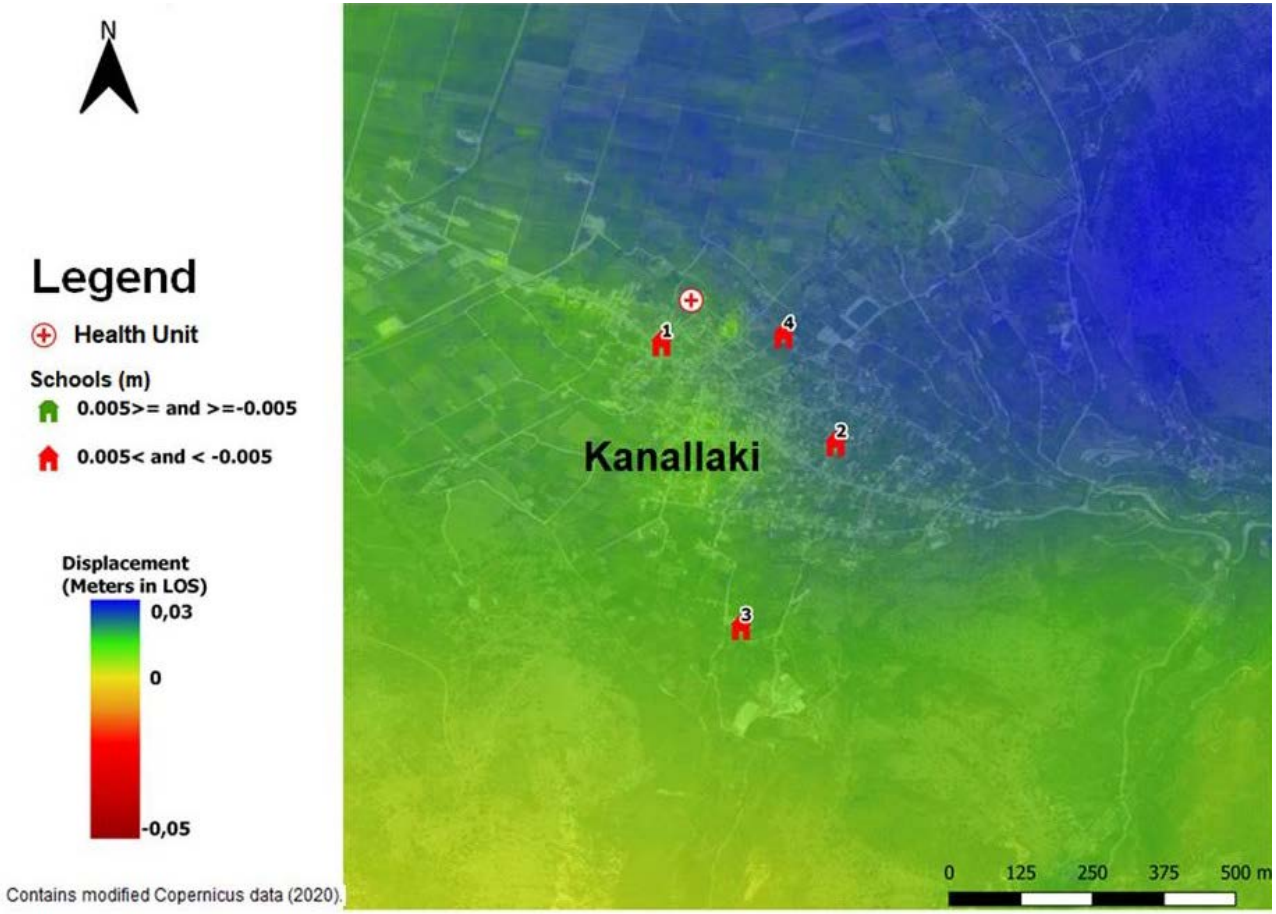
COSEISMIC DEFORMATION & LOCAL EXPOSURE DATA FOR THE AREA OF KANALLAKI VILLAGE

ΧΑΡΟΚΟΠΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ
HAROKOPIO UNIVERSITY

UNIVERSITY OF WESTERN MACEDONIA

HELLENIC REPUBLIC
National and Kapodistrian University of Athens
EST. 1837

Ο.Α.Σ.Π.



From *Gatsios et al. (2020)*

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POST-DISASTER INSPECTIONS BASED ON LOCAL EXPOSURE & ON COSEISMIC DINSAR RESULTS

COSEISMIC DEFORMATION & NATIONAL INFRASTRUCTURES

ΧΑΡΟΚΟΠΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ
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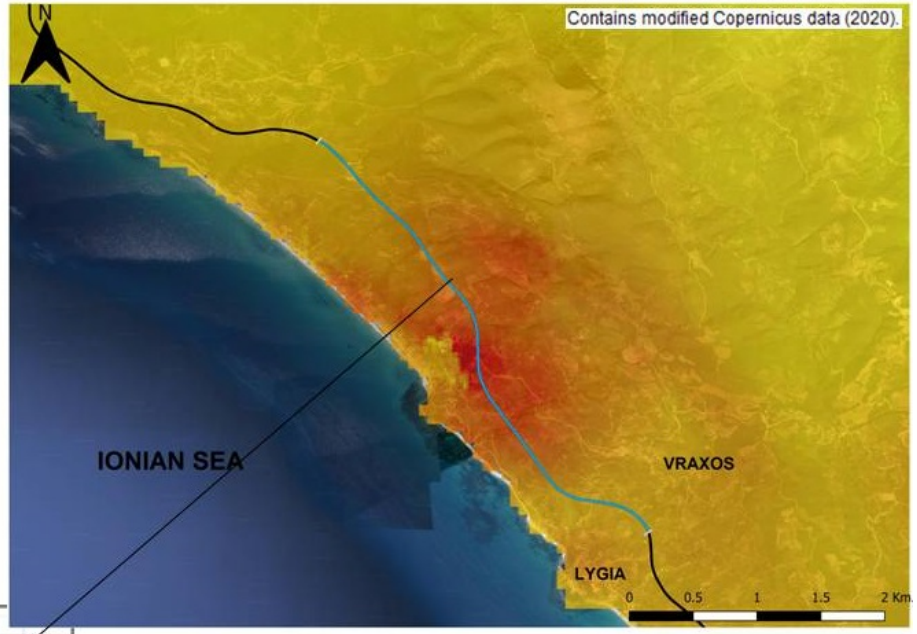
Histogram showing the deformation in LOS along transportation national road (North to South)



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EARTHQUAKE ENVIRONMENTAL EFFECTS
INDUCED BY THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE

Rockfalls were observed along the steep slopes of the provincial and municipal network of Parga Municipality and along the borders with the Souli, Preveza and Dodoni Municipalities. These slopes are mainly composed of limestones and secondarily of scree. The rockfalls resulted in damage on the asphalt pavement and temporary traffic disruption.

▲ Photos by P. Paschos (HSGME)

◀ Photo by E. Lekkas (NKUA)

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EARTHQUAKE ENVIRONMENTAL EFFECTS
INDUCED BY THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE

Rockfalls were generated along the road leading from Aidonia to Kanallaki. These slope failures resulted in damage on the asphalt pavement and temporary traffic disruption.

https://www.facebook.com/100003283659915/videos/2759528444166584/

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EARTHQUAKE ENVIRONMENTAL EFFECTS
INDUCED BY THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE

Hydrological anomalies were also observed in the earthquake affected area. These phenomena included water turbidity at the Acheron River. Large amounts of water coming up from the river springs became extremely turbid and were observed to be brown. This phenomenon is attributed to the mixing of the spring water with high amounts of sediments or to junction and interaction between the seismic fault and the aquifer.

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EARTHQUAKE ENVIRONMENTAL EFFECTS
INDUCED BY THE MARCH 21, 2020, Mw 5.7 EPIRUS EARTHQUAKE

Temporary turbidity in the Acheron River was also observed in the area of Dragon Cave. It was attributed to rockfalls along the steep river slopes and to the subsequent mixing of the unstable geological material with the river water.

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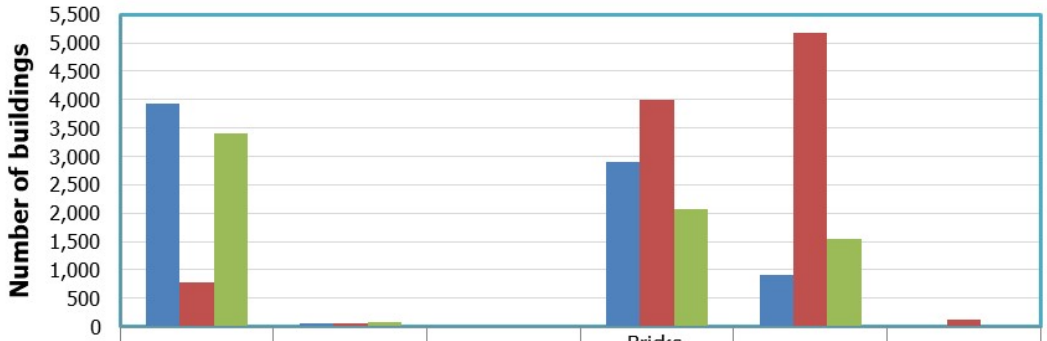
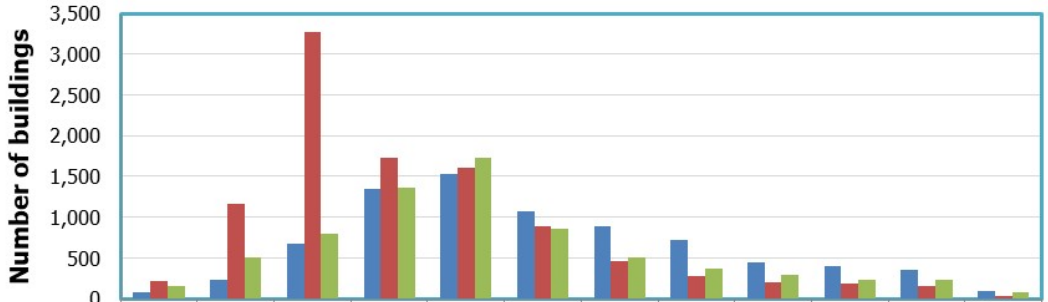
DOMINANT BUILDING TYPES OF THE EARTHQUAKE AFFECTED AREA



	Concrete	Metal	Wood	Bricks-Concrete blocks	Stone	Other material
PARGA	3,924	58	5	2,902	914	26
DODONI	791	63	7	3,996	5,172	134
SOULI	3,411	82	17	2,074	1,542	25



	before 1919	1919 - 1945	1946 - 1960	1961 - 1970	1971 - 1980	1981 - 1985	1986 - 1990	1991 - 1995	1996 - 2000	2001 - 2005	after 2006	Under construction
PARGA	73	238	681	1,342	1,523	1,068	884	716	450	407	350	97
DODONI	218	1,159	3,265	1,724	1,601	890	461	280	197	185	155	28
SOULI	163	512	802	1,360	1,736	861	506	366	298	227	236	84

The dominant building types are the following:

(a) Buildings with brick and concrete block masonry (8,972 buildings)

(b) Buildings with reinforced concrete frame and infill walls (8,126 buildings)

(c) Buildings with stone masonry (7,628 buildings)

(d) Metal structures (203 buildings)

(e) Buildings with other construction materials (185 buildings)

(f) Wooden structures (29 buildings).

The majority of the buildings have been constructed from 1946 to 1981. More specifically 4,748 buildings from 1946 to 1960, 4,426 buildings from 1961 to 1970 and 4,860 from 1971 to 1981.

Data from the 2011 Buildings' Census conducted by the *Hellenic Statistical Authority (2011)*

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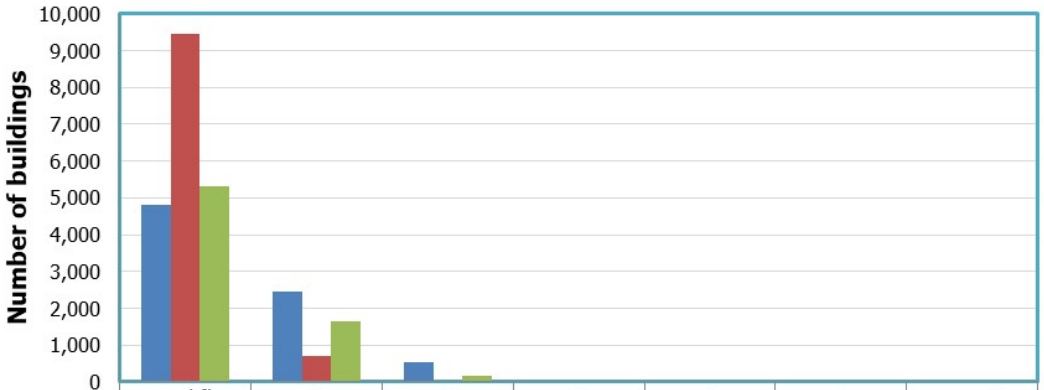
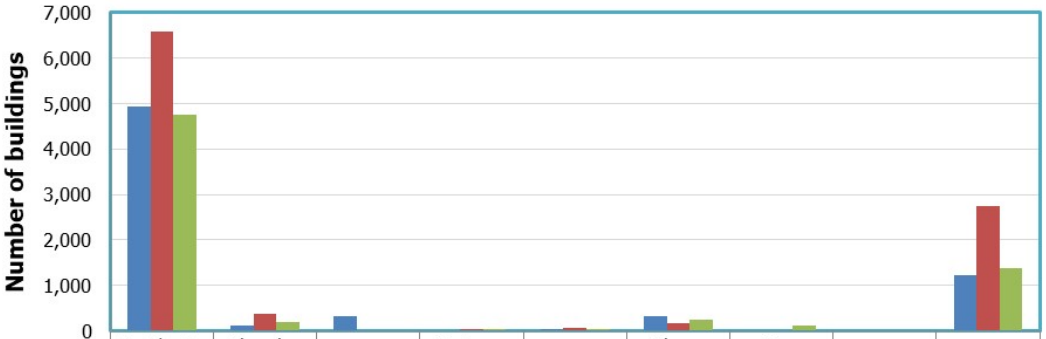
DOMINANT BUILDING TYPES OF THE EARTHQUAKE AFFECTED AREA



	ground floor	1	2	3	4	5	over 6
PARGA	4,816	2,461	521	27	4	0	0
DODONI	9,443	693	27	0	0	0	0
SOULI	5,320	1,643	177	11	0	0	0

The majority of the buildings in the earthquake affected areas have only ground floor (19,579 buildings). Buildings with 1 and 2 floors follow with 4,797 and 725 structures respectively. There is a small number of higher buildings.



	Residential building	Church - Monastery	Hotel	Factory-Lab	School	Shop-Office	Car parking	Hospital	Other use
PARGA	4,929	126	334	28	53	330	28	1	1,232
DODONI	6,592	373	3	35	75	181	23	3	2,745
SOULI	4,751	190	13	47	51	235	115	1	1,384

The majority of the buildings are residential (16,272 buildings). Shops and offices followed with 746 buildings, while the monumental buildings including churches and monasteries are 689.

Data from the 2011 Buildings' Census conducted by the *Hellenic Statistical Authority (2011)*

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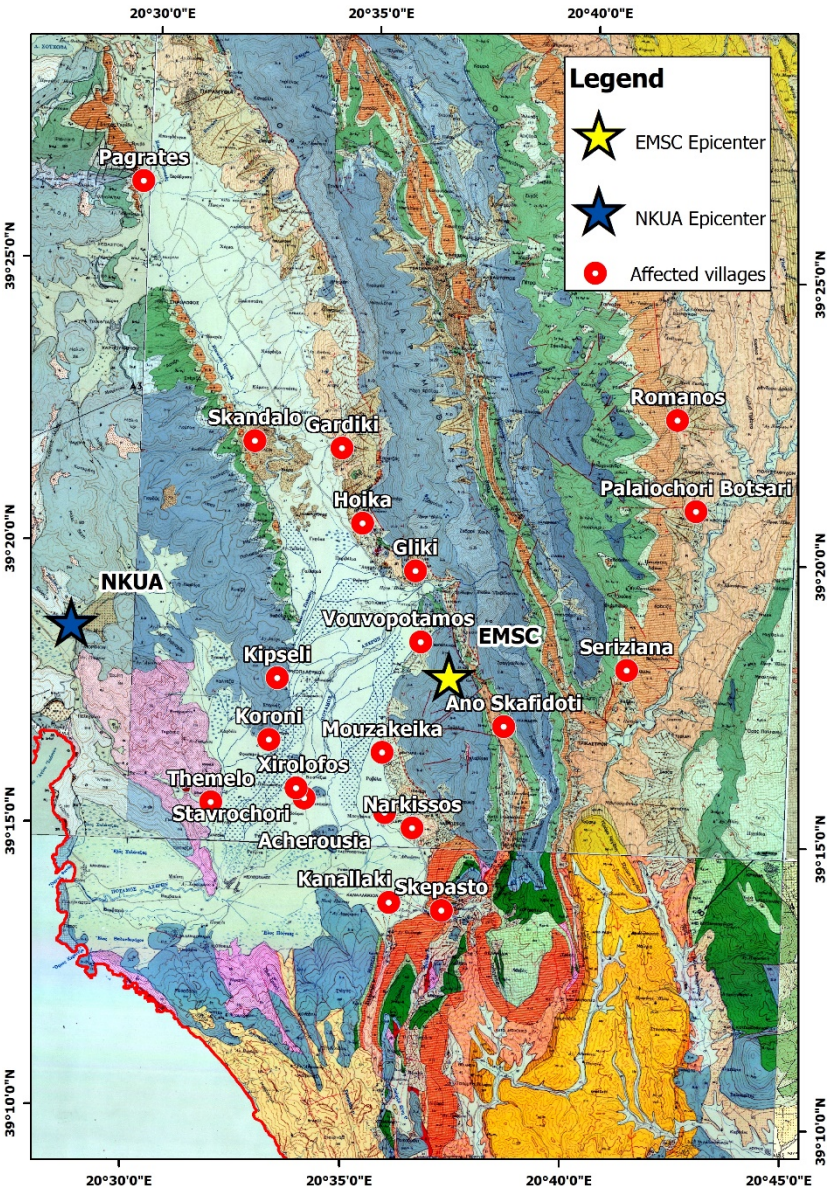
SPATIAL DISTRIBUTION OF BUILDING DAMAGE



Building damage was observed in Parga, Souli and Dodoni municipalities. More specifically, the most affected villages were the following:

(a) Kanallaki, Skepasto, Narkissos, Kastri, Koroni, Stavrochori, Mouzakeika, Vouvopotamos, Acherousia, Kipseli, Themelo and Ano Skafidoti in **Parga** municipality

(b) Xirolofos, Pagrates, Skandalo, Gardiki, Gliki and Hoika in **Souli** municipality

(c) Seriziana, Paleochori Botsari and Romanos in **Dodoni** municipality.

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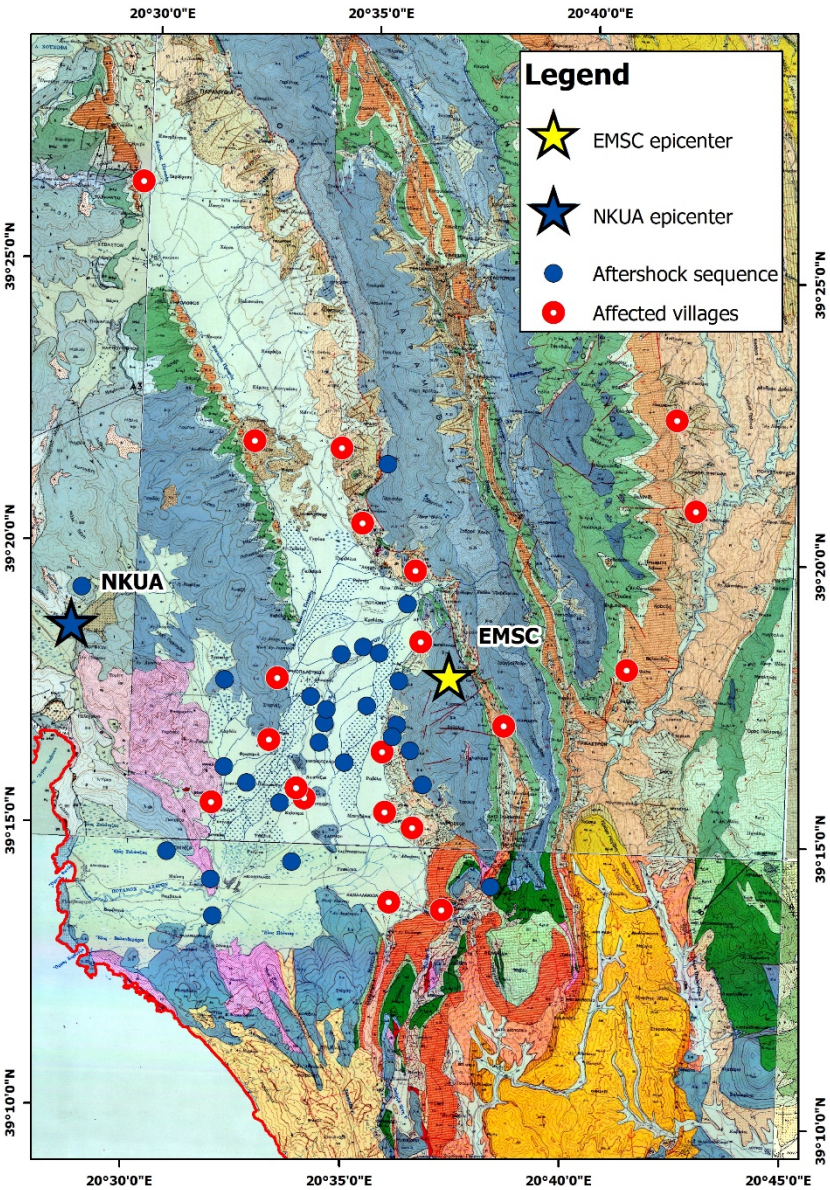
SPATIAL DISTRIBUTION OF BUILDING DAMAGE



As regards the geological setting of affected villages, most of them were founded on recent deposits. More specifically:

- **12** were founded on **scree**,
- **4** on Pantokrator **limestones** of the Ionian unit,
- **2** on **alluvial** deposits,
- **2** on Triassic **breccia** of the Ionian unit and
- **1** on Vigla **limestones** of the Ionian unit.

The most affected villages are located in the area where the aftershock sequence took place.

The coordinates of the mainshock epicenter and the parameters of the aftershock sequence has been provided by Assistant Professor *George Kaviris* (National and Kapodistrian University of Athens).

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RECENT DEPOSITS IN THE EARTHQUAKE AFFECTED AREA

Views of scree and talus cones along the western slopes of Paramythia Mts.
14 of the most affected villages were founded on these deposits.

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DAMAGE TO LOAD-BEARING MASONRY BUILDINGS

The buildings with masonry load-bearing walls suffered the most by the earthquake. Structural and non-structural damage were observed. Structural damage included mainly partial collapse as well as large and extensive cracking of the masonry walls. Characteristic example of partial collapse of a building with masonry load-bearing walls in Kanallaki village.

The columns right and left of the glass panel are separated from the walls. This is usual in buildings constructed in the center of old villages and it is attributed to development and touristic purposes that allows large openings in the ground floor. The masonry walls have been removed and a concrete or metal frame is constructed. From the static safety point of view, this is accepted, but from the antiseismic behavior point of view, this is unaccepted for the buildings with the observed undesirable results in the case of an earthquake.

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DAMAGE TO LOAD-BEARING MASONRY BUILDINGS

Heavy structural damage to load-bearing masonry buildings comprising partial collapse of the masonry walls

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DAMAGE TO LOAD-BEARING MASONRY BUILDINGS




(up) Non-structural damage comprising detachment of plaster from the masonry walls.
(down) Structural damage comprising partial collapse of the masonry walls

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DAMAGE TO LOAD-BEARING MASONRY BUILDINGS




Buildings with masonry load-bearing walls suffered also detachment of plasters from the masonry load-bearing walls and extensive cracking of the walls. The observed damage indicate that building are located in the (macro- or micro-) epicentral area.

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DAMAGE TO LOAD-BEARING MASONRY BUILDINGS

(up) Symmetrical detachment of the top four corners edges of a building with masonry load-bearing walls. The observed cracks indicate bounce of the roof indicating that the building is located in the epicentral area. (down) Diagonal cracking of the masonry load-bearing walls.

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NON-STRUCTURAL DAMAGE TO REINFORCED CONCRETE BUILDINGS

Non-structural damage to the reinforced concrete buildings included mainly cracking and detachment of plasters from infill walls and cracking of the brick masonry.

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NON-STRUCTURAL DAMAGE TO REINFORCED CONCRETE BUILDINGS

Non-structural damage to this reinforced concrete building included mainly cracking and detachment of plasters from infill walls

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STRUCTURAL DAMAGE TO REINFORCED CONCRETE BUILDINGS

Damage to buildings with reinforced concrete frame and infill walls were observed not only on non-structural but also to structural elements. Failure of columns of the ground floor was observed in several structures. The columns were heavily damaged in their lower parts greatly affecting the antiseismic performance and the stability of the structure.

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STRUCTURAL DAMAGE TO REINFORCED CONCRETE BUILDINGS

More examples of failure of columns of the ground floor. Buckling of reinforcement bar, bursting of over-stressed elements and compression damage of structural elements were observed in several buildings of the affected area.

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STRUCTURAL DAMAGE TO REINFORCED CONCRETE BUILDINGS

The presented structural damage indicates short column function

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DAMAGE TO MONUMENTAL STRUCTURES

Cracking and detachment of plasters were caused in various parts of the structures

▲ The beneficial action of the tie rods is observed.
◀ The impact of the vertical component of the earthquake ground motion is observed.

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CONCLUSIONS

The March 21, 2020 Mw 5.7 earthquake in Epirus has been generated by the rupture of a NW-SE striking reverse fault. Based on the geological setting of the affected area, the two structures considered as the causative fault are the Paramythia and Souli thrust faults. The aftershocks were distributed within the western part of the Acheron River basin.

The affected area experienced similar earthquakes in its historical past. The May 14, 1895, Mw 6.3 earthquake affected the same area resulting in 75 fatalities and heavy building damage corresponding to maximum intensity of X. The same fault zone of Paramythia – Souli has been considered as the causative fault of the 1895 earthquake.

The 2020 earthquake induced environmental effects including slope failures and hydrological anomalies. Slope failures comprised rockfalls along the road network and the hydrological anomalies included water turbidity in Acheron River water.

As regards the building stock of the earthquake affected area, the dominant building types are:

(a) buildings with brick and concrete block masonry,
(b) buildings with reinforced concrete frame and infill walls and
(c) buildings with stone masonry.
(d) Buildings with mixed systems and constructions with interventions, additions and modifications, which most often result in the reduction of the static and seismic safety of the structures. These operations are either performed for the building restoration (after an earthquakes, landslides, aging of materials, bombing or fire) or for economic reasons (development, tourism, family expansion).

Most of them were constructed from 1946 to 1981. The majority of them have only ground floor and up to 1 to 2 floors.

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CONCLUSIONS

The earthquake affected area is extended in Parga, Souli and Dodoni municipalities of Epirus. 21 villages suffered damage. The majority was founded on post-alpine deposits and the minority on alpine formations of the Ionian geotectonic unit. Scree and alluvial deposits were observed in 14 villages, while Ionian formations, including limestone and breccia, in 7 villages.

The affected villages were mainly distributed along the eastern margin of the Acheron River basin and within the lower Acheron river valley, close to major tectonic structures and along contacts juxtaposing alpine and post-alpine deposits.

Low-rise buildings with masonry load-bearing walls composed of bricks, stones and concrete blocks suffered the most by this earthquake. Structural damage included partial collapse of the masonry and extensive cracking of the masonry. Non-structural damage included detachment of plasters and small cracks of the walls.

The reinforced concrete buildings suffered not only non-structural but also structural damage, but in small extent. The structural damage included mainly failure of columns of the ground floor, while non-structural damage included detachment of plasters from and small cracks in the brick infill walls.

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The March 21, 2020 Mw 5.7 Epirus (Greece) Earthquake

Kanallaki, 2020