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The September 21, 2019 Mw 5.6 Durrës (Albania) earthquake

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About

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

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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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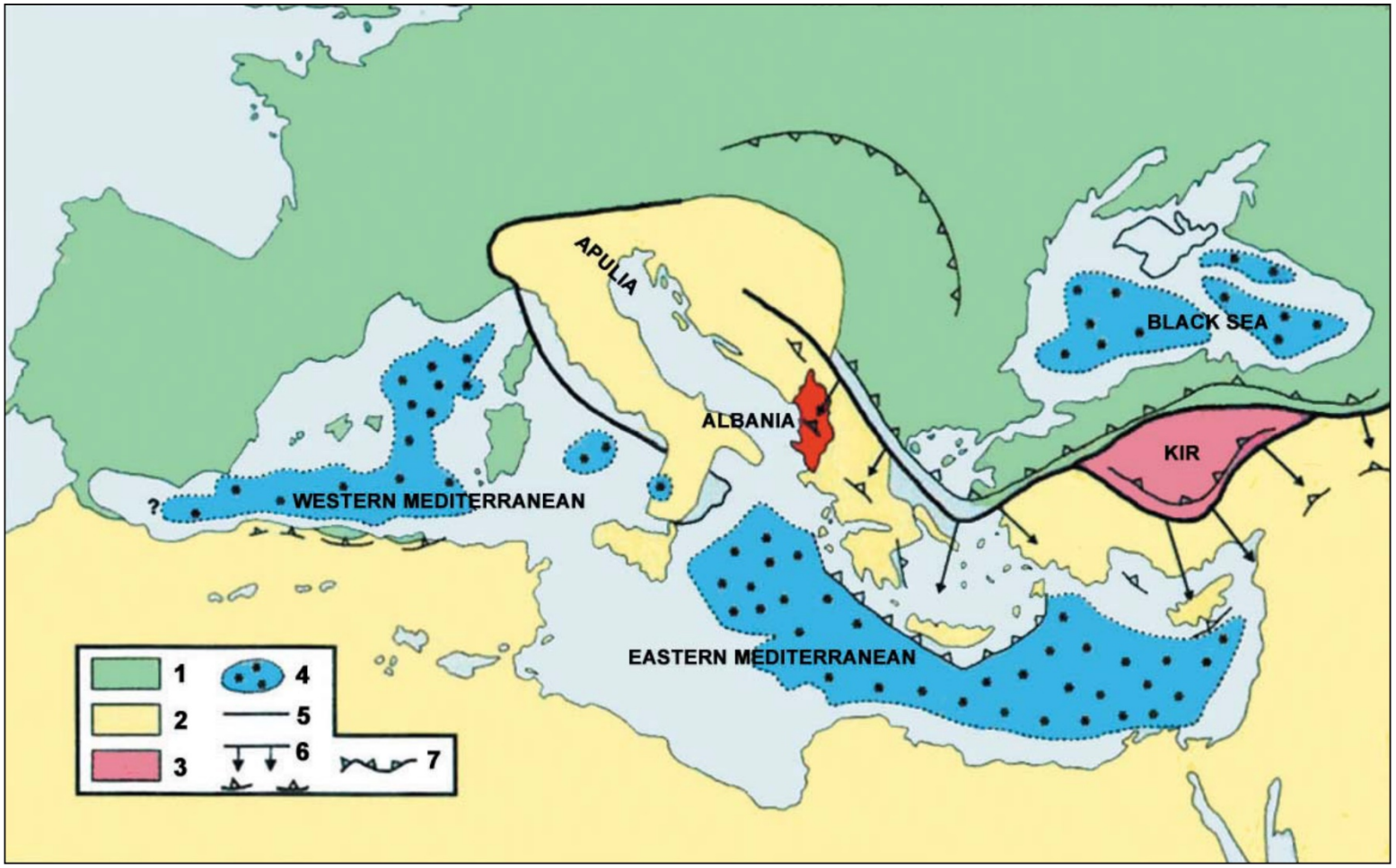
LOCATION OF ALBANIA IN THE ALPINE HYMALAYAN BELT



Legend 1: Euro-Asiatic Continent; 2: African continent; 3: Kishir block; 4: Present Oceanic Basins; 5: Boundaries of Mesozoic Oceans; 6: Boundaries of Mesozoic Ocean and the Main Ophiolithic Nappes; 7: Troughs of present and past subduction.

From *Ricou (1986)*

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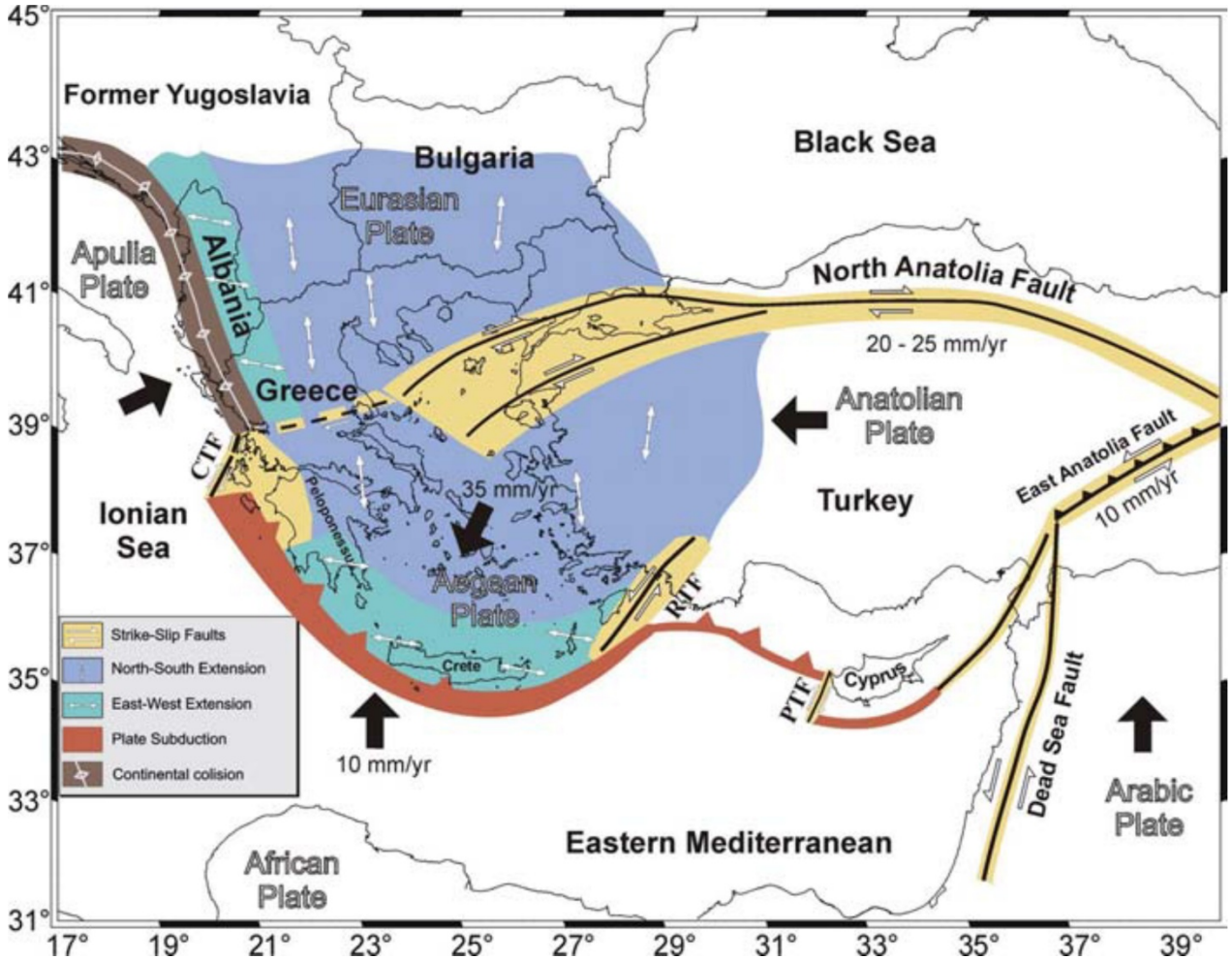
PLATE MOTIONS INVOLVED IN THE ACTIVE TECTONICS OF THE EASTERN MEDITTERANEAN



Simplified map of the Eastern Mediterranean illustrating the large plates involved in the active tectonics. Black arrows indicate the direction over the greater Aegean Sea.

From *Papazachos et al. (1998)*

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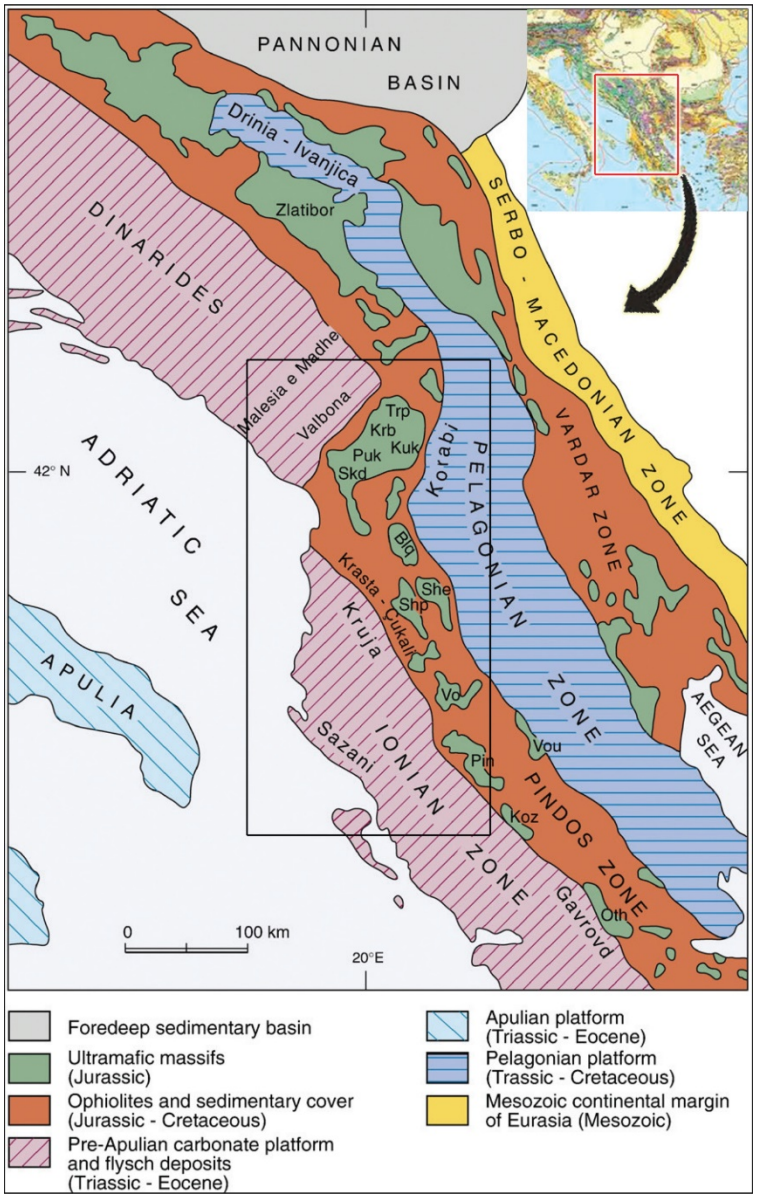
LOCATION OF ALBANIDES IN DINARIDES – ALBANIDES – HELLENIDES BELT



The Albanides are located between the Dinarides in the north and Hellenides in the south. This range is included in the north-eastern edge of the African plate, which has already undergone orogeny.

In Albania, the foldbelt is made up of three geological terranes: (**1**) a Western zone of Early Oligocene-Middle Miocene fold-and-thrust nappes of sedimentary rocks derived from proximal facies of the continental margin of Adria making up the External Albanides, (**2**) a Central belt made up of an ophiolitic nappe occupying more than 4000 km^2, the Mirdita ophiolite, and of underlying thrust slices of both continental and oceanic origin and (**3**) an Eastern zone (the Korabi-Palegonian zone) of Hercynian basement of Ordovician to Devonian low grade metamorphic rocks unconformably overlain by Permian-Lower Triassic rift-related deposits followed by Middle Triassic-Upper Jurassic platform carbonates.

From *Meshi et al. (2014)*

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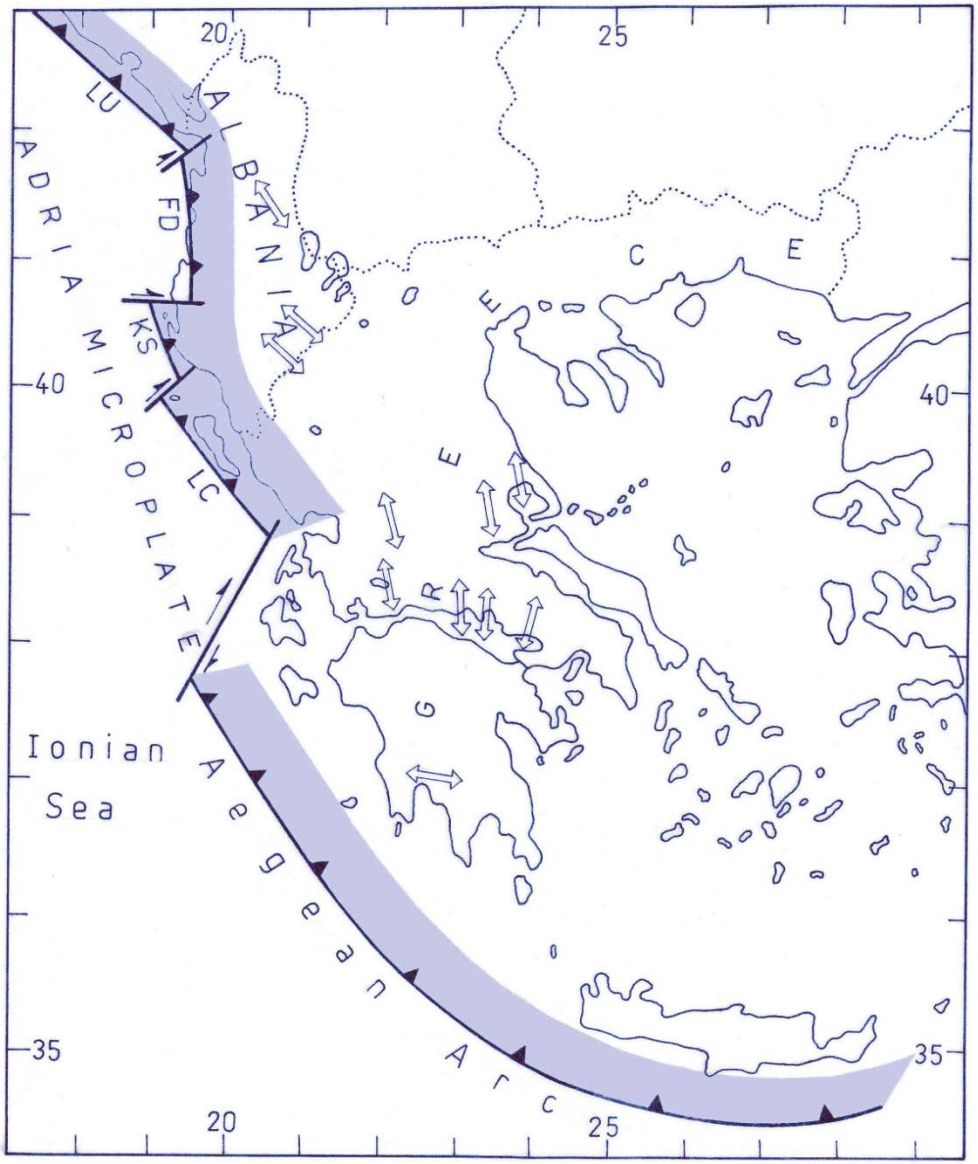
ALBANIAN OROGENIC FRONT THRUST CONTACT WITH THE ADRIA MICROPLATE



The convergent boundary between the Albanian orogen and Adria is now well constrained to be located in the Ionian and Adriatic offshore. The Albanian orogenic thrust front is cut and displaced by the Othoni Island-Dhermi, the northern Sazani Island, and the Gjiri i Drinit-Lezha strike-slip faults, which divide the orogen into separate segments showing diachronous development (Aliaj, 1998, 2000). The following segments of the orogenic thrust front of the Albania orogen have been recognized:

1. The NW-SE trending Lefkas-Corfu segment

2. The NW-SE trending Karaburuni-Sazani Island segment

3. The ~N-S trending Frakulla-Durresi segment

4. The WNW-ESE trending Lezha-Ulqini segment

◀ Adriatic collision and Aegean Arc. Segments of Adriatic collision frontal thrust are noted by capital letters: **LC**: Lefkas-Corfu, **KS**: Karaburuni- Sazani Island, **FD**: Frakulla-Durresi, and **LU**: Lezha-Ulqini. The strike-slip faults cutting the orogen front, from south to north, are as follows: the Othoni Island-Dhermi, the northern Sazani Island and the Gjiri i Drinit-Lezha faults (From *Aliaj, 2006*)

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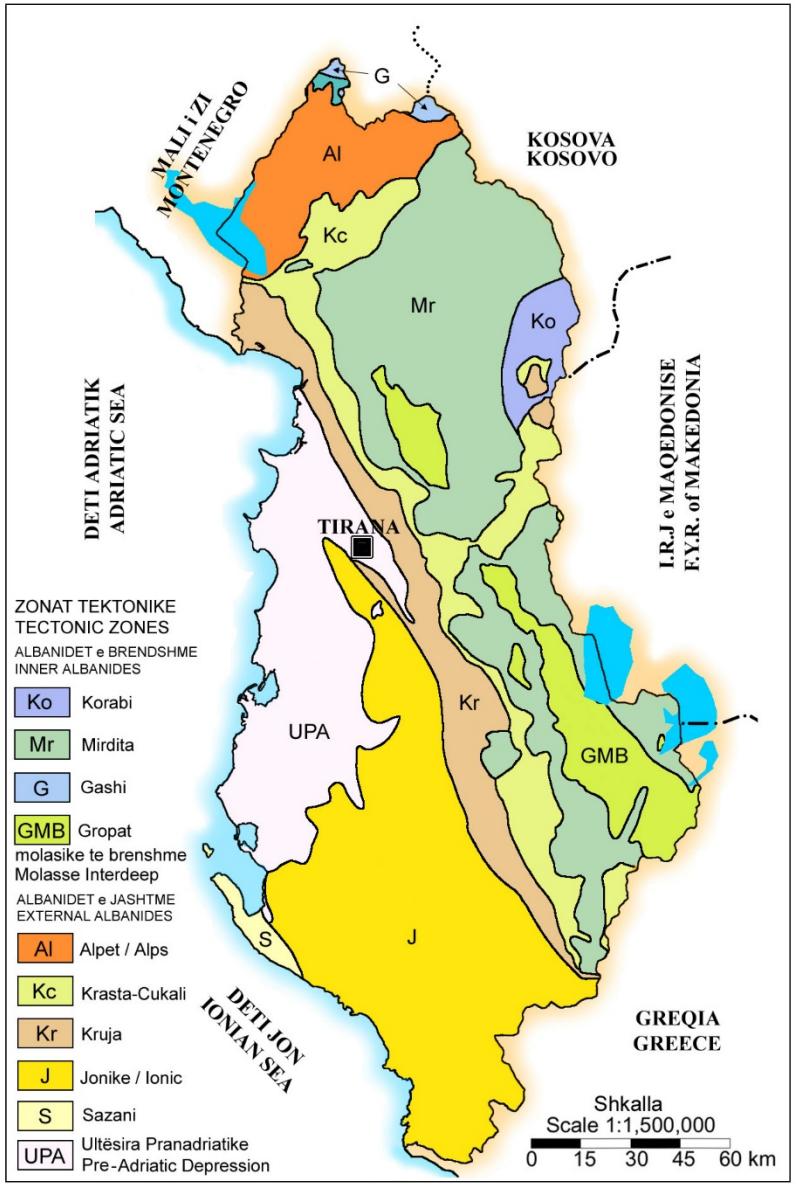
GEOLOGY OF ALBANIDES



Two major tectonic zones form the Albanides:

(a) the Internal Albanides in the eastern part and

(b) the External Albanides in the western part of Albania.

The **Internal Albanides** are characterized by presence of the immense and intensive tectonized ophiolitic belt, which is displaced from E to W as an overthrust nappe. Internal Albanides has been affected by the paleotectonic stage. There are two viewpoints about the placement of the ophiolites: either an allochthone character of the ophiolitic nappe or autochthon ophiolitic belt. Tectonic development of the Internal Albanides has been during Triassic and Jurassic.

The **External Albanides** was developed out of the western passive margin and continental shelf of the Adriatic plate. The External Albanides are affected only by the later paleotectonic stages, and are characterized by regular structural belts, which are associated with thrust and over tectonic.

From *Frasheri and Bushati (2008)*

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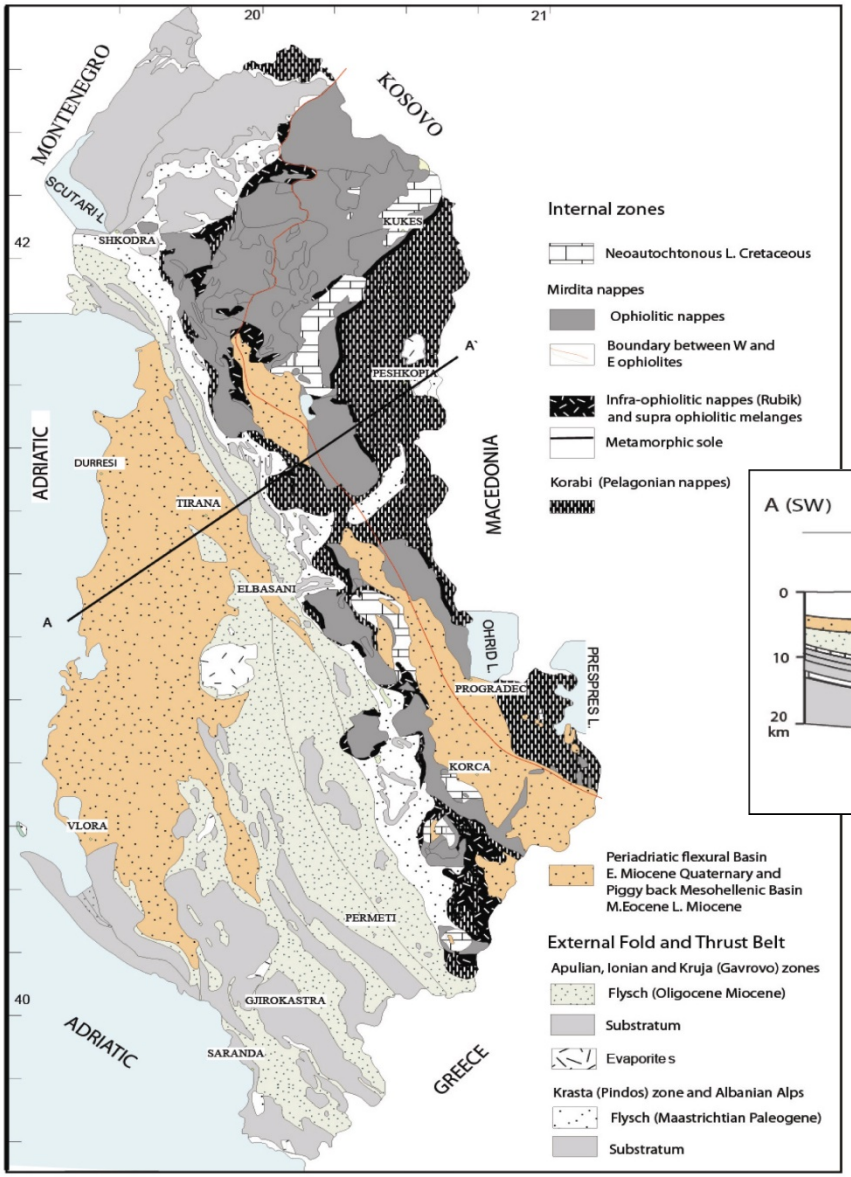
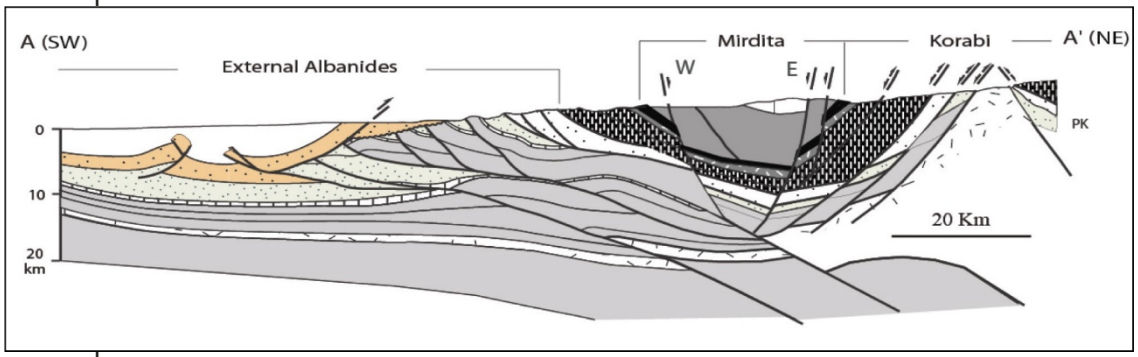
GEOLOGY OF ALBANIDES



Geological map of Albania (*Muceku et al., 2006*) and the cross-section of the Albanides (*Muceku et al., 2008*).



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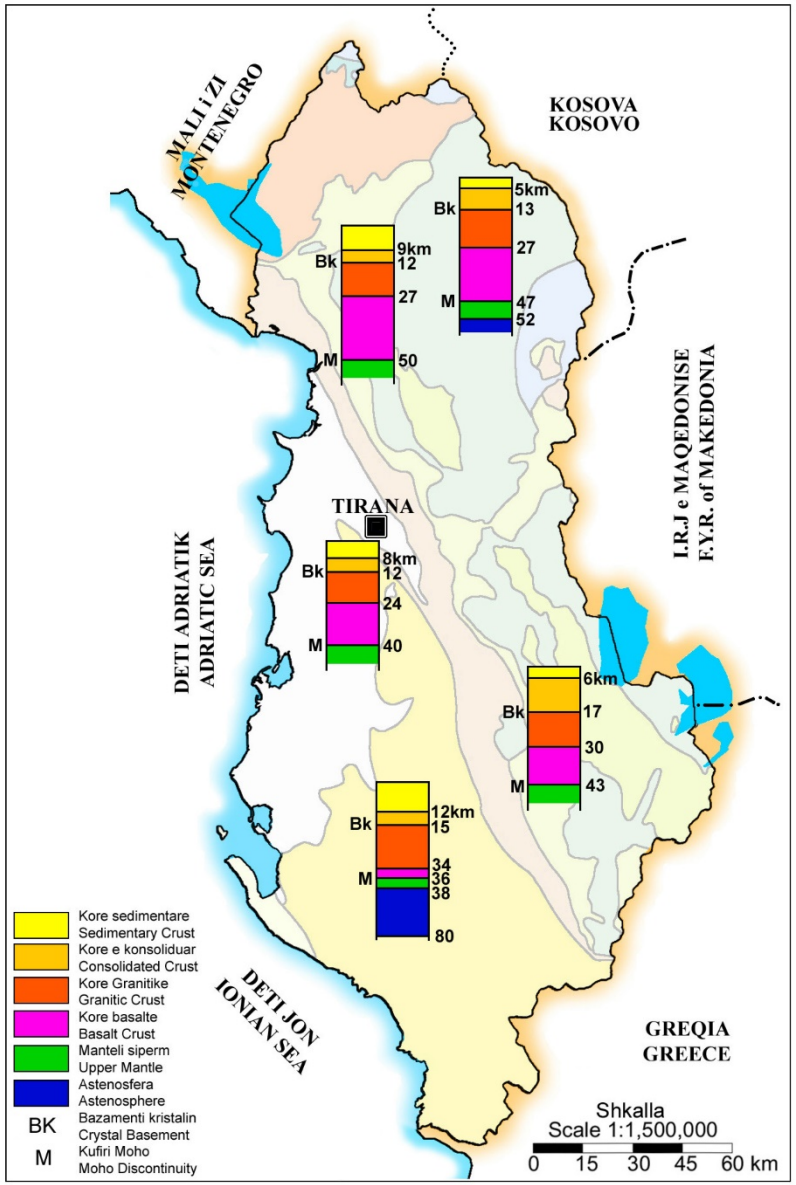
GEOLOGICAL STRUCTURE OF EARTH'S CRUST AND UPPER MANTLE IN ALBANIA



Geophysical data reveal that the Earth crust becomes thicker from central regions of Adriatic towards Albanides in land. The sedimentary crust has 8-9 km thick in Adriatic seashore and reaches up to 15 km in northwestern regions of Albania. The depth of Moho discontinuity is 40 -50 km. Its deepest part is in northwestern part of Albania.

◀ Geologic structure of Earth's Crust and Upper mantle based on seismological studies.

Legend

1: Sedimentary Crust
2: Consolidated Crust
3: Granite Crust
4: Basalt Crust
5: Upper mantle
6: Asthenosphere
7: BK – Crystal Basement
8: M – Moho Discontinuity

From *Frasheri and Bushati (2008)*

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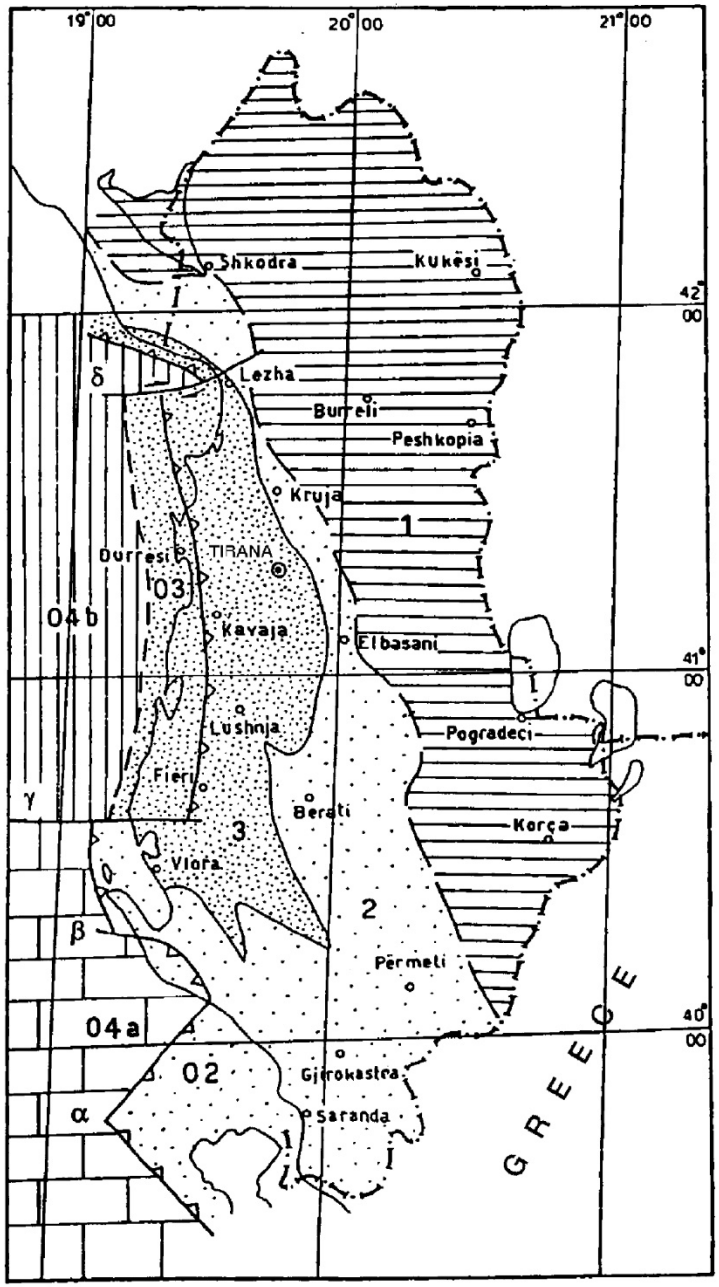

NEOTECTONIC ZONATION OF ALBANIA

Four large **neotectonic units** have been recognized in Albania based on the sense, intensity and chronology of vertical movements:

1. Internal Alpine unit
affected by post-Pliocene extensional tectonics

2. External Alpine unit
strongly affected by pre-Pliocene compression movements

3. Peri-Adriatic foredeep
strongly affected by post-Pliocene compression movements

4. Pliocene-Quaternary Foreland
in Adriatic and Ionian offshore
(04a –Apulian platform; 04b –Albanian Basin)

From *Aliaj (1998)* and *Aliaj et al. (2000)*

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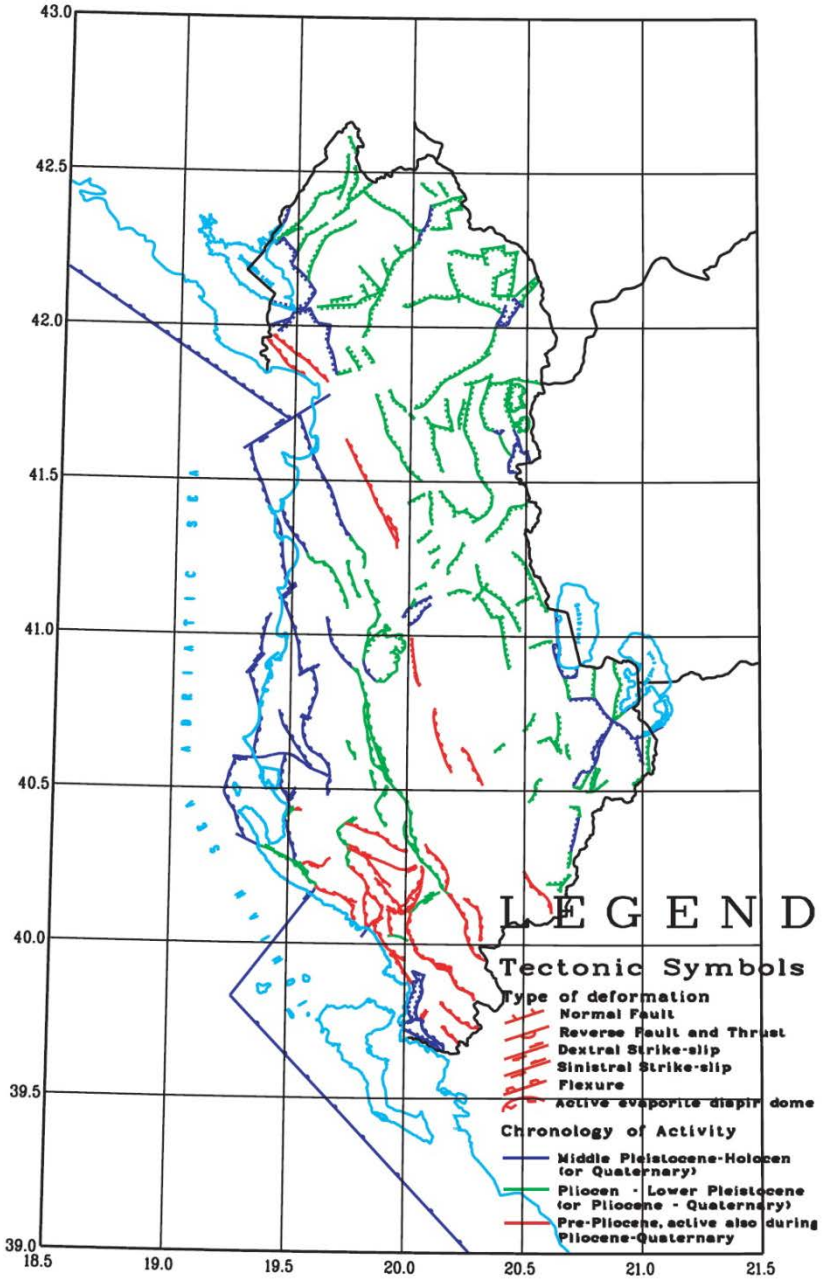

ACTIVE FAULT ZONES AND FAULTS OF ALBANIA

Three longitudinal and two transverse **active fault zones** are evidenced into the Albanian orogen:

1. The NW up to nearly NNW trending Ionian-Adriatic thrust fault zone

2. The NW trending Shkodra-Mati-Librazhdi graben fault zone

3. The N-S trending Peshkopi-Korça graben fault zone

4. The NE trending Shkodra-Tropoja normal fault zone

5. The NE trending Elbasani-Dibra normal fault zone

From *Aliaj (2000)*

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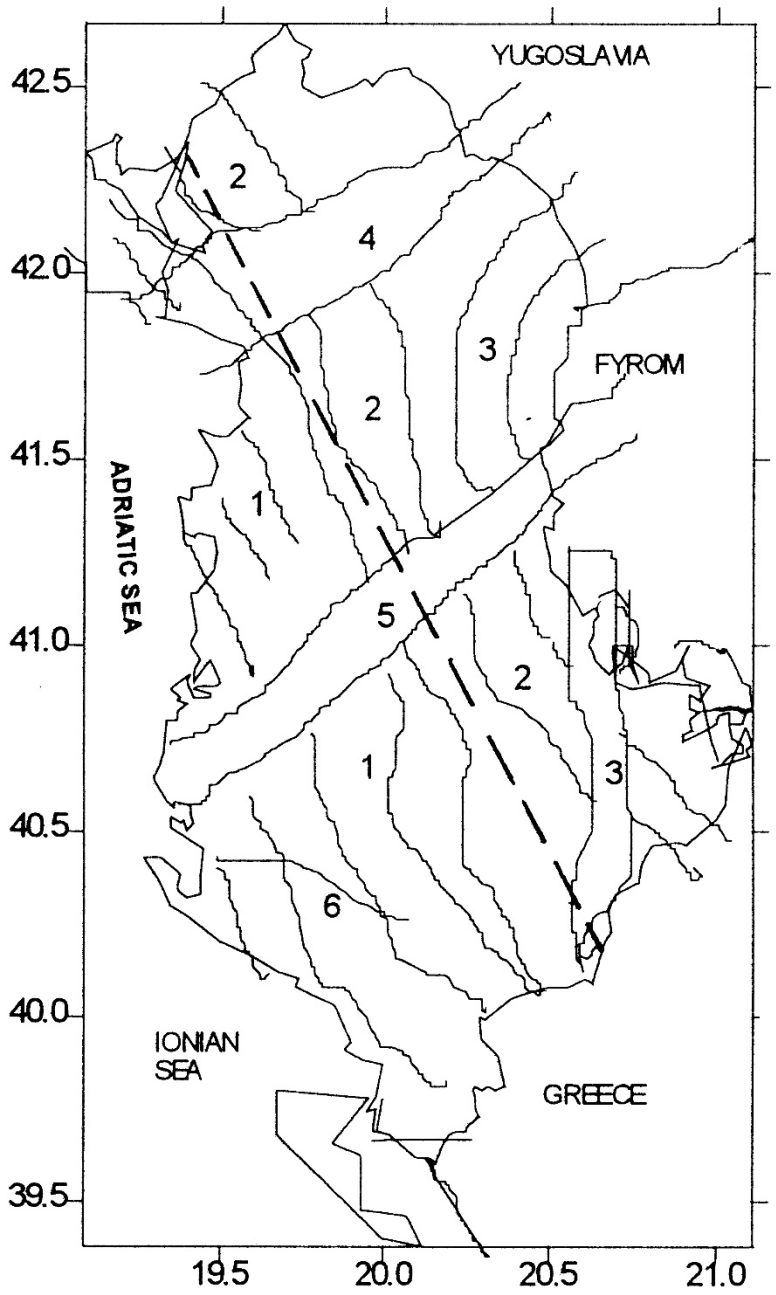

MAIN SEISMOGENIC ZONES OF ALBANIA

The most important **seismogenic zones** of Albania are:

1. the Ionian-Adriatic longitudinal seismogenic zone, which marks the boundary between the Adriatic microplate and the Albanian orogen

2. the Mat-Moker-Bilisht longitudinal seismogenic zone

3. the Drini-Ohri-Korça seismogenic zone

4. the Shkoder-Peja transversal seismogenic zone

5. the Lushnja-Elbasan-Diber transversal seismogenic zone

6. the Vlora-Tepelena transversal seismogenic zone

From *Aliaj (1988)* and *Aliaj and Muço (1996)*

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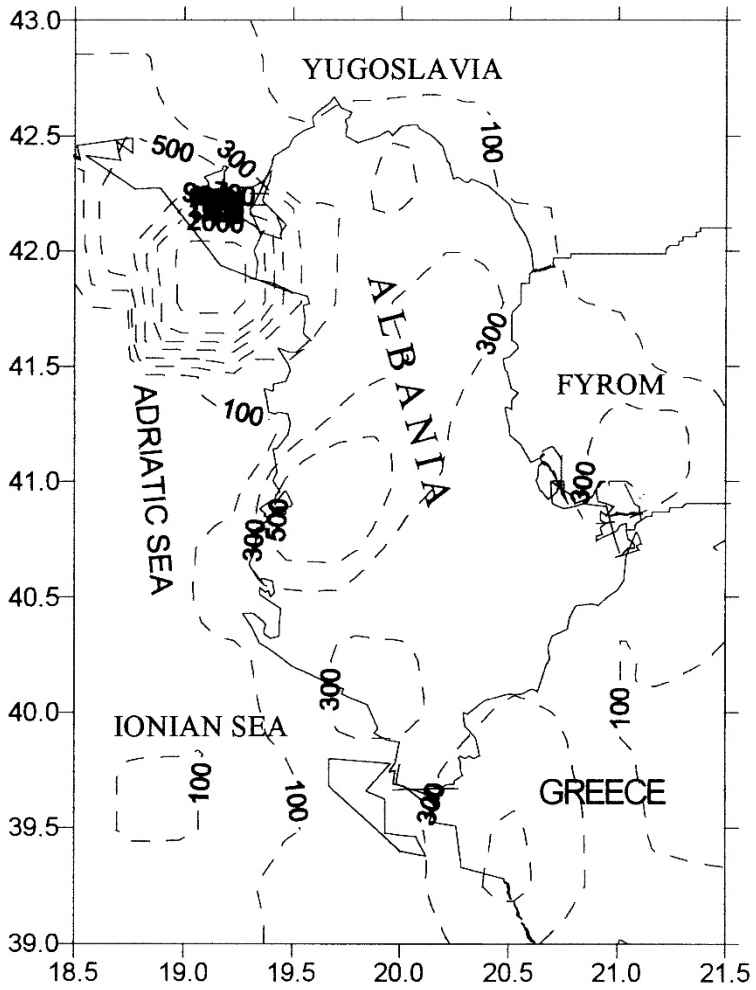
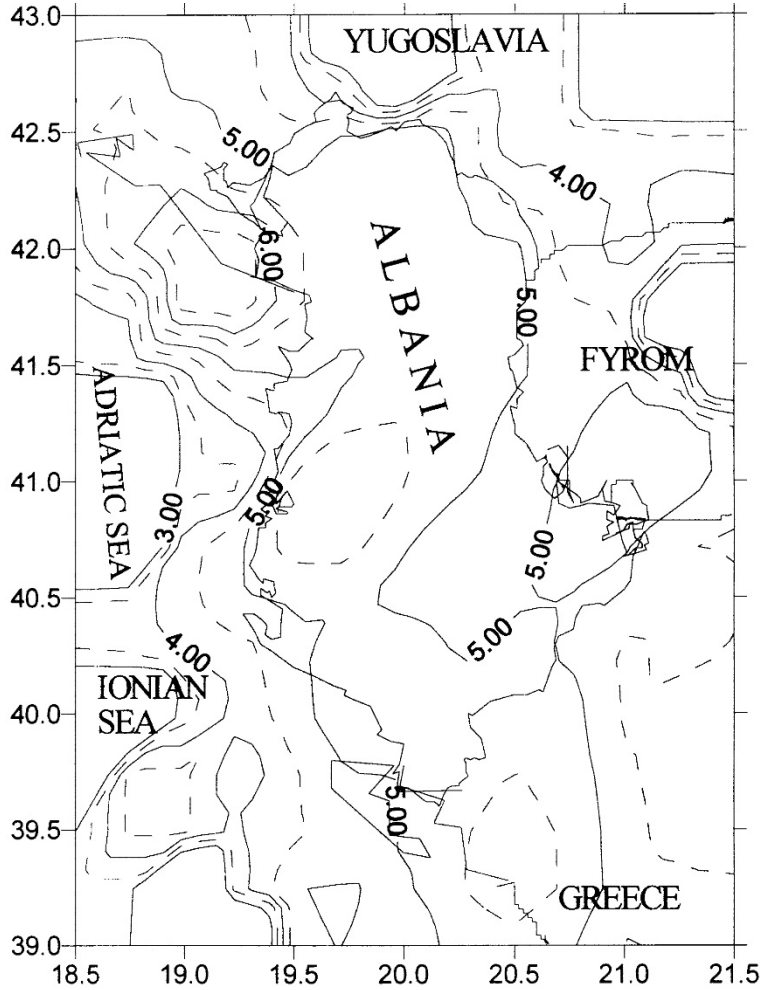
DISTRIBUTION OF SEISMIC ENERGY RELEASED IN ALBANIA



Distribution of seismic energy released in Albania, 1976-1995
From *Muço 1998*



Distribution of cumulative magnitudes for Albania, 1976-1995
From *Muço 1998*

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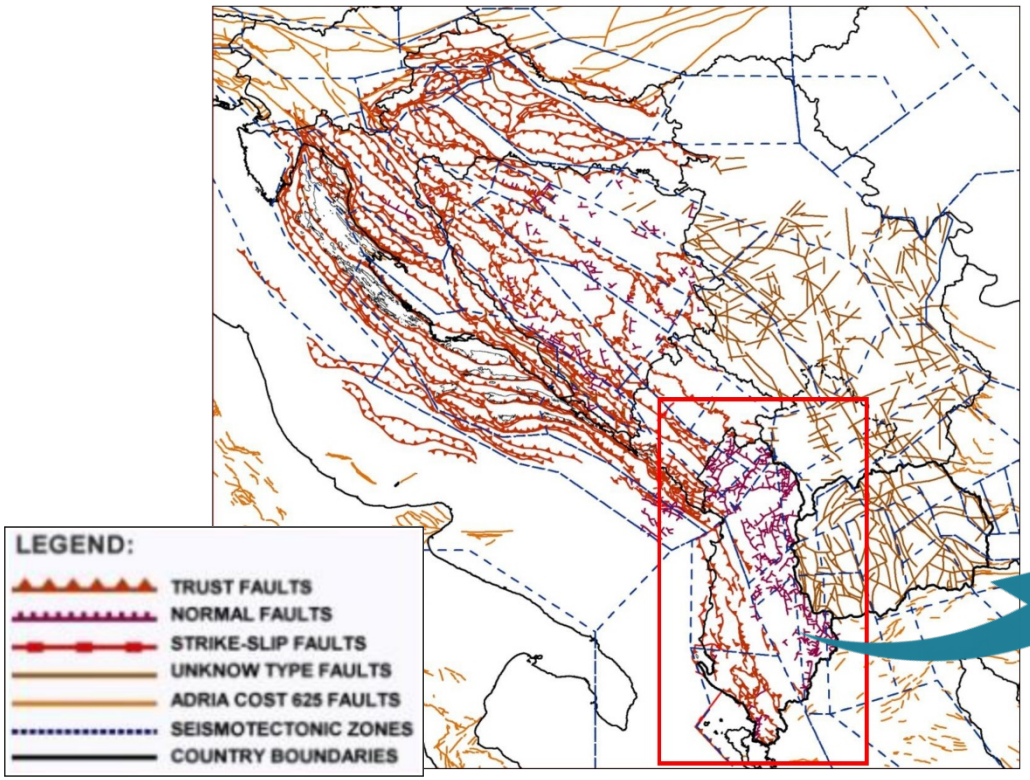
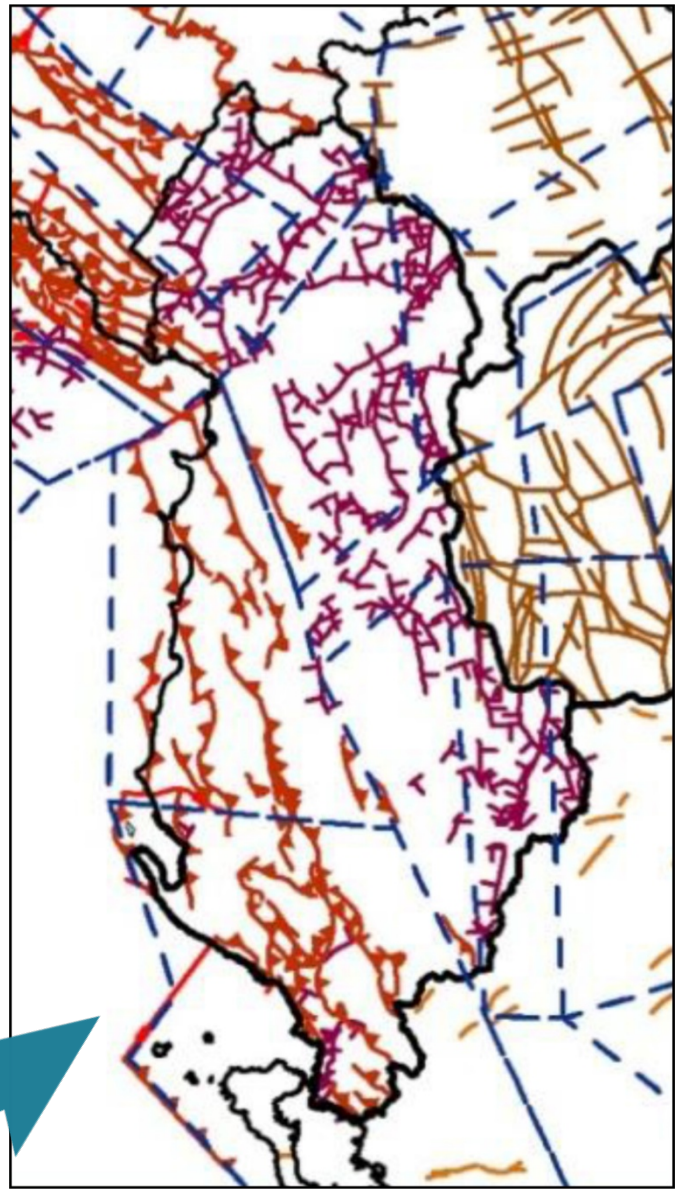
ACTIVE FAULTS OF ALBANIA

Fault zones in **Eastern Albania** are mostly defined by the influence of **normal faults**. The majority of them in directions of 325°-350°. The **Western Albania** fault zones are characterized by **reverse faulting** – at the range of 40-50% stretching along the coastal shore (165°), while the appearance of strike slip faults is in range of 15% of total tectonic activity. The influence of normal faulting style ranges from 30 to 40% - in this case very close to the major directivity of trust fault type.





From *NATO SfP Project No. 983054 (BSHAP)*

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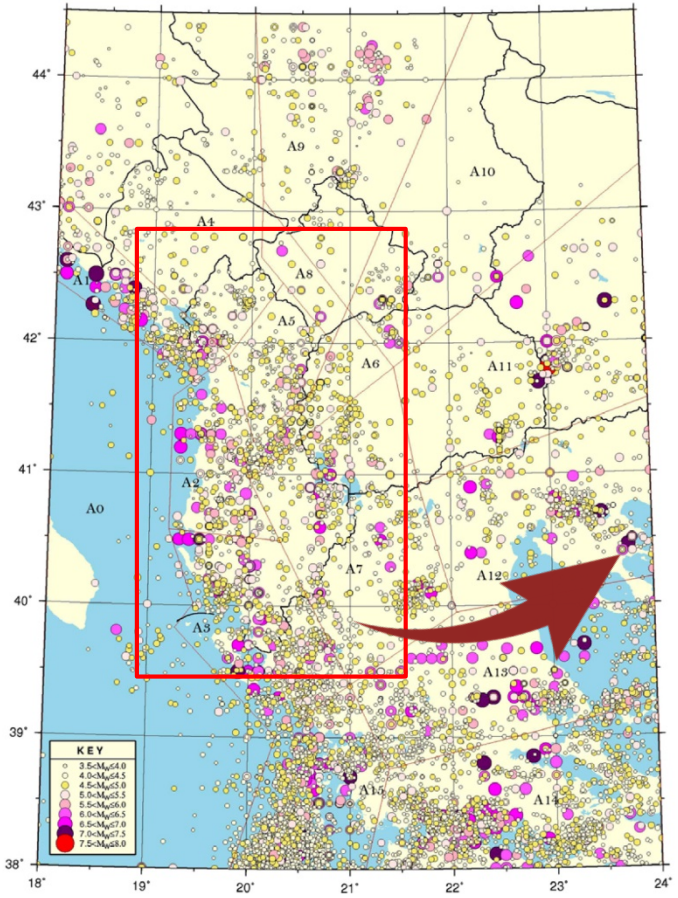
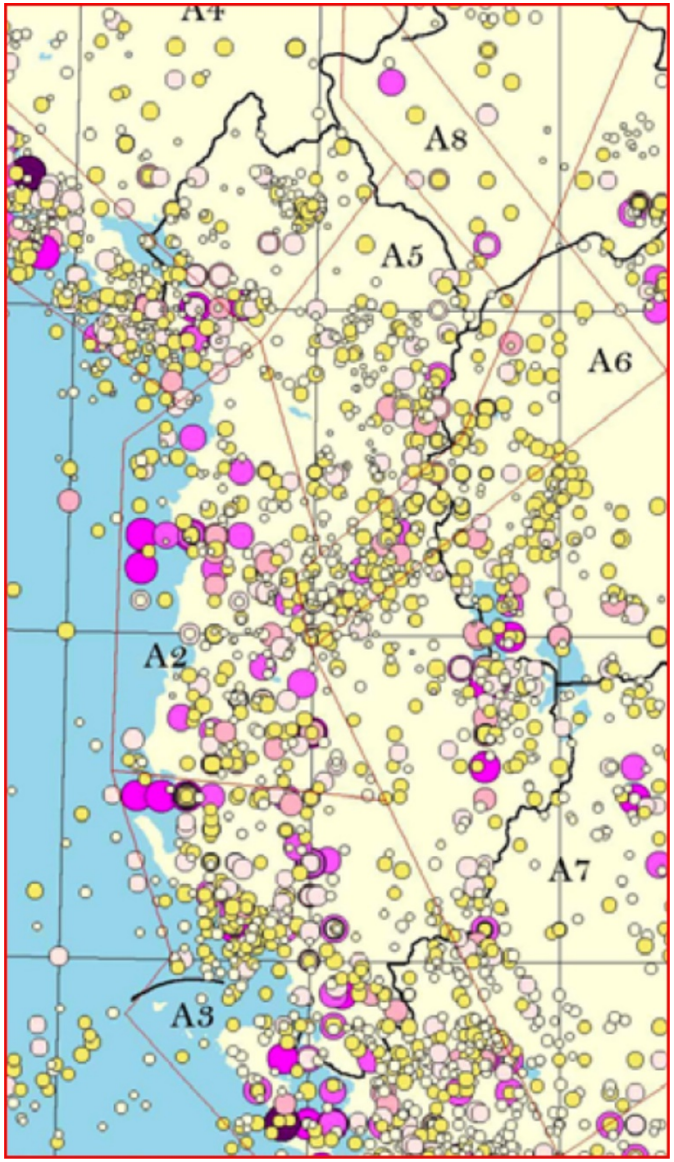
SEISMICITY OF ALBANIA

The seismicity of Albania is characterized by an intensive seismic microactivity (1.0<M≤3.0), many small earthquakes (3.0<M≤5.0), rare medium-sized earthquakes (5.0<M≤7) and very seldom by strong earthquakes (M>7.0) (*Sulstarova et al, 2003*).





Distribution of Mw≥4.0 earthquake epicenters in Albania from 510 B.C. to December, 31, 2008.

From *Fundo et al. (2012)*

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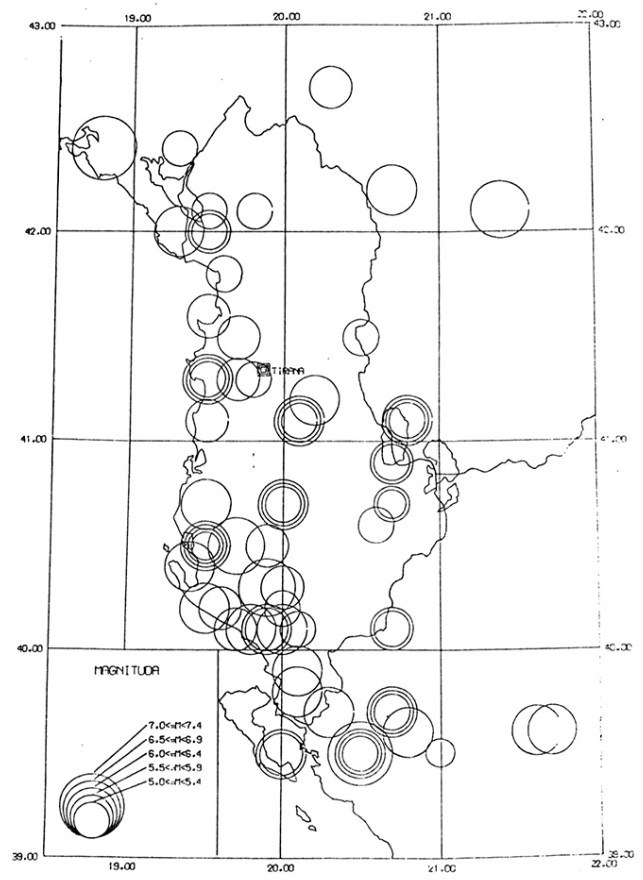
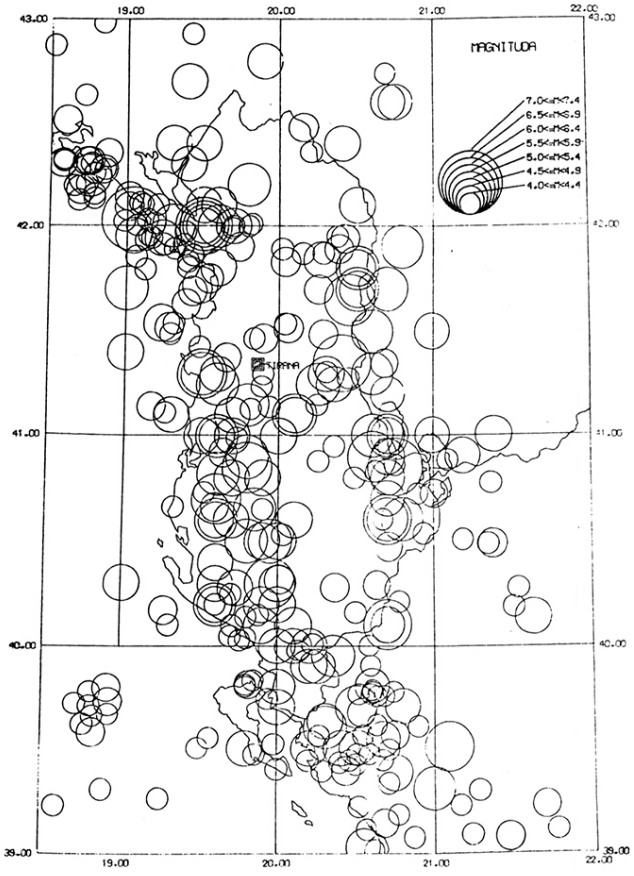
EARTHQUAKE EPICENTERS IN ALBANIA

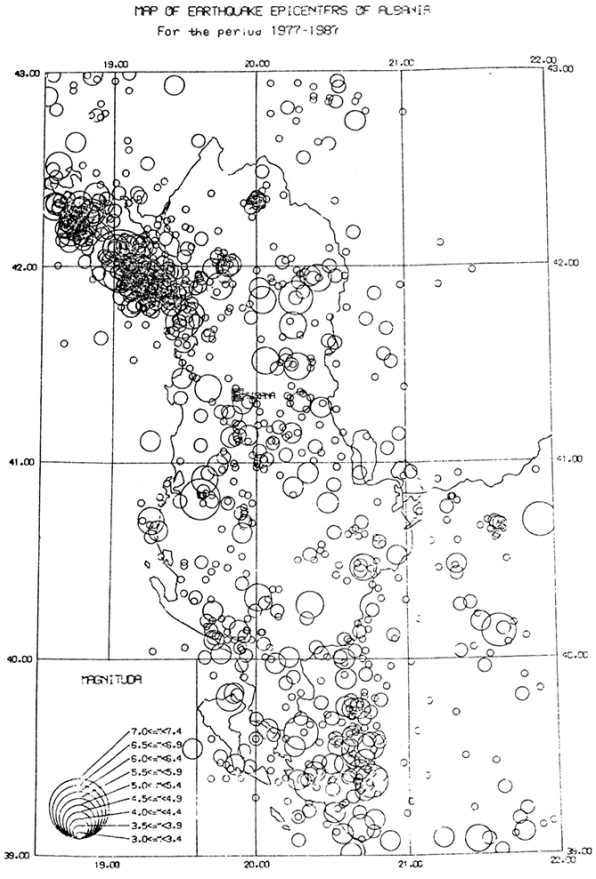
Earthquake Epicenters
before 1900



Earthquake Epicenters
from 1901 to 1987
(for the period 1901-1970 M≥5.0
and for 1971-1987 M≥4.0)



Earthquake Epicenters
from 1977 to 1987
(M≥3.0)



From *Sulstarova (1996)*

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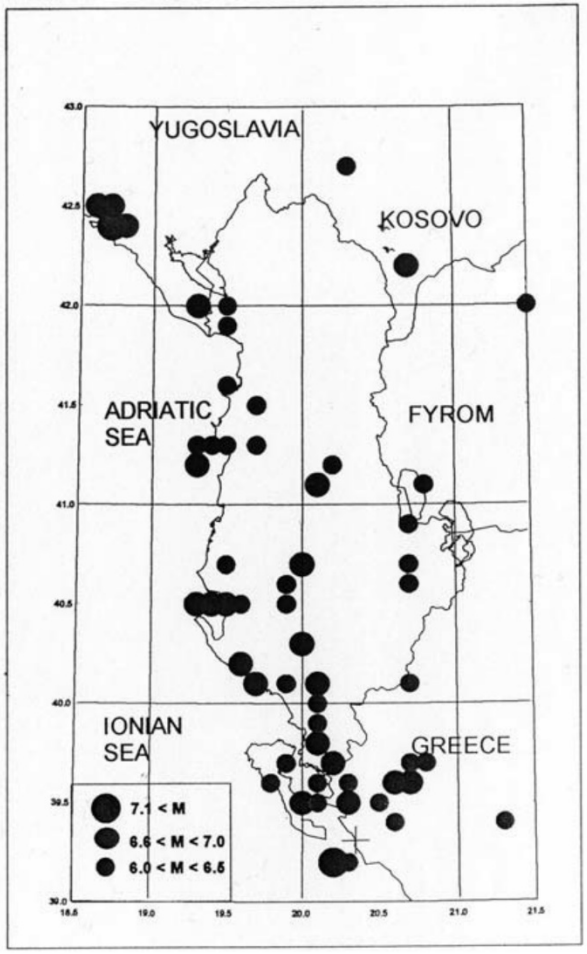
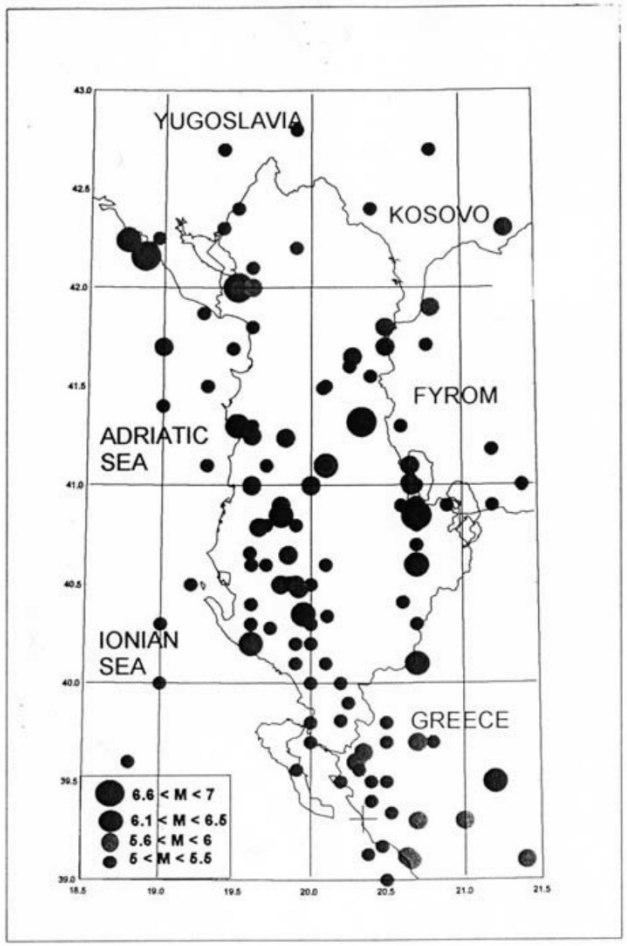
EARTHQUAKE EPICENTERS IN ALBANIA

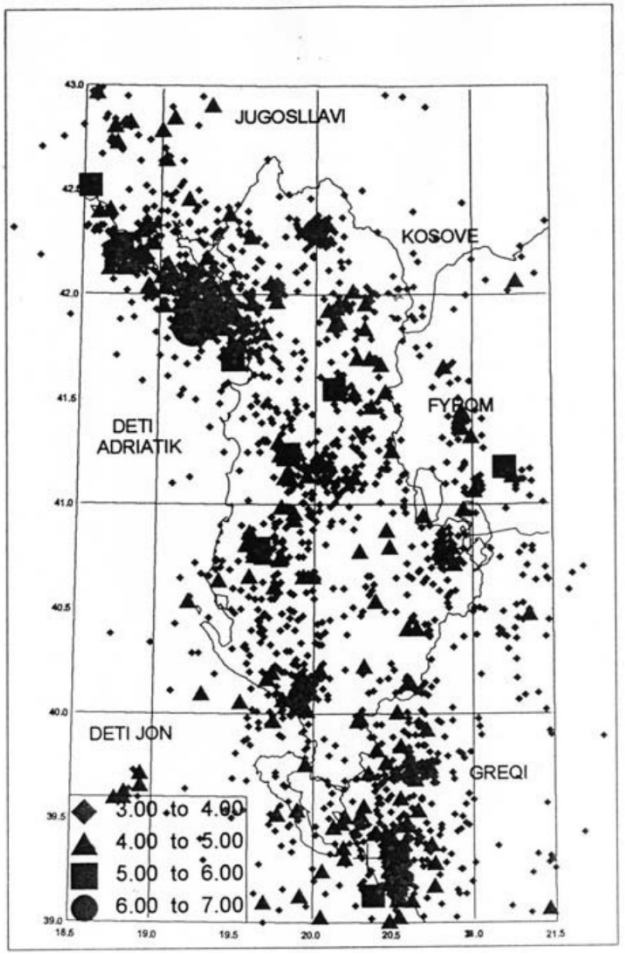
Epicenters of historical earthquakes for the period 58-1900 (M > 6.0)



Earthquake epicenters for the period 1900-2005 (M>5.0)



Earthquake epicenters for the period 1976-2005 (M>3.0)



From *Aliaj (2007)*

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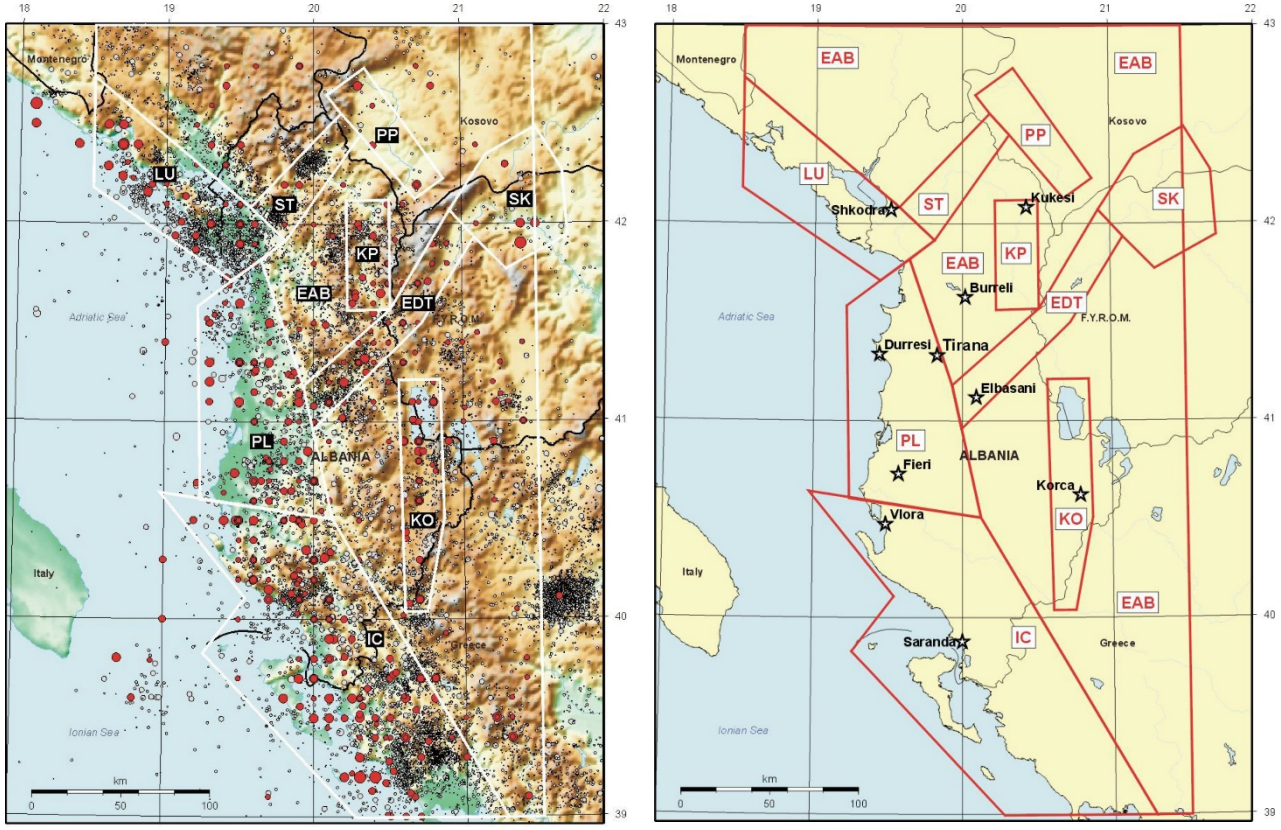
EARTHQUAKE SOURCE MODEL AND SEISMIC SOURCE ZONES IN ALBANIA



LU: Lezha – Ulqini with Mmax=7.2

PL: Periadriatic Lowland with Mmax=7.03

IC: Ionian Coast with Mmax=7.0

PP: Peja – Prizreni with Mmax=6.8

KP: Kukesi – Peshkopia with Mmax=6.96

KO: Korça – Ohrid with Mmax=6.97

ST: Shkodra – Tropoja with Mmax=6.58

EDT: Elbasani – Dibra – Tetova with Mmax=6.89

SK: Skopje with Mmax=6.5

EAB: Eastern Albanian Background with Mmax=5.5

From *Aliaj et al. (2004)*

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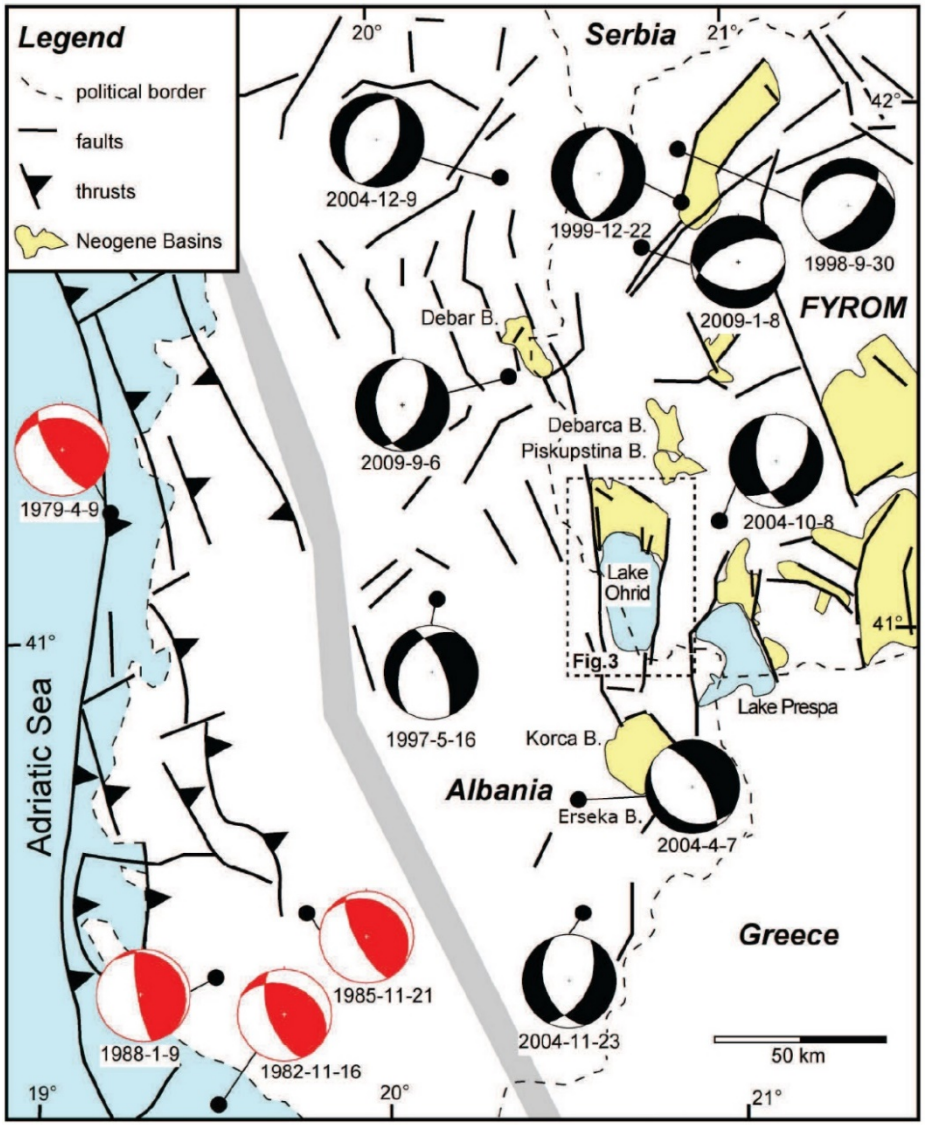
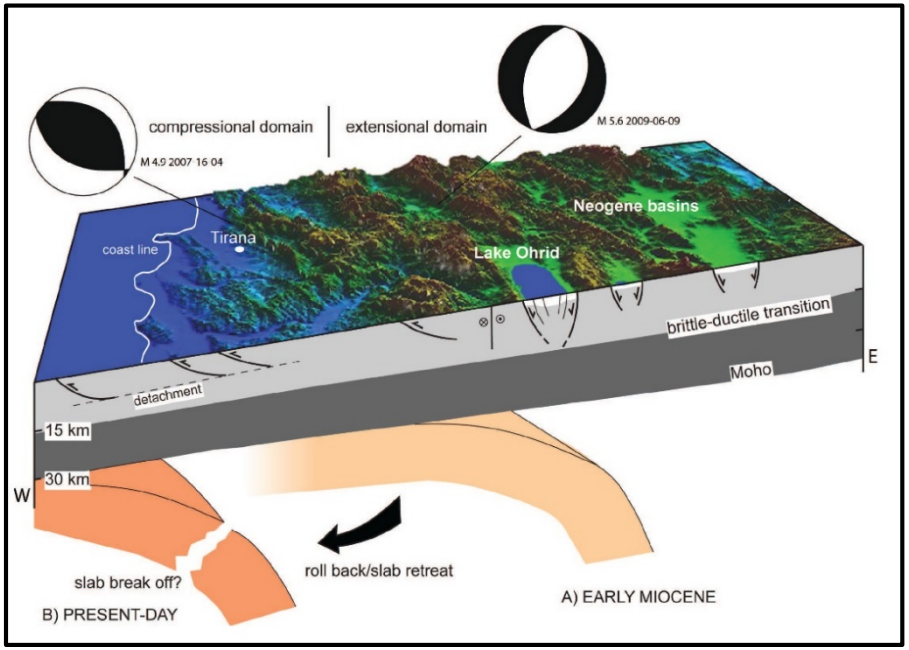
ACTIVE FAULTS, EARTHQUAKES AND FAULT PLANE SOLUTIONS IN ALBANIA



◀ Fault plane solutions of several earthquakes in the triangle of Albania, North Macedonia and Greece (*Hoffman, 2013*). **Black beachballs** indicate **normal faulting**. **Red beachballs** indicate **thrust faulting**. **Grey zone** divides compressional and extensional domains associated with Neogene basins and normal faults.

▼ Structural cross section from the Adrian coast to the Neogene basins in the Balkanides. The frontal part is characterized by thrusts, whereas the basins are formed within the extensional domain (*Hoffman, 2013*).



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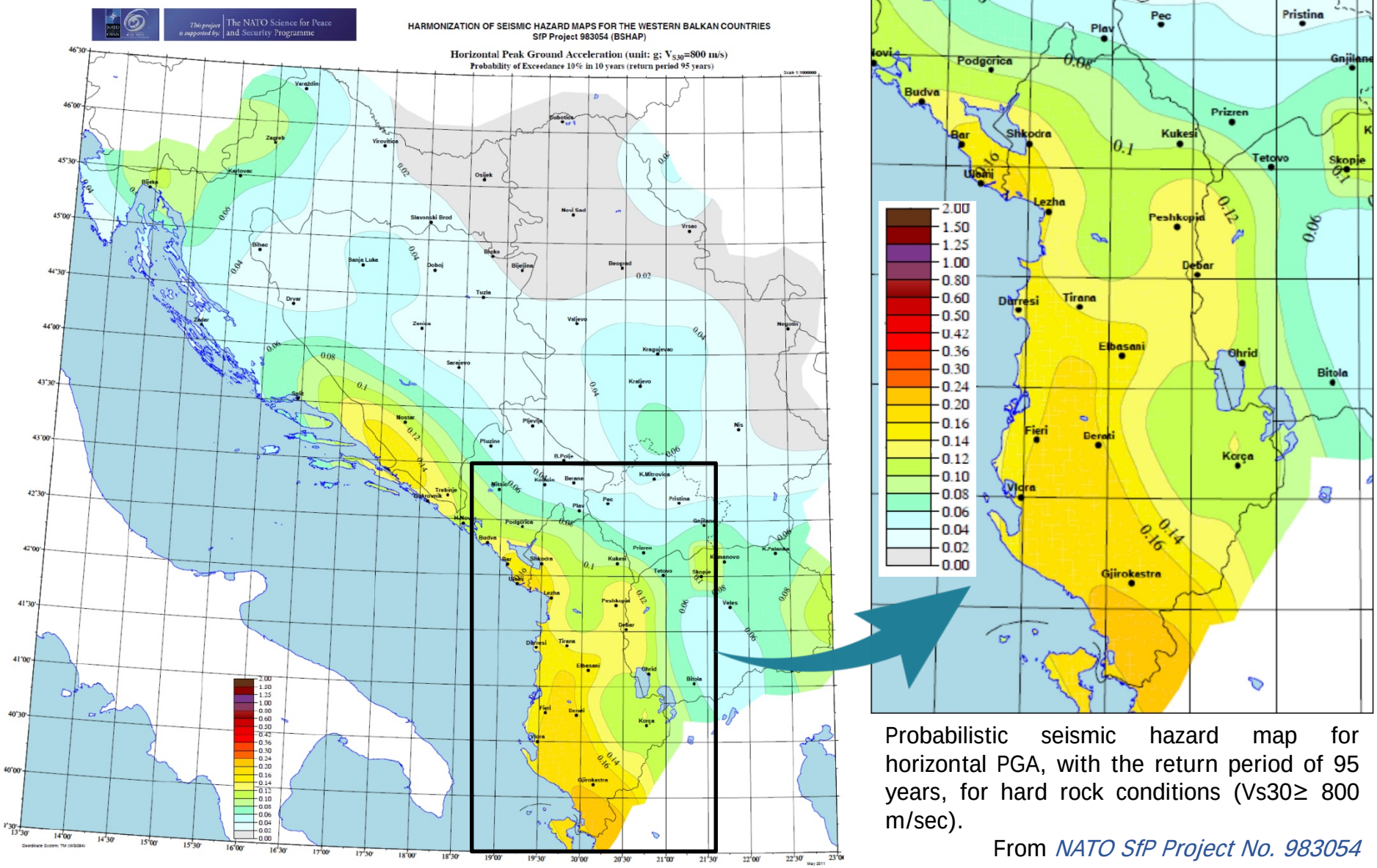
SEISMIC HAZARD OF ALBANIA



Probabilistic seismic hazard map for horizontal PGA, with the return period of 95 years, for hard rock conditions (Vs30≥ 800 m/sec).

From *NATO SfP Project No. 983054*

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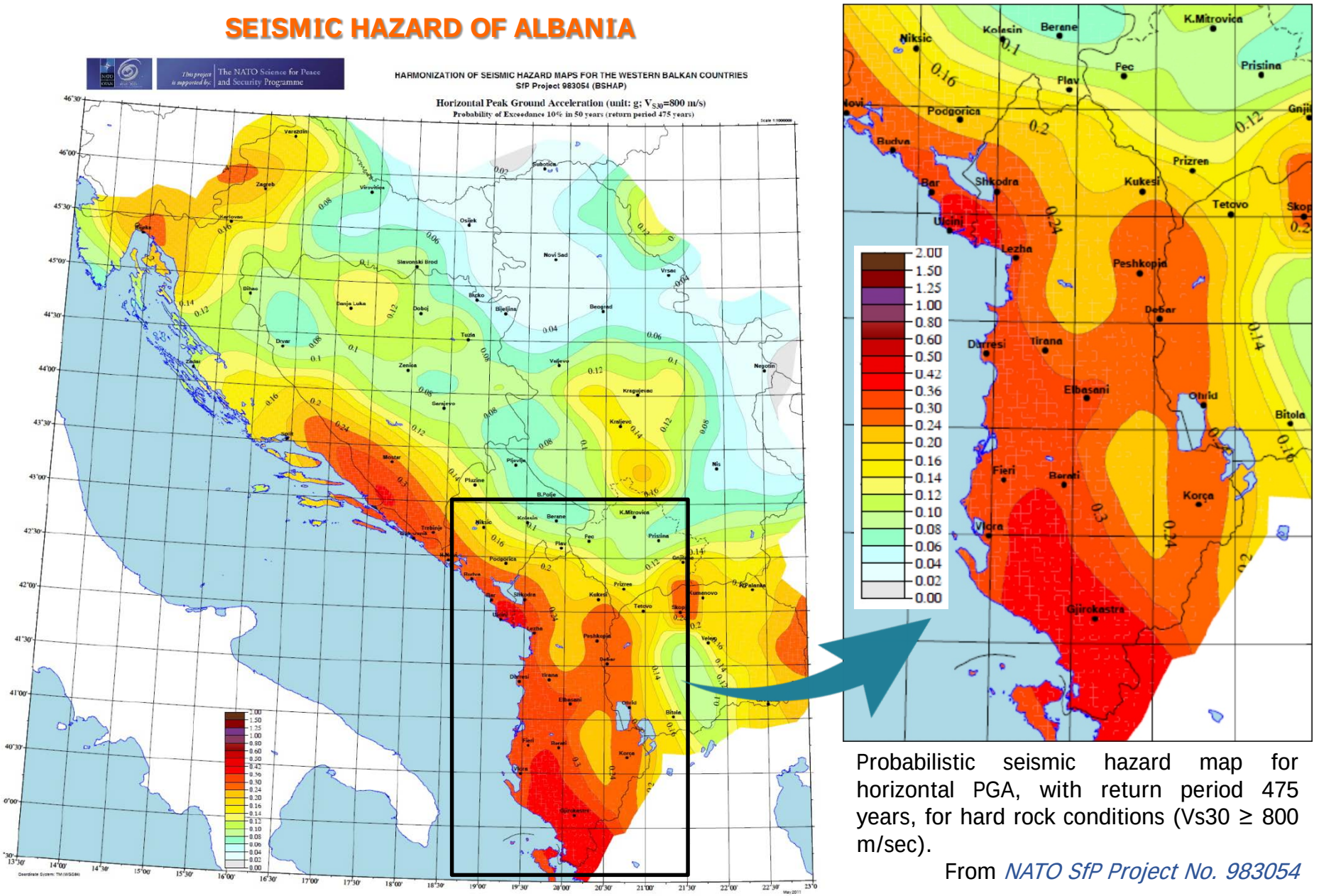
SEISMIC HAZARD OF ALBANIA



Probabilistic seismic hazard map for horizontal PGA, with return period 475 years, for hard rock conditions (Vs30 ≥ 800 m/sec).

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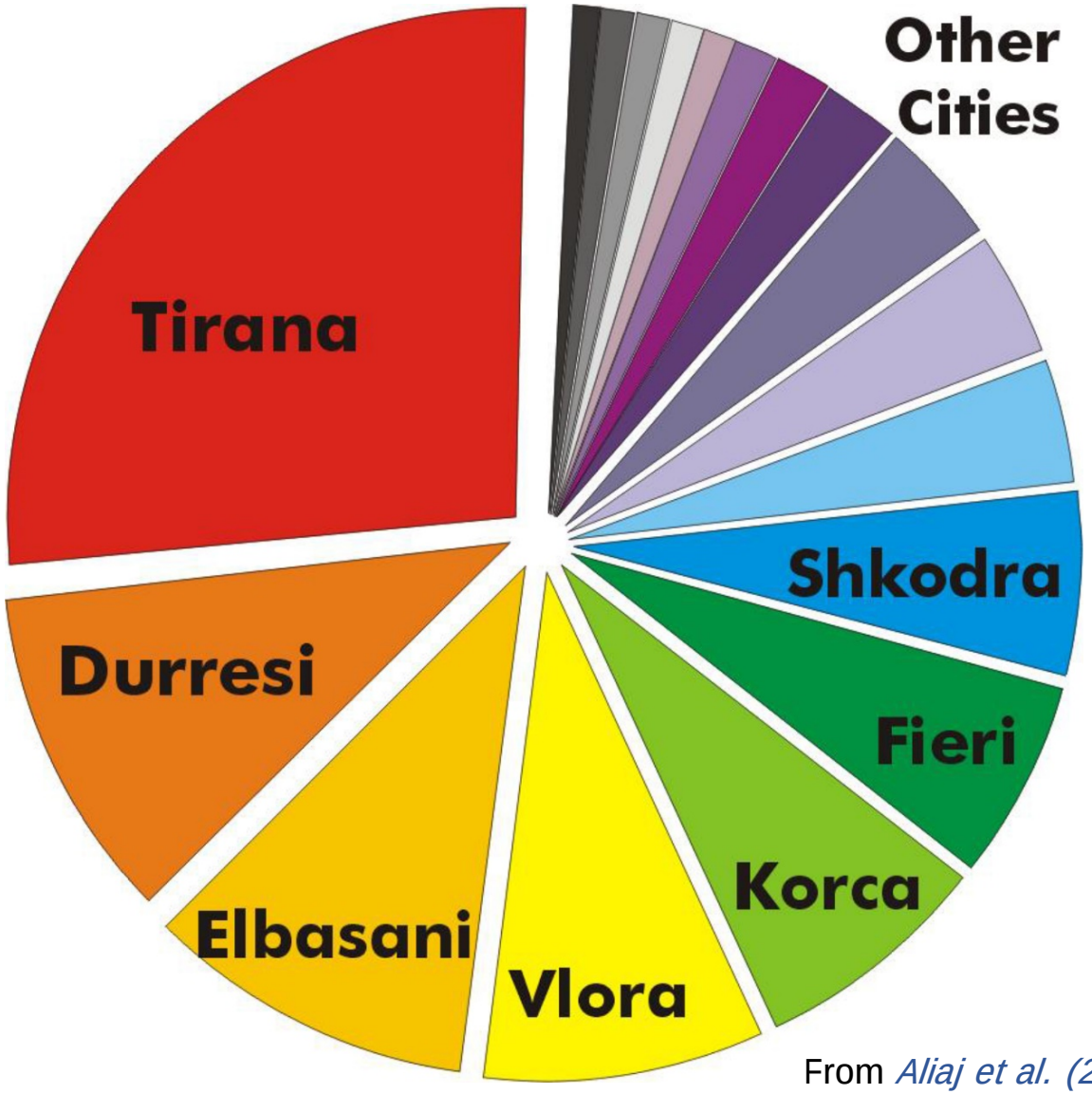
URBAN SEISMIC RISK IN ALBANIA



Tirana and Durrës account for more than one quarter of the urban seismic risk.

Albania's six largest cities at risk account for over two-thirds of the urban risk.

From *Aliaj et al. (2004)*

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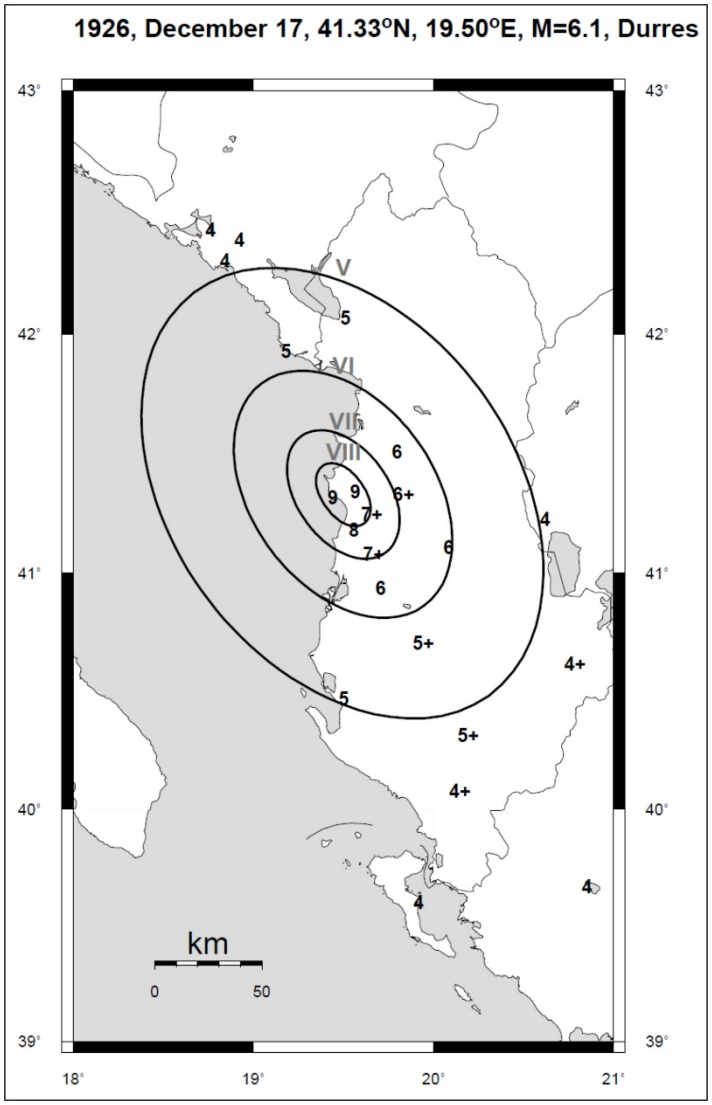
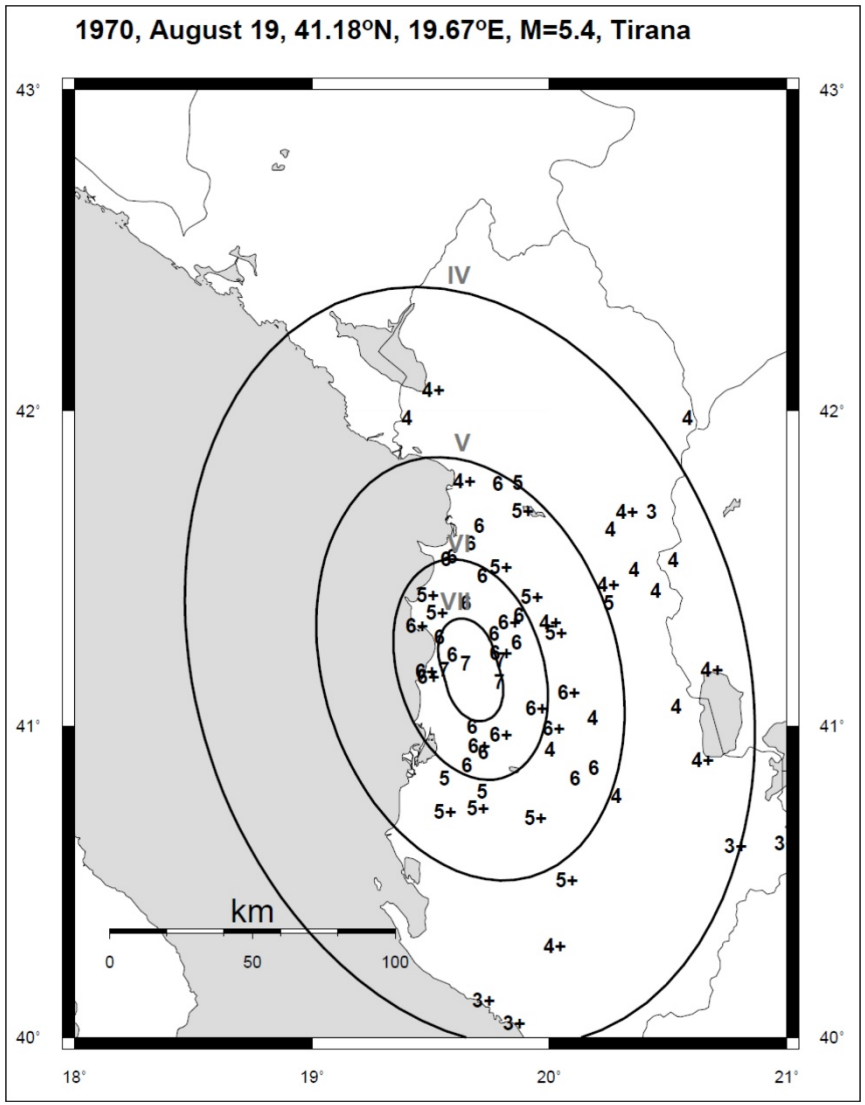
ISOSEISMAL MAPS OF PREVIOUS SHALLOW EVENTS IN THE 2019 EARTHQUAKE-AFFECTED AREA





From *Papazachos et al. (2001)*

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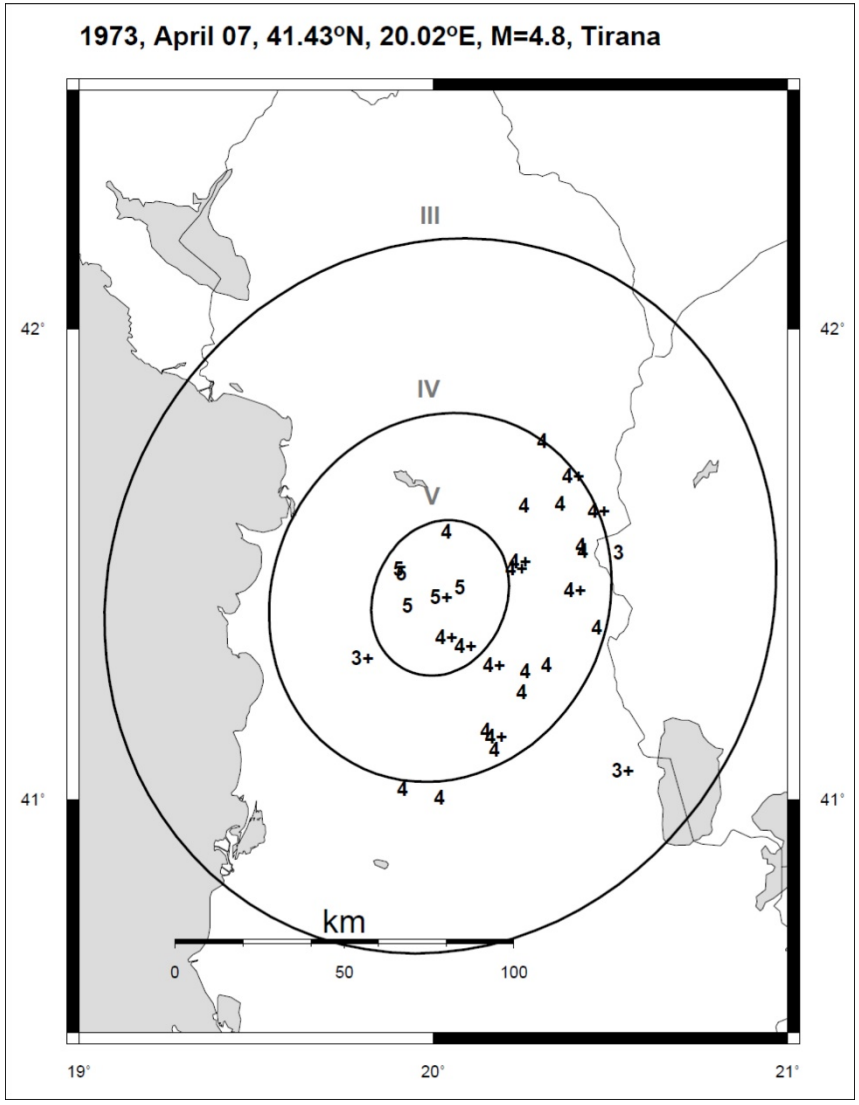
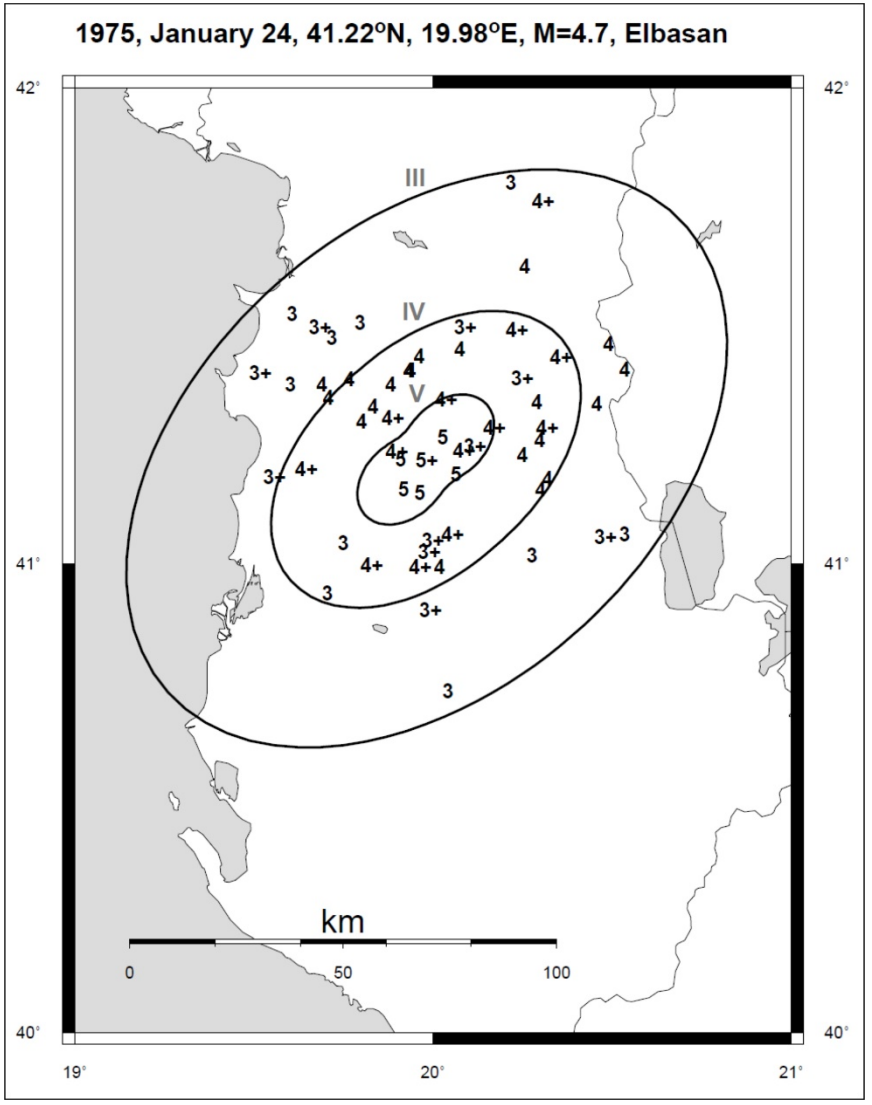
ISOSEISMAL MAPS OF PREVIOUS SHALLOW EVENTS IN THE 2019 EARTHQUAKE-AFFECTED AREA





From *Papazachos et al. (2001)*

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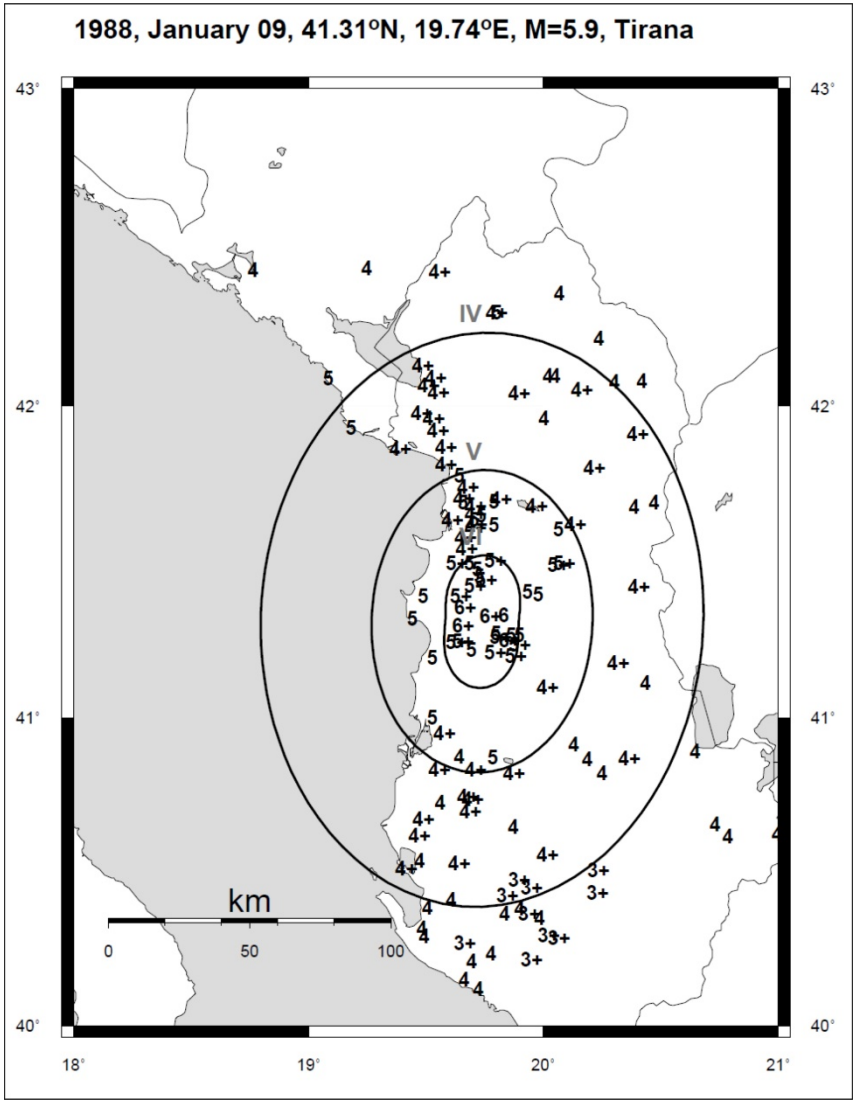
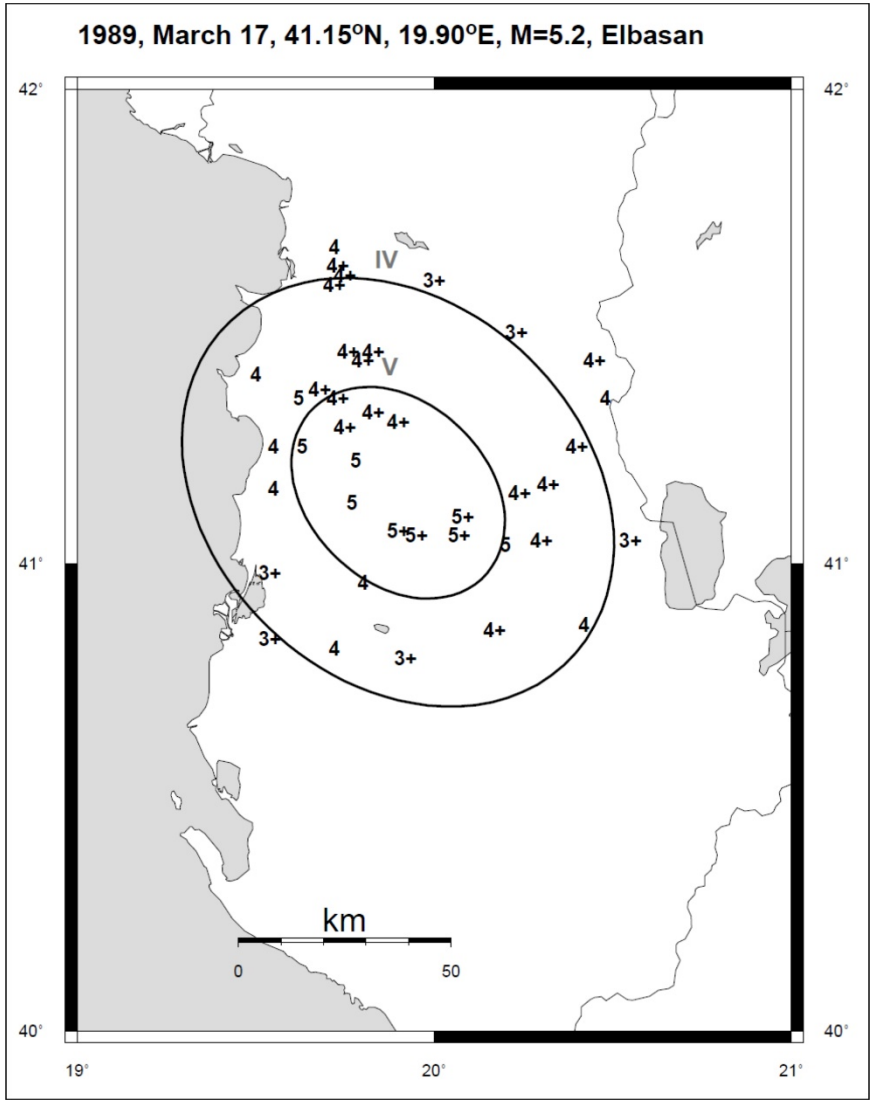
ISOSEISMAL MAPS OF PREVIOUS SHALLOW EVENTS IN THE 2019 EARTHQUAKE-AFFECTED AREA





From *Papazachos et al. (2001)*

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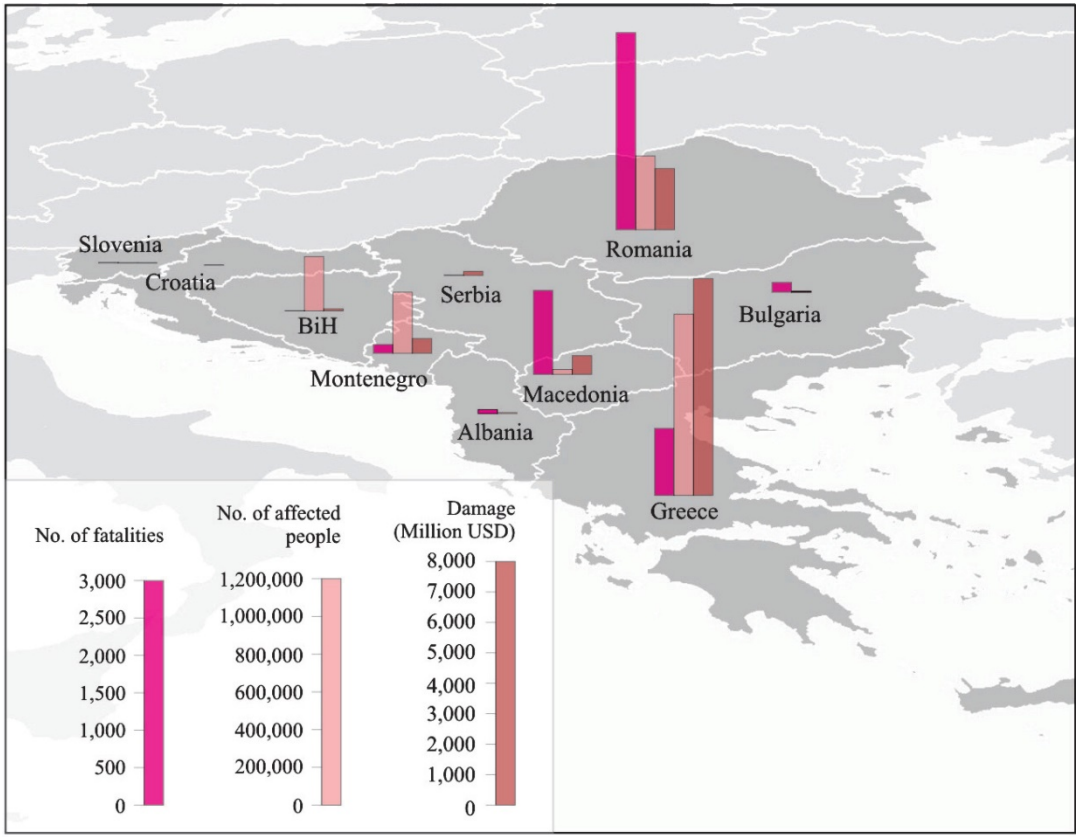
IMPACT OF ALBANIA EARTHQUAKES ON POPULATION AND ECONOMY



◀ Losses due to historical earthquakes in the Balkan region for 1900-2010.

From *EM-DAT: The OFDA/CRED International Disaster Database (Université Catholique de Louvain, Brussels, Belgium)*

Country	Location	Date (d/m/y)	Killed	Affected	Damage, million USD
Albania	Shupenze	30.11.1967.	11	134	n/a
	Northern	15.04.1979.	35	350	n/a
	Lushnje	16.11.1982.	1	5005	n/a
	Tirana	09.01.1988.	-	690	n/a
	Kukes	20.09.1998.	-	2100	n/a
	Peshkopia	07.09.2009.	-	150	n/a
		Total	47	8429	n/a

◀ Summary of recorded and analyzed earthquake EM-DAT data for Albania from 1900-2010

From *Abolmasov et al. (2011)*

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THE SEPTEMBER 21, 2019, Mw 5.6 DURRËS EARTHQUAKE

On September 21, 2019, an earthquake struck the central western part of Albania. It was assessed as Mw 5.6. Its epicenter was located offshore Durrës and its focal depth was about 18 km. An Mw 5.1 aftershock generated 10 minutes after the main shock.

The main shock was felt in the neighboring Montenegro, Italy and Greece, especially in Corfu Island. Fortunately, no fatalities were recorded, while injuries attributed to falling objects, debris and panic were reported.

Based on the focal plane solutions provided by several seismological institutes and observations, both the mainshock and its largest aftershock were generated by the activation of a NW-SE striking reverse fault.

From the geological point of view, the earthquake affected area covers a large part of the Tirana depression, which is located at the northeastern side of the wider Periadriatic depression. Moreover, it is dominated by reverse faults disrupting not only onshore but also offshore Durrës, which are characterized by activity not only during Pliocene - Lower Pleistocene but also during Middle Pleistocene - Holocene. It is concluded that there is consistency between fault plane solutions and field geological data.

Based on the field survey conducted by the authors shortly after the September 21, 2019, Mw 5.6 Durrës earthquake, it is concluded that only secondary effects were observed comprising slope movements and liquefaction phenomena. Landslides were induced at slopes along the road leading from Durrës to Kavaje (Shkembi i Kavajes) resulting in temporary traffic disruption. Liquefaction phenomena were detected in the area east of Durres port and were indicated by ejected sand and water on pavements and small scale subsidence.

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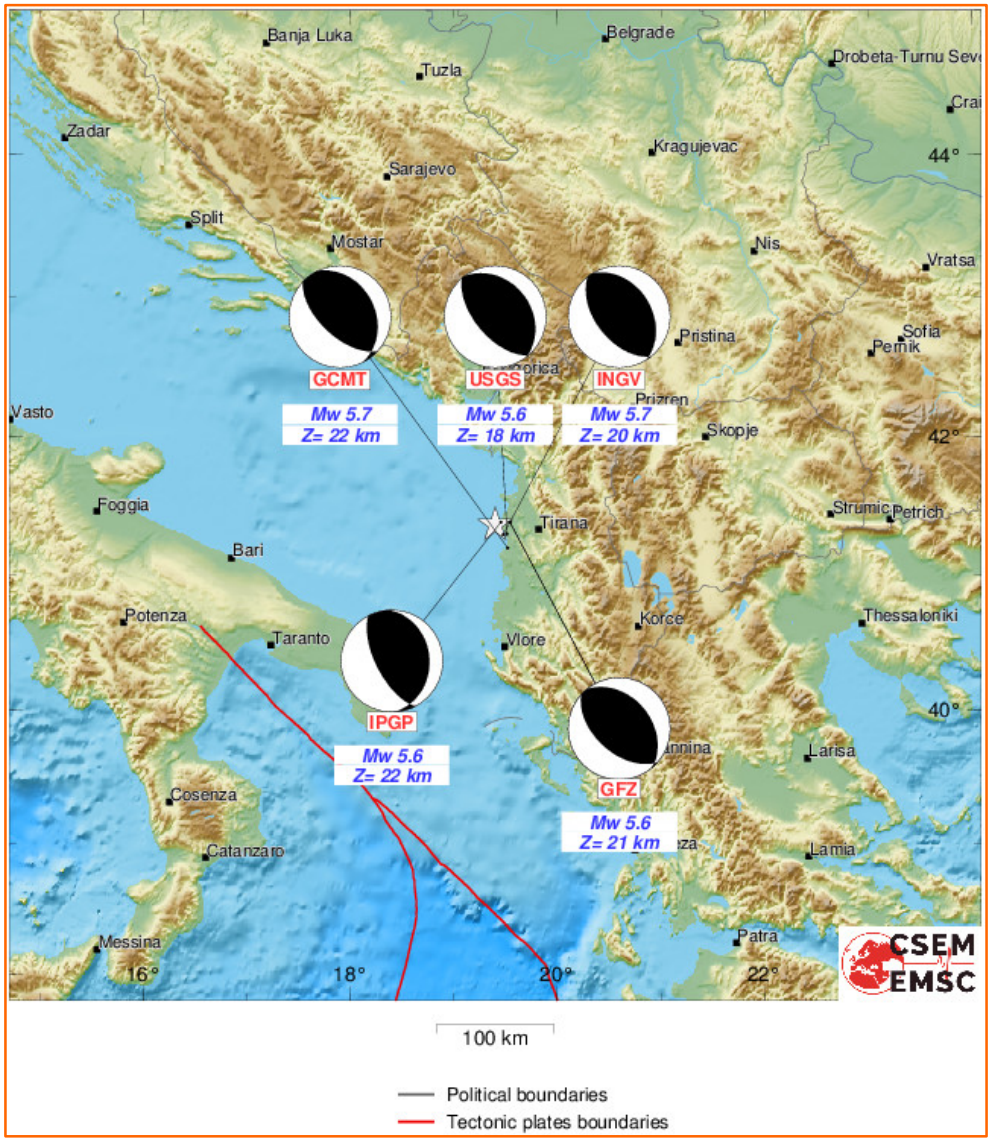
QUICK SOLUTIONS AND REGIONAL MOMENT TENSORS FOR THE SEPTEMBER 21, 2019 MAINSHOCK



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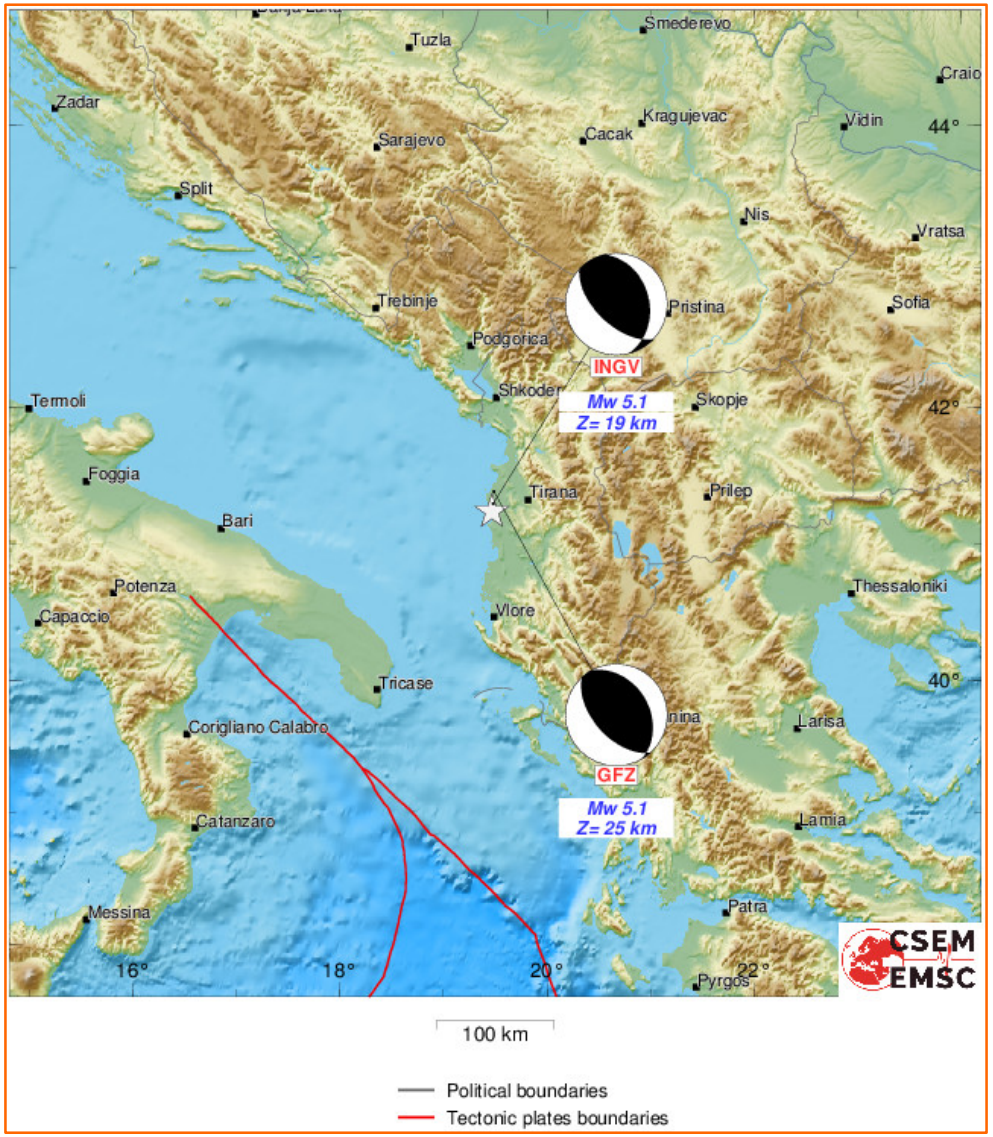
QUICK SOLUTIONS AND REGIONAL MOMENT TENSORS FOR THE LARGEST AFTERSHOCK



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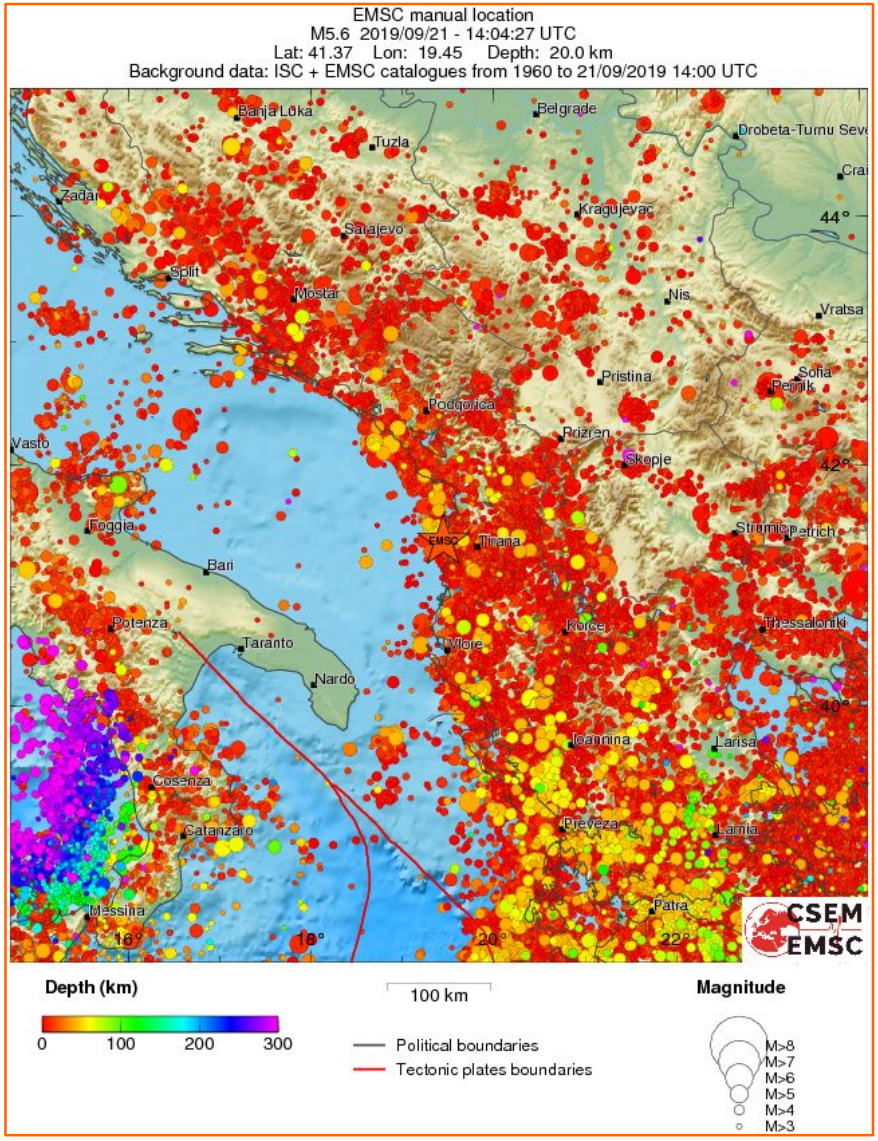
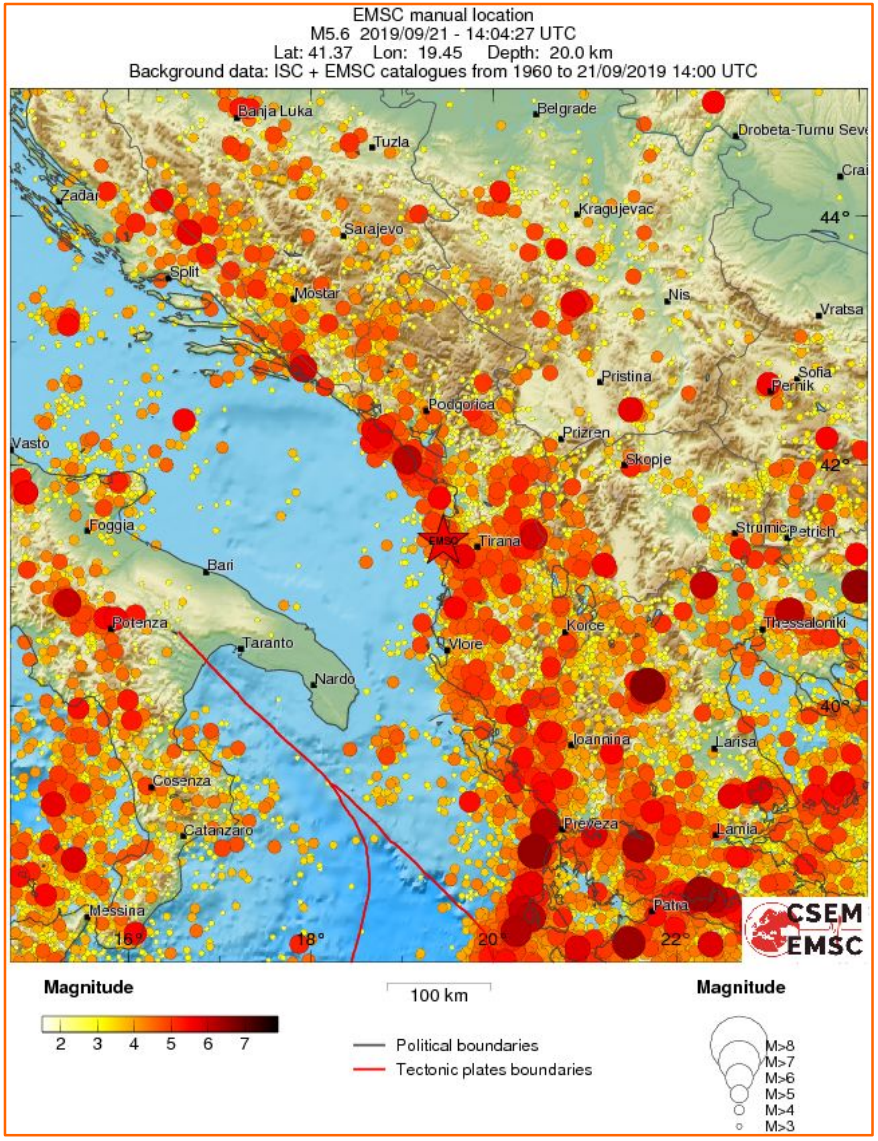
DEPTH AND MAGNITUDE OF REGIONAL SEISMICITY





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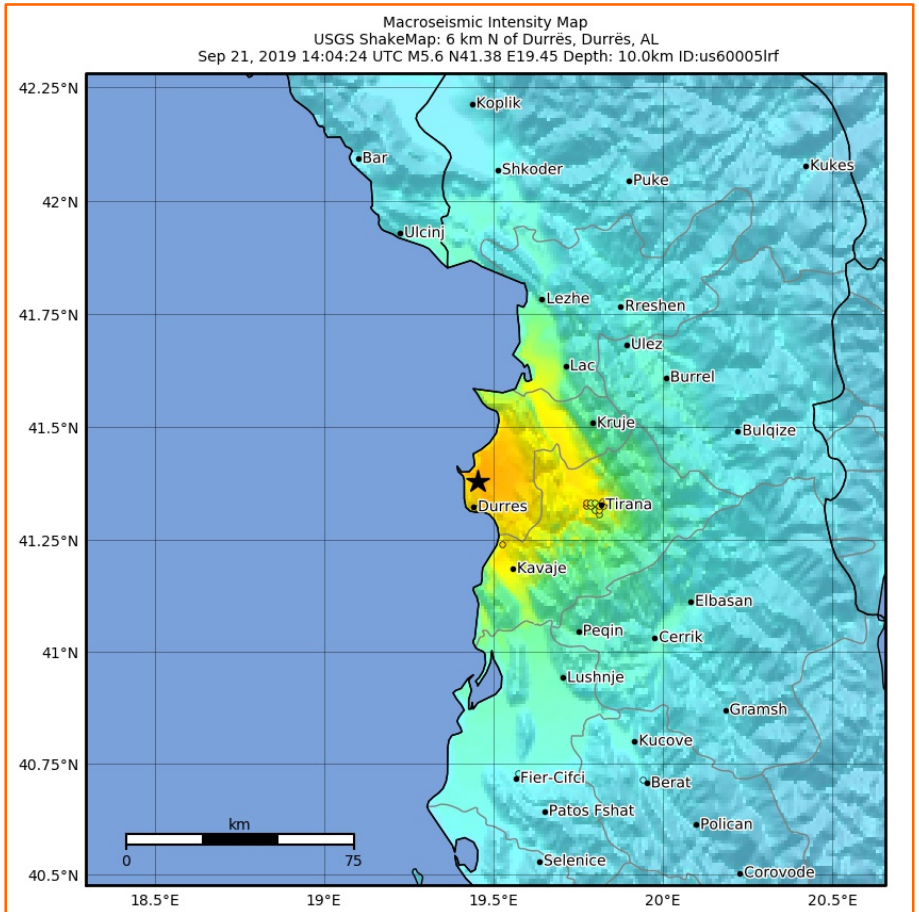
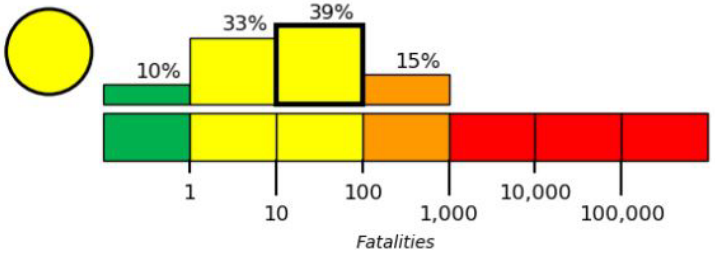
INTENSITY MAP AND ESTIMATED LOSSES OF THE 2019 ALBANIA EARTHQUAKE



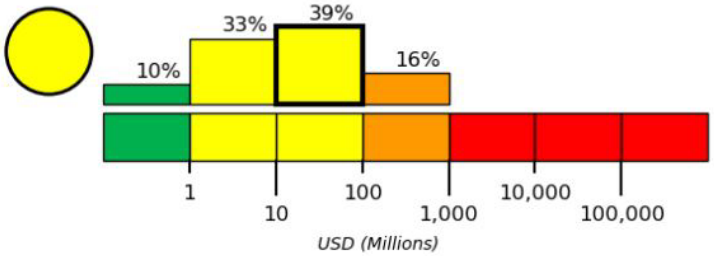
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.05	0.3	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.02	0.13	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Worden et al. (2012) Version 4: Processed 2019-09-22T14:05:05Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

ESTIMATED FATALITIES



ESTIMATED ECONOMIC LOSSES



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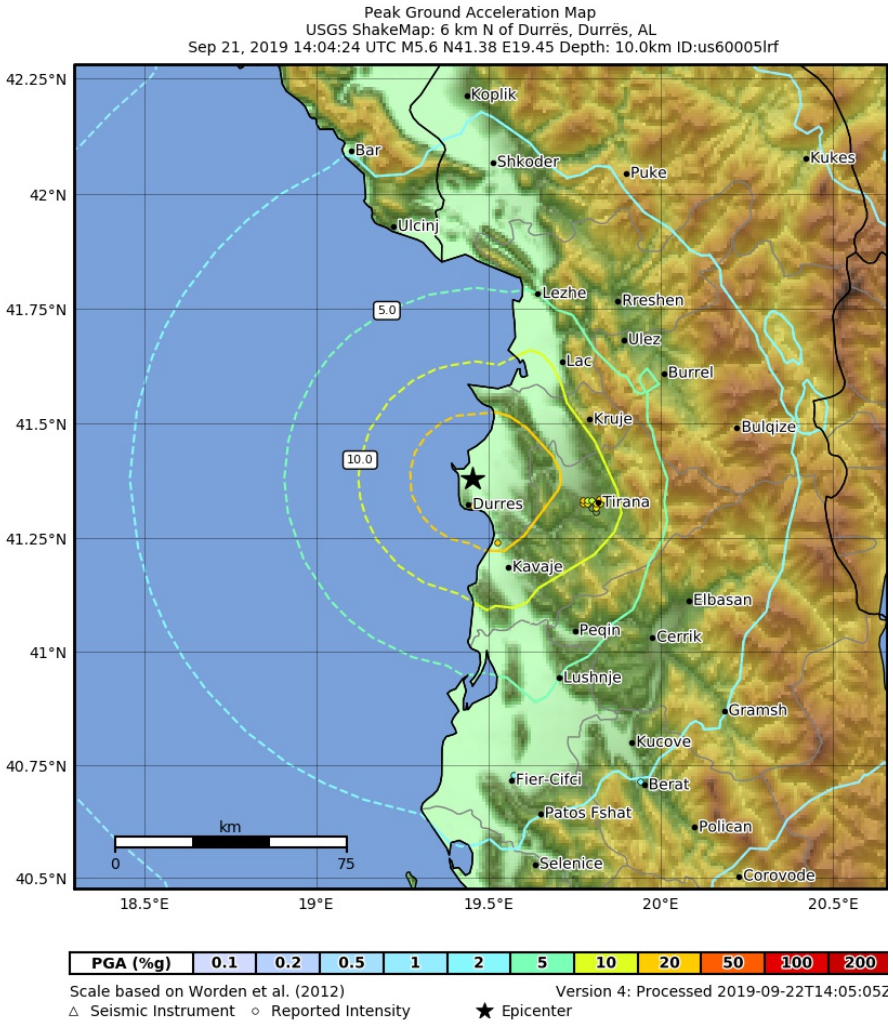
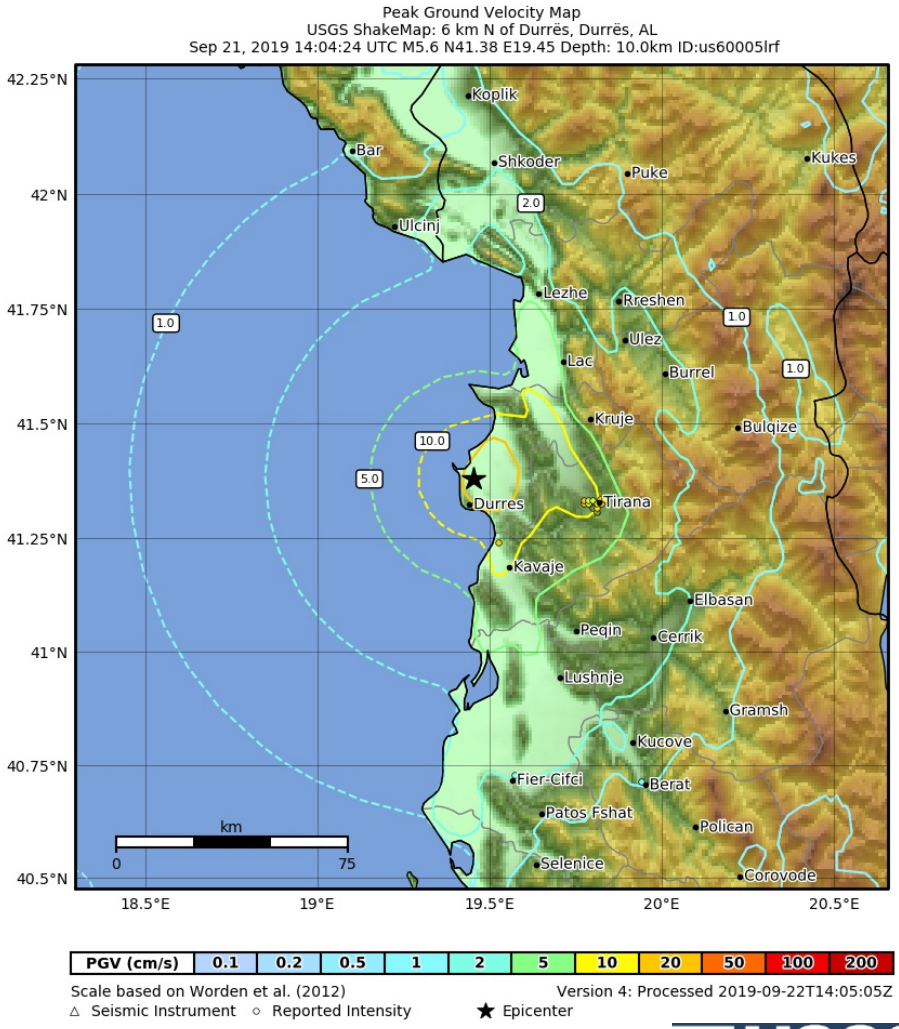
PEAK GROUND ACCELERATION AND VELOCITY MAPS FOR THE MAINSHOCK





USGS science for a changing world

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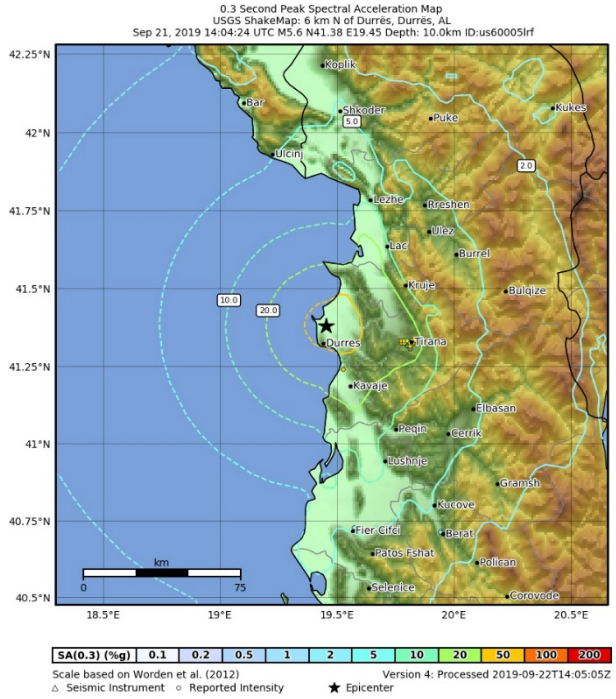
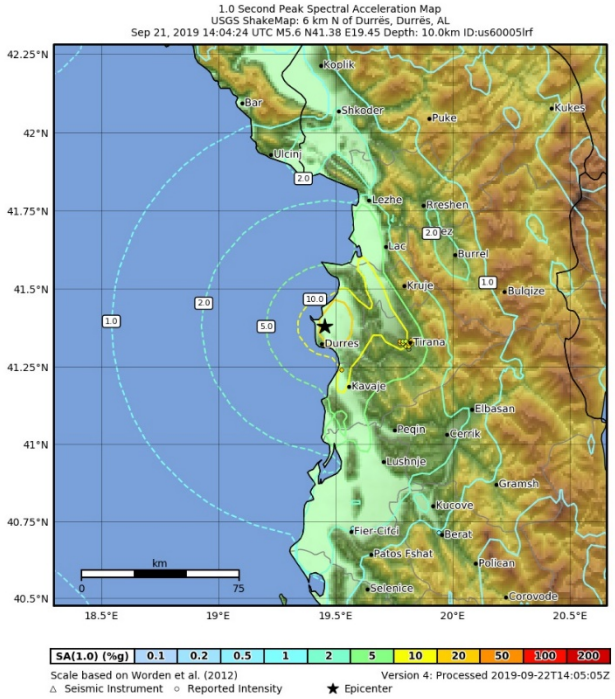
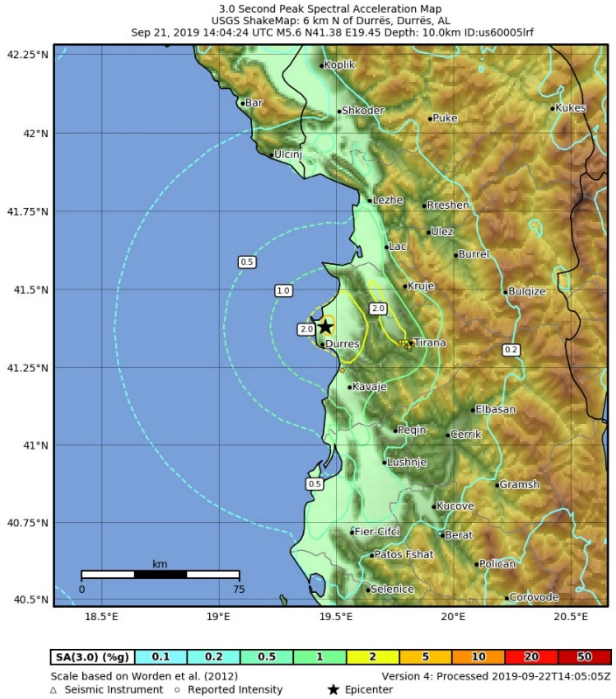
PEAK SPECTRAL ACCELERATION MAPS FOR THE MAINSHOCK







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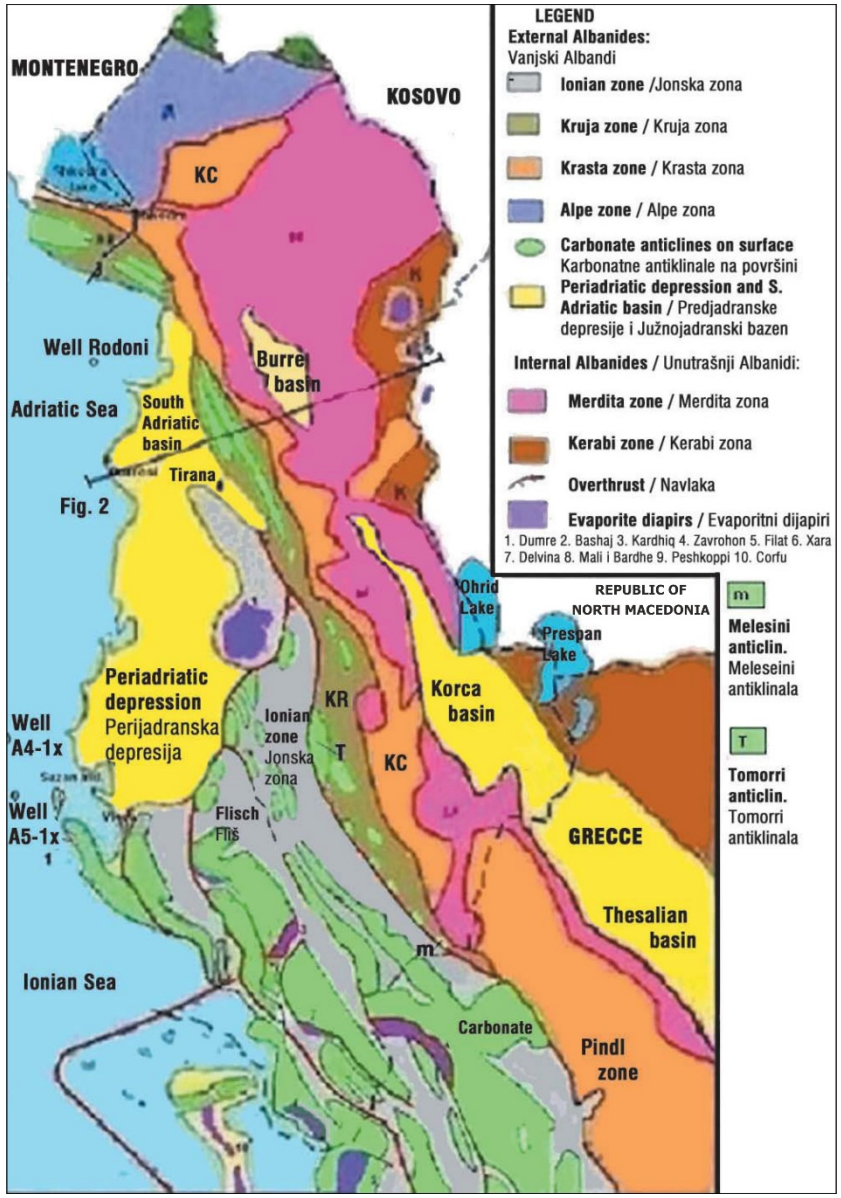
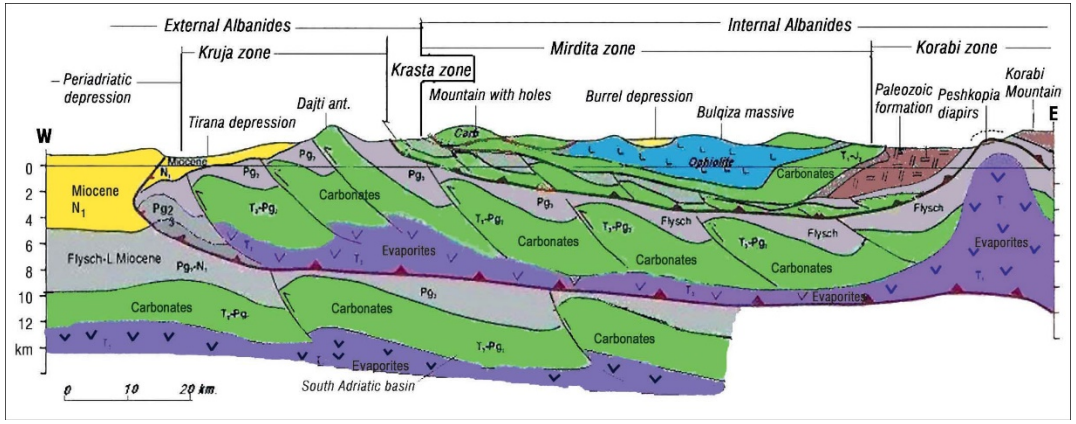
GEOLOGICAL STRUCTURE OF PERI-ADRIATIC DEPRESSION



Schematic geological cross-section through the Albanides and South Adriatic basin



The Peri-adriatic depression represents the basin between the External Albanides orogenetic belts and Apulian platform (Sazani zone in Albania).

The whole post carbonatic deposition is represented by a terrigenous sedimentation (molasses of Serravalian-Tortonian-Messinian-Pliocene). Its positioning and distribution were definitely performed in a basin, included in South Adriatic basin. The basin overlies Ionian zone in south-east and the Kruja zone (Gavrovo zone) to the far east. From south-east to north-east, the thickness of the molasses increases, reaching 5000 - 7000 m in north of Rodoni area (offshore).

From *Velaj (2012)*

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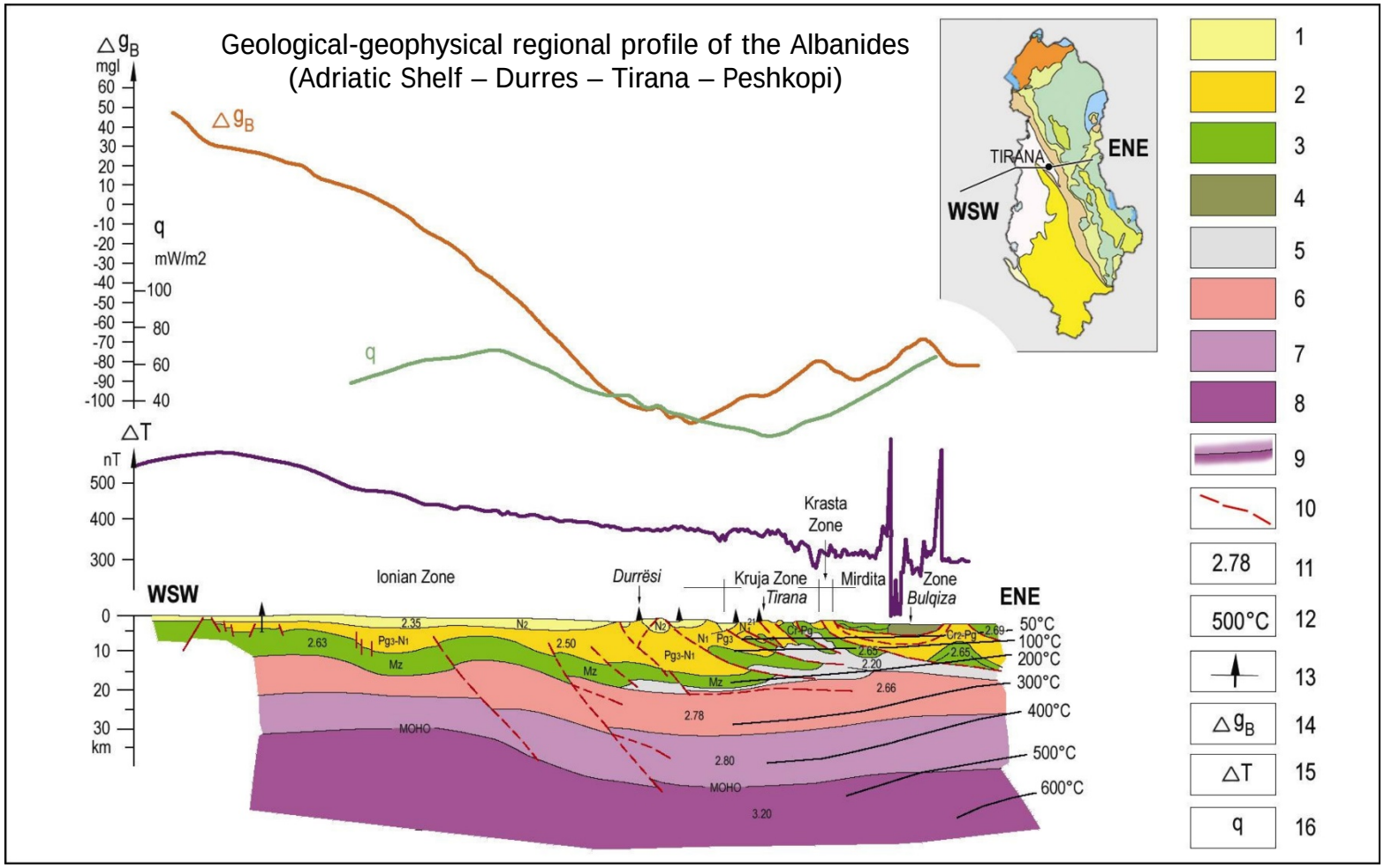
GEOLOGICAL STRUCTURE OF PERI-ADRIATIC DEPRESSION



1: Miocene -Pliocene Molasses, **2**: Paleogene-Lower Neogene Flysch and Flyschoidal Formation, **3**: Mesozoic-Eocene Carbonate Formation, **4**: Ultrabasic Rocks, **5**: Salt, **6**: Upper Crust, **7**: Lower Crust, **8**: MOHO Discontinuity, **9**: Thrust tectonics, **10**: Crustal Fractures, **11**: Density, **12**: Temperature, **13**: Deep Wells, **14**: Bouguer Anomaly, **15**: Magnetic Anomaly, **16**: Heat Flow Density

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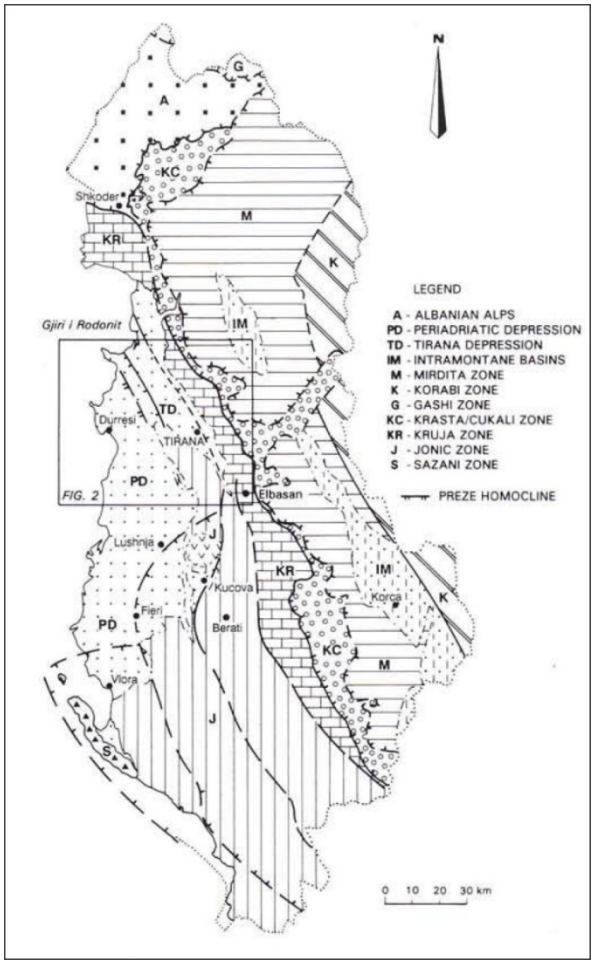
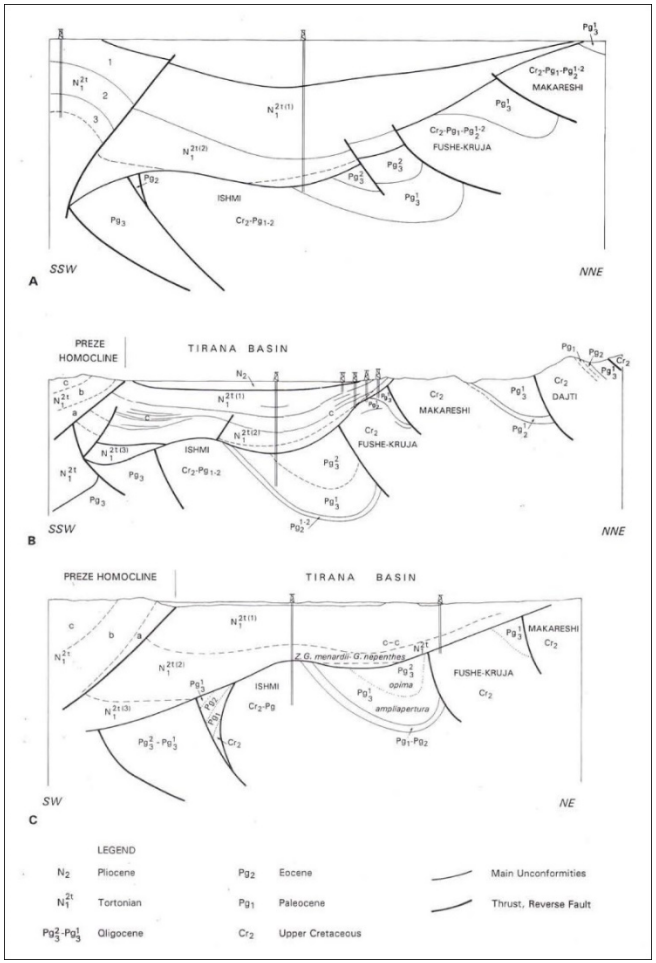
GEOLOGICAL STRUCTURE OF TIRANA DEPRESSION





The Tirana Depression (TD) is iocated in the eastern and inner part of the Periadriatic Depression (PD). The TD is regarded as a foredeep filled by a mainly deep-marine succession in the Albanian offshore. It differs from the PD in some evolutional phases.

The present day TD area is characterized by prevailing continental and shallow marine sediments. Deep marine sediments are restricted to Oligocene-earliest Miocene and Serravallian-Tortonian p.p. and crop out only along the western margin of the depression.

The structural features allow localization of the TD between the front of west-verging Dinaric structures and the opposite verging Paper-Rova anticline – Preze homocline alignment.

From *Guri et al. (1995)* and *Gelait et al. (1997)*

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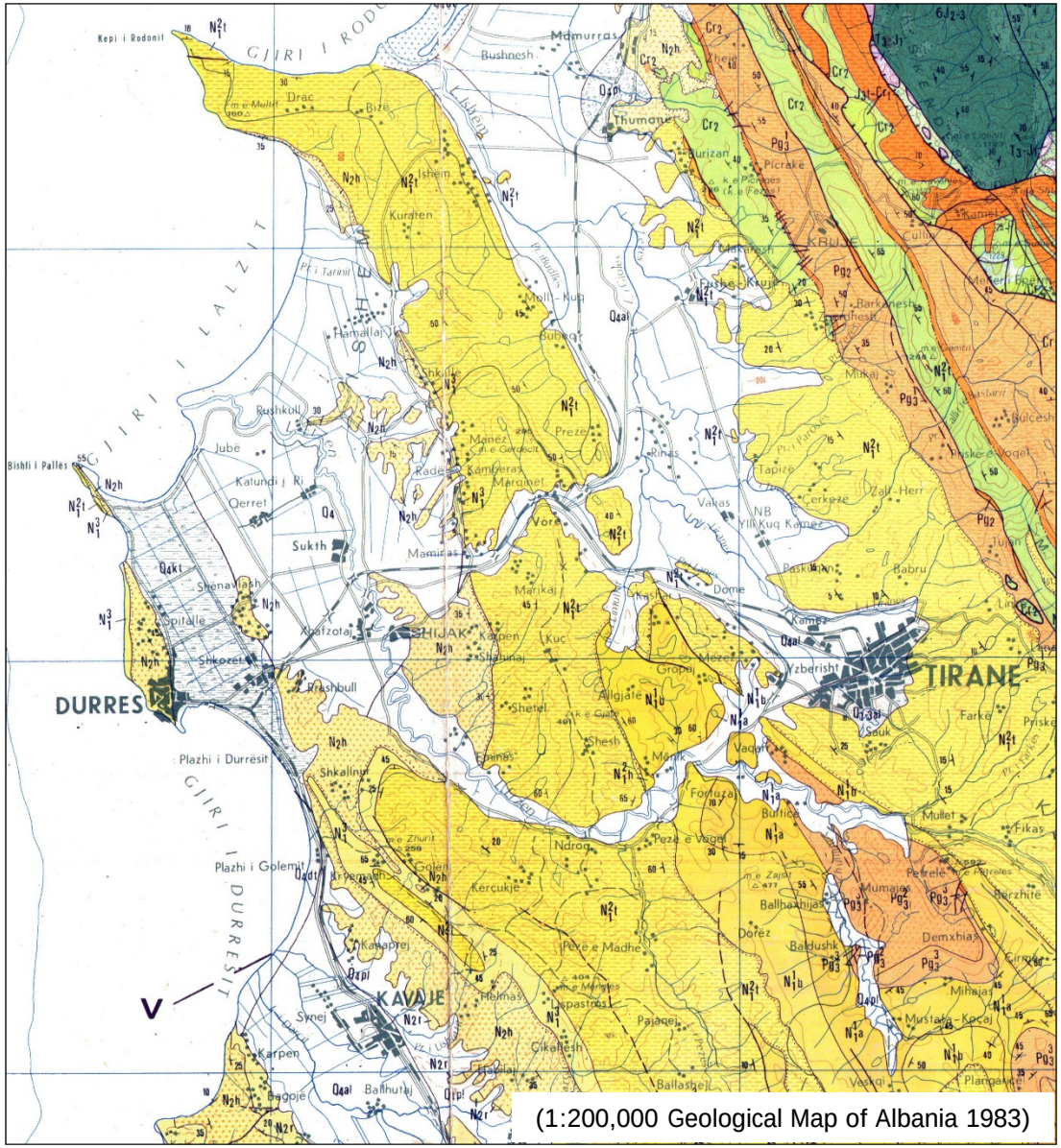
GEOLOGY OF THE SEPTEMBER 2019 EARTHQUAKE AFFECTED AREA



(1:200,000 Geological Map of Albania 1983)

Q_{4al}	Alluvial deposits with gravels, sand etc
Q_{4kt}	Marshy deposits, clays, sands and peat
Q_4	Recent mixed deposits including alluvial and marshy deposits etc
N_2h	Pliocene clays
N_1^2t	Tortonian sandstones, clays and conglomerates
N_1^3	Messinian sandstones, clays and gypsum
N_1^1b	Burdigalian marls, clays and limestones
N_1^1aj	Lower Aquitanian. Gray marine clays, moraines and coal
Pg_3^3	Upper Oligocene clay-sandstone with limestone, massive sands, clays and coal
Pg_3^2	Middle Oligocene flysch with clays and sandstone, conglomerates, limestone, coals and charcoal.
Pg_3^1	Lower Oligocene flysch with clay and sandstone.

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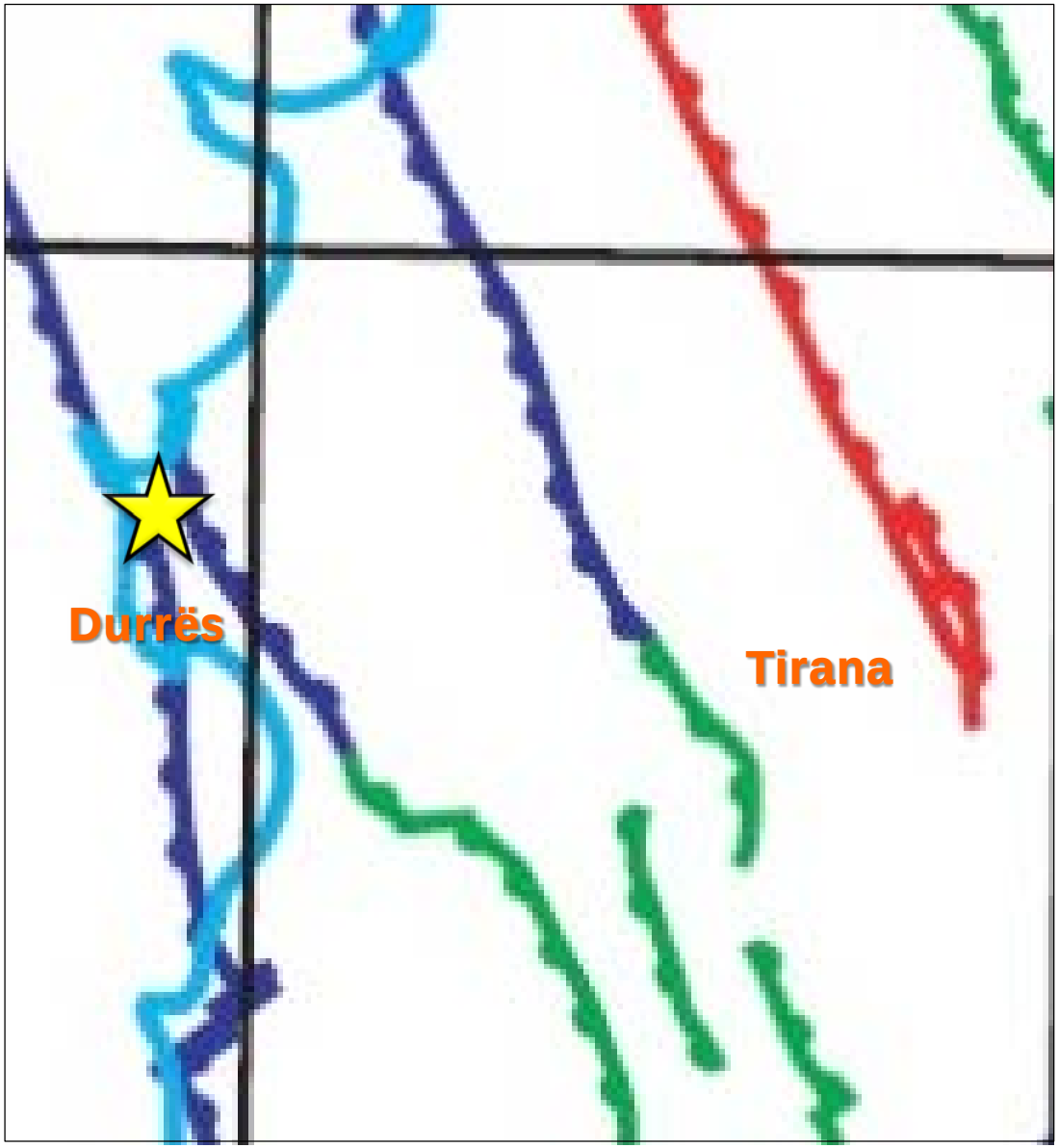
ACTIVE FAULT ZONES AND FAULTS OF THE SEPTEMBER 2019 EARTHQUAKE AFFECTED AREA



The 2019 earthquake affected area is dominated by NW-SE striking reverse active faults.

Blue lines correspond to faults activated during Middle Pleistocene - Holocene (or Quaternary), the green lines to faults activated during Pliocene - Lower Pleistocene and the red lines to faults activated during Pre-Pliocene period. The star corresponds to the epicenter of the Mw 5.6 Durrës earthquake occurred in September 21, 2019.

From *Aliaj (2000)*

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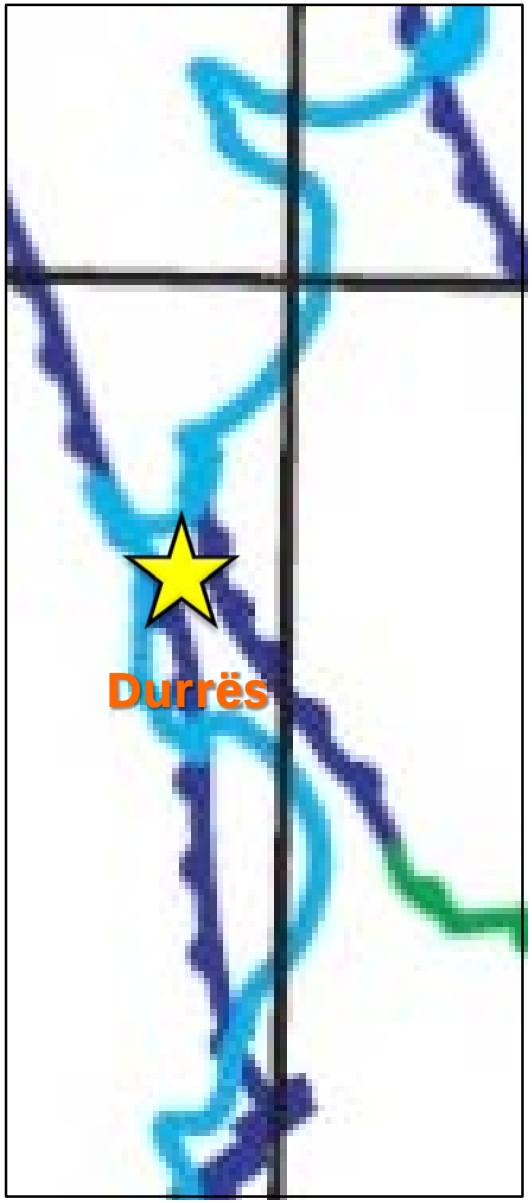
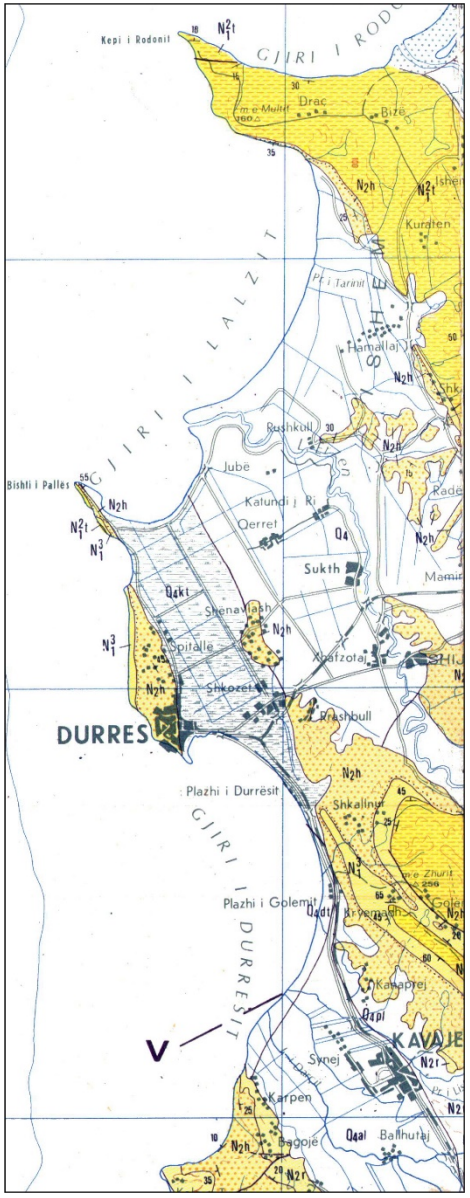
GEOLOGY OF THE EPICENTRAL AREA





The epicentral area is composed of:

Q_{4al}	Alluvial deposits with gravels, sand etc
Q_{4kt}	Marshy deposits, clays, sands and peat
Q_4	Recent mixed deposits including alluvial and marshy deposits etc
N_2h	Pliocene clays
N_1^2t	Tortonian sandstones, clays and conglomerates
N_1^3	Messinian sandstones, clays and gypsum

From *Geological map of Albania (1983) and Aliaj (2000)*

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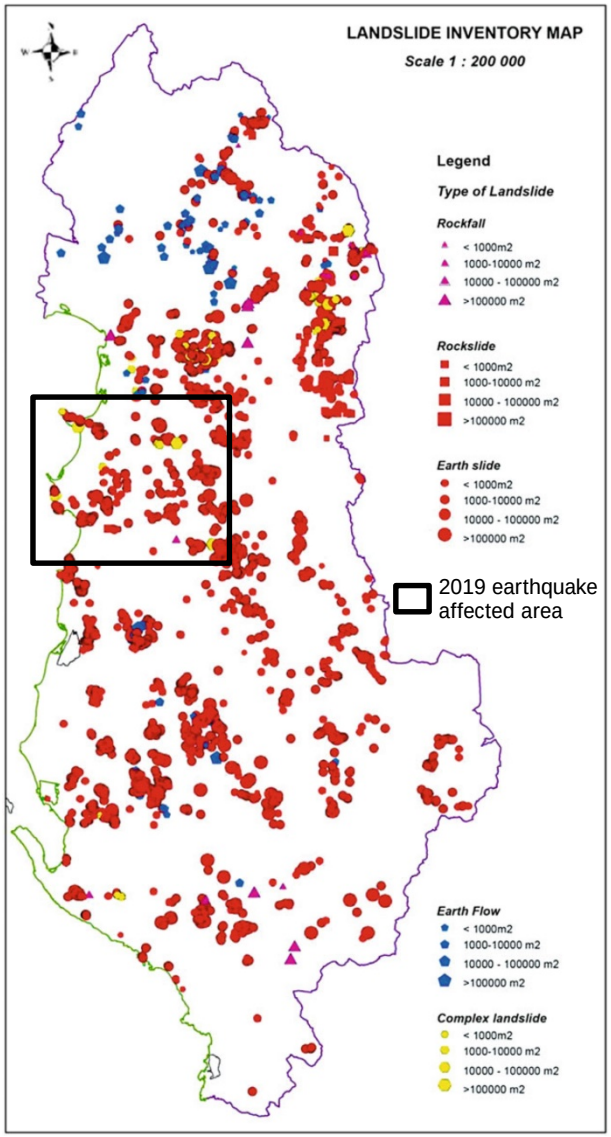
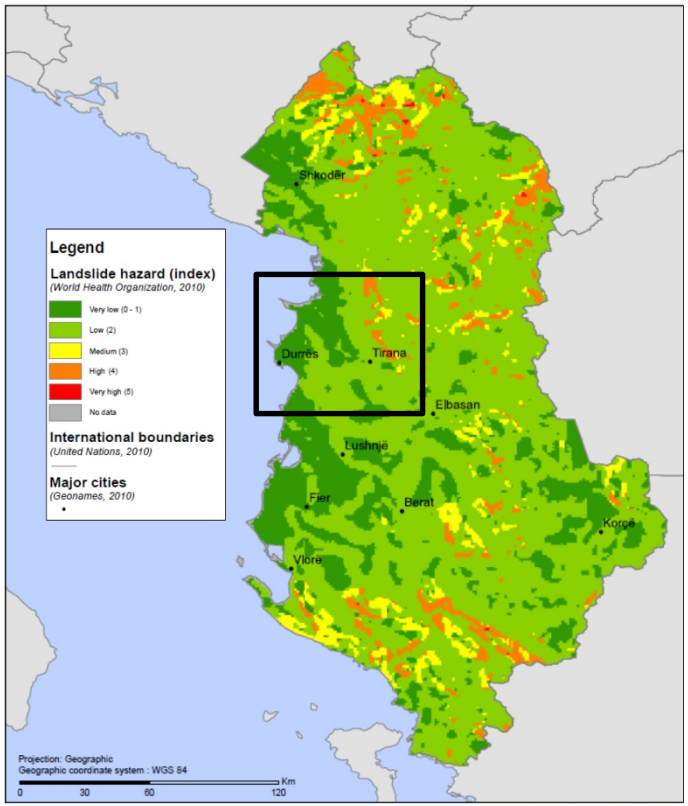
LANDSLIDE INVENTORY MAP AND LANDSLIDE CLASSIFICATION IN ALBANIA

From *Jaupaj et al. (2017)*



In Albania, many areas are prone to slope failure due to geological features, diverse terrain topography, high mountains, steep valley slopes, high intensity spring-autumn rainfall, deep weathering associated with the humid climate and man-modified slopes. The landslides observed in Albania are mostly rotational and they are spread over almost all of the territory of Albania. They are small to moderate and occur mostly on clay and flysch formations on slopes between 15° and 25°.



Urban areas are more prone to landslides compared to other kinds of land-usage because human activities and modification of the landscape play an important role in triggering landslides. Almost 75% of landslides in Albania are mainly triggered by heavy rainfalls.

The 2019 earthquake affected area has previously suffered by earth slides, earth flows and complex landslides. However, based on the Landslide Hazard Distribution Map (WHO, 2010), the landslide hazard of the area is very low (0-1) to low (2).

From *WHO (2010)*

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ENVIRONMENTAL EFFECTS INDUCED BY THE SEPTEMBER 2019 EARTHQUAKE

Slope movements in Shkembi i Kavajes

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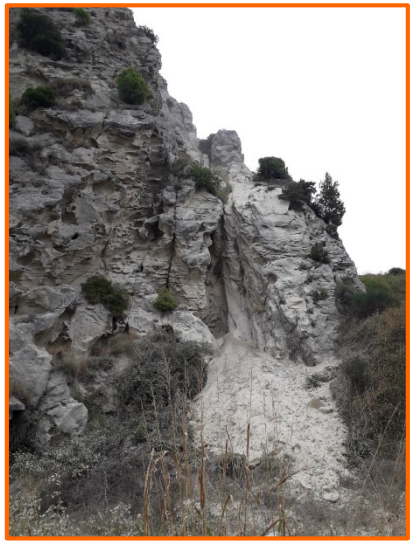
ENVIRONMENTAL EFFECTS INDUCED BY THE SEPTEMBER 2019 EARTHQUAKE

Slope movements in Shkembi i Kavajes



Landslides were induced along the road leading from Durres to Kavaje, located southeast of Durrës. The landslide affected area comprises steep slopes formed by Pliocene clays. The mobilized material temporarily blocked the road without any other serious effects on the road asphalt surface, vehicles and drivers.

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ENVIRONMENTAL EFFECTS INDUCED BY THE SEPTEMBER 2019 EARTHQUAKE

Liquefaction phenomena

Liquefaction phenomena were observed along the coastal area of Durrës and more specifically in the area located east of Durrës port. They were of local character and comprises mixture of ejected sand and water as well as small scale subsidence observed on pavement.

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IMPACT OF EARTHQUAKE ON BUILDINGS AND INFRASTRUCTURES

Based on the field survey conducted by the authors shortly after the September 21, 2019, Mw 5.6 Durrës earthquake, the following conclusions can be drawn:

- As regards the impact on infrastructures, electricity supply network and water facilities were knocked out in Tirana, Durrës and some other western and central districts.

- As regards the impact on the building stock, the mainshock induced damage to buildings of Durrës, Tirana and several settlements of the broader area.

- The dominant building types in the affected area comprise unreinforced structures with load-bearing masonry walls and buildings with reinforced-concrete (RC) framing system and infill baked clay and/or concrete walls. Moreover, mixed types were also observed. The majority of recent buildings have been constructed according to the KTPs – Albanian Technical Codes, which were first issued and implemented in 1963 and last updated in 1989.

- Non-structural damage was observed to buildings with reinforced concrete frame comprising mainly detachment of plaster pieces from the unreinforced masonry infill wall, pounding phenomena between adjacent buildings, separation cracks between RC framing members and infill walls, damage of non – bearing elements supported by RC cantilevers.

- The unreinforced structures with the load-bearing masonry walls suffered the most by the earthquake due to reasons comprising old construction age, poor quality of construction, poor workmanship, interventions made by people, the design code of the time - if ever was applied - lack of maintenance and inadequate repair after previous damaging seismic events. This type suffered not only non-structural damage but also structural damage including partial or total collapse of the load-bearing masonry walls.

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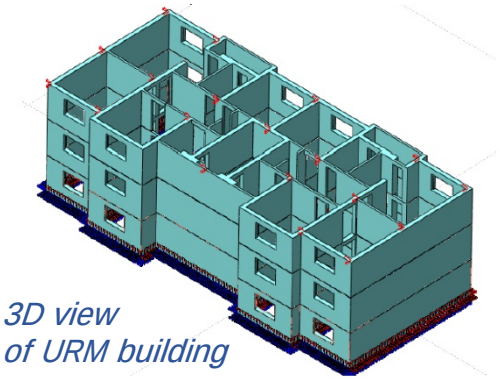
DOMINANT BUILDING TYPES IN THE AFFECTED AREA

Unreinforced masonry buildings in Durrës



3D view of URM building

Unreinforced masonry (URM) is one of the most common structural types for low-rise construction in Albania. The construction of these buildings took place during the communist period (1944-1990).

Most of the existing URM have been designed considering only gravity loads without any consideration of seismic criteria. Moreover, past studies and earthquake reconnaissance team reports have suggested that unreinforced masonry structures are highly prone to seismic actions. Therefore, this type of structures has high seismic vulnerability over the country

From *Bilgin and Huta, (2016)*

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DOMINANT BUILDING TYPES IN THE AFFECTED AREA

During the last five decades, buildings in Albania has been designed and constructed according to the Albanian code. This code was initially introduced as a legal provision (KTP – 63) in 1963, last improved and updated (KTP – 89) in 1989 and still in force.

The EN version of Eurocodes has been used for the design of structures in Albania since several years ago. Many industries and companies operating in civil engineering have introduced ENs in their products and procedures.

Despite of this fact, according to the Albanian legislation in the field of construction, the design of structures still must follow the KTPs – Albanian Technical Codes. Therefore, Eurocodes are National Standards that can be used voluntarily. They must be approved as “Albanian Technical Codes” and replace old ones.

Recent reinforced concrete structures in Durrës

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DOMINANT BUILDING TYPES IN THE AFFECTED AREA

Floor and ceiling systems consist mainly of brick units and concrete beams. In most of the cases, a flat slab system is employed, resulting thus, to a more flexible structure.

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EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS

Detachment of plasters from the infill walls close to the contact with the surrounding RC frame or detachment of plasters from the RC frame close to the junction line attributed to buildings' pounding were observed. Some of this damage occurred at intermediate levels may be attributed to the development of higher modes of vibration (due to the higher flexibility of one or both of the structures).

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EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS

The pounding phenomena in this case resulted in impact and creation of a gap at the upper levels of the buildings. This damage is due to the development of the lowest mode of vibration (the first mode), in opposition to the case presented just before. This phenomenon occurs in more stiff structures.

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EARTHQUAKE DAMAGE TO BUILDINGS IN TIRANA

This type of pounding is similar to the one presented in previous photos from Durrës. All those cases indicate that many structures in Albania are quite flexible characterized mainly by lack of stiffening elements, shear walls etc.

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EARTHQUAKE DAMAGE TO BUILDINGS IN TIRANA

Pounding of a more flexible structural addition (due to its high aspect ratio: height/base) over a more rigid structure, during which higher modes of vibration are created.

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EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS

The effect of the vertical component of the earthquake ground motion is obvious: horizontal cracks (top right figure) combined with vertical cracks in the middle of the span of the beam (bottom right figure).

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EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS

Effect of the vertical shaking component on the brick wall standing on the RC cantilever (that is excited vertically)

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EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS

Effect of the vertical component of the earthquake ground motion on the brick wall parapet standing on the RC cantilever (similar to the previously presented case). The opening of the crack is diminished at the top due to the rails fastening.

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EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS

Separation of brick walls from the members of the RC framing system, which is a common phenomenon due to the deformational incompatibility between the two structural elements.

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EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS

Strong indication of the dominance of the vertical component of the earthquake ground motion at Durrës city located in the epicentral region.

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EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS

Separation of the infill brick walls from the R/C framing system

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EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS

Effect of the vertical component of the earthquake ground motion
in combination with the horizontal one on brick walls on an RC cantilever.

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EARTHQUAKE DAMAGE TO BUILDINGS IN TIRANA

A large part of the projective cornice of the Faculty of Geology and Mining building collapsed during the mainshock, while other parts were ready to collapse after the event. The falling debris crushed two cars parked in the yard close to the building.

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EARTHQUAKE DAMAGE TO BUILDINGS IN TIRANA

One may observe that the cantilever is supported by the triangle ribs. The ribs are superficially connected to the back standing masonry wall (justified by the well distinguished imprints of the fallen ribs). This is an inherent problem of improper workmanship, which must be locally checked and repaired, not only at the case shown, but also in other similar parts of the Faculty. The resulting risk is quite obvious and high, since the aforementioned cantilevers may fall down any time, even without any seismic motion.

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EARTHQUAKE DAMAGE TO BUILDINGS IN TIRANA

In the Faculty of Geology and Mining of the Polytechnic University of Tirana, detachment of large pieces of plaster from the masonry walls was also observed. Large vertical cracks were also detected along the corners of the building resulting in separation of stones.

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EARTHQUAKE DAMAGE TO BUILDINGS IN ZHUR VILLAGE

Non-structural and structural damage to an unreinforced masonry building in Zhur village comprising detachment of plaster pieces from the masonry load-bearing walls and partial collapse of the masonry walls respectively.

Photos in this page from *EPA-EFE/MALTON DIBRA*

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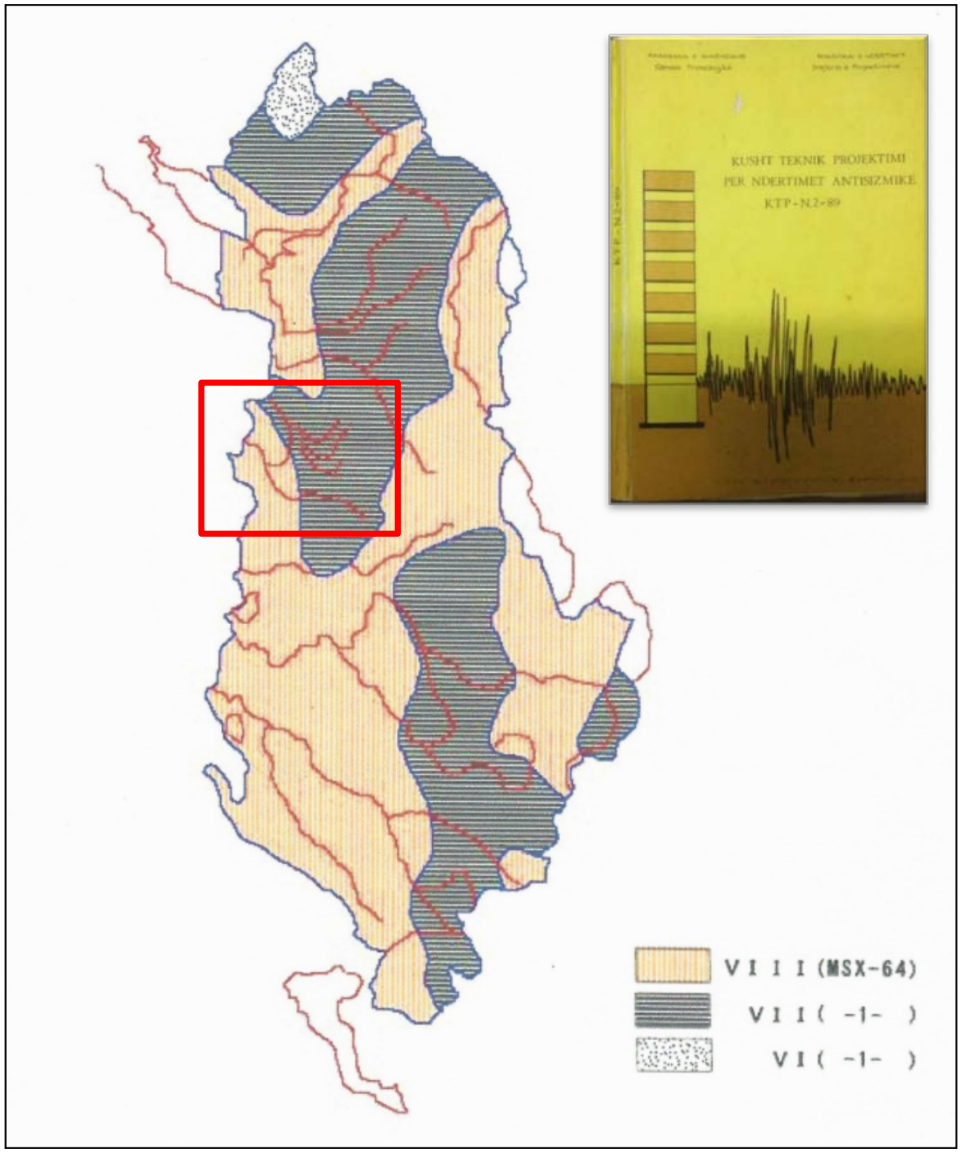
SEISMIC ZONATION MAP OF ALBANIA



Seismic zonation map of Albania from the Earthquake Resistant Design Regulations, issued by the Seismic Center, Academy of Science of Albania, Department of Design, Ministry of Construction (1989).

It is significant to note that the seismic zonation map in the seismic code of Albania comprises zones based on observed seismic intensities and not on design accelerations.

We may conclude that the resulted intensities from the earthquake under consideration, are within the limits specified in the Seismic Zonation Map.

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The September 21, 2019 Mw 5.6 Durrës (Albania) earthquake