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The January 24, 2020 Mw 6.8 Elazığ (Turkey) 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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THE JANUARY 24, 2020, Mw 6.8 ELAZIĞ EARTHQUAKE

On January 24, 2020, an earthquake struck the eastern part of Turkey. Based on various seismological observatories and institutes including KOERI, USGS, INGV, GCMT, CPPT, ERD, IPGP, GFZ and EMSC , the magnitude has been assessed as Mw 6.7 or 6.8. Its epicenter was located in the Elazığ province, at a distance of about 20 km southwest of the Lake Hazar. Its focal depth ranged from 10 to 23 km. Based on the provided focal plane solutions, the mainshock was generated by the activation of a NE-SW striking strike-slip fault. The main shock was felt in the neighboring Armenia, Syria, Iran and Iraq.

The aftershock sequence until January 28, 2020 comprised 640 aftershocks with magnitude ranging from 1.3 to 5.1 (KOERI). 17 aftershocks have been equal to or larger than M 4.0. The largest aftershock was generated on January 25 and its magnitude has been assessed as Mw 5.1.

The most earthquake-affected areas were the Elazığ and Malatya cities in the Elazığ and Malatya provinces respectively. More specifically, Elazığ city was located in a distance of about 34 km north of the epicenter and the Malatya city in distance of 65 km west of the epicenter. Very heavy structural damage comprised partial or total collapse of buildings.

According to the “Turkey Disaster Response Plan”, many working groups were working in the region round the clock in an effort to carry out uninterrupted search and rescue, health, support activities under the coordination of the Disaster and Emergency Management Authority (AFAD) affiliated to the Ministry of Interior Affairs.

Based on the press release of AFAD on January 28, search and rescue activities resulted in the rescue of 45 people. Unfortunately, the earthquake claimed the lives of 41 people, 37 in Elazığ and 4 in Malaya. 1539 of 1607, who applied for medical care in the aftermath of the earthquake, have been released from the hospitals while 68 of them are still under treatment and 13 of them are currently in the intensive care units.

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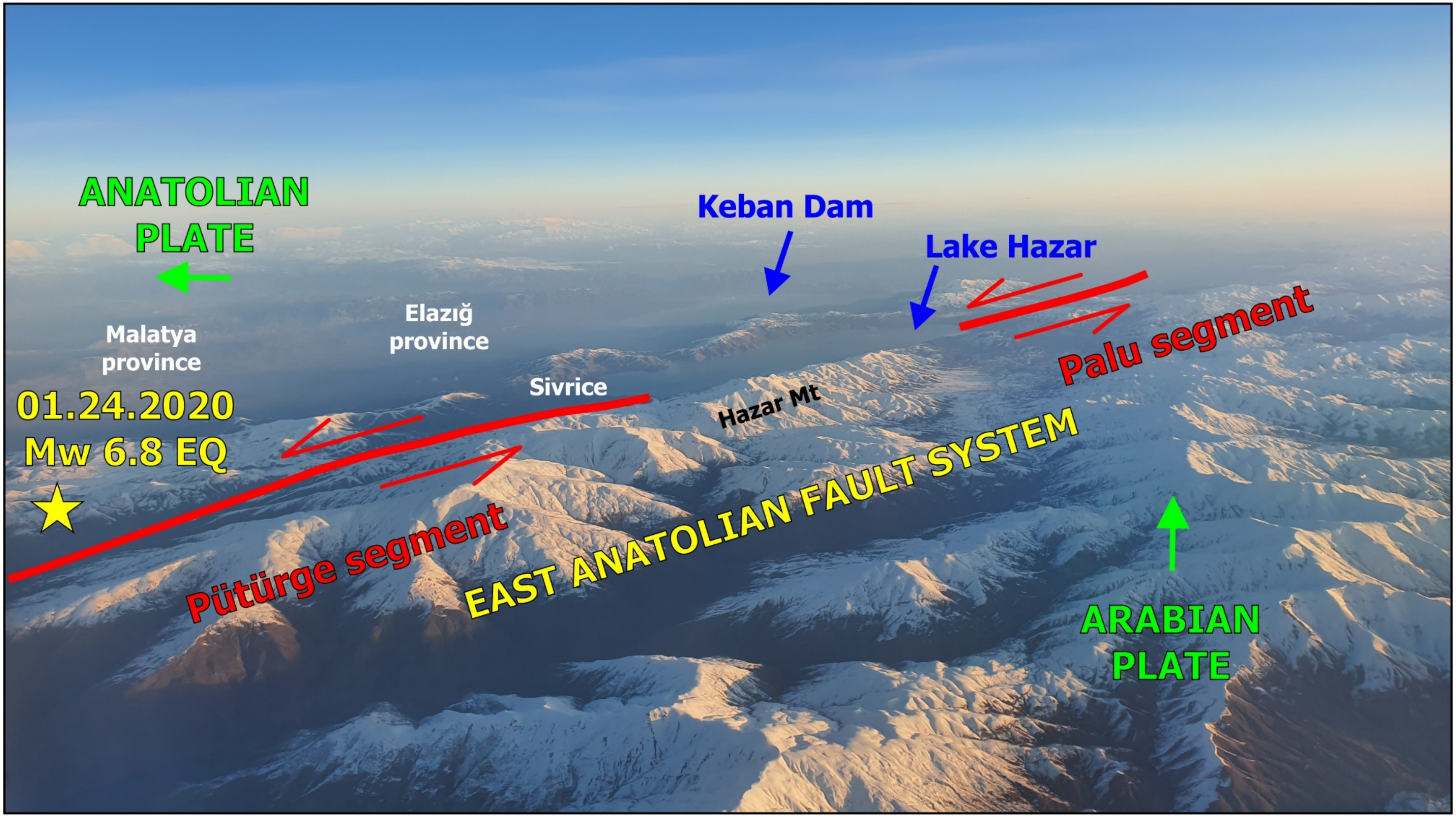
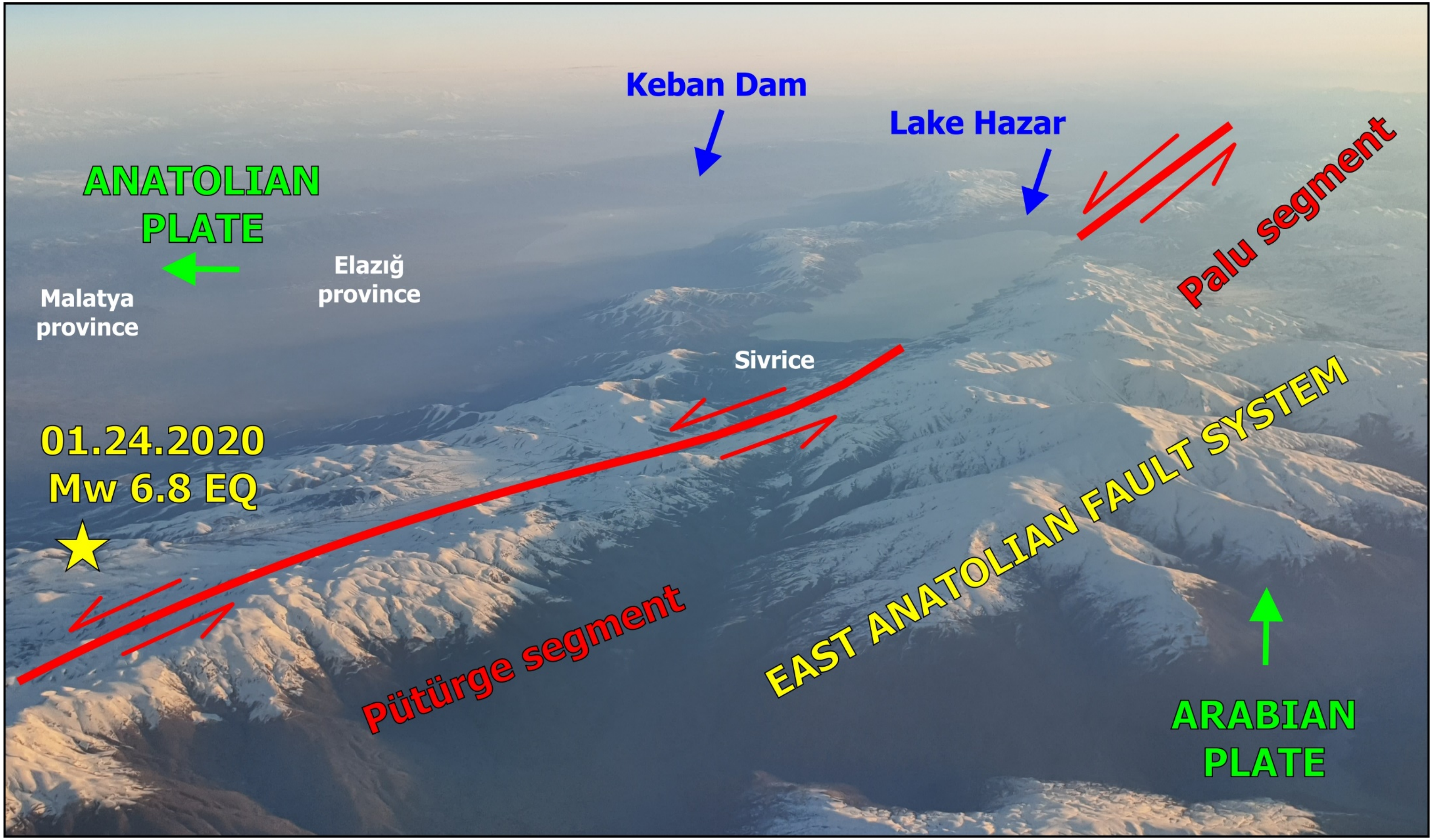
THE JANUARY 24, 2020 Mw 6.8 ELAZIĞ EARTHQUAKE-AFFECTED AREA



The earthquake was generated by the rupture of the Pütürge segment of the East Anatolian Fault System, which comprises a major active left-lateral strike-slip fault zone in eastern Turkey. It forms the tectonic boundary between the Anatolian Plate and the northward-moving Arabian Plate. The most affected areas are the Elazığ city and the Malatya city in the respective provinces. Damage was also reported in Sivrice and Pütürge districts.

THE JANUARY 24, 2020 Mw 6.8 ELAZIĞ EARTHQUAKE-AFFECTED AREA



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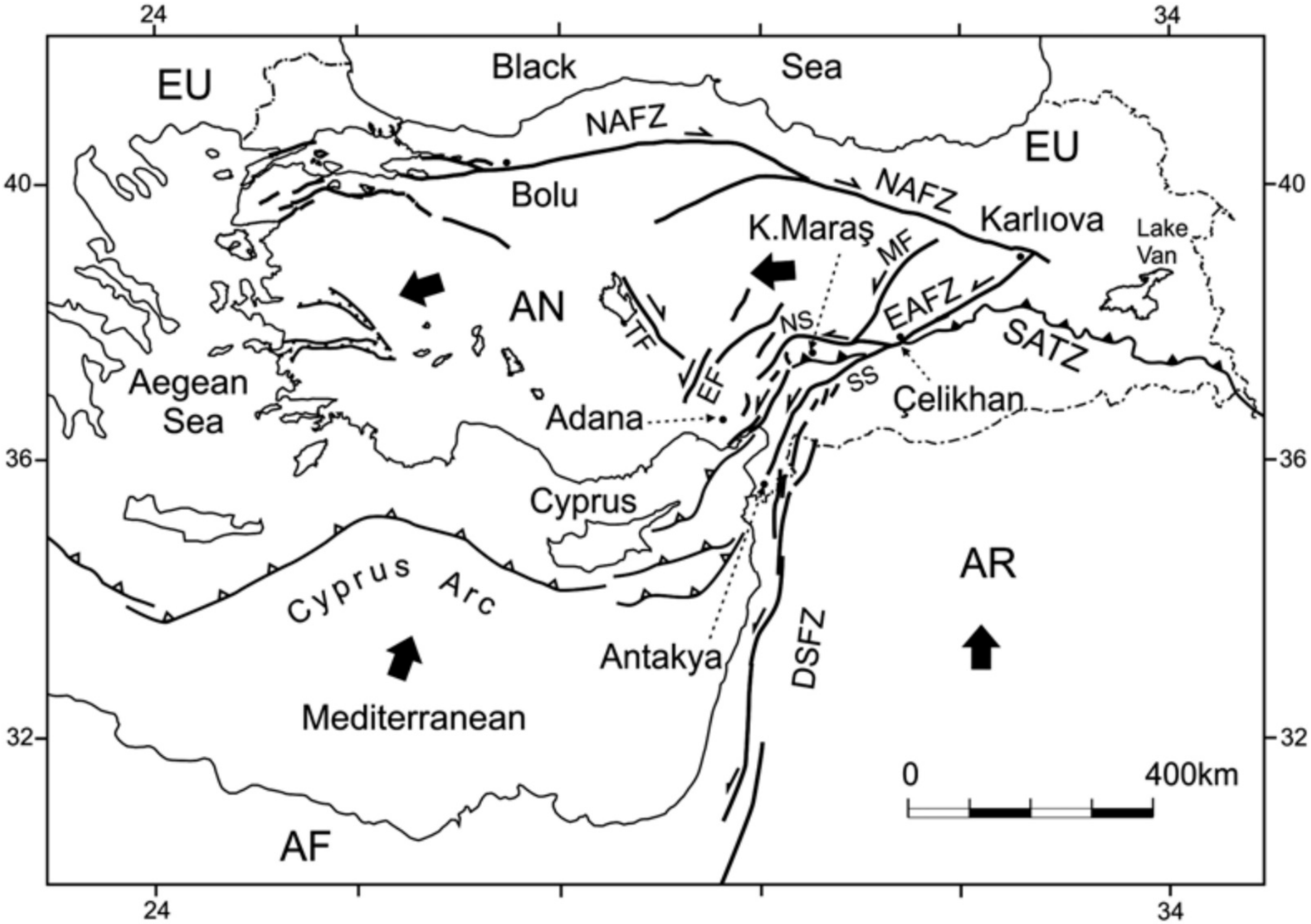
THE MAIN FAULT SYSTEMS OF THE ANATOLIAN AND ARABIAN PLATES BOUNDARIES



AN: Anatolian microplate; **AF**: African plate; **AR**: Arabian plate; **EU**: Eurasian plate; **NAFZ**: North Anatolian Fault Zone; **EAFZ**: East Anatolian Fault Zone; **DSFZ**: Dead Sea Fault Zone; **MF**: Malatya Fault; **TF**: Tuzgölü fault; **EF**: Ecemiş fault; **SATZ**: Southeast Anatolian Thrust Zone; **SS**: southern strand of the EAFZ; **NS**: northern strand of the EAFZ (From *Duman and Emre, 2013*).

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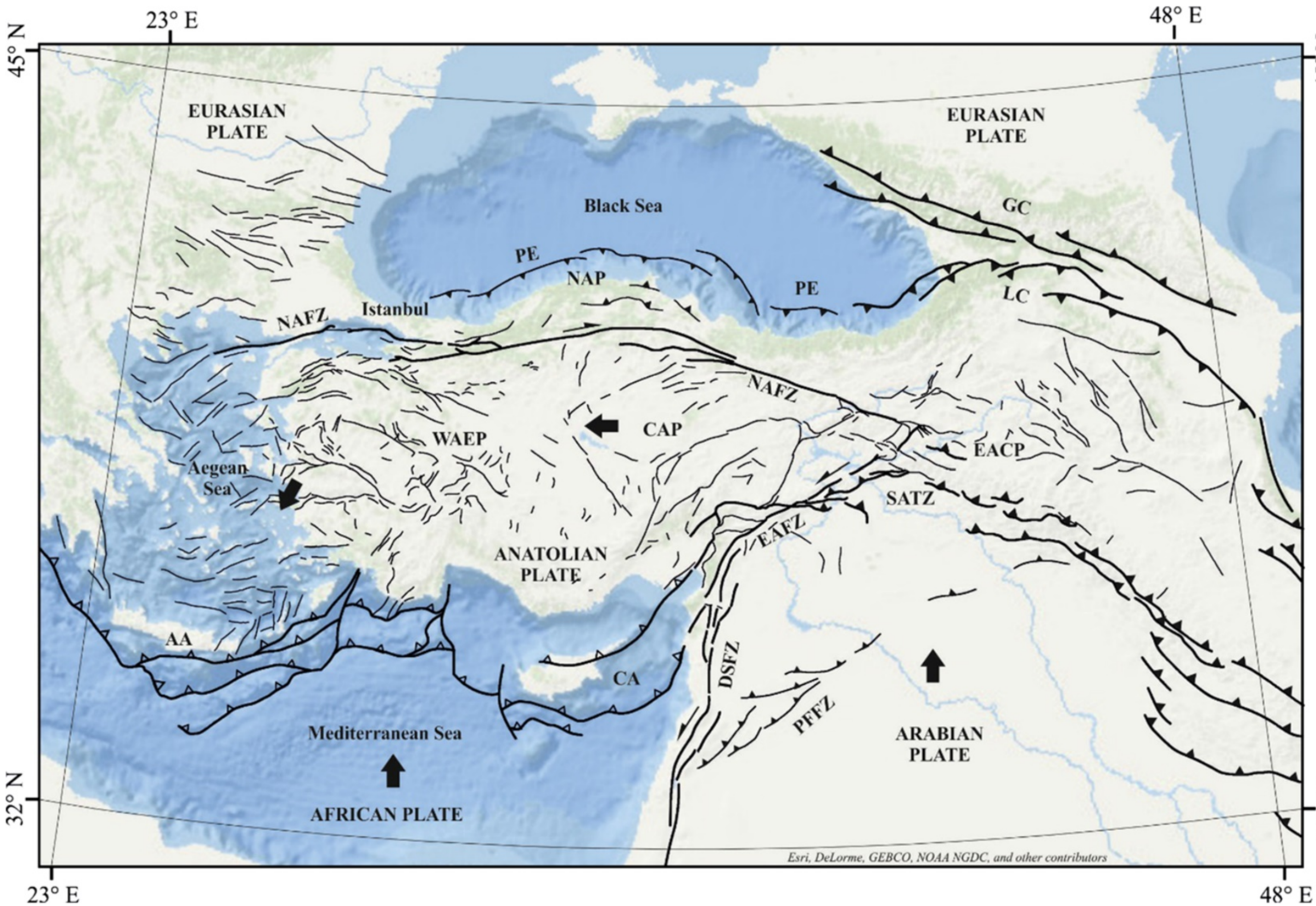
ACTIVE FAULT MAP OF THE EASTERN MEDITERRANEAN REGION



The active fault map of Turkey illustrating the North Anatolian Fault Zone and the Eastern Anatolian Fault Zone among others (From *Duman et al., 2016*). The epicenter of the January 24, 2020 Eastern Turkey is located along the main strand of the Eastern Anatolian Fault Zone.

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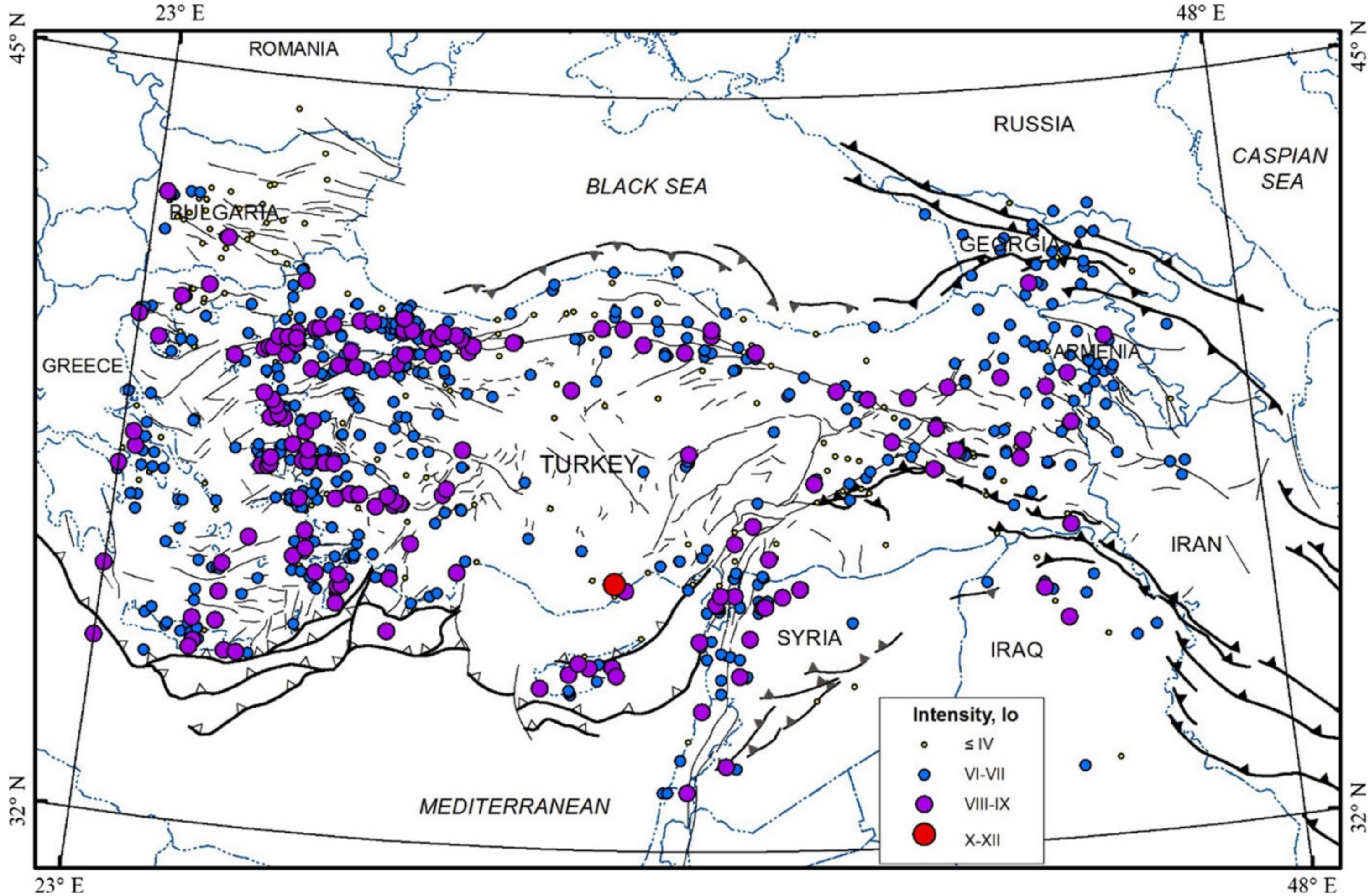
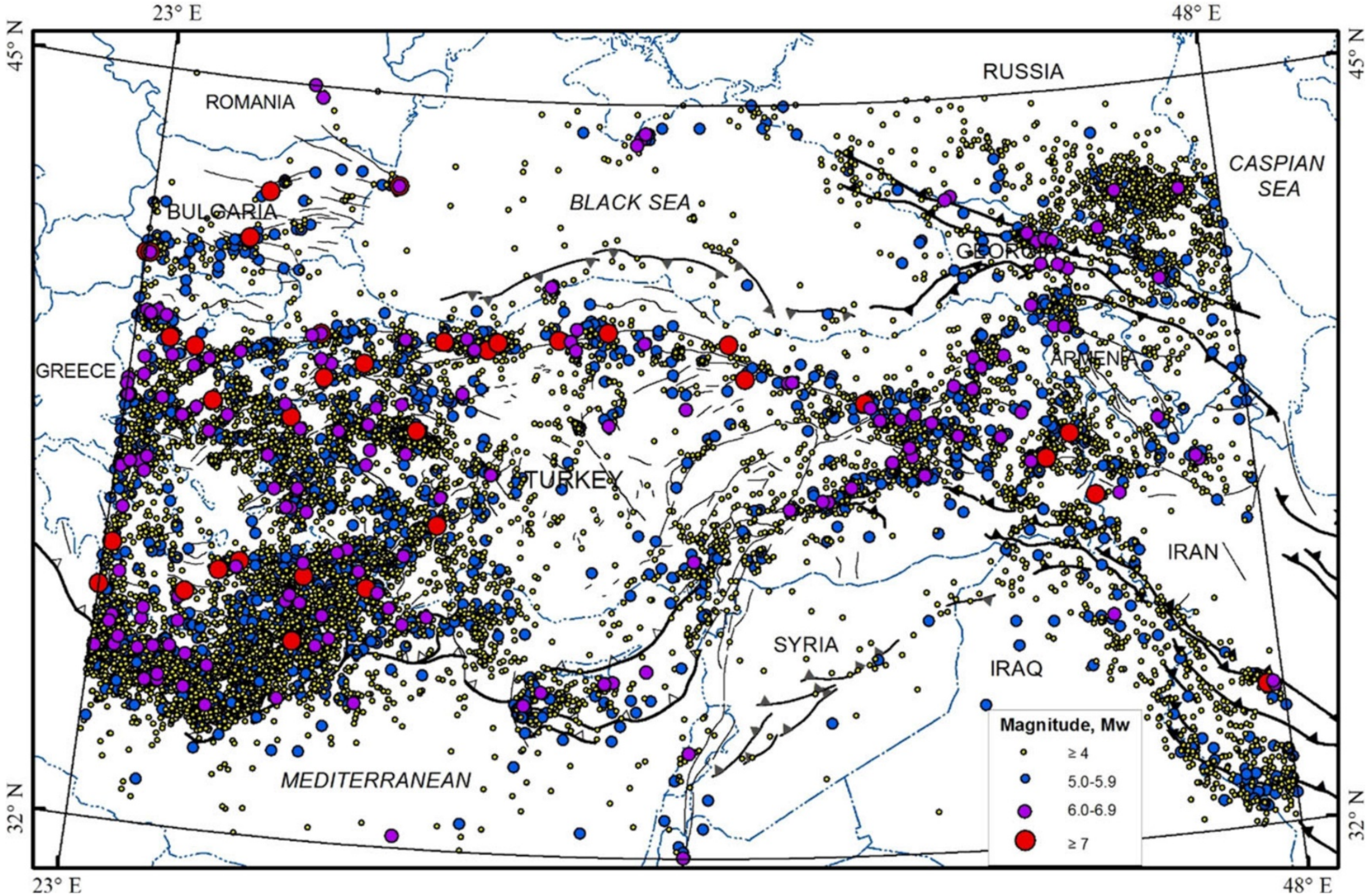
HISTORICAL SEISMICITY OF THE ANATOLIA REGION



Historical earthquake distribution across Turkey and the surrounding region from BC 2000 to AD 1900. Symbols represent the epicentral intensity.
(From *Duman et al., 2016*)

RECENT SEISMICITY OF THE ANATOLIA REGION



Seismicity of the Anatolia region from 1900 to 2012.
The earthquakes with moment magnitude Mw ≥ 4.0 are presented.
(From *Duman et al., 2016*)

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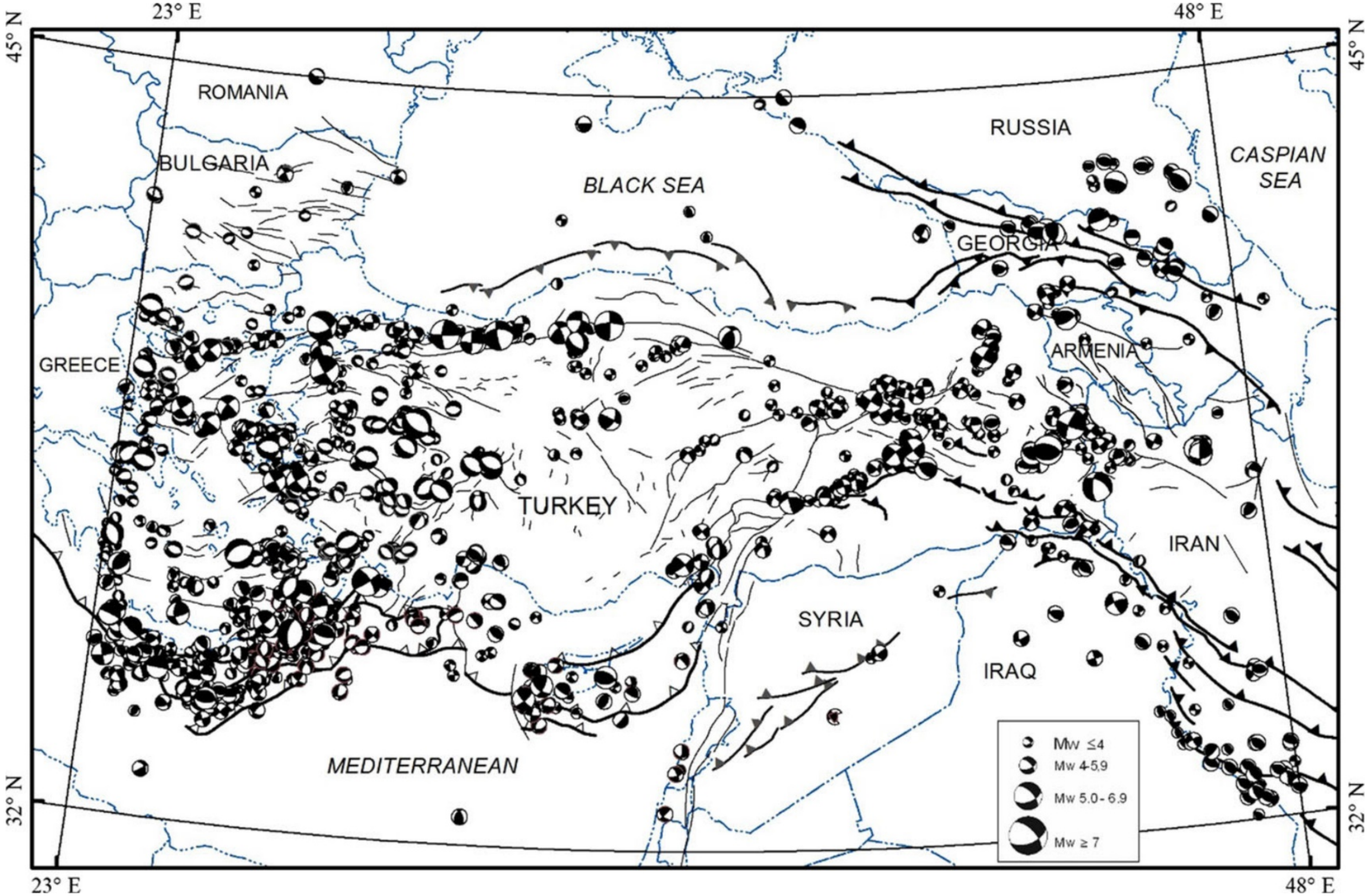
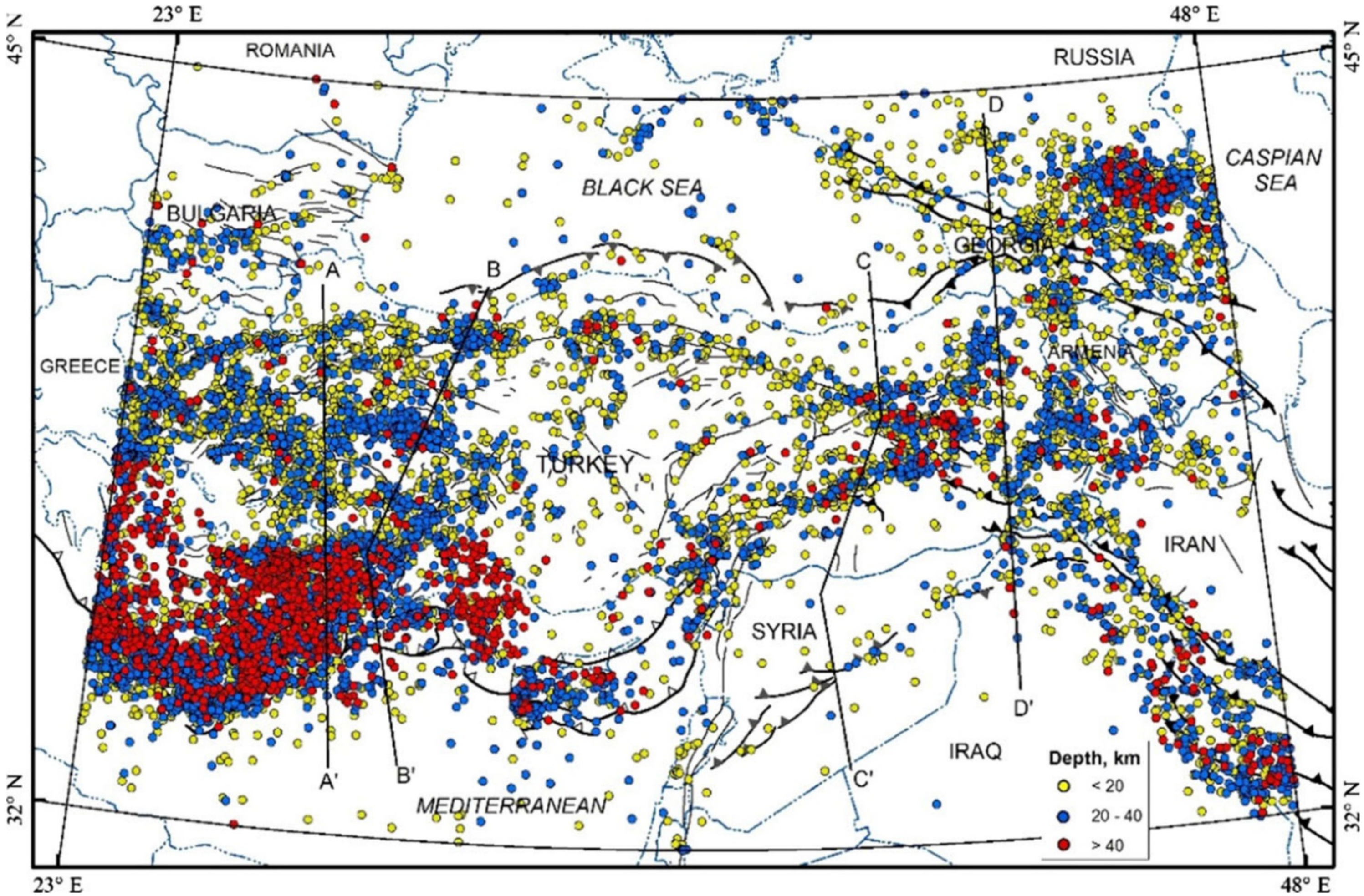
FOCAL MECHANISM SOLUTIONS OF EARTHQUAKES AND ACTIVE FAULTS IN TURKEY



Distributions of the lower hemisphere equal area projection plots of the focal mechanism solutions of earthquakes and active faults in Turkey and the surrounding region. The size of each beachball is related to the earthquake magnitude. The strike slip earthquakes prevails along the North Anatolian and the East Anatolian Fault Zones.

(From *Duman et al., 2016*)

SEISMICITY FROM 1900 TO 2012 ACROSS TURKEY



Distribution of the seismicity from 1900 to 2012 across Turkey
and the surrounding region based on focal depth
(From *Duman et al., 2016*)

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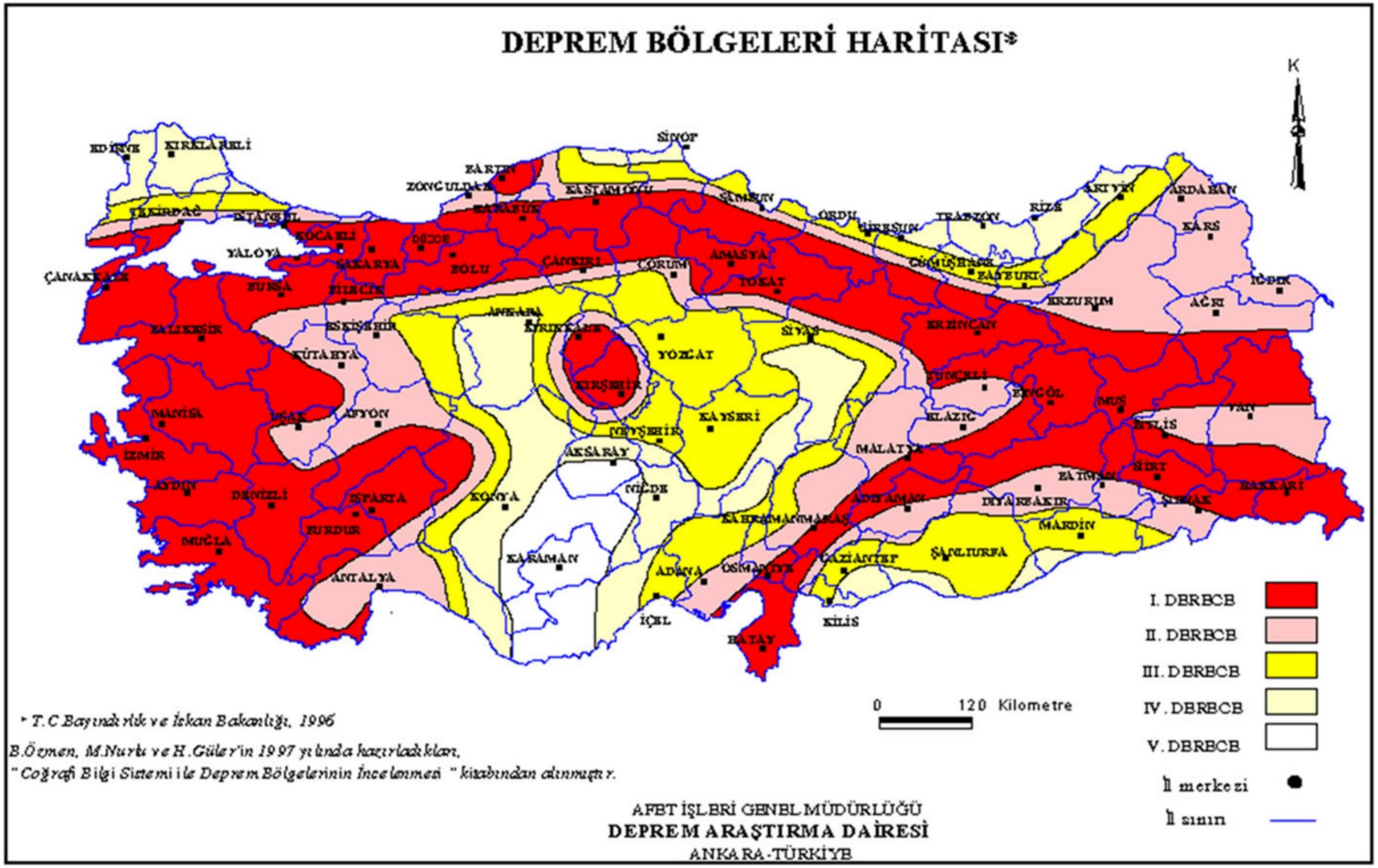
THE 1996 EARTHQUAKE ZONATION MAP OF TURKEY



The 1996 earthquake zonation map of Turkey (http://www.deprem.gov.tr/tr/kategori/deprem-bolgeleriharitasi-28841). **Zone 1 represents the highest seismic hazard** whereas pink, yellow and light yellow colors represent Zones 2, 3 and 4 respectively that display the decreasing trend in seismic hazard. The white color is the no seismic hazard zone (From *Akkar et al., 2018*).

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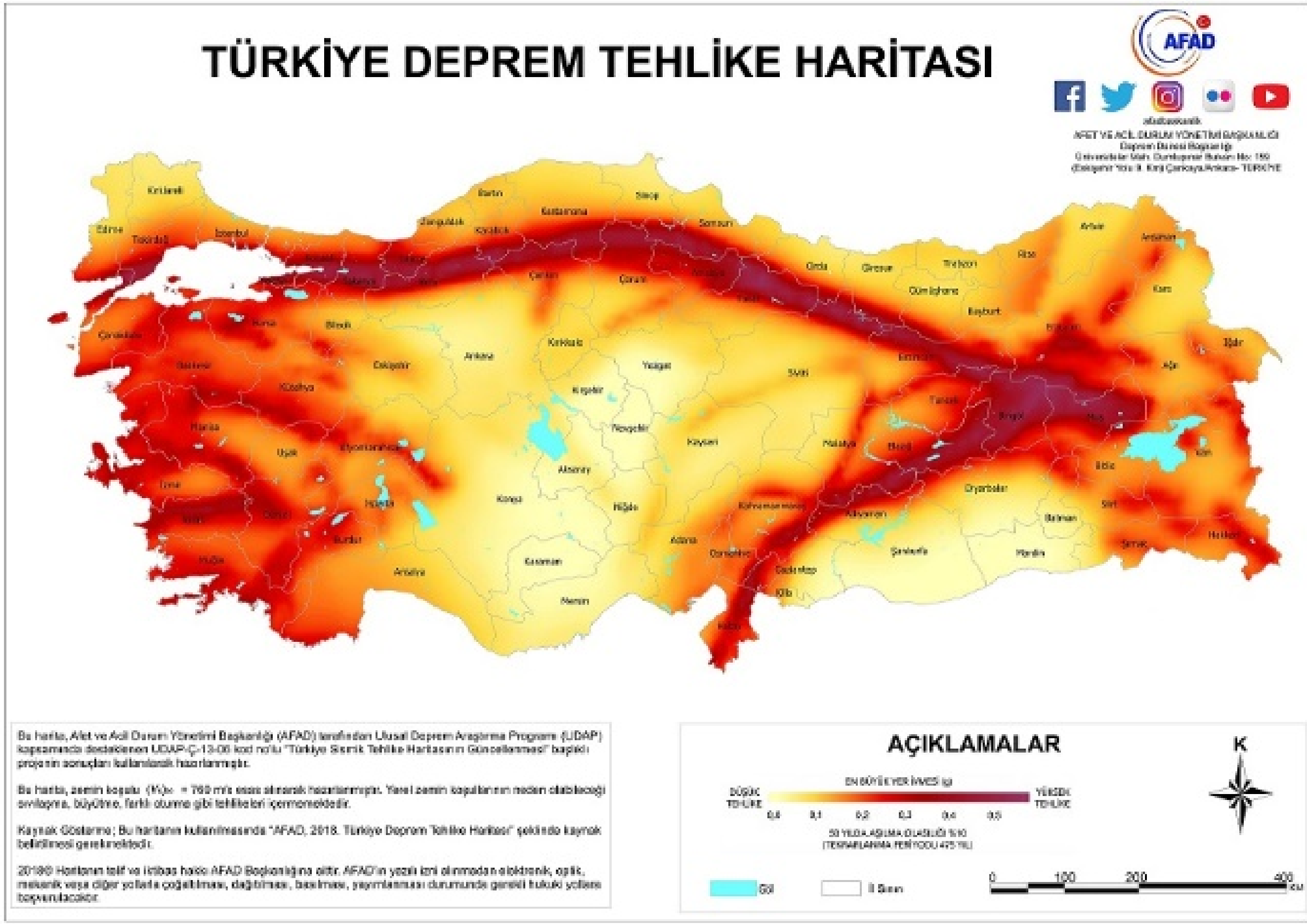
THE 2019 EARTHQUAKE HAZARD MAP OF TURKEY



The new Earthquake Hazard Map of Turkey has been prepared with much more detailed data considering the latest earthquake source parameters, earthquake catalogs and new mathematical models. It came into force on January 1, 2019. Unlike the previous earthquake zonation map, in the new map, instead of the earthquake zones, the highest ground acceleration values were shown and the concept of "earthquake zone" was eliminated.

(From *https://deprem.afad.gov.tr/deprem-tehlike-haritasi*)

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THE ACTIVE LEFT-LATERAL STRIKE-SLIP EAST ANATOLIAN FAULT SYSTEM

The East Anatolian Fault (EAF) constitutes a complex left-lateral strike-slip fault zone that separates the Anatolian plate from the Arabian plate.

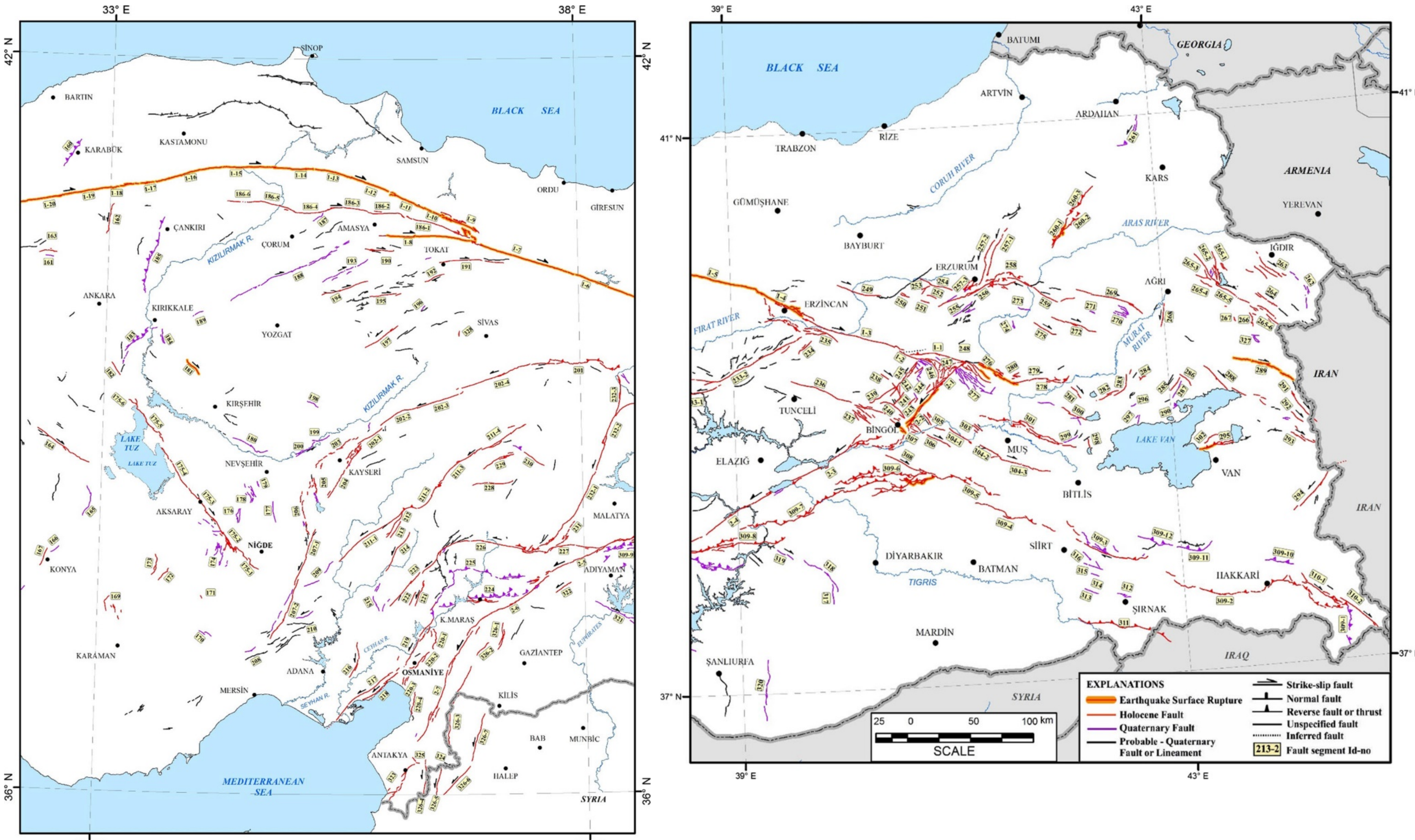
The eastern part of the EAF exhibits a 295-km long narrow deformation zone where it takes the form of a single fault trace except for jog structures. This narrow zone implies a zone of higher strength and of more brittle - non ductile deformation However, to the west it is divided into northern and southern fault strands and becomes a 65-km wide deformation zone. The southern strand is the main fault. The main EAF zone is about 580 km-long between Karlıova and Antakya including the southern strand, and is divided into the 7 fault segments from NE to SW, namely, the Karlıova (2-1), Ilıca (2-2), Palu (2-3), Pütürge (2-4), Erkenek (2-5), Pazarcık (2-6), and Amanos (2-7) segments (numbers refer to the following map). The lengths of the segments vary from 31 to 112 km, while their strikes vary from N35°E to N75°E.

The northern strand of the EAF, called the Sürgü-Misis Fault (SMF) system, is about 380 km between Çelikhan and the Gulf of Iskenderun, exhibiting characteristic active left-lateral fault features. It consists of 9 fault segments, which are, from NE to SW, the Sürgü (227), Göksun (226), Savrun (223), Çokak (222), Misis (216), Toprakkale (219), Yumurtalık (218), Karatas¸ (217) and Düziçi-Iskenderun (220) fault segments, respectively.

Two surface ruptures that developed along the EAF in the twentieth century have been mapped. These are ruptures associated with the 1971 Ms 6.8 Bingöl earthquake and the 2010 Mw 6.1 Karakoçan earthquake. Additionally it is known that the EAF to the east of Lake Hazar was also ruptured by the 1874 Ms 7.1, 1875 Ms 6.7, and 1866 Ms 7.2 earthquakes.

(From *Emre et al., 2013, 2016*)

THE EAST ANATOLIAN STRIKE-SLIP FAULT SYSTEM



(From *Emre et al., 2016*)

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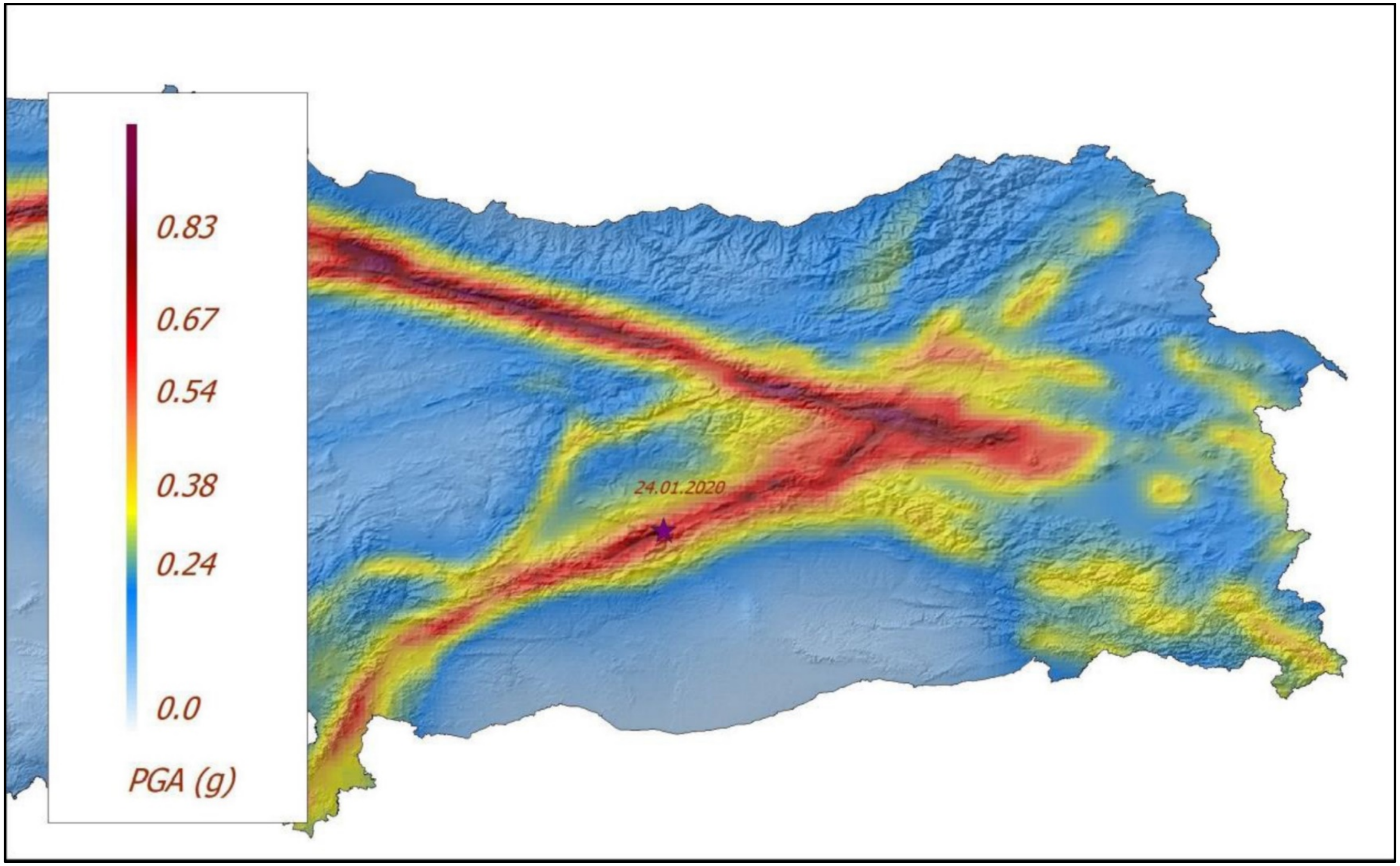
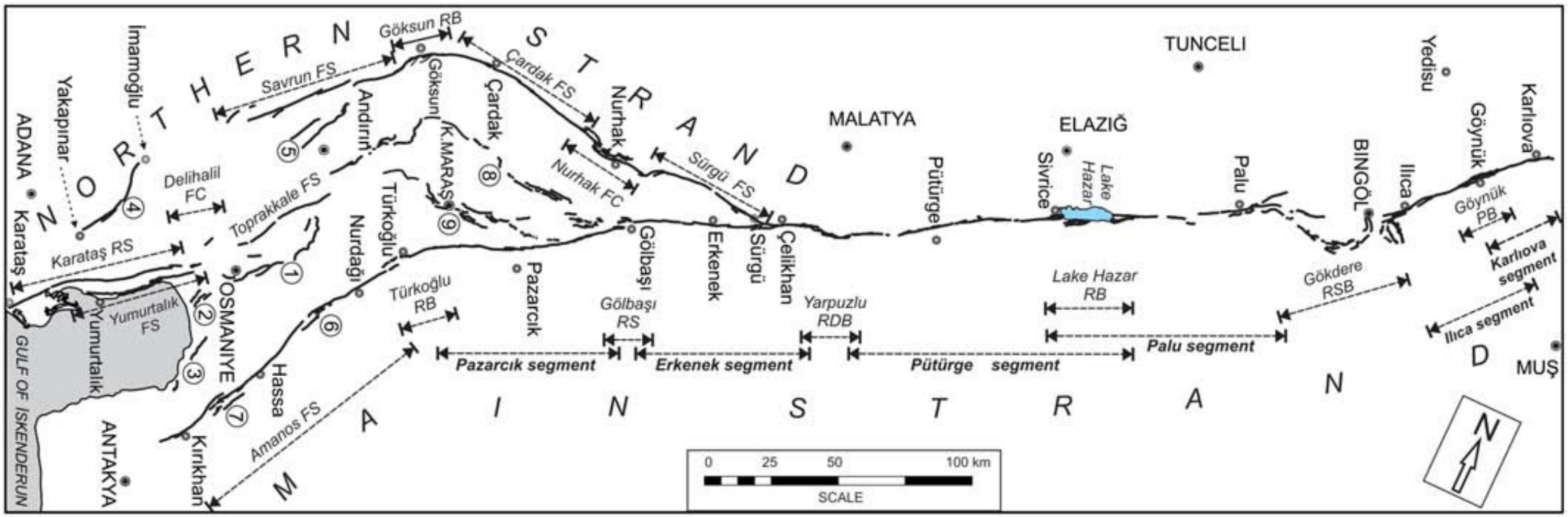
PROBABILISTIC SEISMIC HAZARD MAP OF EASTERN TURKEY



475 year return period regional peak ground acceleration (PGA) distribution according to the recently updated (2018) probabilistic earthquake hazard map of Turkey. The vicinity of the Pütürge segment is associated with PGA values in the order of 0.6-0.7 g. (From https://eqe.boun.edu.tr/sites/che.boun.edu.tr/files/elazig-sivrice_earthquake_24-01-2020-bu-koeri_earthquake_engineering_v1.pdf)

THE EAST ANATOLIAN STRIKE-SLIP FAULT SYSTEM



Map of the East Anatolian strike-slip fault system showing strands, segments and fault jogs. **FS**: fault Segment; **RB**: releasing bend; **RS**: releasing stepover; **RDB**: restraining double bend; **RSB**: restraining bend; **PB**: paired bend; (**1**) Düziçi–Osmaniye fault segment; (**2**) Erzin fault segment; (**3**) Payas fault segment; (**4**) Yakapınar fault segment; (**5**) Çokak fault segment; (**6**) Islahiye releasing bend; (**7**) Demrek restraining stepover; (**8**) Engizek fault zone; (**9**) Maraş fault zone (From *Duman and Emre, 2013*).

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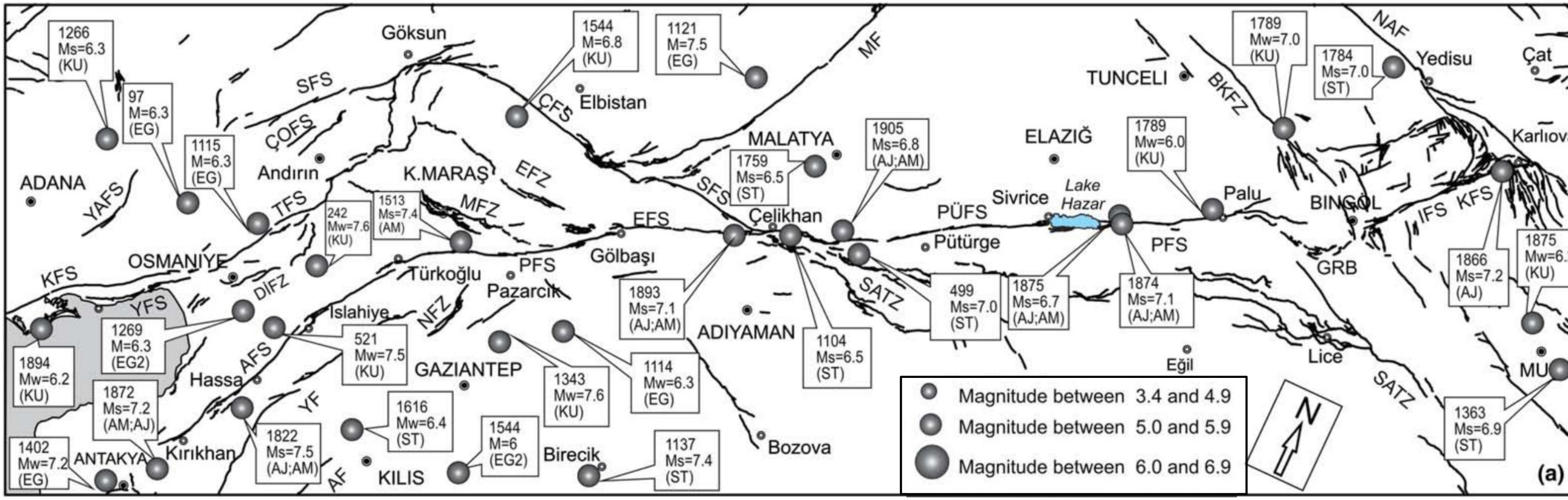
DISTRIBUTION OF HISTORICAL EARTHQUAKES ALONG THE EAST ANATOLIAN FAULT SYSTEM



From *Duman and Emre (2013)*

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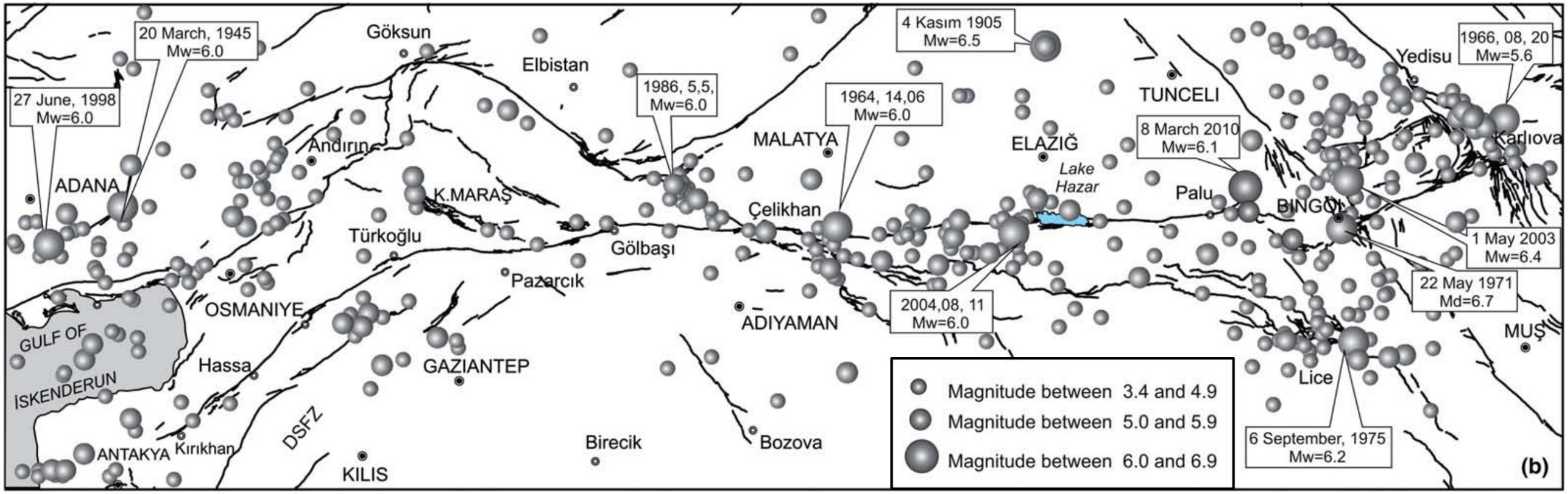
DISTRIBUTION OF INSTRUMENTALLY RECORDED EARTHQUAKES ALONG THE EAST ANATOLIAN FAULT SYSTEM



From *Duman and Emre (2013)*

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THE PÜTÜRGE GAP ALONG THE MAIN FAULT STRAND OF THE EAST ANATOLIAN FAULT SYSTEM

The Pütürge segment extends between the Lake Hazar releasing bend and the Yarpuzlu restraining double bend. The fault traverses mountainous terrain and tends to follow linear valleys, where it cuts Palaeozoic-Mesozoic metamorphic rocks, Mesozoic ophiolitic mélange and volcanosedimentary rocks. Measured geological offsets of basement rocks and morphological offsets in the Fırat River valley vary from 9 to 22 km.

The segment varies from transtensional to transpressional modes from east to west. The segment comprises sections with lengths varying from 21 to 28 km, separated from each other by restraining stepovers and a bend about 0.5 km wide. The segment is characterized by two parallel faults 9 km long to the west of Lake Hazar.

The segment cuts and offsets various rivers including Fırat River. Duman and Emre (2013) measured an 11 km left-lateral offset in the valley to the SW of Lake Hazar. This measurement represents the total fault offset from Pliocene to recent time. Systematic left lateral offsets are developed in the tributaries of the Şiro River and range from several tens of meters to one kilometer long. Cumulative left-lateral offsets of about 550 and 450 m were measured in the Delan and Bobik rivers.

The timing of the previous surface rupture is unknown. The 1875 (Ms 6.7) and 1905 (Ms 6.8) earthquakes might have been generated along this segment based on Ambraseys (1988).

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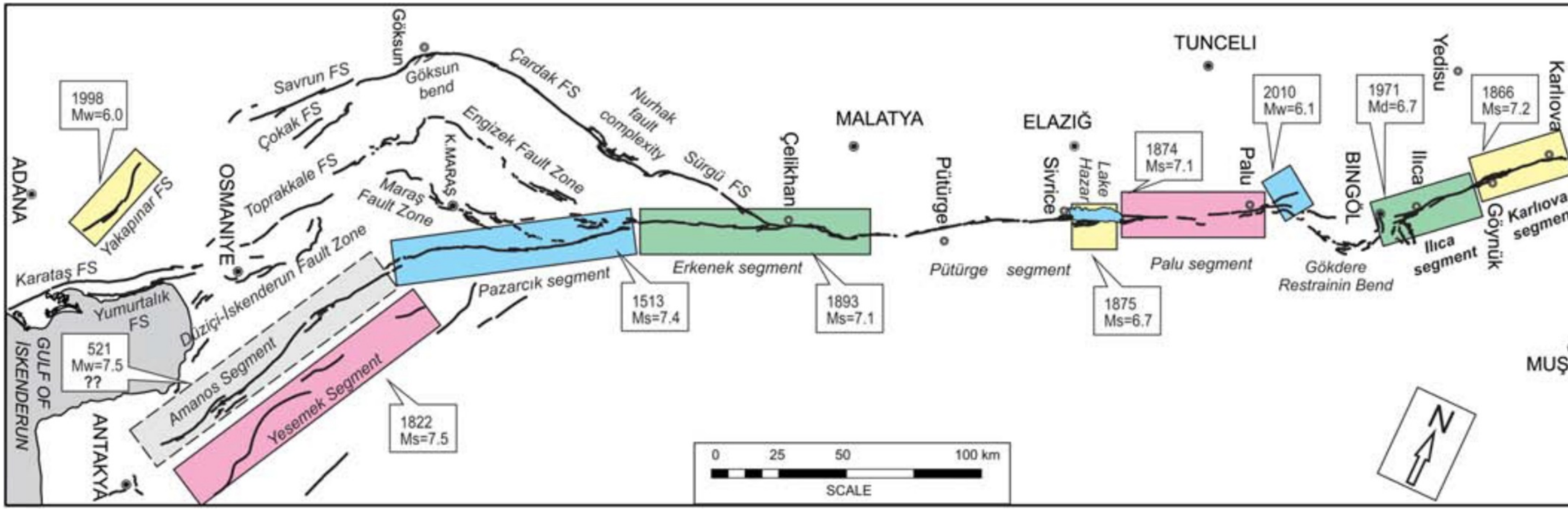
SURFACE RUPTURES PRODUCED BY LARGE EARTHQUAKES AND SEISMIC GAPS
THE PÜTÜRGE GAP



Surface ruptures produced by large earthquakes during the 19th and 20th centuries along the Eastern Anatolian Fault System. Ruptured fault segments are highlighted. Seismic gaps are recognized on some segments of the Eastern Anatolian Fault System based on historical and instrumental earthquake data (From *Duman and Emre, 2013*). The January 24, 2020 Eastern Turkey earthquake was generated along the **Pütürge gap**.

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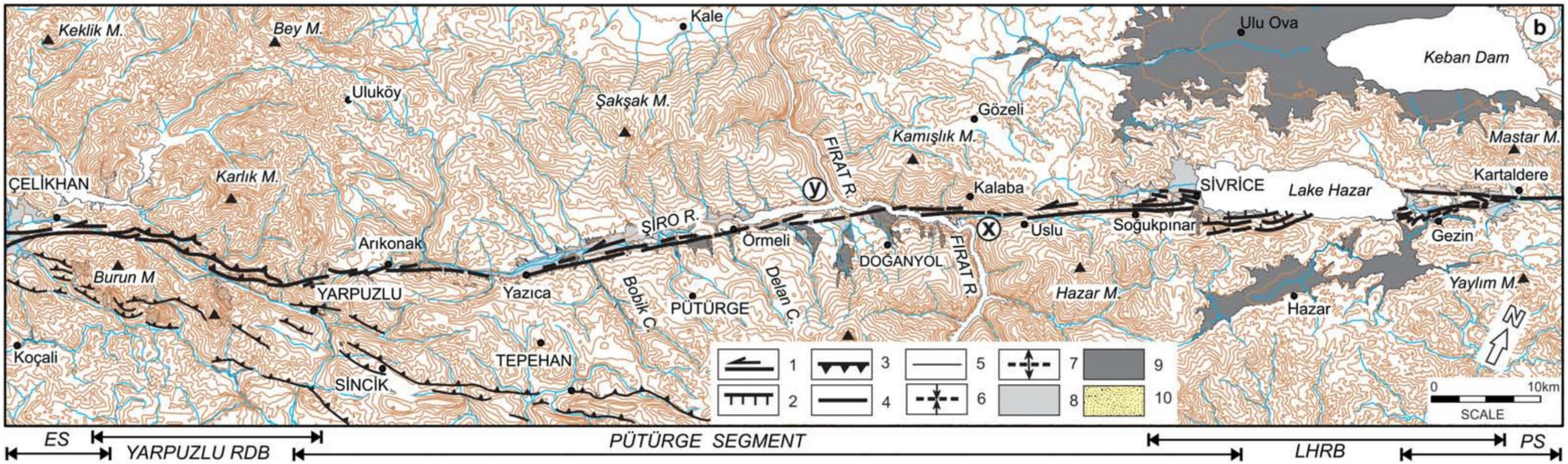
THE PÜTÜRGE GAP ALONG THE MAIN FAULT STRAND OF THE EAST ANATOLIAN FAULT SYSTEM



Map of the Pütürge segment of the East Anatolian fault system. **LHRB**: Lake Hazar releasing bend; **PS**: Palu segment; **ES**: Erkenek segment; **H**: hill; M: mountain; **C**: creek; **1**: left lateral strike-slip fault; **2**: normal fault; **3**: reverse or thrust fault; **4**: East Anatolian Fault; **5**: Southeastern Anatolian Thrust Zone; **6**: syncline; **7**: anticline; **8**: undifferentiated Holocene deposits; **9**: undifferentiated Quaternary deposits; **10**: landslide, “x” and “y” are used to indicate the amount of slip (From *Duman and Emre, 2013*).

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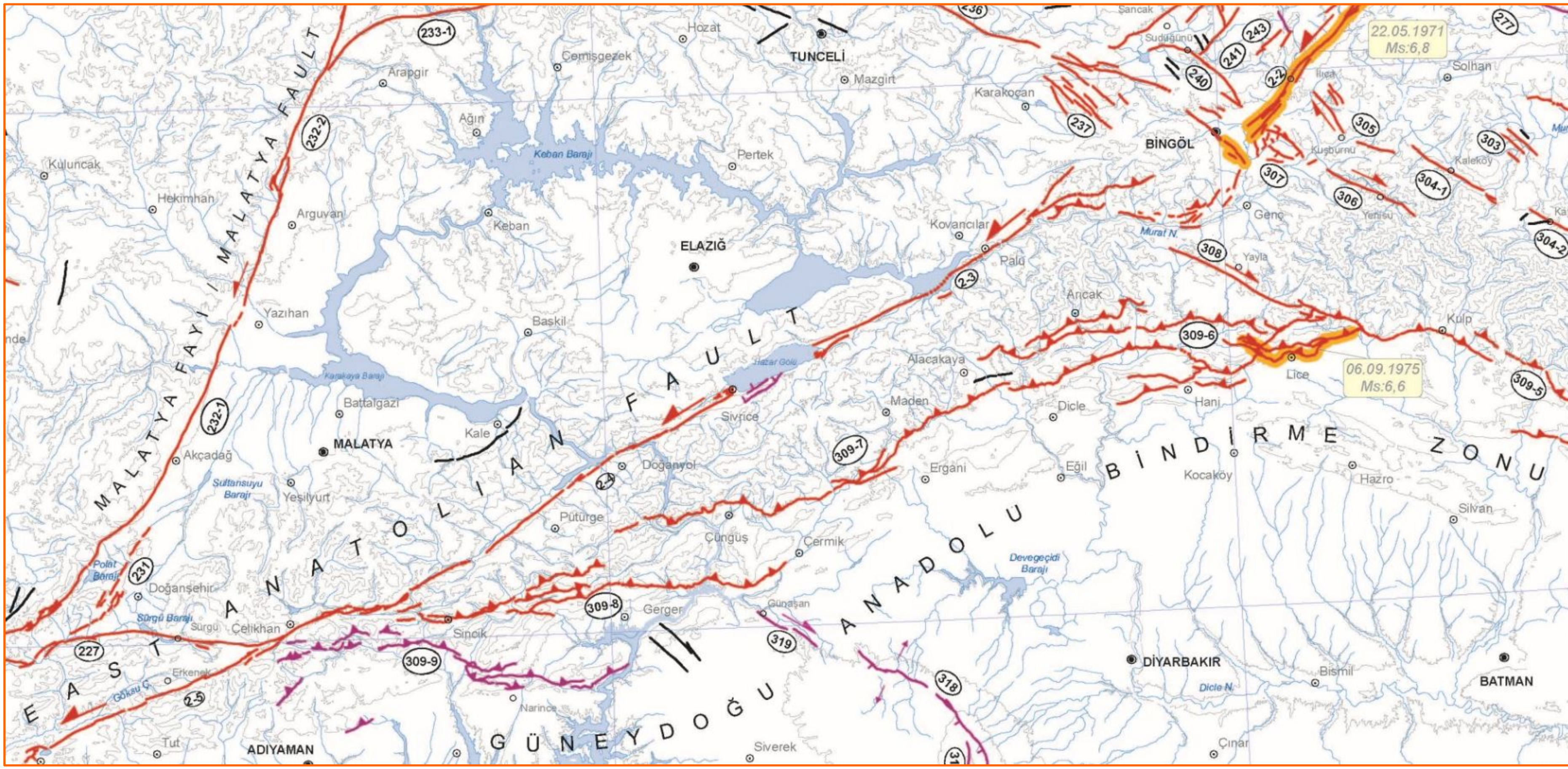
THE PÜTÜRGE GAP ALONG THE MAIN FAULT STRAND OF THE EAST ANATOLIAN FAULT SYSTEM



Map of the Pütürge segment (2-4) of the East Anatolian fault system
(From the *Active Fault Map of Turkey in 1:1250000 scale by Emre et al., 2013*)

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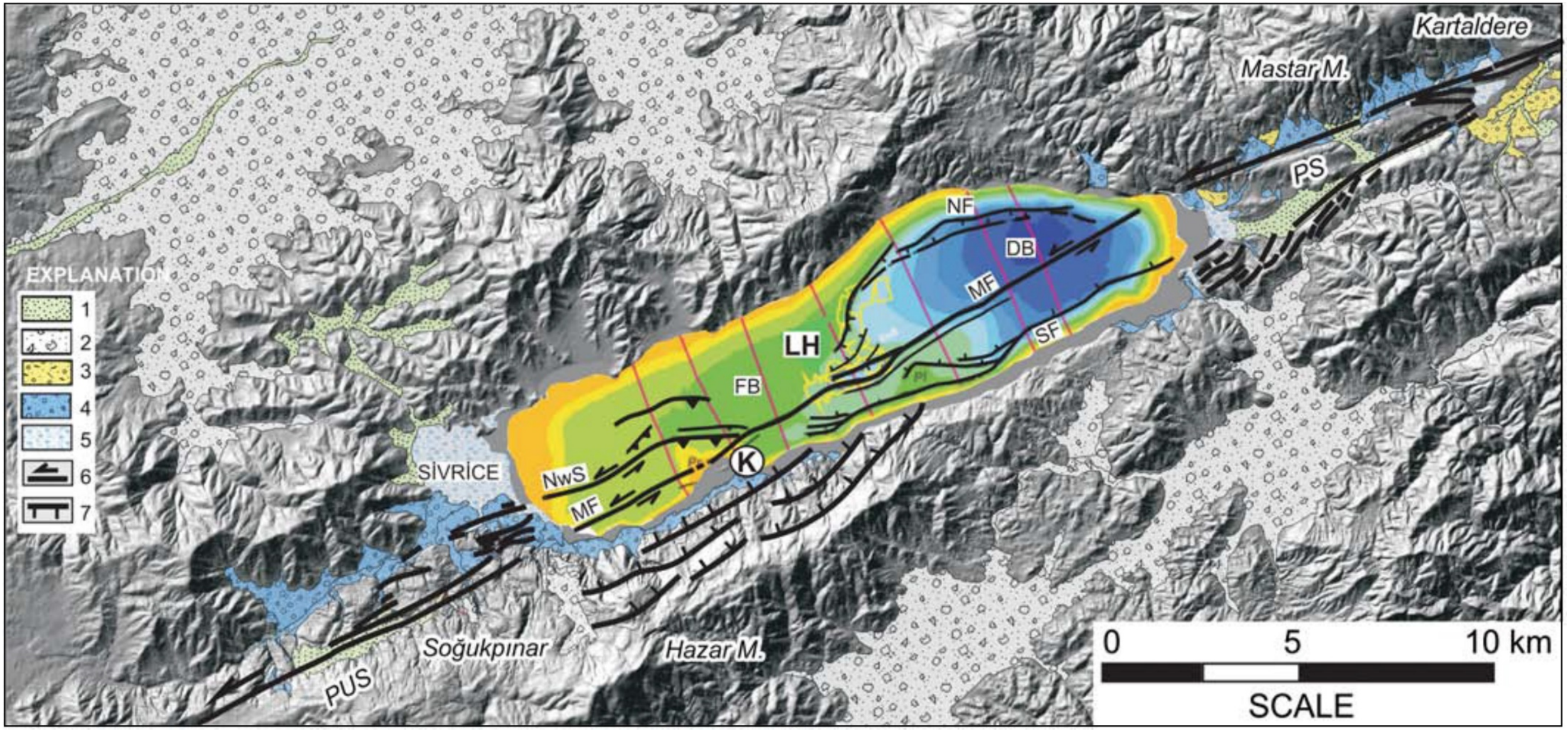
THE PÜTÜRGE GAP AND ITS ACCOMPANIED STRUCTURES



Active fault and Quaternary geological map of the Lake Hazar releasing bend and its vicinity. **PS**: Palu segment; **PUS**: Pütürge segment; **LH**: Lake Hazar; **K**: Kilise Island; **MF**: Master Fault; **NF**: Northern Fault; **SF**: Southern Fault; **NwS**: Northwestern Splay; **DB**: deep basin; **FB**: flat basin; **SeB**: small-elongated basin; **M**: mountain; **1**: Holocene river bed deposits; **2**: Holocene floodplain deposits; **3**: colluvium; **4**: Holocene fan deposits; **5**: Holocene marsh deposits; **6**: left-lateral strike-slip fault; **7**: normal fault (From *Duman and Emre, 2013*).

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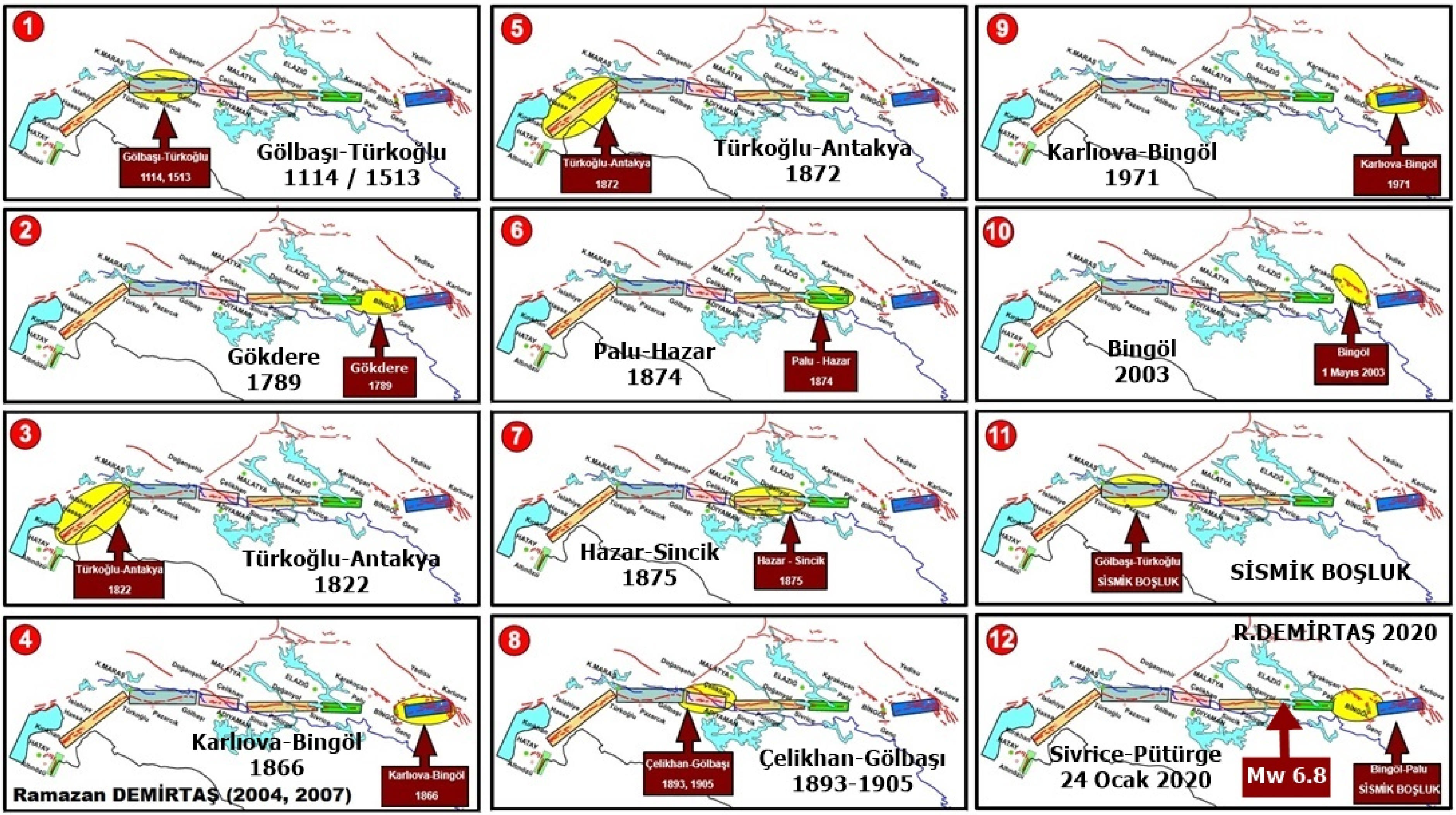
THE EAST ANATOLIAN STRIKE-SLIP FAULT SYSTEM
LARGE EARTHQUAKES AND SEISMIC GAPS



https://twitter.com/Paleosismolog/status/1221394032661880833/photo/1

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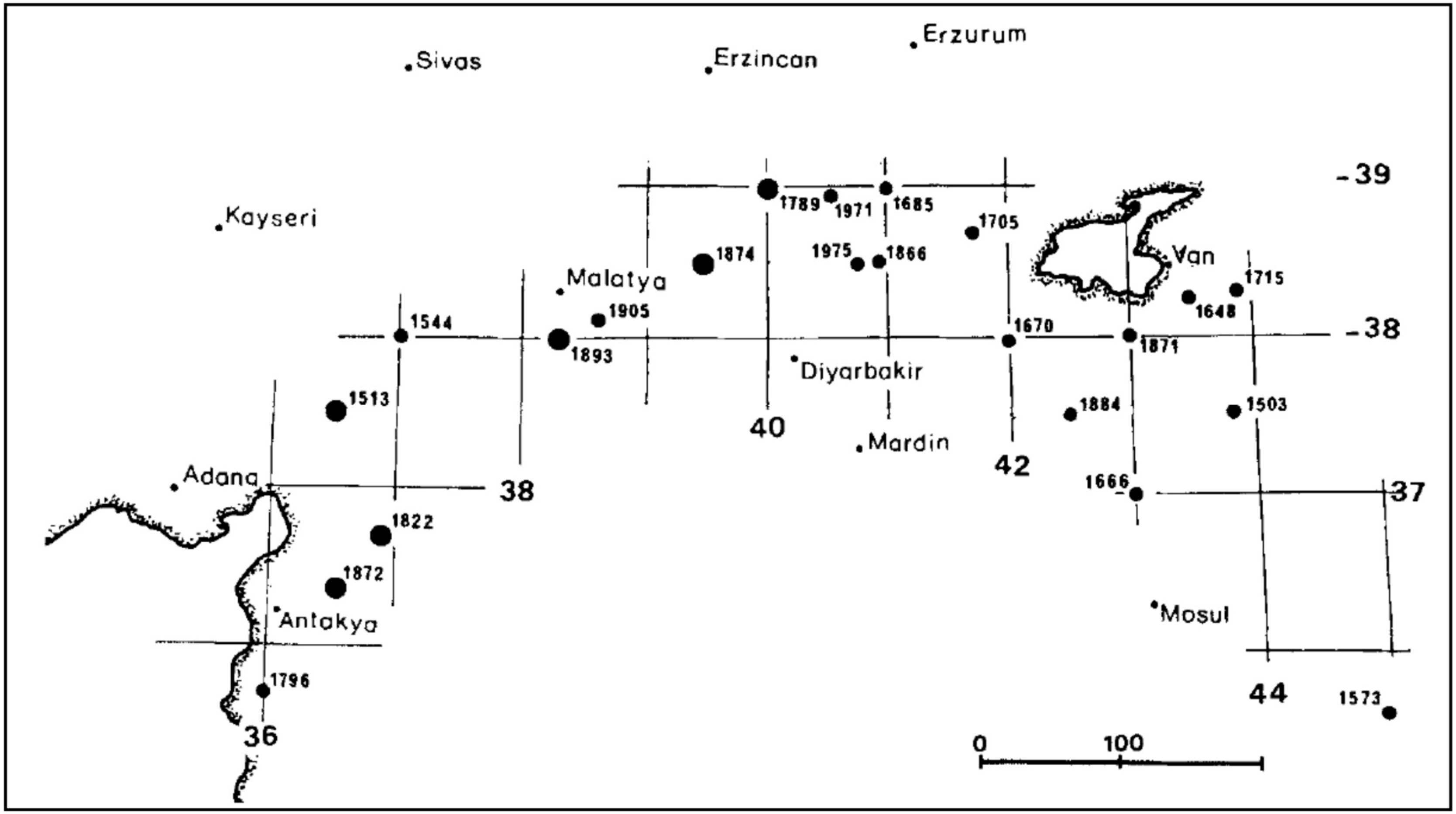
HISTORICAL EARTHQUAKES IN THE EAST ANATOLIAN FAULT SYSTEM



Distribution of earthquakes in the East Anatolian Fault Zone from 1500 to 1988, marked with year of occurrence. Size of dots corresponds to magnitudes 6.0 and 7.0 respectively (From *Ambraseys, 1989*).

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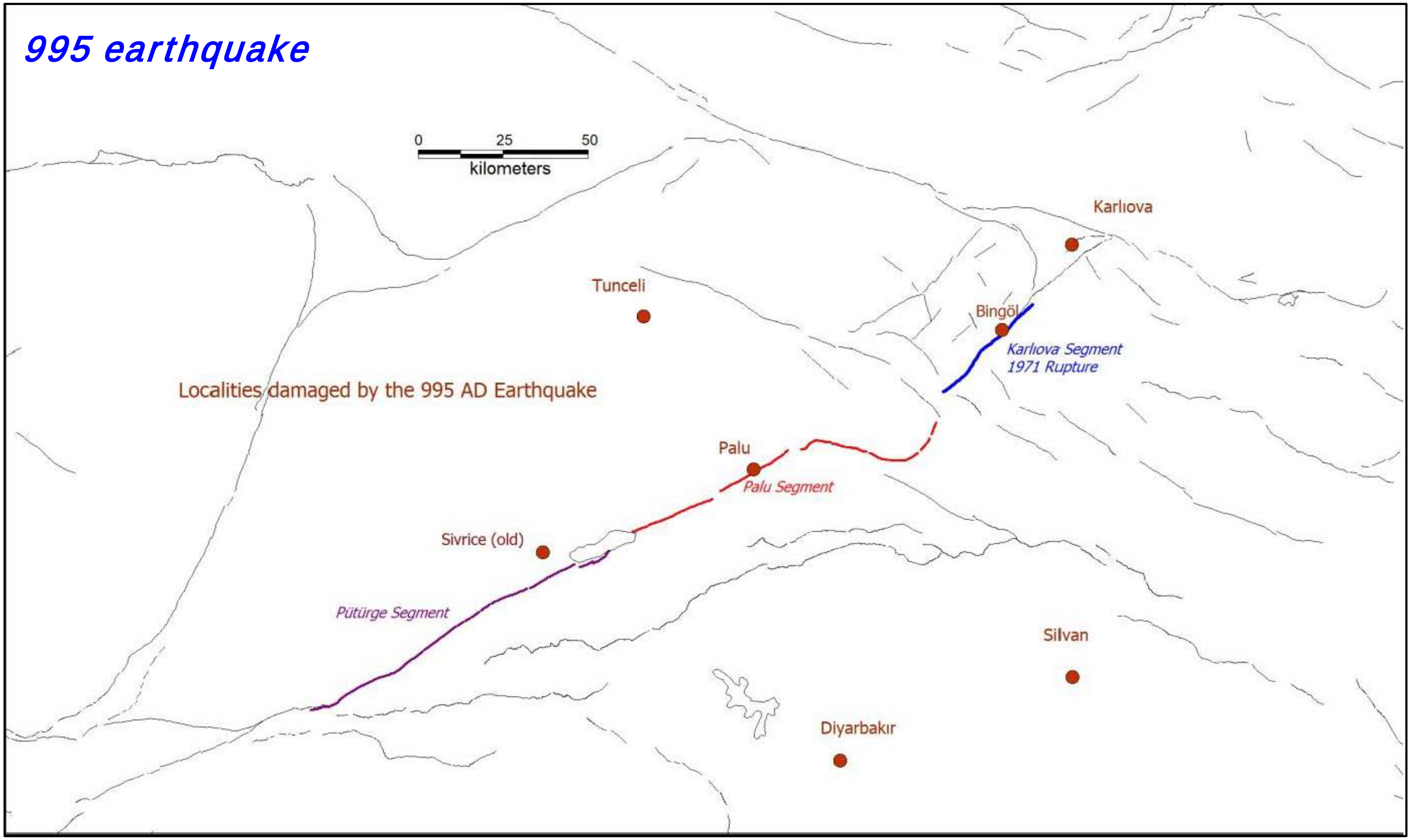
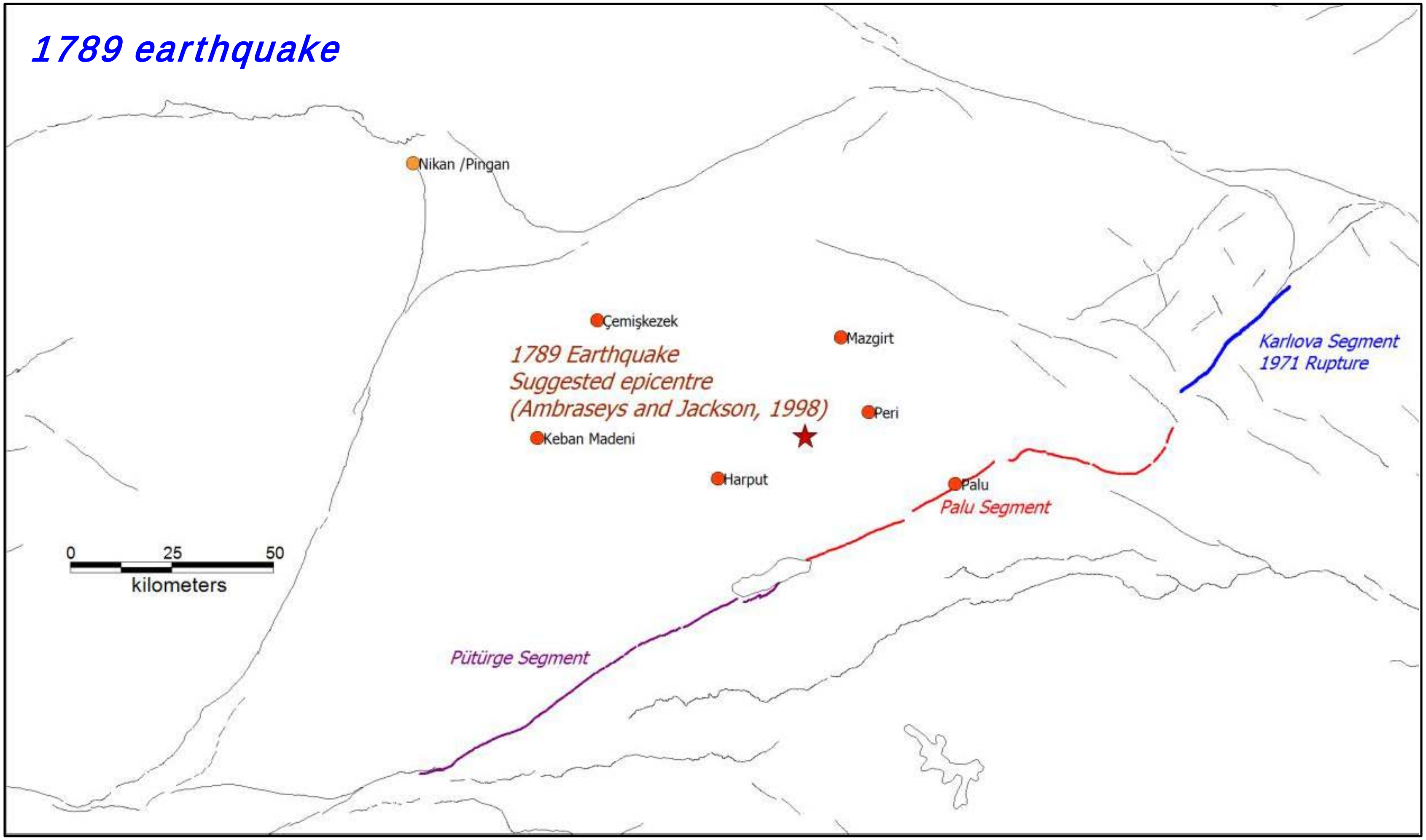
HISTORICAL EARTHQUAKES AND DAMAGED LOCALITIES IN THE EAST ANATOLIAN FAULT SYSTEM



Localities damaged from the 995 earthquake based on Guidoboni et al. (1994) and Ambraseys (2009) (From https://eqe.boun.edu.tr/sites/che.boun.edu.tr/files/elazig-sivrice_earthquake_24-01-2020-bu-koeri_earthquake_engineering_v1.pdf)

HISTORICAL EARTHQUAKES AND DAMAGED LOCALITIES IN THE EAST ANATOLIAN FAULT SYSTEM



Localities damaged from the May 28, 1789 Elazığ earthquake based on Ambraseys (2009)
(From https://eqe.boun.edu.tr/sites/che.boun.edu.tr/files/elazig-sivrice_earthquake_24-01-2020-bu-koeri_earthquake_engineering_v1.pdf)

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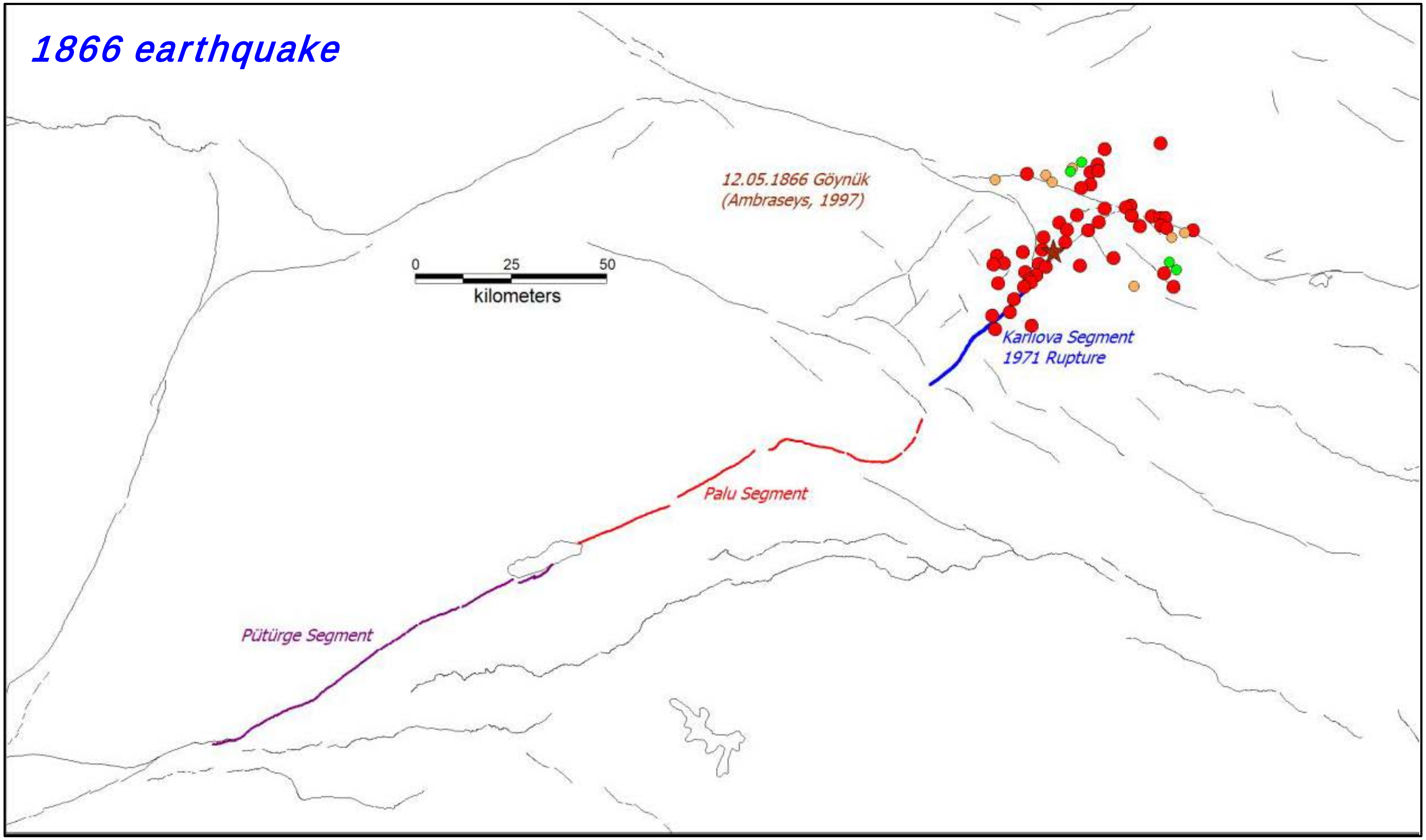
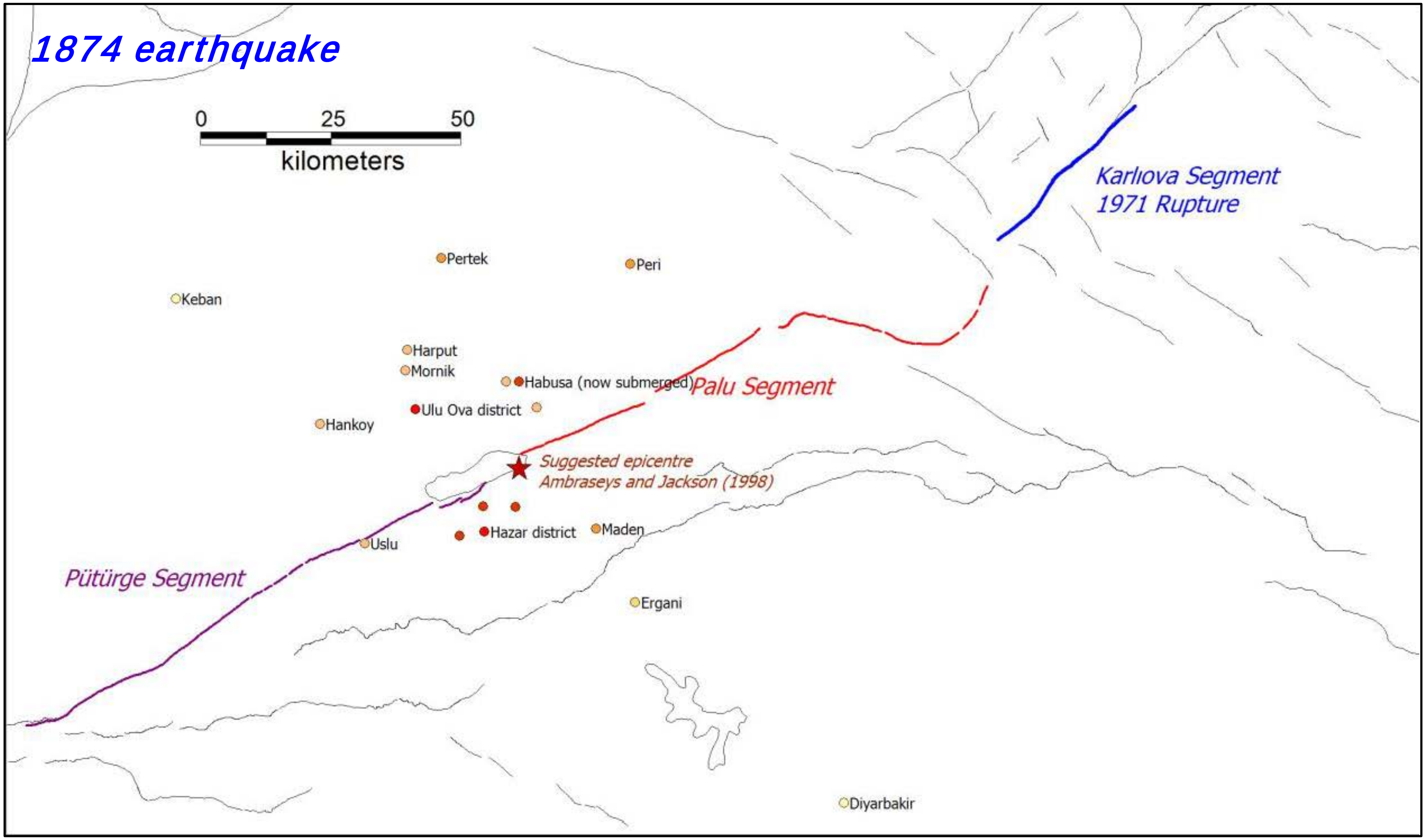


Localities damaged from the May 12, 1866 Göynük earthquake based on Ambraseys (1997) (From https://eqe.boun.edu.tr/sites/che.boun.edu.tr/files/elazig-sivrice_earthquake_24-01-2020-bu-koeri_earthquake_engineering_v1.pdf)

HISTORICAL EARTHQUAKES AND DAMAGED LOCALITIES IN THE EAST ANATOLIAN FAULT SYSTEM



Localities damaged from the May 3, 1874 Gölcük earthquake based on Ambraseys (2009)
(From https://eqe.boun.edu.tr/sites/che.boun.edu.tr/files/elazig-sivrice_earthquake_24-01-2020-bu-koeri_earthquake_engineering_v1.pdf)

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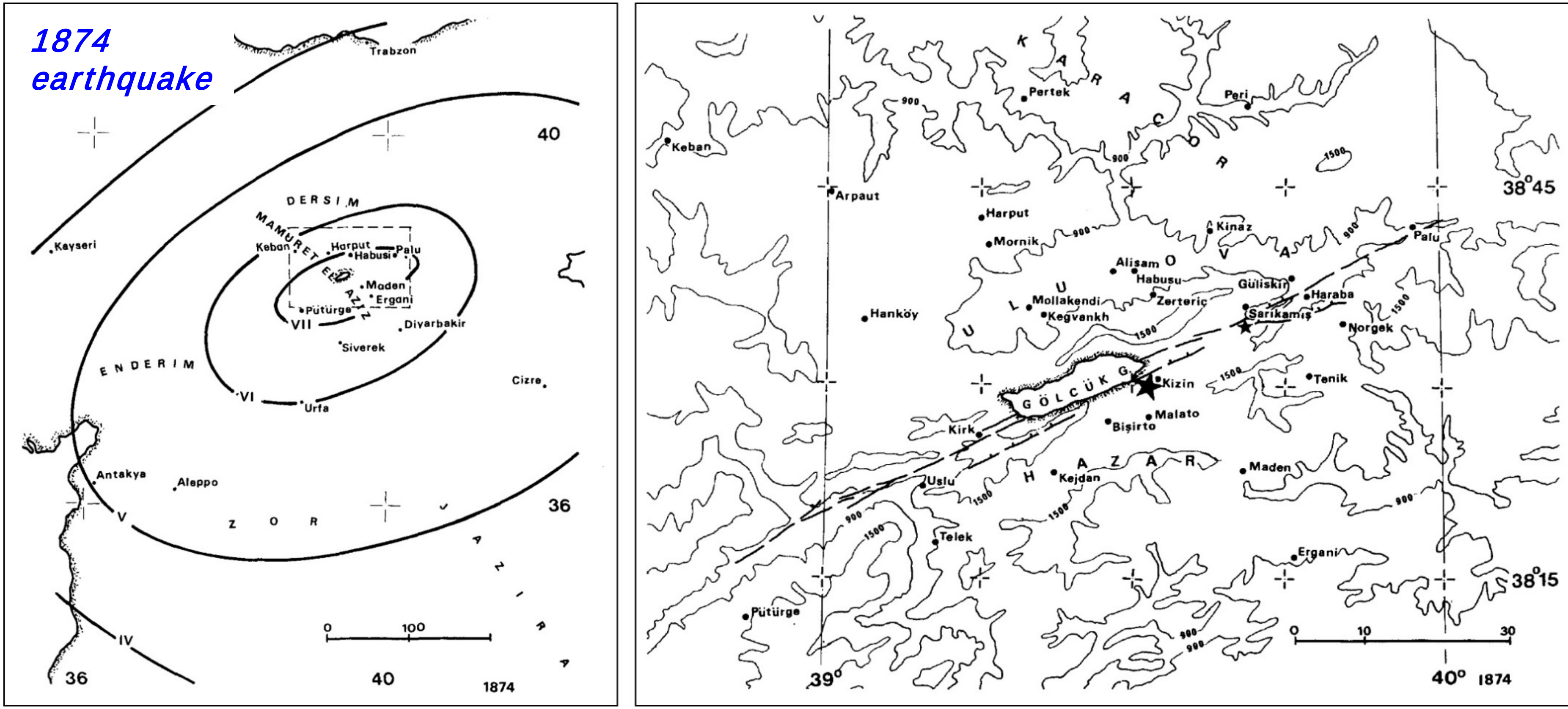

Epicentral region of the Gölcük Gölü earthquake of 1874. Dashed lines show the approximate location of East Anatolian Fault in the epicentral region. Large star indicates adopted location of epicentre and small star shows epicentre of foreshock of January 14, 1874 (From *Ambraseys, 1989*).

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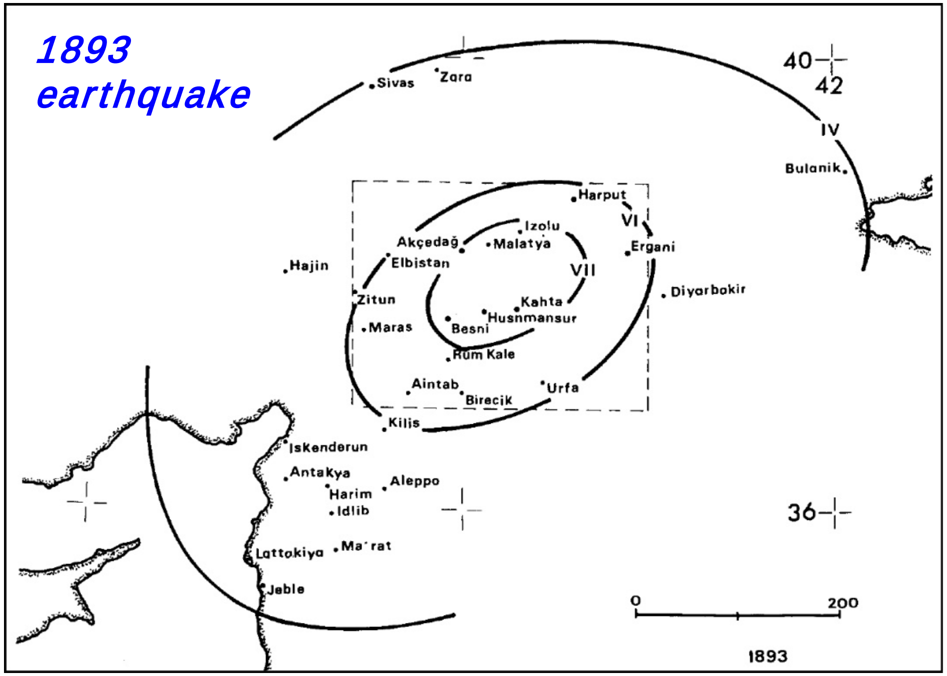
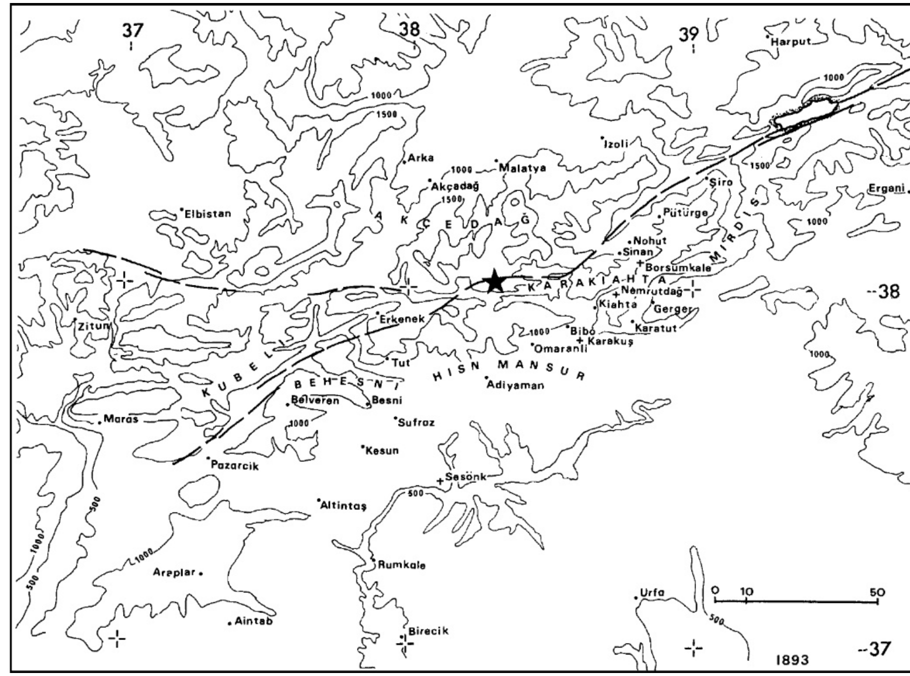
HISTORICAL EARTHQUAKES AND DAMAGED LOCALITIES IN THE EAST ANATOLIAN FAULT SYSTEM





Macroseismic intensities and epicentral area of South Malatya earthquake of 1893. Dashed lines show the East Anatolian Fault system and star shows adopted location of the epicenter. Crosses indicate abandoned sites (From *Ambraseys, 1989*).

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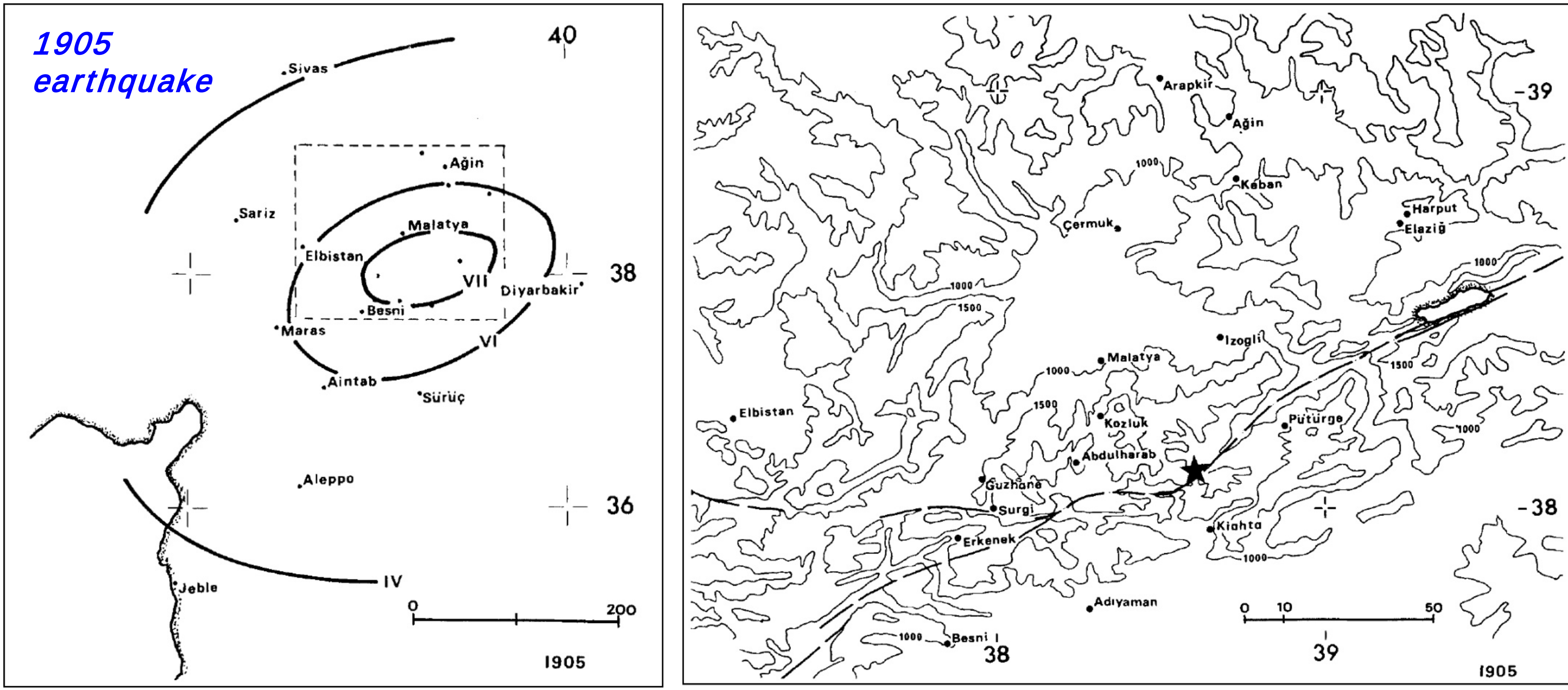
HISTORICAL EARTHQUAKES AND DAMAGED LOCALITIES IN THE EAST ANATOLIAN FAULT SYSTEM



Macroseismic intensities and epicentral area of the Malatya earthquake of 1905. Dashed lines show location of East Anatolian Fault system and star shows adopted macroseismic epicentre (From *Ambraseys, 1989*).

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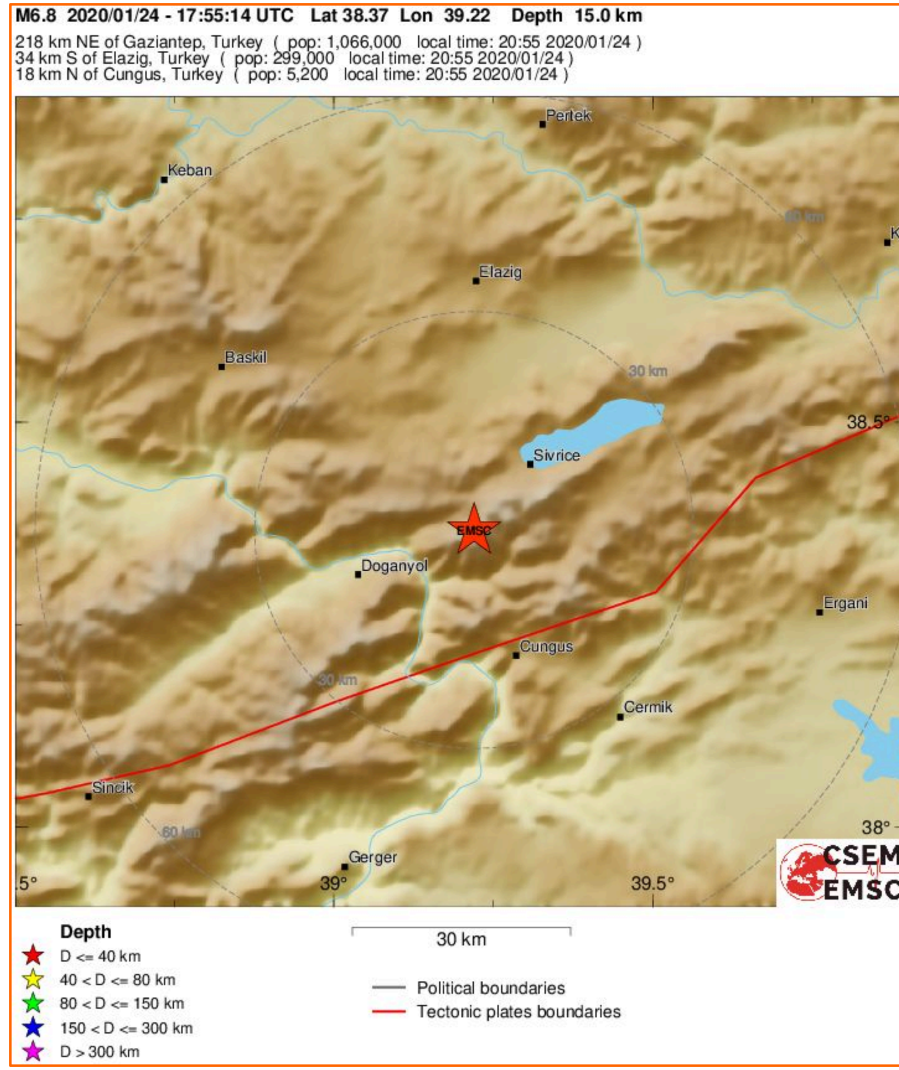
EPICENTER FOR THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE



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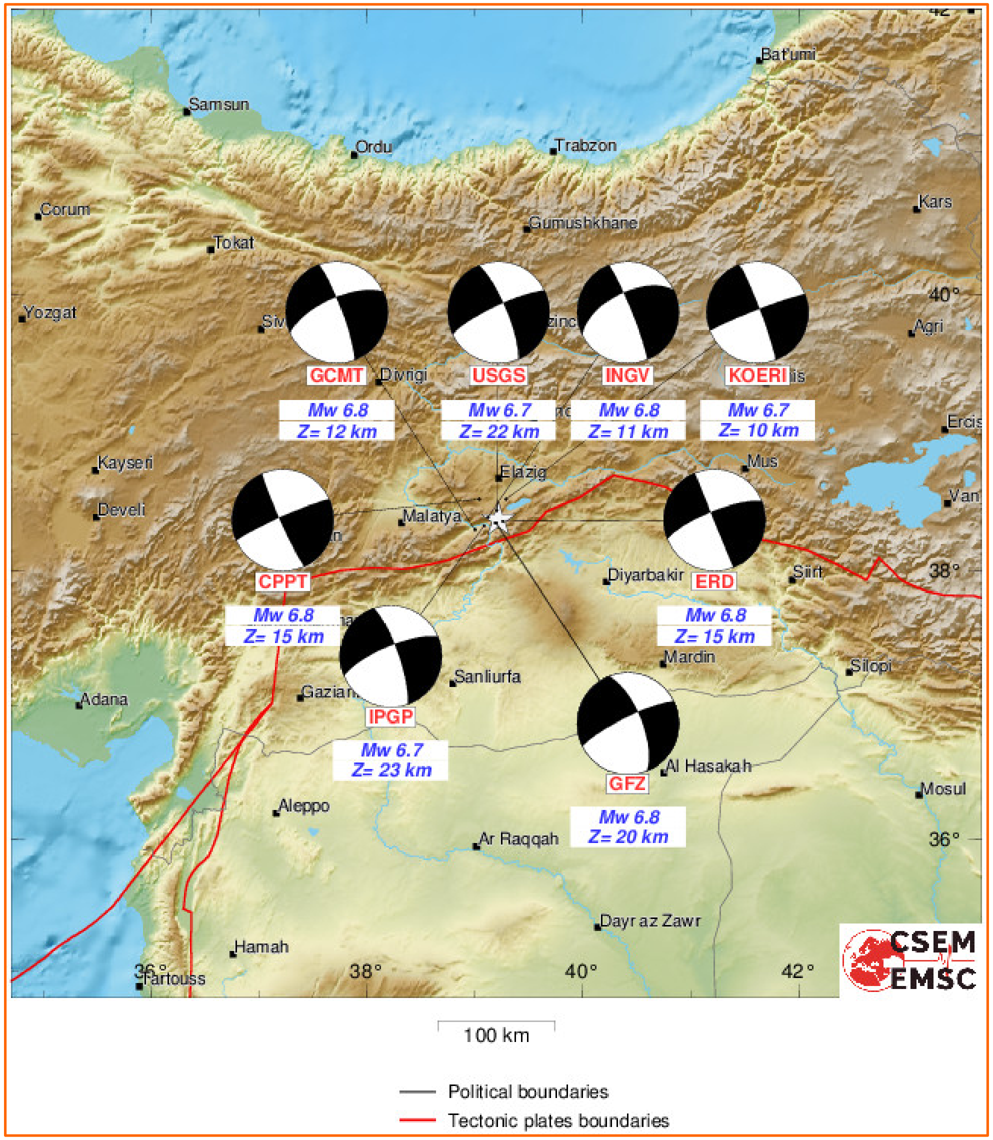
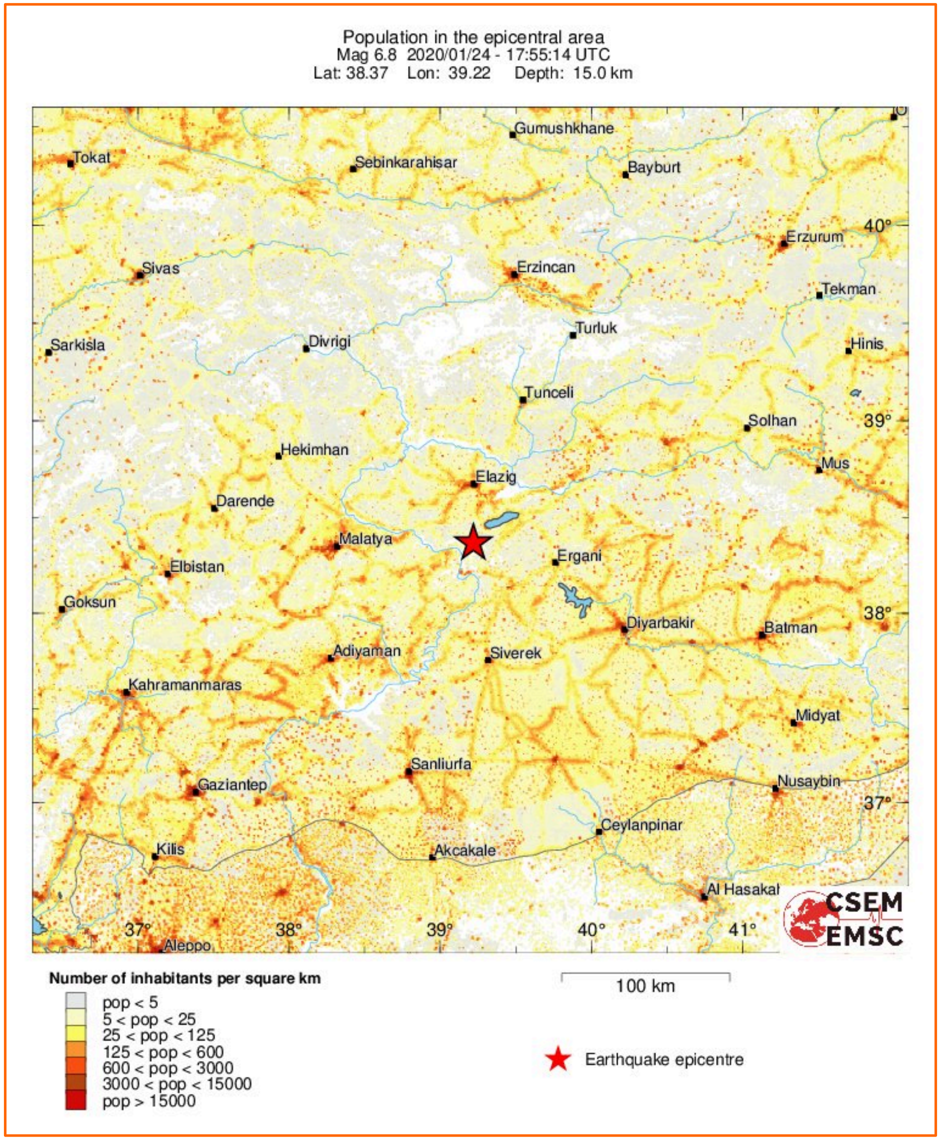
QUICK SOLUTIONS AND REGIONAL MOMENT TENSORS FOR THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE



DISTRIBUTION OF POPULATION IN THE EPICENTRAL AREA OF THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE



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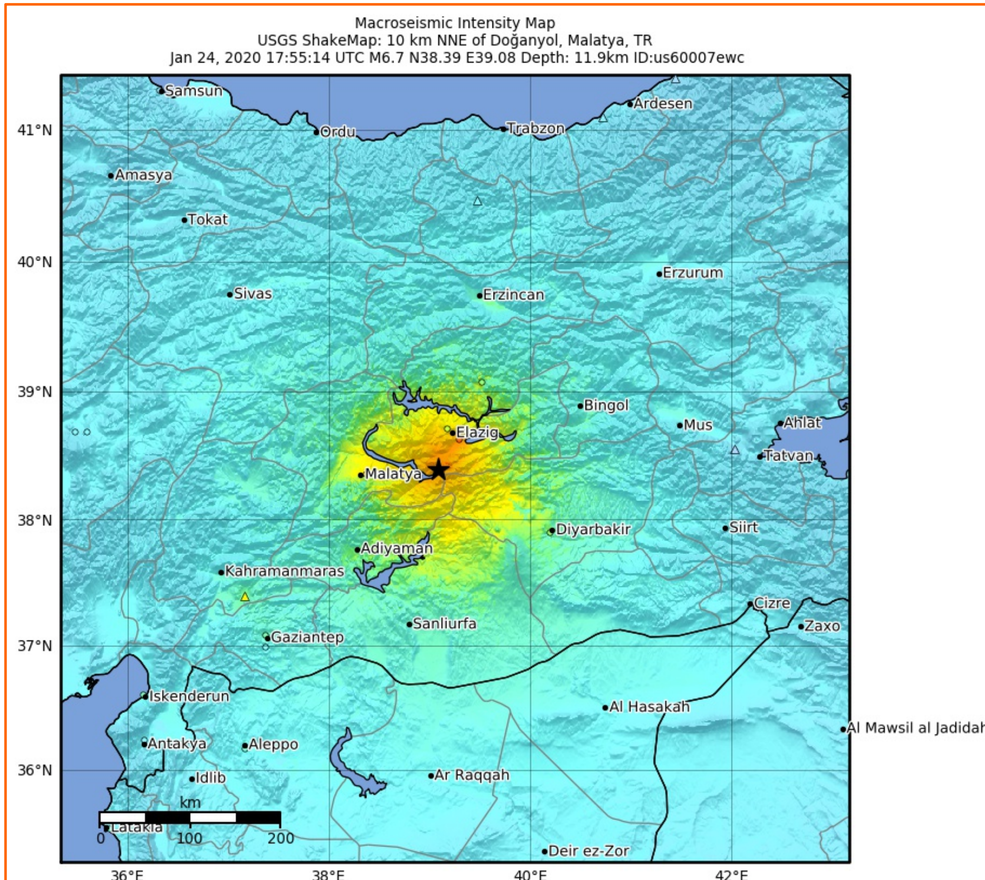
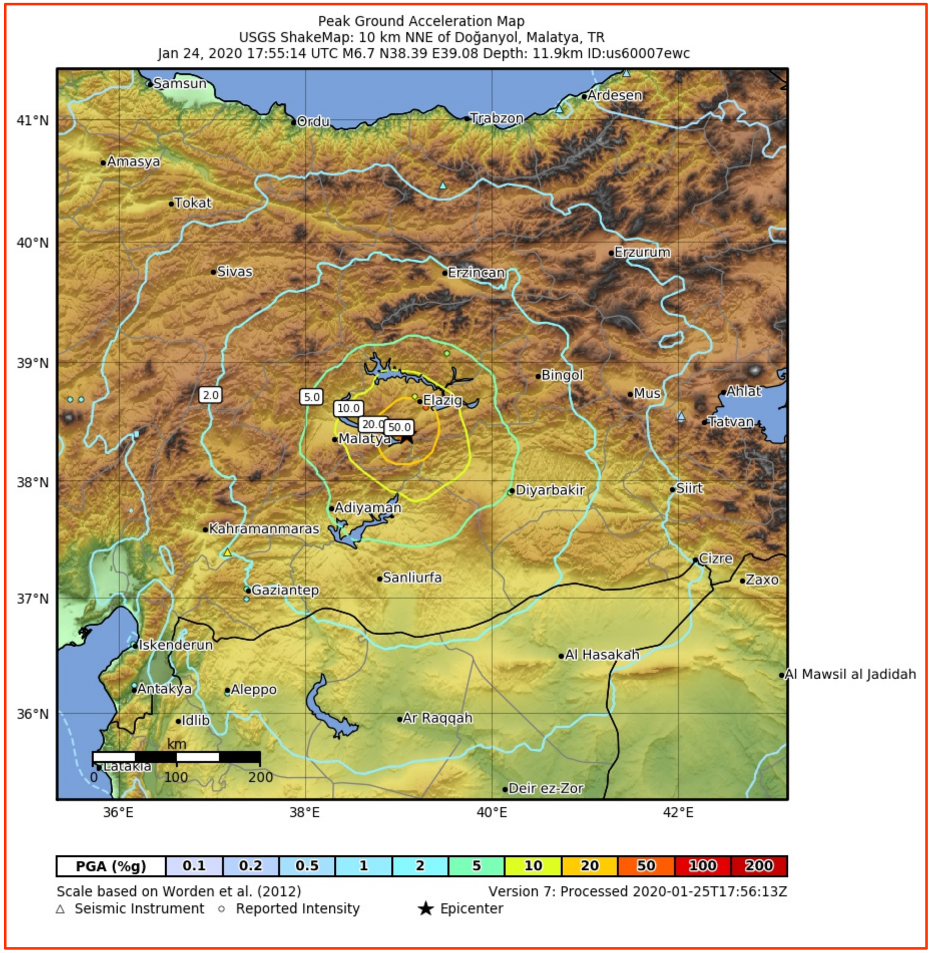
INTENSITY MAP
FOR THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE

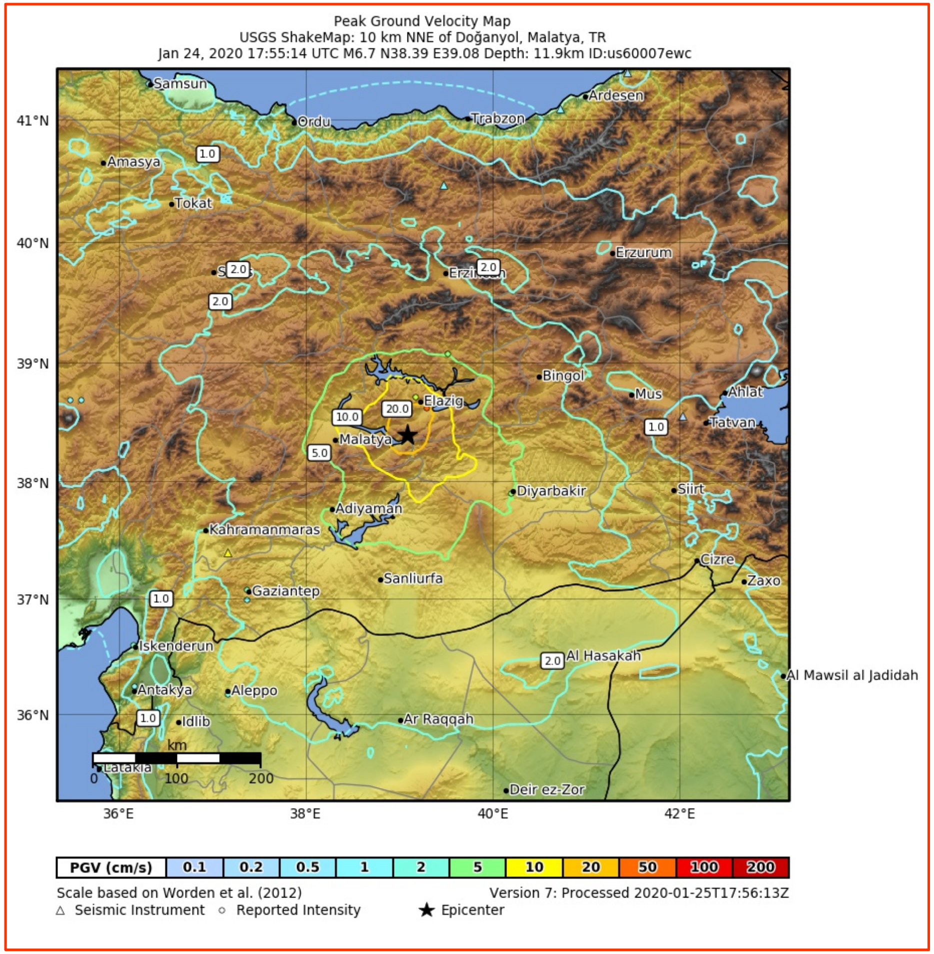


SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.05	0.3	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.02	0.13	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII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

Scale based on Worden et al. (2012) Version 7: Processed 2020-01-25T17:56:13Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

PEAK GROUND ACCELERATION AND PEAK GROUND VELOCITY MAPS FOR THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE





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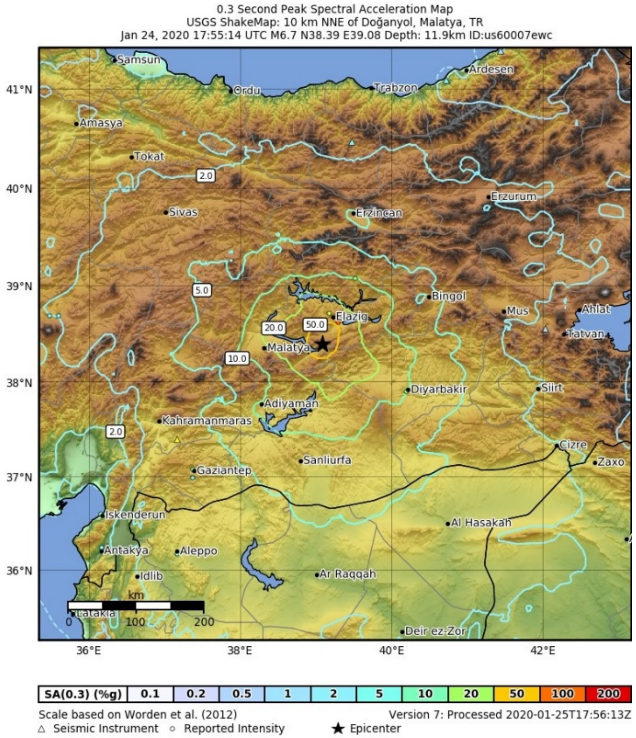
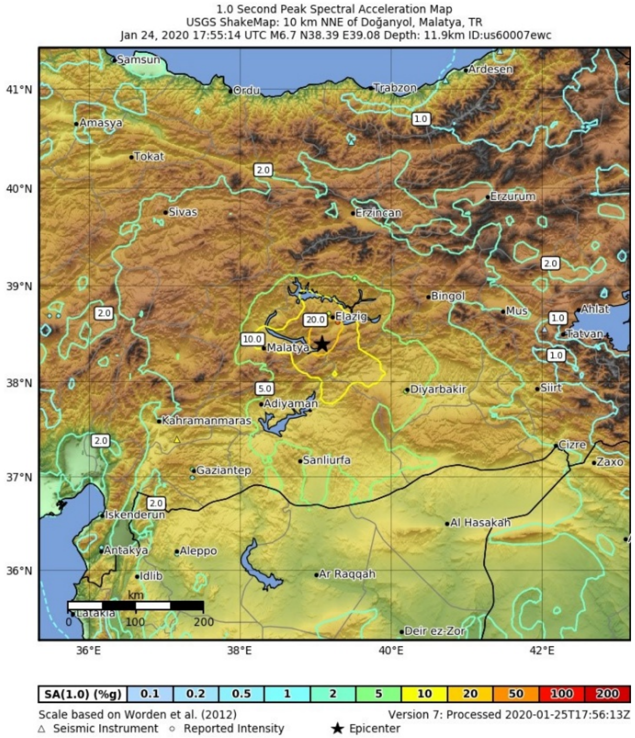
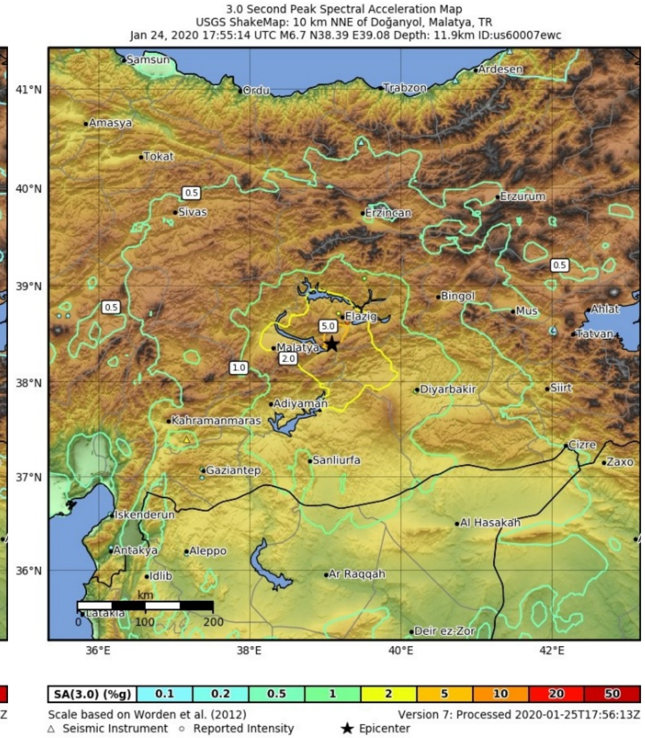
SPECTRAL RESPONSE FOR THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE







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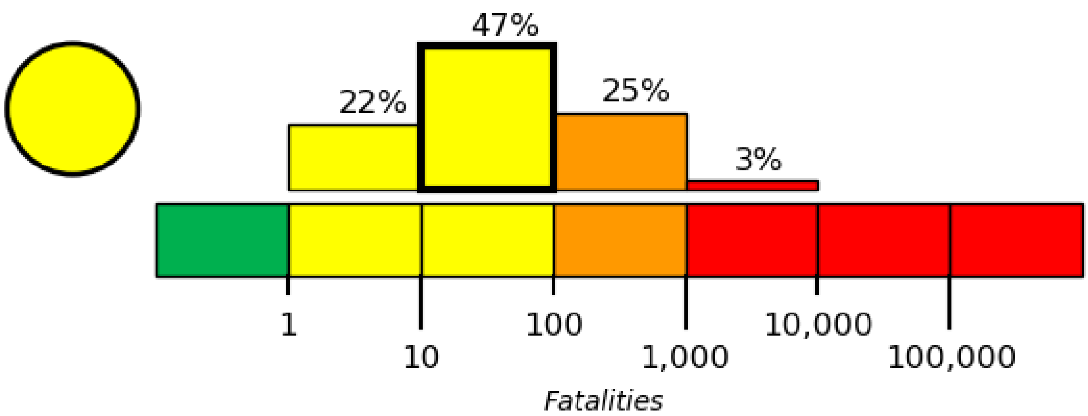
ESTIMATED LOSSES
FOR THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE

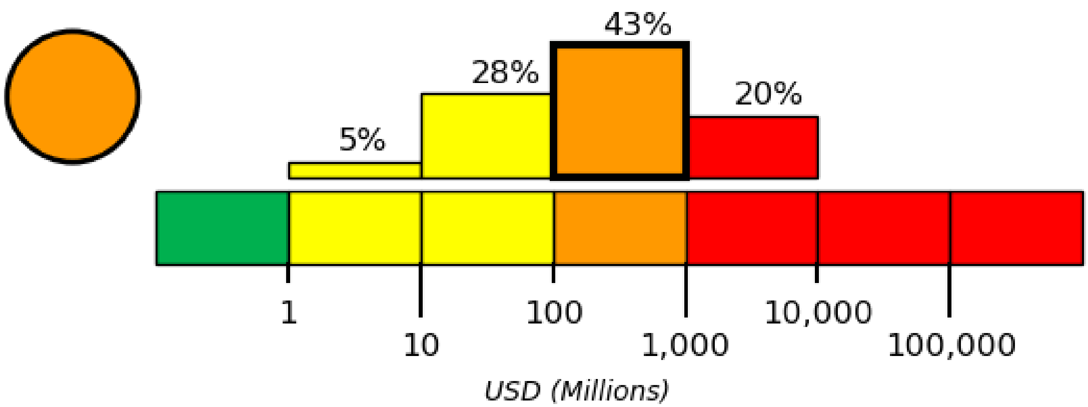
Estimated fatalities



Yellow alert for shaking-related fatalities. Some casualties are possible.

https://earthquake.usgs.gov/archive/product/losspager/us60007ewc/us/1579975220832/onepager.pdf

Estimated Economic Losses



Orange alert for economic losses. Significant damage is likely and the disaster is potentially widespread. Estimated economic losses are less than 1% of GDP of Turkey. Past events with this alert level have required a regional or national level response.

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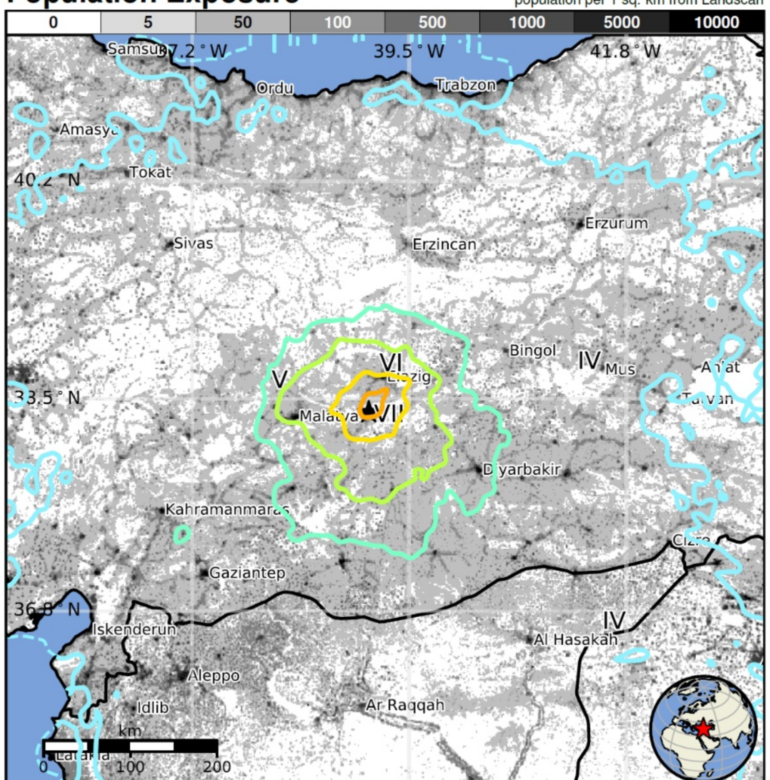
POPULATION EXPOSURE
TO THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE SHAKING

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k=x1000)		–*	5,051k*	33,390k*	2,061k	1,248k	390k	29k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	None	None	None	V. Light	Light	Moderate	Mod./Heavy	Heavy	V. Heavy
	Vulnerable Structures	None	None	None	Light	Moderate	Mod./Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure



PAGER content is automatically generated, and only considers losses due to structural damage.
Limitations of input data, shaking estimates, and loss models may add uncertainty.
https://earthquake.usgs.gov/earthquakes/eventpage/us60007ewc#pager

Structures

Overall, the population in this region resides in structures that are a mix of vulnerable and earthquake resistant construction. The predominant vulnerable building types are unreinforced brick masonry and adobe block construction.

Historical Earthquakes

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1998-06-27	369	6.3	VIII(19k)	145
2003-05-01	135	6.3	VIII(25k)	177
1966-08-19	232	6.8	VIII(15k)	3k

Recent earthquakes in this area have caused secondary hazards such as landslides that might have contributed to losses.

Selected City Exposure

from GeoNames.org

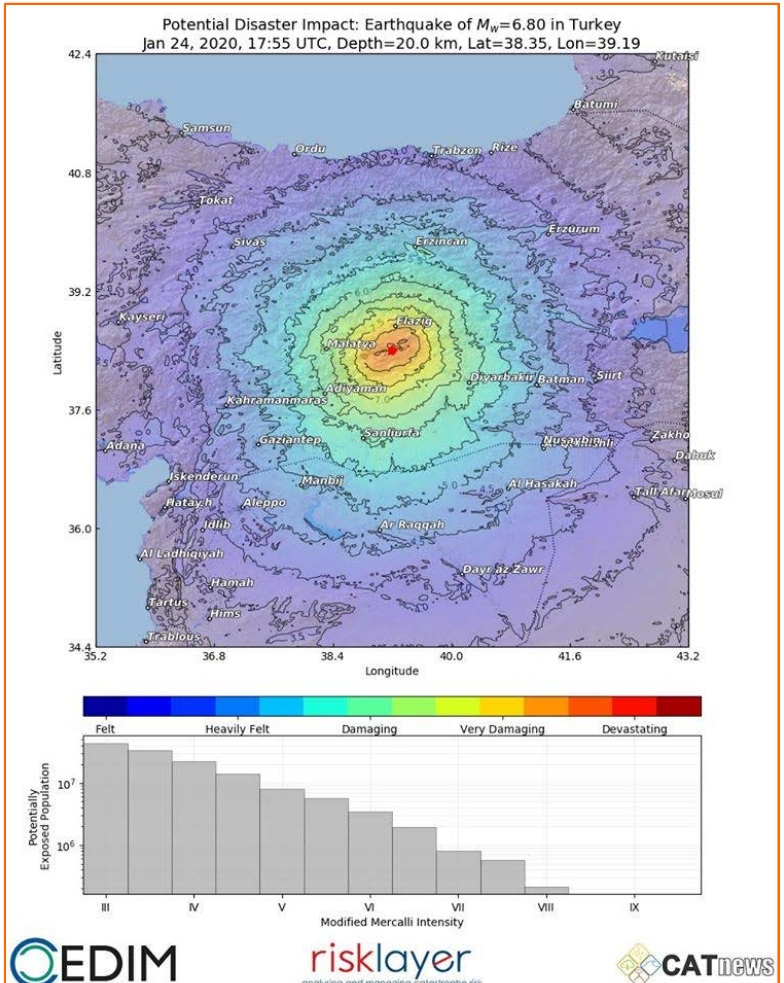
MMI	City	Population
VIII	Gozeli	<1k
VIII	Mollakendi	<1k
VII	Hankendi	<1k
VII	Doganyol	6k
VII	Sivrice	5k
VII	**Elazig**	**298k**
V	**Diyarbakir**	**645k**
IV	**Gaziantep**	**1,066k**
IV	**Aleppo**	**1,602k**
IV	Mosul	1,740k
III	Adana	1,249k

bold cities appear on map. (k=x1000)

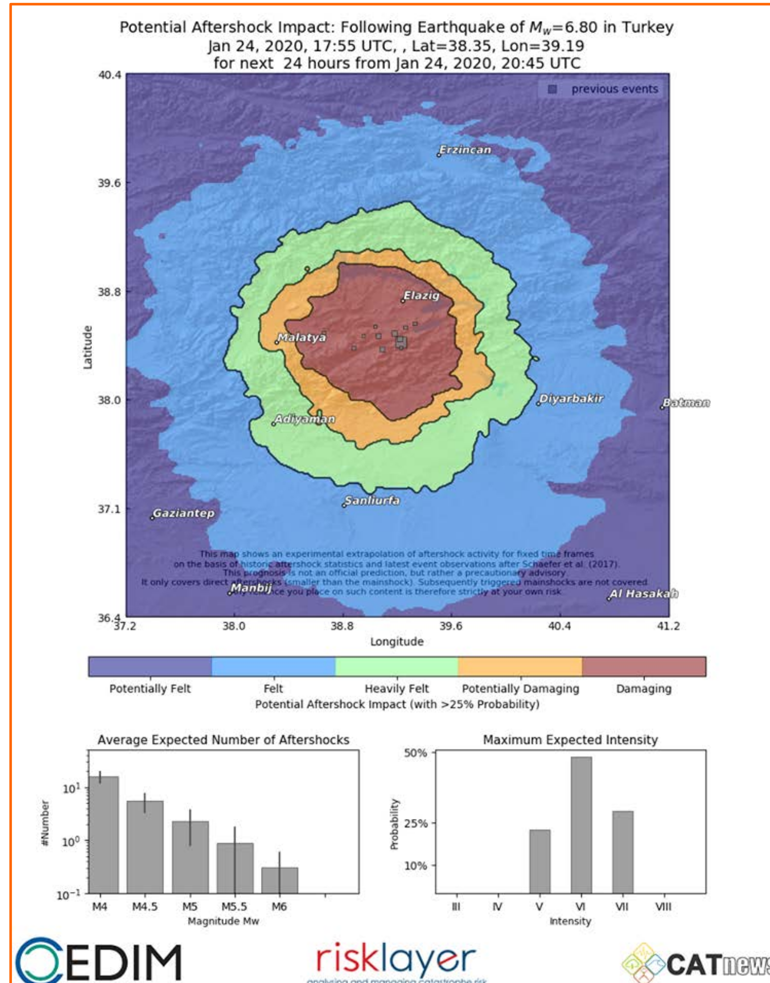
Event ID: us60007ewc

https://earthquake.usgs.gov/archive/product/losspager/us60007ewc/us/1579975220832/onepager.pdf

POTENTIAL DISASTER IMPACT AND POTENTIAL AFTERSHOCK IMPACT MAPS FOR THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE

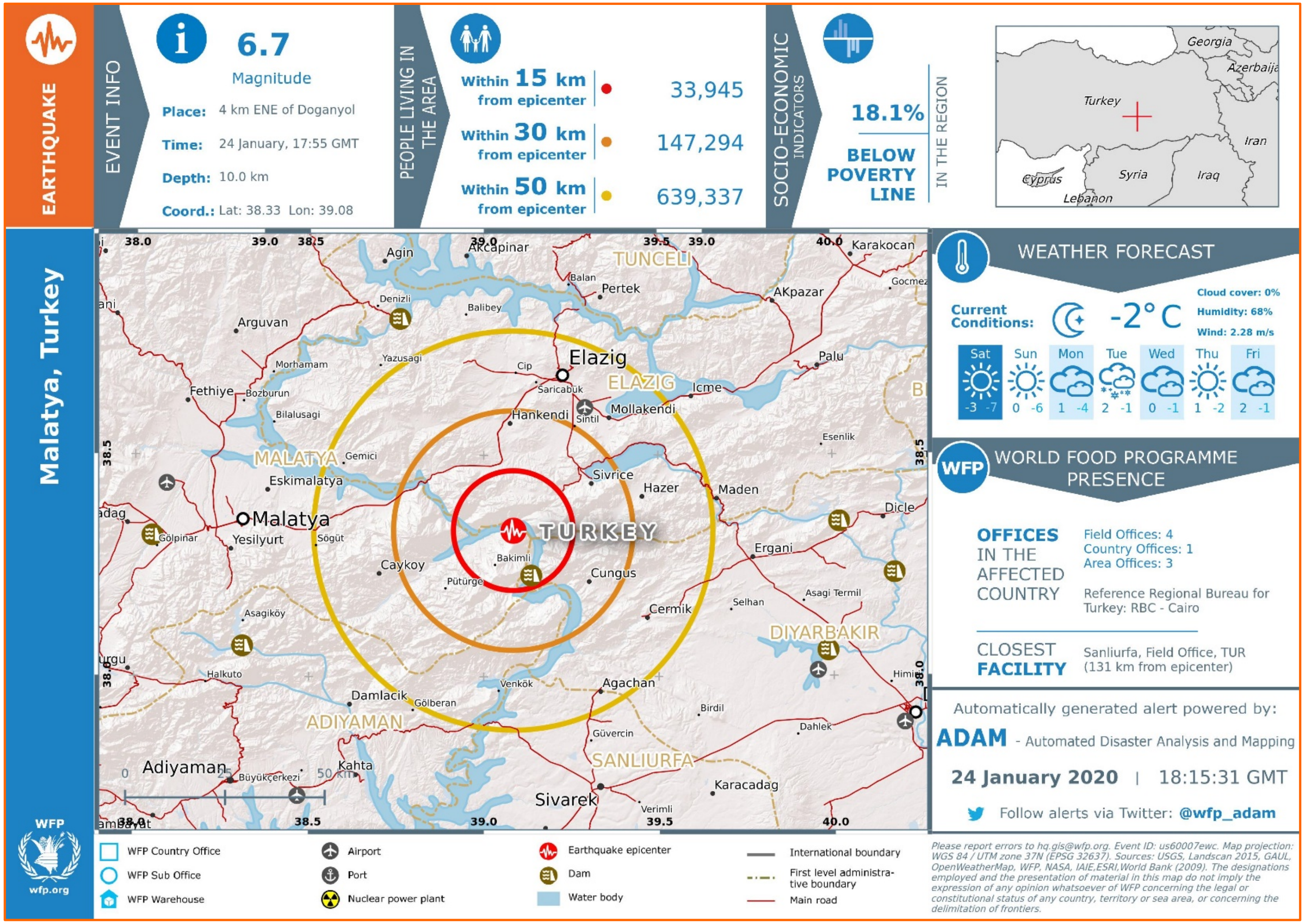


https://www.facebook.com/catnewsde/photos/a.335140110019648/1279674702232846/?type=3&theater



https://www.facebook.com/catnewsde/photos/a.335140110019648/1279763705557279/?type=3&theater

AUTOMATICALLY GENERATED DISASTER ALERT FOR THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE



Automatic Disaster Analysis and Mapping (ADAM) Disaster Alerts
https://twitter.com/WFP_ADAM/status/1220772150568804356/photo/1

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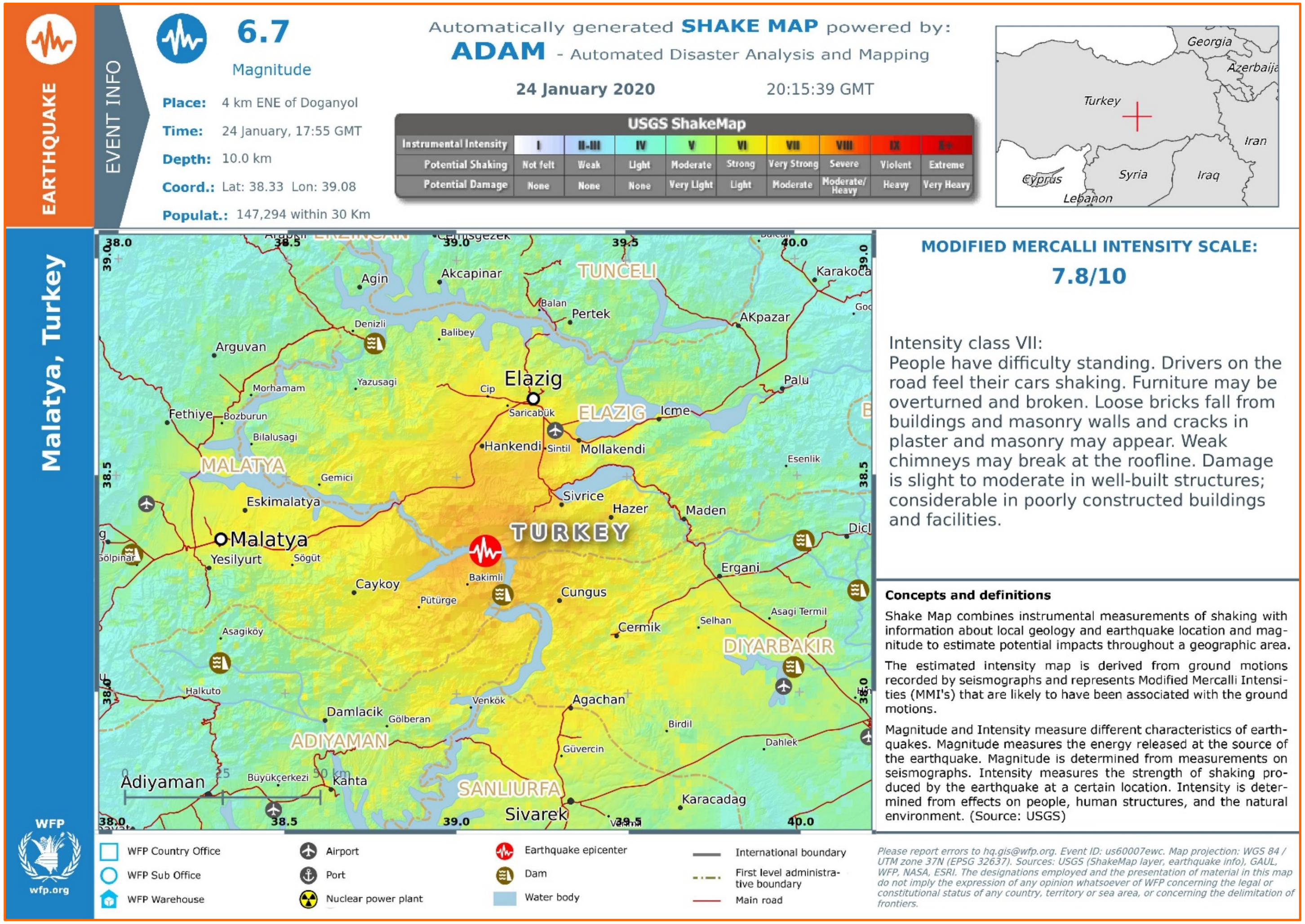
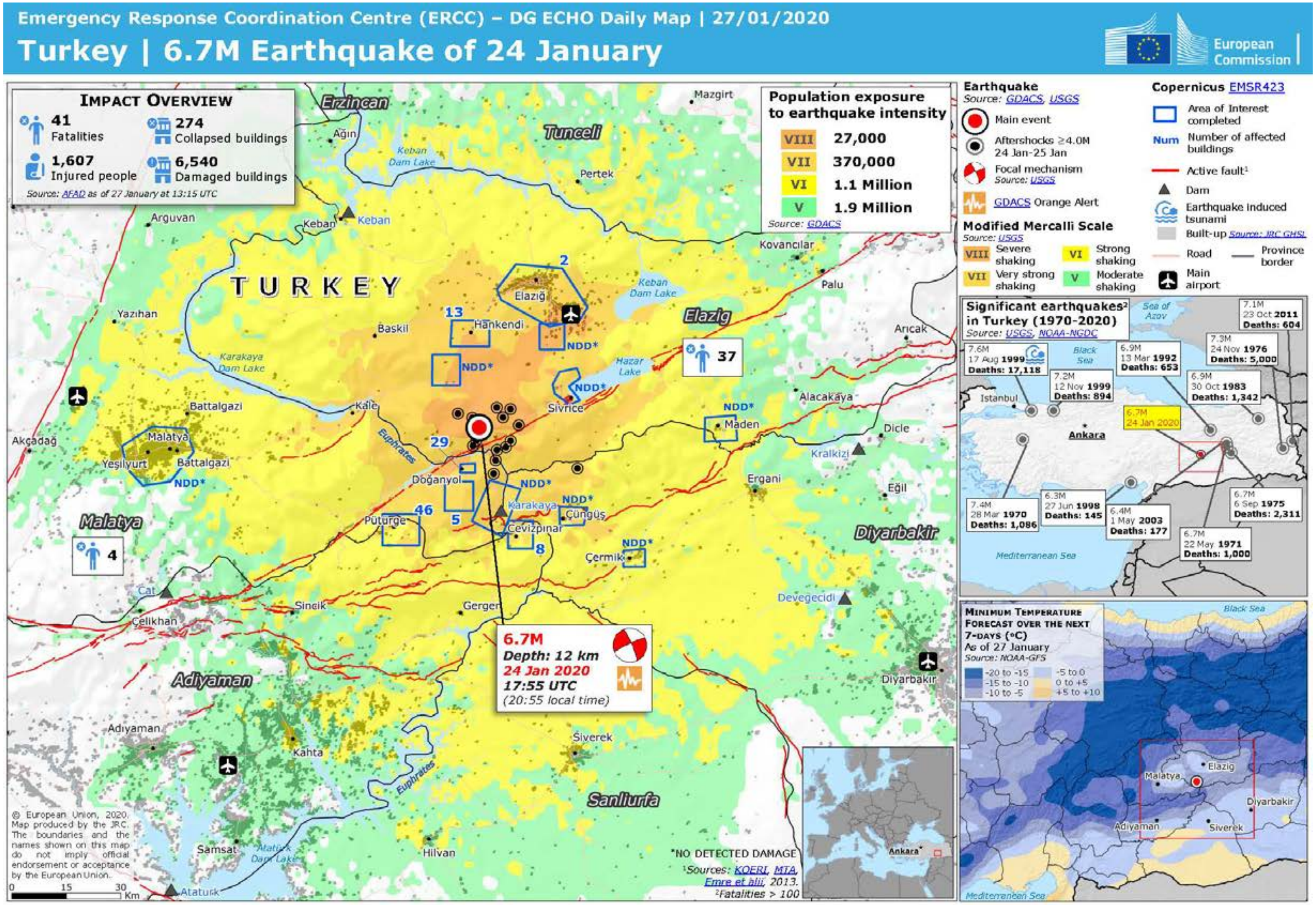
AUTOMATICALLY GENERATED SHAKE MAP FOR THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE



Automatic Disaster Analysis and Mapping (ADAM) Disaster Alerts
https://twitter.com/WFP_ADAM/status/1220804828819009537/photo/1

EMERGENCY RESPONSE COORDINATION CENTER - DG ECHO DAILY MAP ON JANUARY 27, 2020



https://erccportal.jrc.ec.europa.eu/getdailymap/docId/3207

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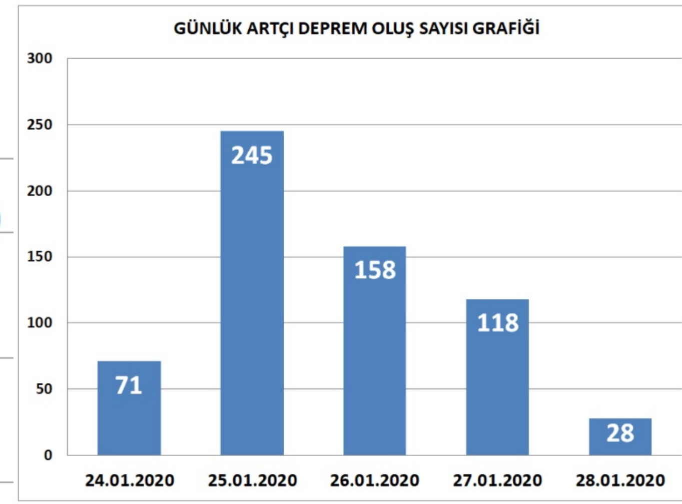
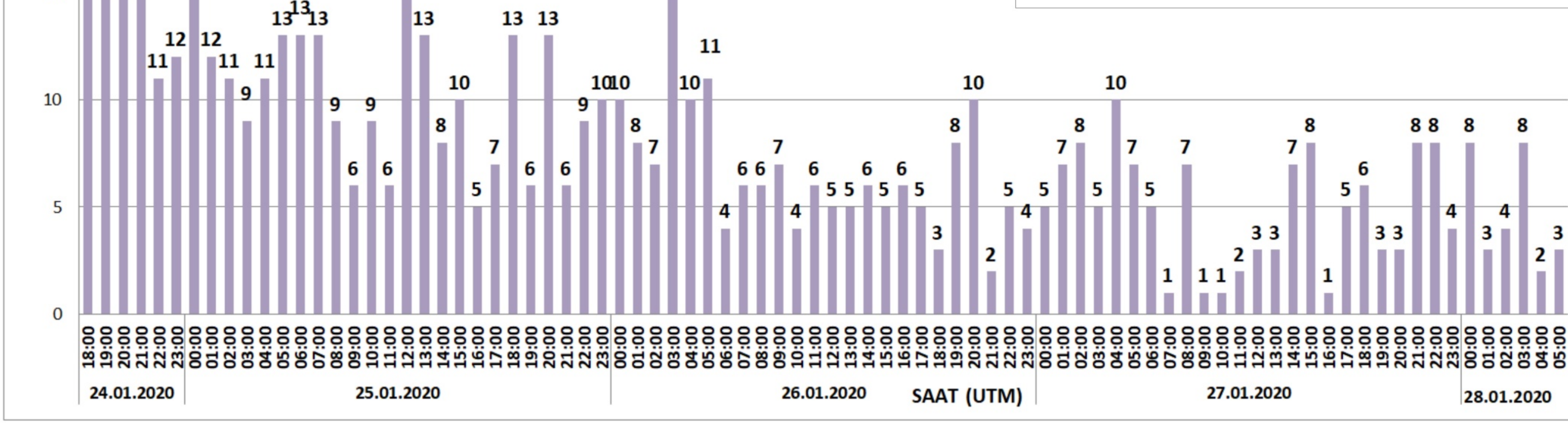
KANDiLLi OBSERVATORY AND EARTHQUAKE RESEARCH INSTITUTE 1868

AFTERSHOCK SEQUENCE OF THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE

Number of aftershocks generated after the mainshock on January 24 to January 28, 2020. The number of aftershocks is decreasing over time.





From http://www.koeri.boun.edu.tr/sismo/2/wp-content/uploads/2020/01/24_Ocak_2020_Sivrice_Elazig_Depremi_V8.pdf

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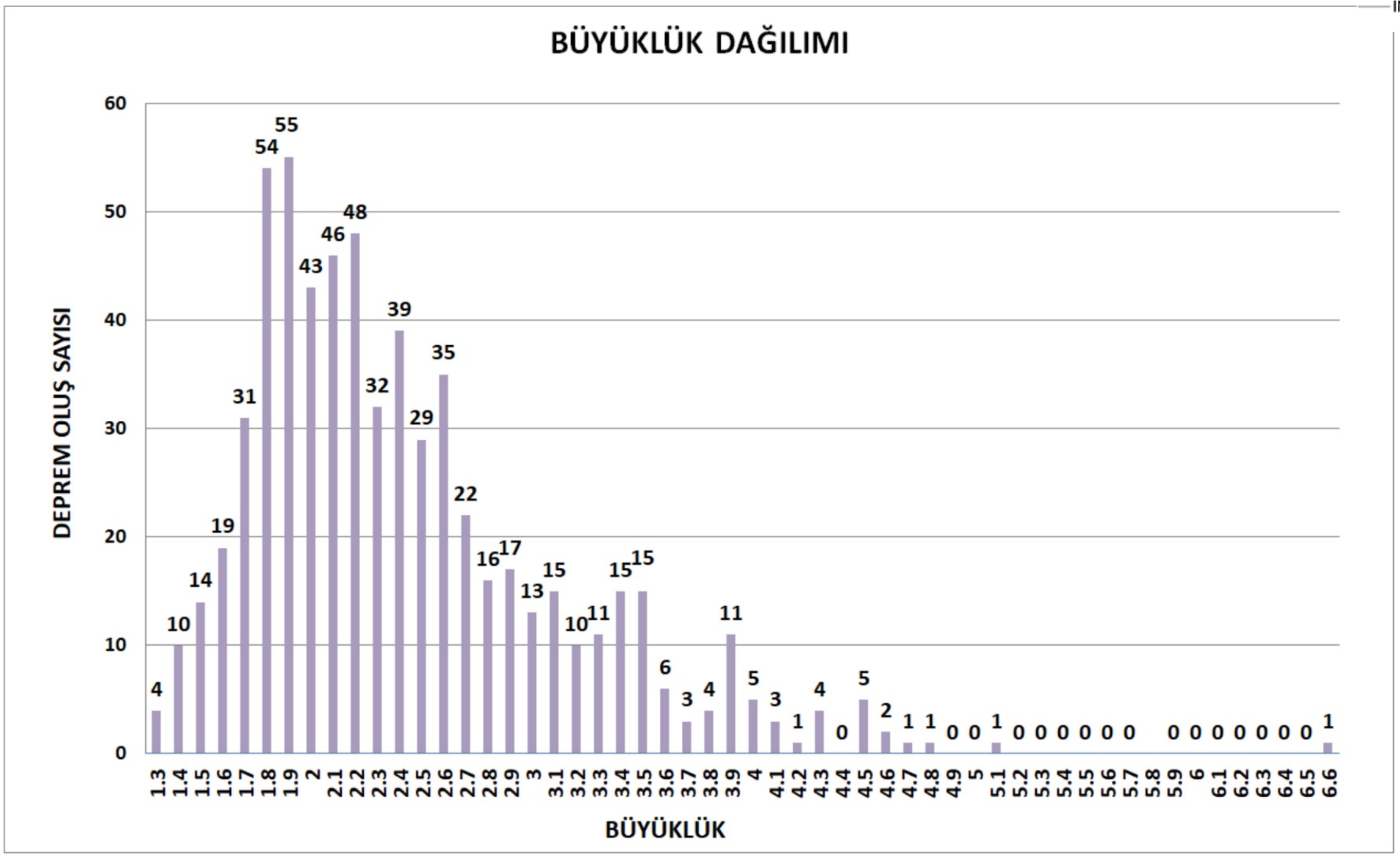
KANDİLLİ OBSERVATORY AND EARTHQUAKE RESEARCH INSTITUTE 1868

AFTERSHOCK SEQUENCE OF THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE



The aftershock sequence from January 24-28, 2020 comprised 640 seismic events. 22 events have been assessed between 4.0 and 4.9. The largest aftershock has been assessed as 5.1 on January 25.
(From http://www.koeri.boun.edu.tr/sismo/2/wp-content/uploads/2020/01/24_Ocak_2020_Sivrice_Elazig_Depremi_V8.pdf).

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SURFACE DISPLACEMENT INDUCED BY THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE

The research team of the National Observatory of Athens (NOA) comprising Dr. Athanassios Ganas, Research Director of the Geodynamic Institute of NOA, Varvara Tsironi, PhD Candidate in the Patras University and NOA researcher and Dr. Sotirios Valkaniotis, scientific collaborator of NOA) presented the first results of the processing of the satellite synthetic aperture radar (SAR) images for the M=6.8 earthquake in Elaziğ (Eastern Turkey) (pages 49-50). The image is very clear except for areas covered with snow (mountain peaks) and deep valleys that the satellite cannot observe.

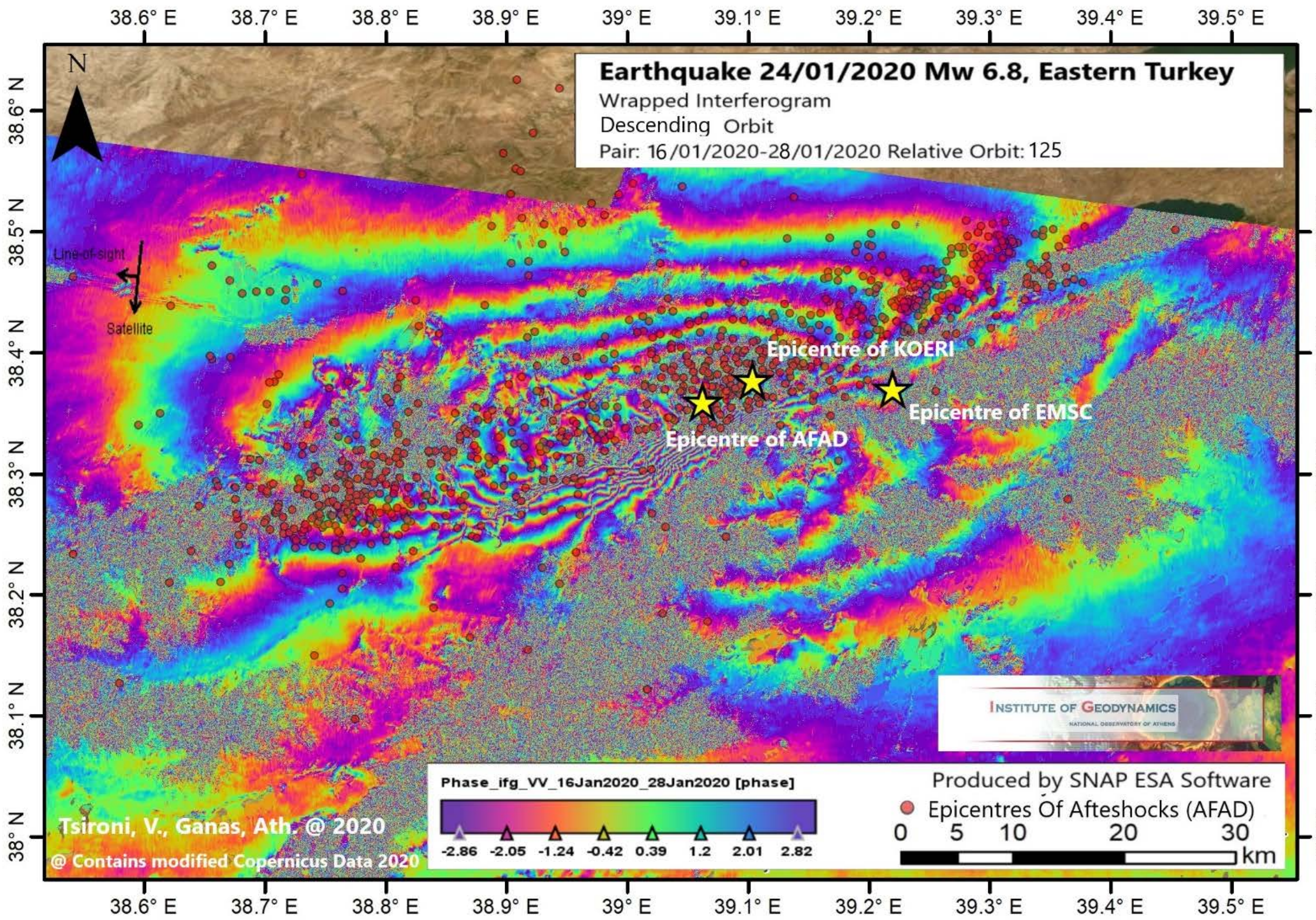
Based on the data presented by the research team of the National Observatory of Athens (NOA), the following can be drawn:

The wrapped interferogram shows that the northern fault block presented displacement of 19.6 cm and the southern fault block displacement of 14 cm. Close to the ruptured fault the displacement has been measured as 28 cm. These measurements coincides with the left lateral strike-slip offset of the Eastern Anatolian Fault Zone as well as with the seismological data including fault plane solutions and aftershock distribution of the main shock. Based on the data presented it is concluded that (i) the total length of the rupture is 40 km, (ii) the fault plane dips northwards and (iii) the deformation area is 3500 km^2 (50 km on the N-S axis and 70 km on the E-W axis).

In total, relative displacement of about 55 cm was measured along the line of sight (LOS) on either side of the ruptured fault (Puterge segment) and the length of the rupture was assessed as 40 km.

From *Tsironi and Ganas (2020)* and *Valkaniotis, Tsironi and Ganas (2020)*

SURFACE DISPLACEMENT
INDUCED BY THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE



Wrapped interferogram (descending orbit) for the January 24, 2020 Mw 6.8 Elazığ earthquake.
From *Tsironi and Ganas (2020)*

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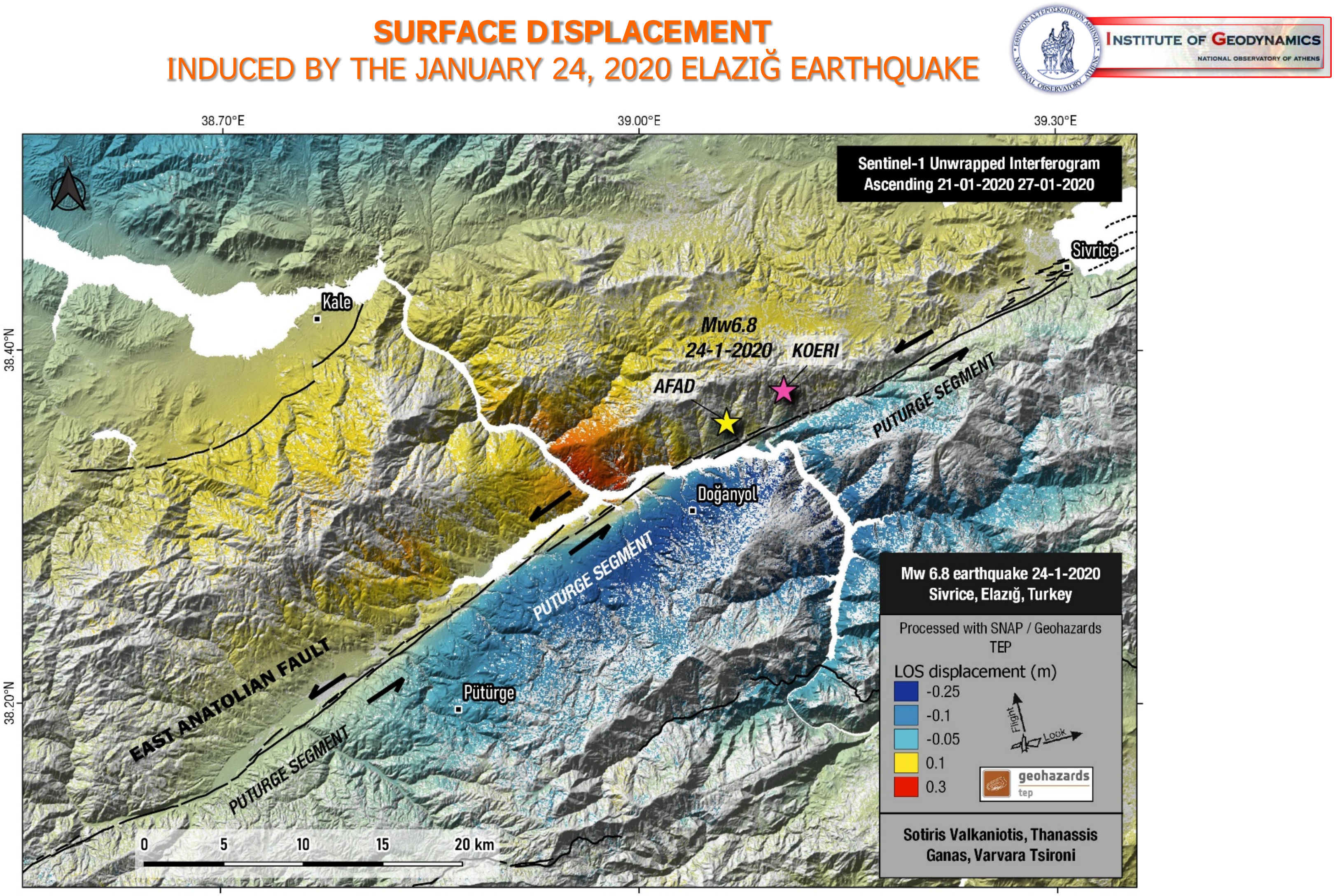
SURFACE DISPLACEMENT
INDUCED BY THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE



Sentinel-1 SAR unwrapped interferogram (ascending orbit) for the January 24, 2020 Mw 6.8 Elazığ earthquake. Color shows displacement relative to satellite (line-of-sight).
From *Valkaniotis et al. (2020)*

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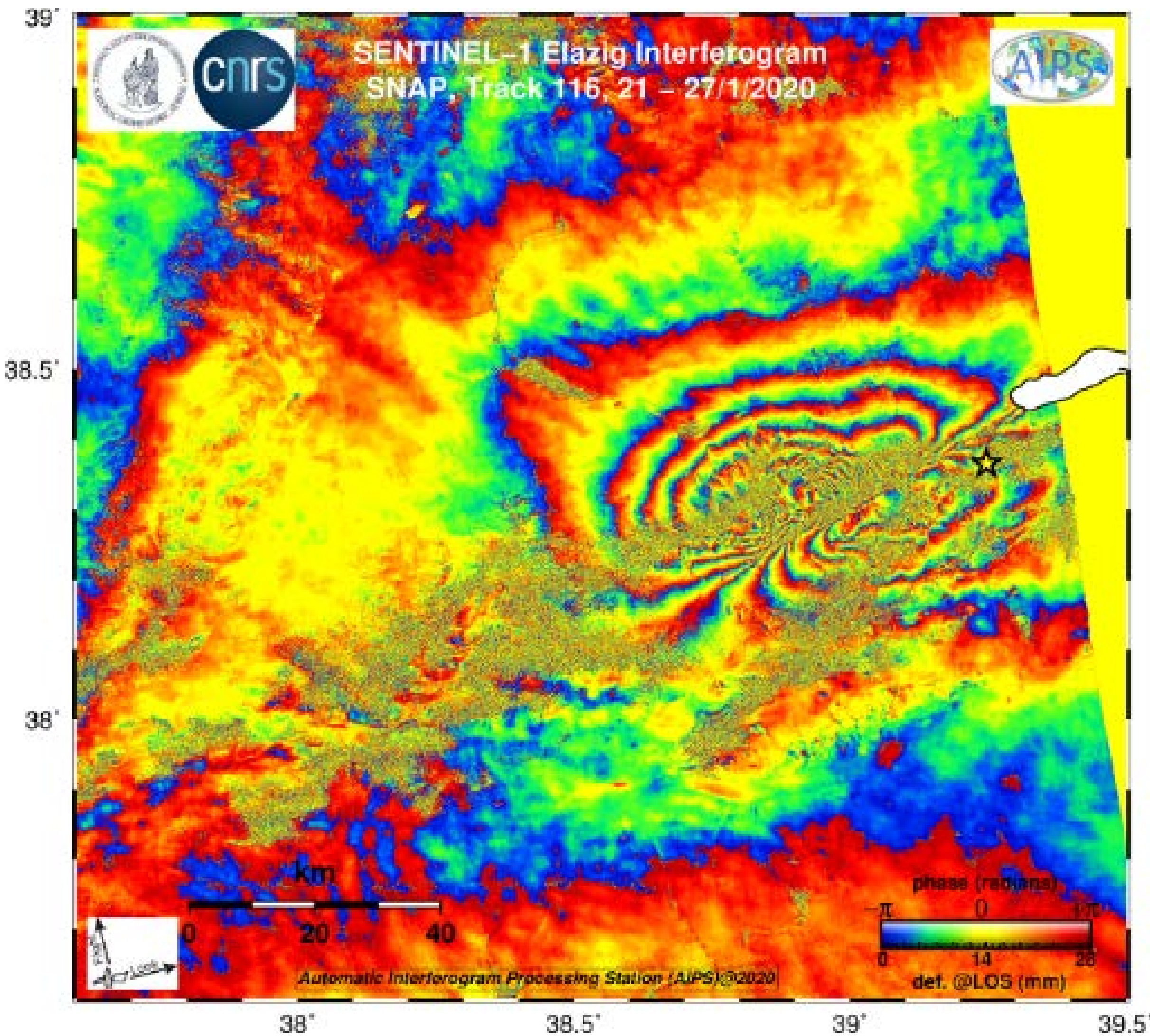
SURFACE DISPLACEMENT
INDUCED BY THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE



Differential interferogram of the January 24, 2020, Mw 6.8 Elazığ, Turkey earthquake.Two acquisitions of ascending track 116 of the SENTINEL-1 (developed by ESA for Copernicus initiate) satellite, i.e. one before (21/1/2020) and one after (27/1/2020) earthquake has been exploited 1/3.

https://twitter.com/LastQuake/status/1222076833711169541

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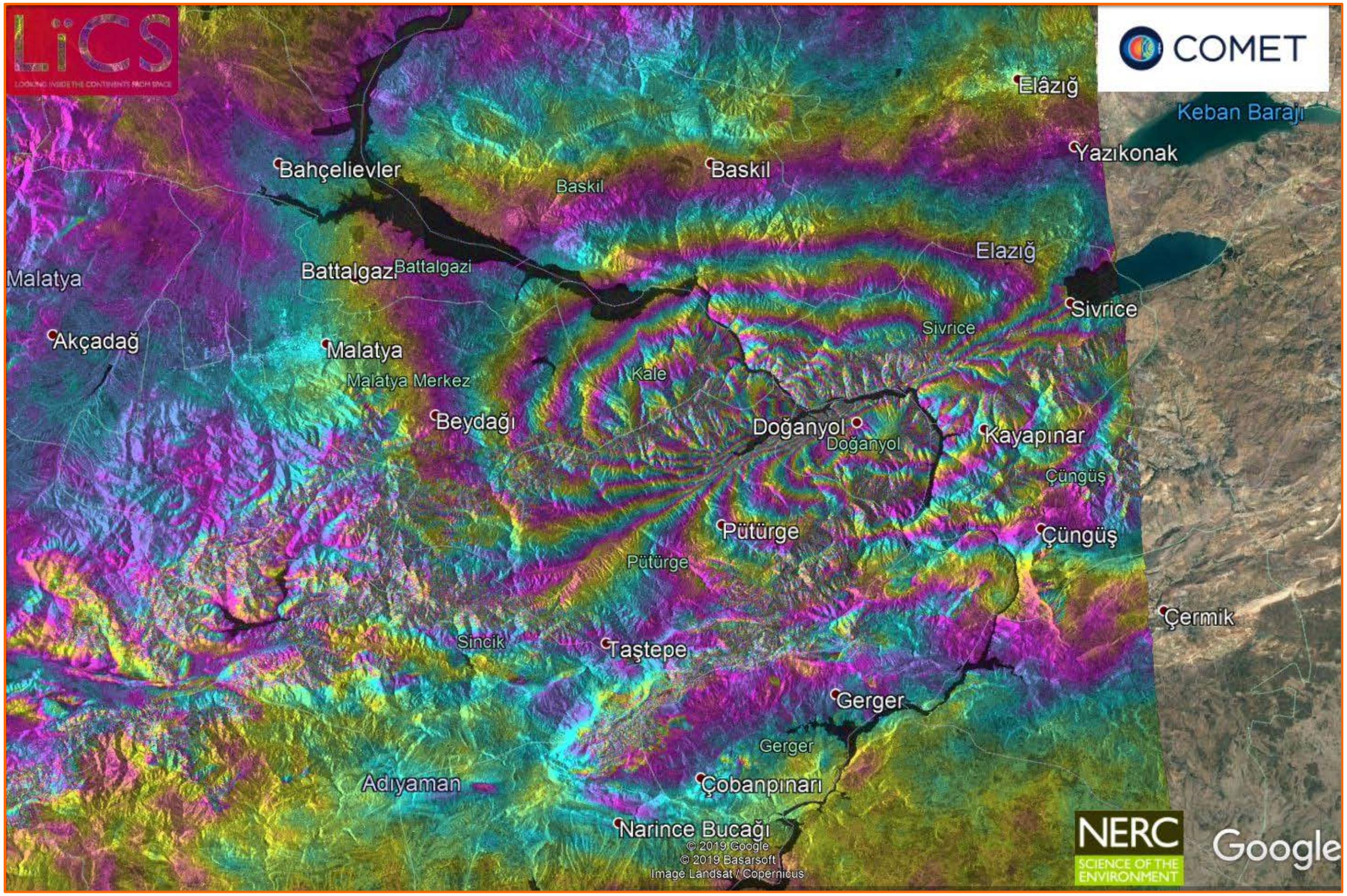
SURFACE DISPLACEMENT
INDUCED BY THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE



Ground surface displacement data from Elazig Turkey earthquake
from the NERC Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics
(From https://twitter.com/jrelliott82/status/1222074014723649536)

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EARTHQUAKE ENVIRONMENTAL EFFECTS
INDUCED BY THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE

Ground cracks were induced in sites with existing instability. No surface faulting has been observed. (From https://twitter.com/tsancar/status/1221480276846616578, https://twitter.com/tsancar/status/1222200667298770945)

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EARTHQUAKE ENVIRONMENTAL EFFECTS
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Ground cracks are attributed to the ground shaking close to gravitational movements observed in the affected area. Rockfalls and landslides were also observed in the same sites.
(From https://twitter.com/tsancar/status/1221480276846616578)

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EARTHQUAKE ENVIRONMENTAL EFFECTS
INDUCED BY THE JANUARY 24, 2020 ELAZIĞ EARTHQUAKE

Liquefaction phenomena were generated along ground cracks. Hydrological anomalies comprised the formation of new hot sping within the Şiro River bed in Pütürge-Malatya area. (From https://twitter.com/tsancar/status/1221480276846616578, https://twitter.com/tsancar/status/1222081414109237248)

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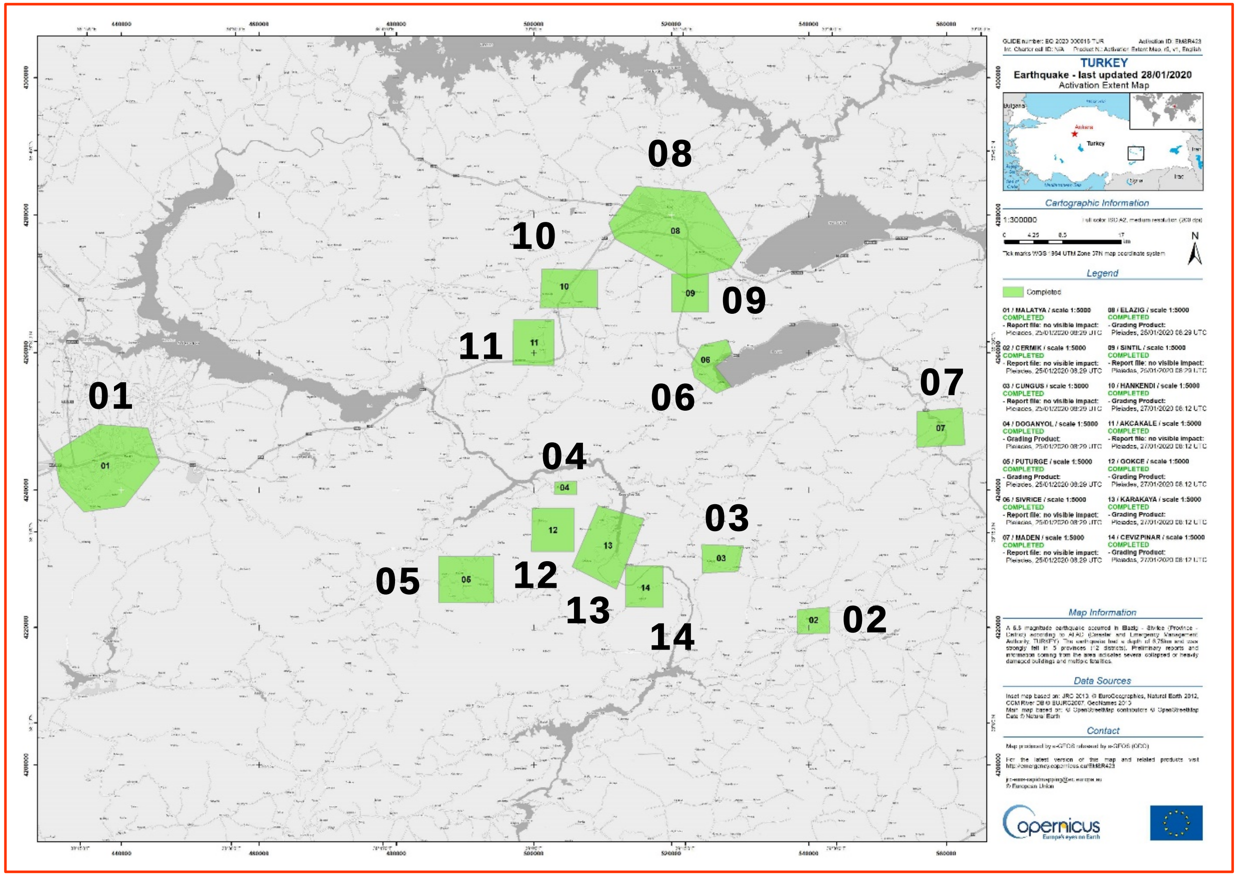
COPERNICUS
EMERGENCY MANAGEMENT SERVICE - MAPPING



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

01 Malatya
02 Cermik
03 Cungus
04 Doganyol
05 Puturge
06 Sivrice
07 Maden
08 Elazig
09 Sintil
10 Hankendi
11 Akcakale
12 Gokce
13 Karakaya
14 Cevizpinar

From
https://emergency.copernicus.eu/mapping/sites/default/files/thumbnails/EMSR423-AEM-1580198124-r05-v1.jpg

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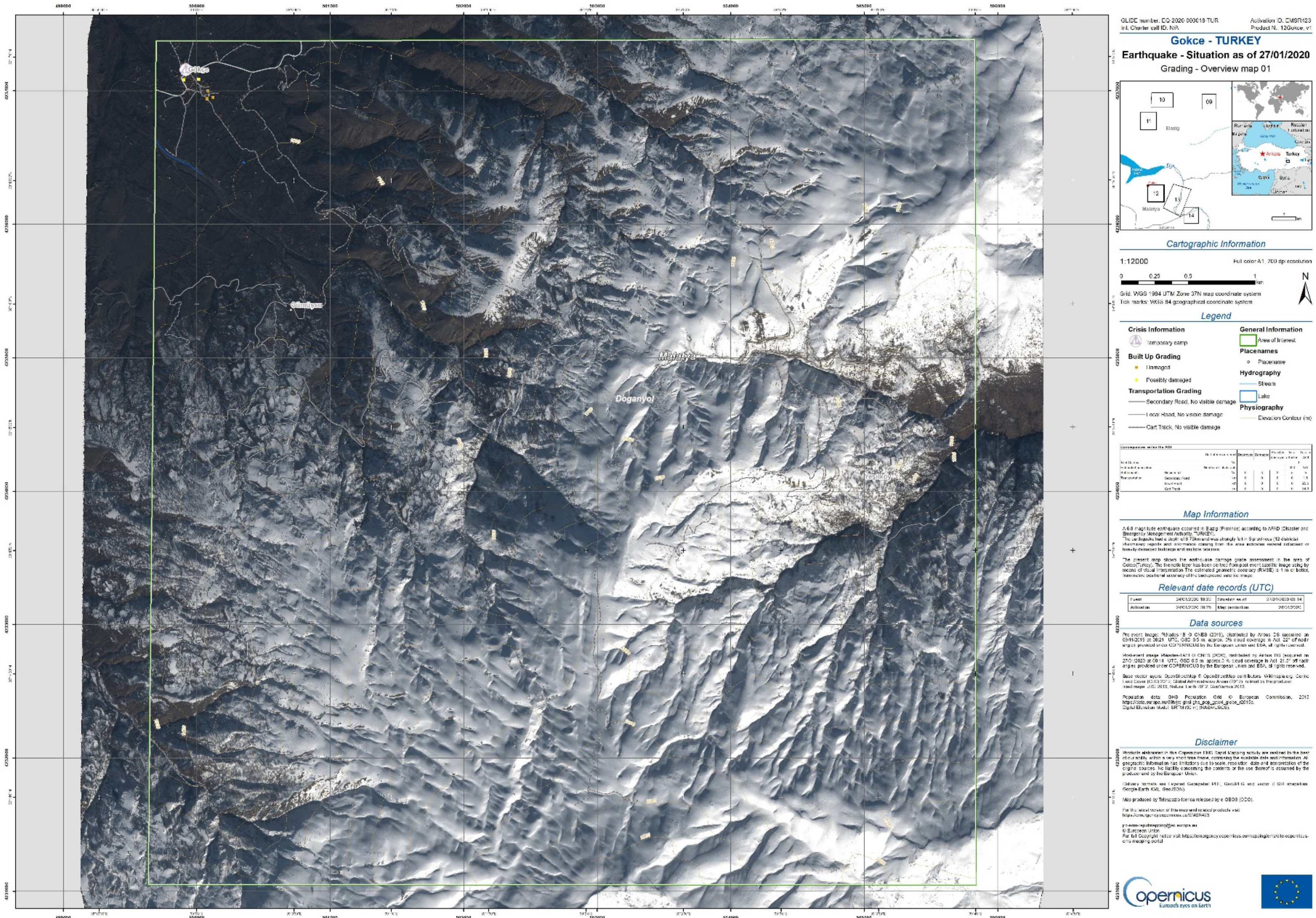
COPERNICUS MAP FOR GÖKÇE



https://emergency.copernicus.eu/mapping/system/files/components/EMSR423_AOI12_GRA_PRODUCT_r1_RTP01_v1.jpg

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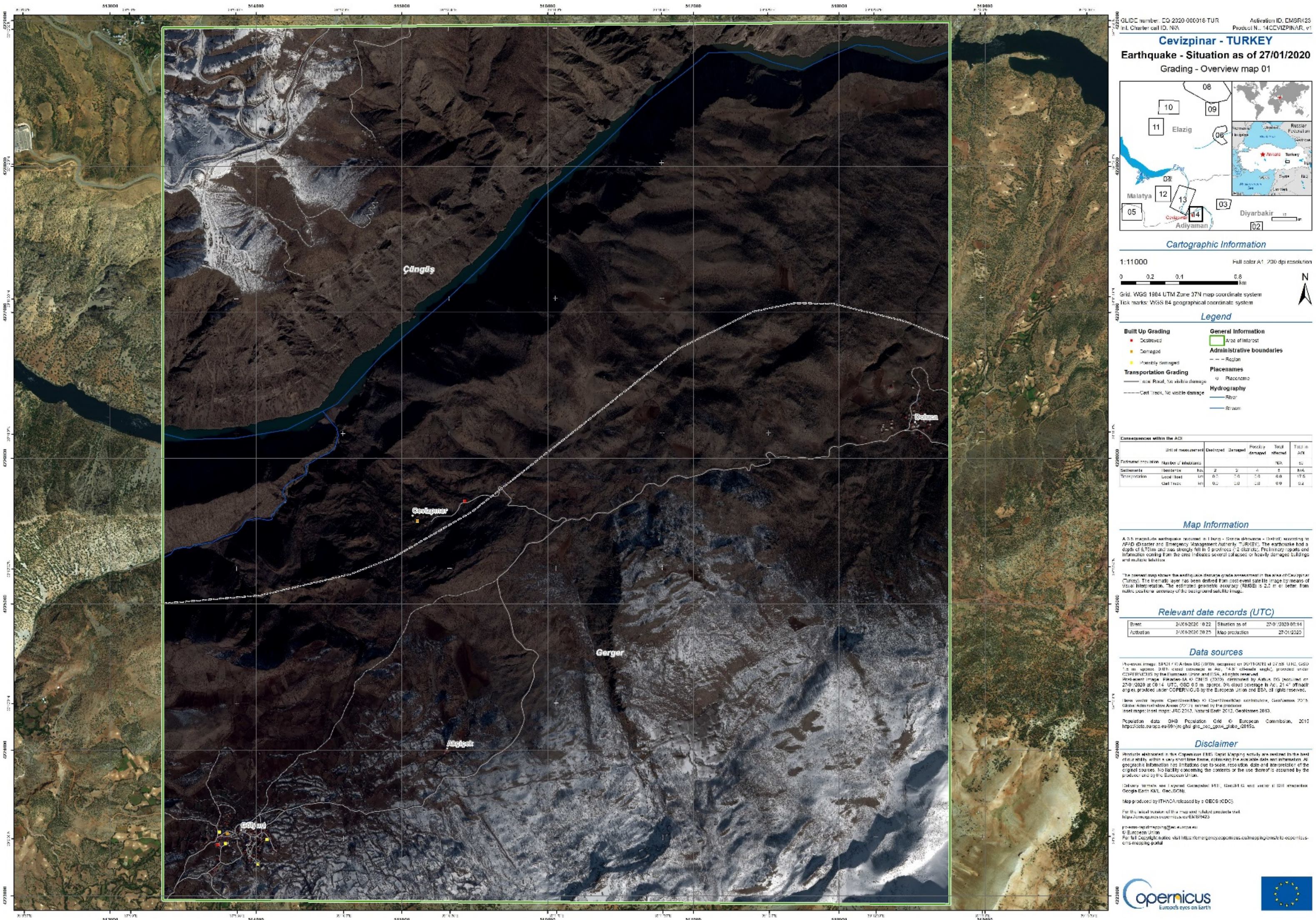
COPERNICUS MAP FOR CEVIZPINAR



https://emergency.copernicus.eu/mapping/system/files/components/EMSR423_AOI14_GRA_PRODUCT_r1_RTP01_v1.jpg

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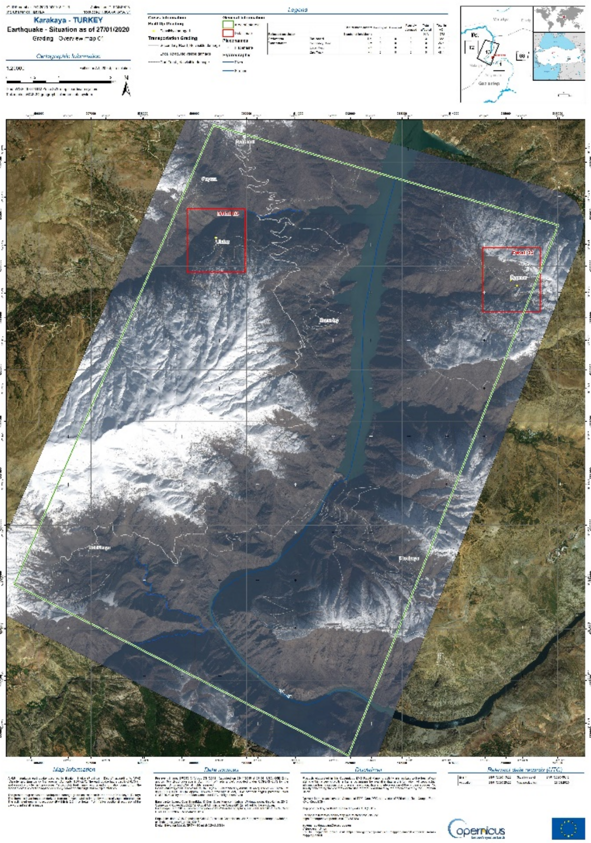
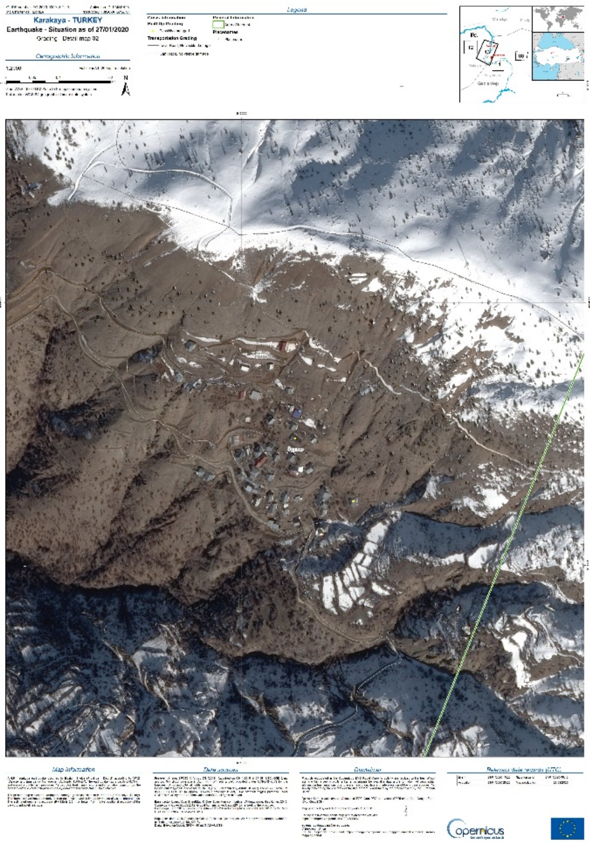
COPERNICUS MAPS FOR KARAKAYA





https://emergency.copernicus.eu/mapping/system/files/components/EMSR423_AOI13_GRA_PRODUCT_r1_RTP01_v1.jpg
https://emergency.copernicus.eu/mapping/system/files/components/EMSR423_AOI13_GRA_PRODUCT_r1_RTP02_v1.jpg
https://emergency.copernicus.eu/mapping/system/files/components/EMSR423_AOI13_GRA_PRODUCT_r1_RTP03_v1.jpg

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COPERNICUS MAP FOR HANKENDI

https://emergency.copernicus.eu/mapping/system/files/components/EMSR423_AOI10_GRA_PRODUCT_r1_RTP01_v1.jpg

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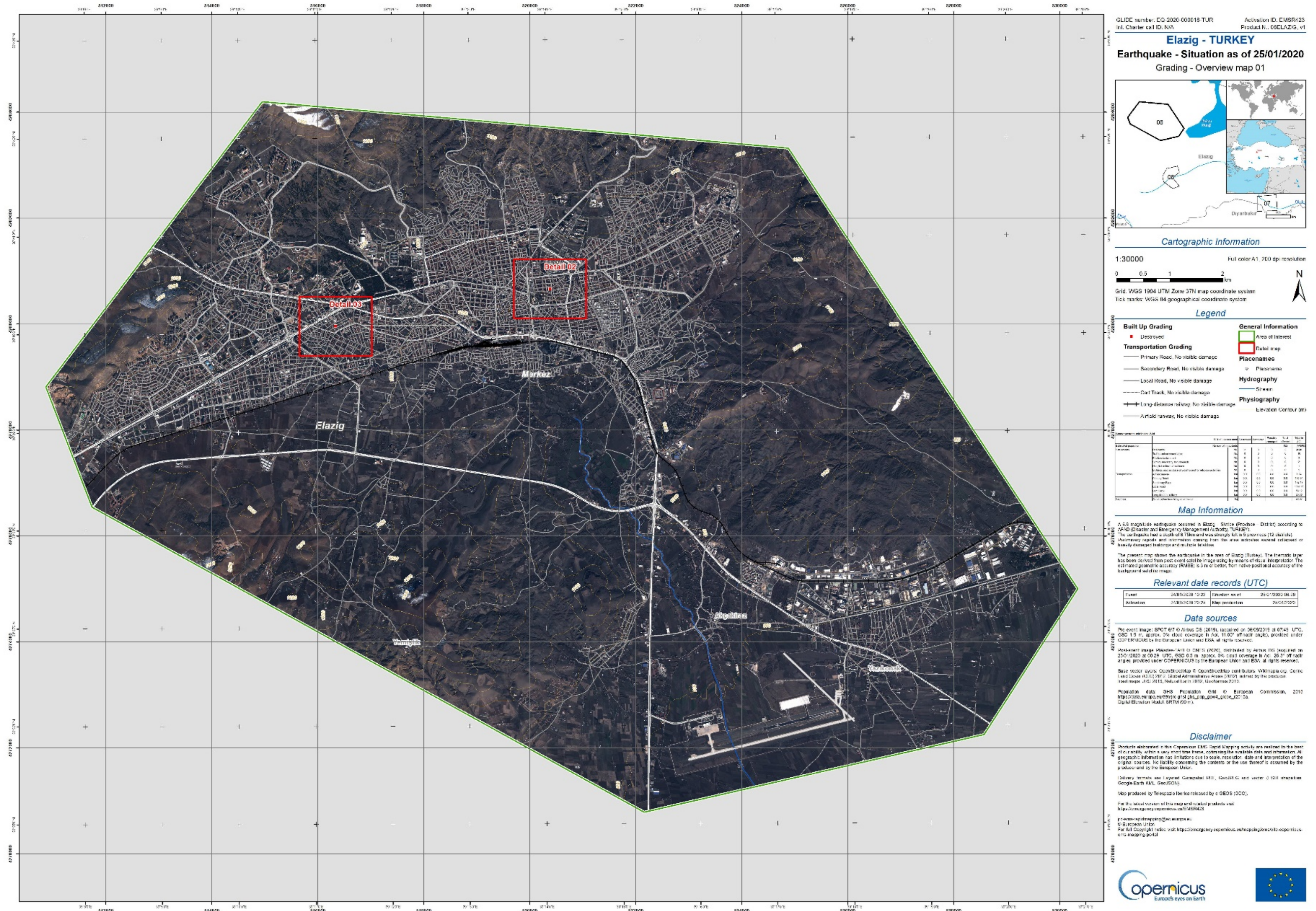
COPERNICUS MAP FOR ELAZIĞ CITY



https://emergency.copernicus.eu/mapping/system/files/components/EMSR423_AOI08_GRA_PRODUCT_r1_RTP01_v1.jpg

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COPERNICUS MAP FOR ELAZIĞ CITY

https://emergency.copernicus.eu/mapping/system/files/components/EMSR423_AOI08_GRA_PRODUCT_r1_RTP02_v1.jpg

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COPERNICUS MAP FOR ELAZIĞ CITY

https://emergency.copernicus.eu/mapping/system/files/components/EMSR423_AOI08_GRA_PRODUCT_r1_RTP03_v1.jpg

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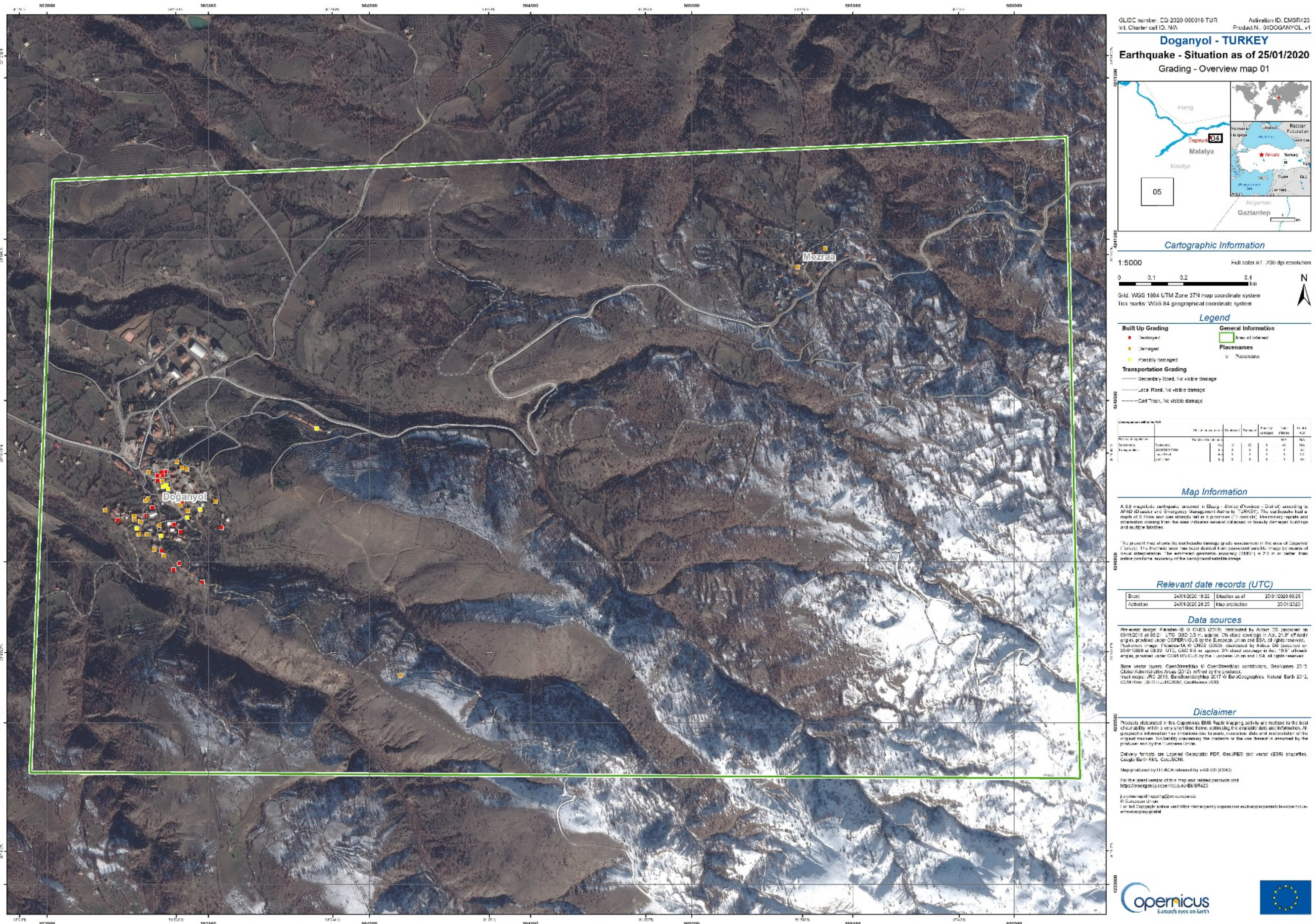
COPERNICUS MAP FOR DOGANYOL



https://emergency.copernicus.eu/mapping/system/files/components/EMSR423_AOI04_GRA_PRODUCT_r1_RTP01_v1.jpg

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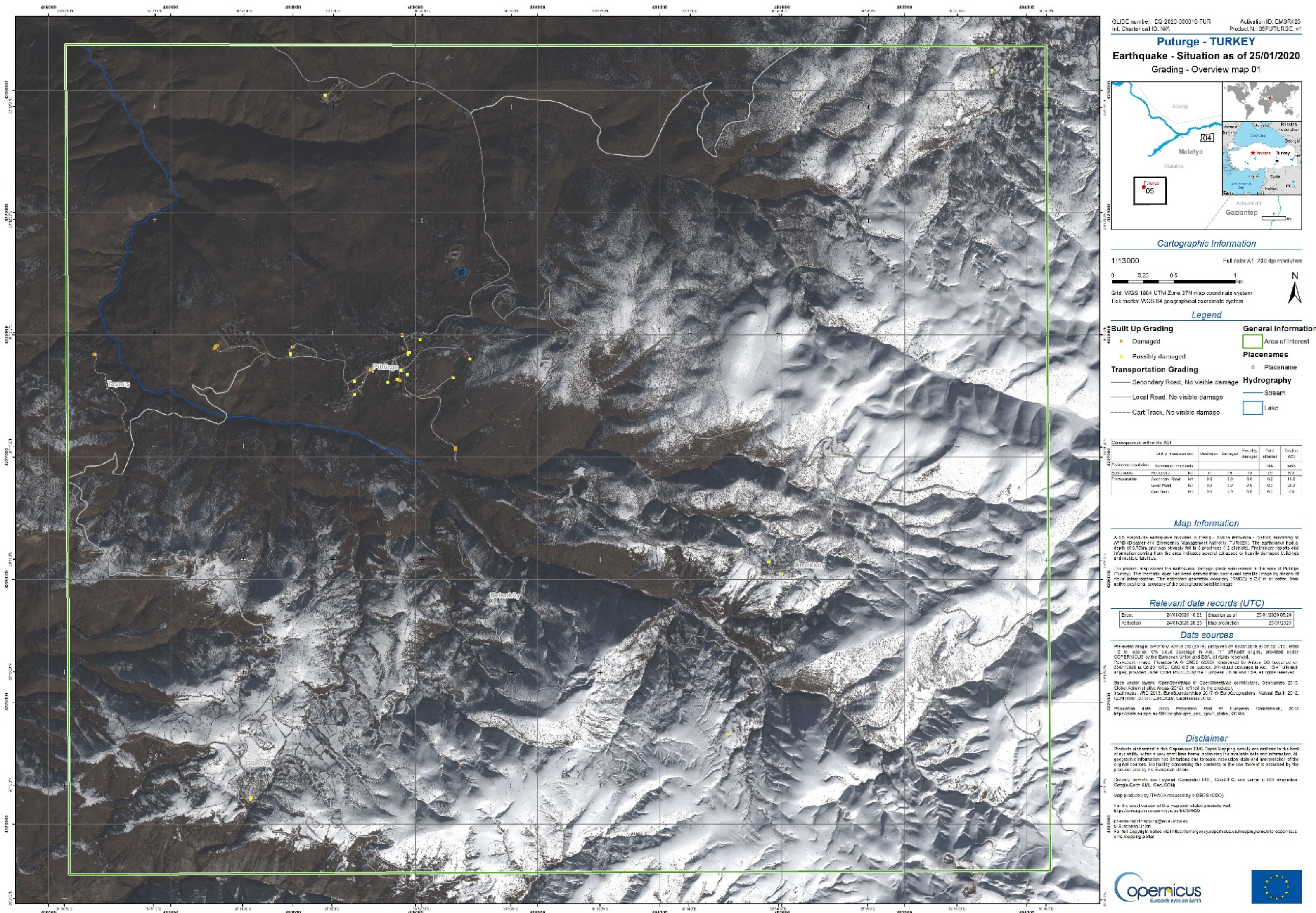
COPERNICUS MAP FOR PÜTÜRGE



https://emergency.copernicus.eu/mapping/system/files/components/EMSR423_AOI05_GRA_PRODUCT_r1_RTP01_v1.jpg

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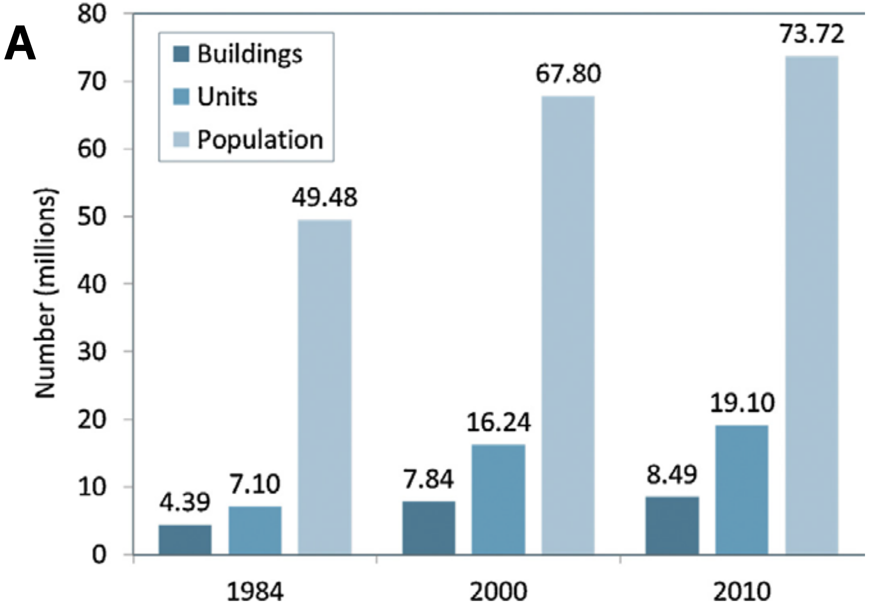
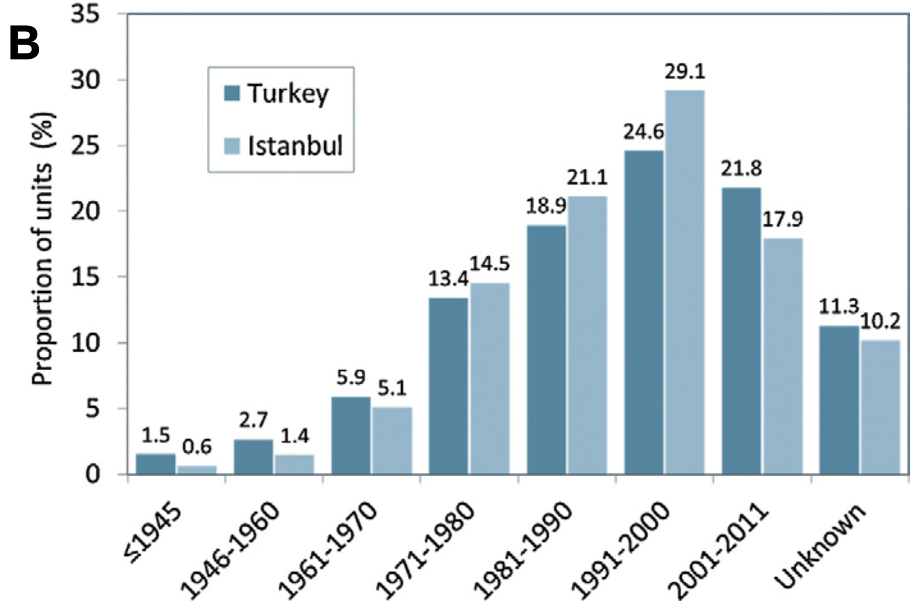
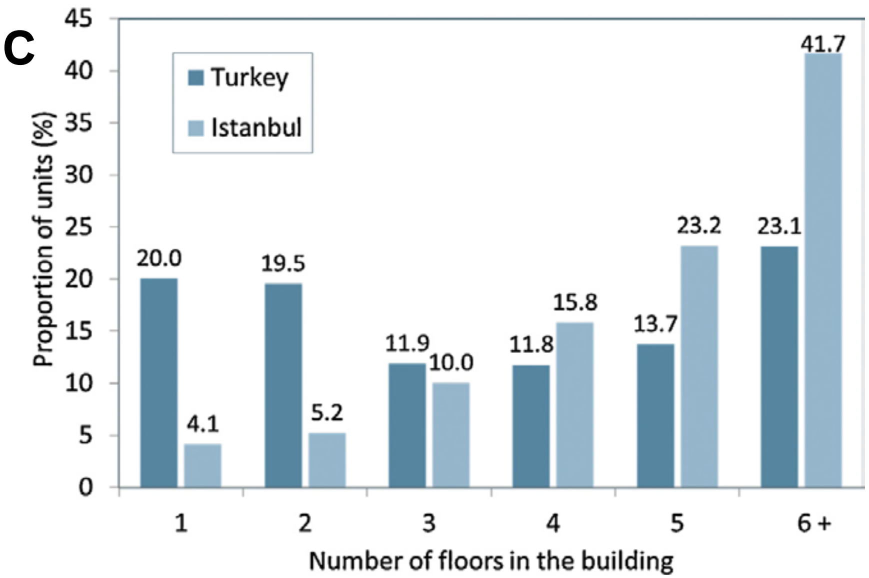
RESIDENTIAL BUILDINGS IN TURKEY







(**A**) Total number of buildings and occupancy units in Turkey

(**B**) Proportions of occupancy units by the construction year of buildings in Istanbul and Turkey

(**C**) Distribution of occupancy units by the number of floors in the building in Istanbul and Turkey

From *Gunes (2015)* and
the Turkish Statistical Institute (TUIK)

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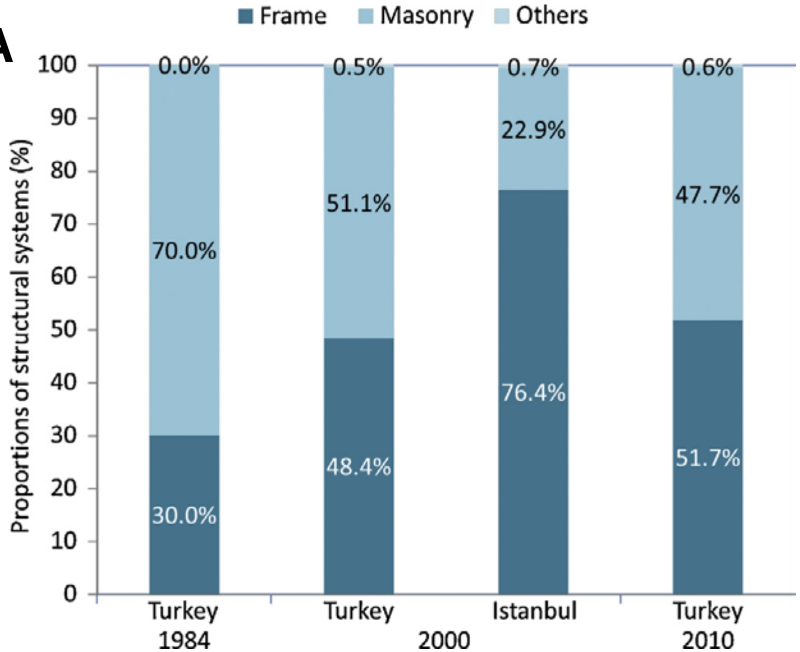
DOMINANT TYPES OF RESIDENTIAL BUILDINGS IN TURKEY

A



(**A**) Distribution of buildings in Istanbul and Turkey by their structural system: frame, masonry, other type.

(**B**) Representative examples of buildings based on their construction period. Four generations are presented: 1960s, 1970s, 1980s, 1990s and later.

From *Gunes (2015)* and *the Turkish Statistical Institute (TUIK)*

B

1st generation buildings (1960s)

2nd generation buildings (1970s)

3rd generation buildings (1980s)

4th generation buildings (90s and later)

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DOMINANT BUILDING TYPES IN THE AFFECTED AREA
REINFORCED CONCRETE (RC) BUILDINGS WITH RC FRAME AND INFILL WALLS OF DIFFERENT PERIODS



In general, Turkish residential buildings in urban regions have reinforced concrete structural systems (*Cogurcu et al., 2015*). However, some of them have several deficiencies, such as low concrete quality, non-seismic reinforcement detailing and inappropriate structural systems including several architectural irregularities among others (*Cogurcu et al., 2015*). Because most of the current buildings in Turkey were constructed before Turkish Earthquake Code 2007 (TEC 2007), their earthquake-resistance features are insufficient and their structural irregularities pose a danger. Another important point is that many of the buildings that have structural irregularities are high-rise buildings.

The previously enforced 2007 version was the first to include state of the art performance based evaluation concepts. It has been revised in 2018 and became legally effective on January 1, 2019.The new code consists of 17 chapters, most of them revised, where there are new chapters on high-rise, seismically isolated, cold-formed steel and timber buildings within the code.

The dominant building type in the affected cities of the 2020 Elaziğ earthquake is the reinforced concrete (RC) structures with RC frame and infill walls. These structures are built in different periods with the more recent ones designed and constructed according to stringent antiseismic building codes.

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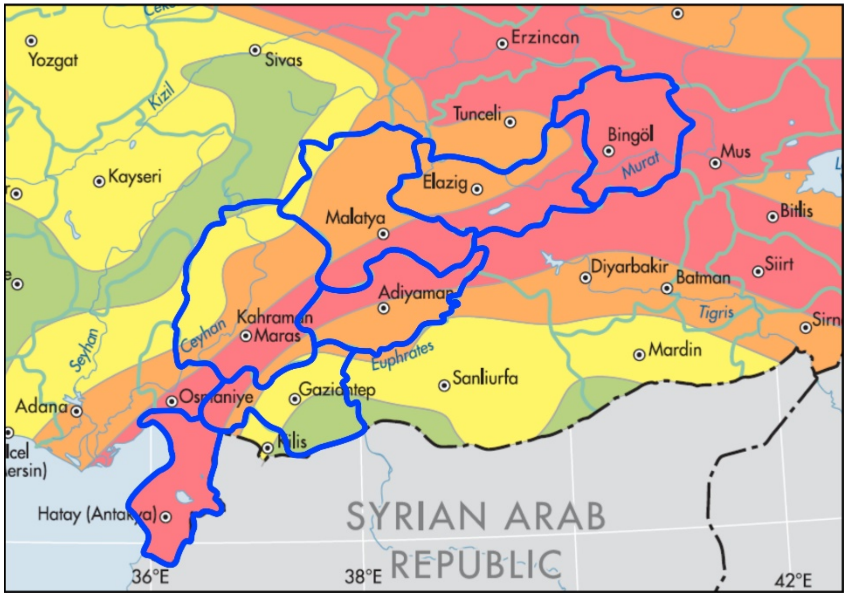
BUILDING INSURANCE AGAINST EARTHQUAKE RISK IN TURKEY

▼ Seismic hazard zones map of Eastern Turkey



▶ Percentage of building insurance against earthquakes in the provinces of Eastern Turkey (data from *AKSAN newspaper* published on *January 25, 2020)*

Deprem ülkesi Türkiye'de konutların sadece yarısı sigortalı. 6.8'lik depremin vurduğu Elazığ'da ise bu oran yüzde 35. Elazığ, Doğu Anadolu fay hattındaki 7 il arasında da en düşük sigorta oranına sahip.

ELAZIĞ ve Malatya'da cuma gecesi meydana gelen 6.8'lik sarsıntı, deprem sigortası olmayan konutları yeniden gündeme geldi. Doğal Afet Sigortaları Kurumu'nun (DASK) verileri, konutların hala yarısının zorunlu deprem sigortası olmadığını ortaya koydu. Verilere depremin etkilediği Doğu Anadolu fay hattındaki illerde bu oran daha düşük. Halen Doğu Anadolu fay hattı üzerinde son dönemde en fazla zarar göre Elazığ ve Malatya'nın yanı sıra Hatay, Kahramanmaraş, Adıyaman, Bingöl ve Gaziantep yer alıyor.

ÜÇ EVDEN İKİSİ SİGORTASIZ

6.8 şiddetindeki büyük depremle sarsılan ve ardından yüzlerce artçı sarsıntının meydana geldiği Doğu Anadolu deprem kuşağı üzerinde bulunan Elazığ, yüzde 35 ile deprem sigortasının en az olduğu illerin başında yer alıyor. Elazığ'da 123 bin 310 konutun sadece 43 bin 147'si sigortalı. Yine depremden en çok etkilenen Malatya'da da 165 bin 690 konuttan 62 bin 984'ü, yani yüzde 38'i sigortalı.

FAY HATTI ÜZERİNDEKİ İLLERDE SİGORTA ORANI

İl	%	Toplam konut	Sigortalı konut
Bingöl	72.3	30.780	22.262
Elazığ	35.0	123.310	43.147
Malatya	38.0	165.690	62.934
Kahramanmaraş	45.7	188.050	85.926
Adıyaman	43.6	78.750	34.347
Gaziantep	52.9	290.980	154.015
Hatay	41.3	274.450	113.290

Toplam konut (Türkiye) 17.682.050
Sigortalı konut (Türkiye) 9.500.000
TÜRKİYE DASK ORANI % 53.8

BİNGÖL BİLİNÇLENDİ

DOĞU Anadolu fay hattı üzerinde DASK oranı Türkiye ortalaması olan yüzde 53.8'i geçen sadece Bingöl var. Bingöl'de DASK oranı yüzde 72.30. Bunda 2003'teki 6.4'lük deprem sonrasında halkın bilinçlenmesinin etkili olduğu belirtiliyor. Yine verilere göre bölgedeki toplam 1.8 milyon konutun sadece 702 bini sigortalı. Türkiye genelinde ise toplam 17.6 milyon konutun 9.5 milyon konutun zorunlu deprem sigortası var. Türkiye'de en yüksek sigorta ise 1999 depreminde 2.500'ün üzerinde kişinin öldüğü Yalova'da bulunuyor. Yalova'daki konutların yüzde 85.5'i sigortalı. Bu oran İstanbul'da ise 67.3 seviyesinde.

SİGORTA BİRLİĞİ'NDEN DEPREMZEDEYE ÇAĞRI

TÜRKİYE Sigorta Birliği Başkanı Atilla Benli, depremde evi, aracı, iş yeri, eşyaları hasar gören sigortalılara çağrıda bulundu. Benli "Depreme karşı yapısal ve yapısal olmayan önlemleri almanın yanı sıra evimizi, işyerimizi sigorta teminatıyla güvenceye almamız da şart. Sigorta teminatı vatandaşımıza depremden sonra hasar tazminatını alıp hayata kaldığı yerden devam etme şansı veriyor" dedi. Benli, sigorta sektörü olarak deprem hasarı olan Elazığ, Malatya ve civar bölgelerdeki sigortalılar için çalışmaları başlattıklarını da belirtti.

Building insurance against earthquakes in Turkey is widespread. The total number of buildings in Turkey is 17.682.050 buildings, of which 9.500.000 buildings (53.8%) are insured. In the January 2020 earthquake-affected area, it is clear that the heavier damage was reported in Elaziğ and Malatya provinces, which are characterized by low percentage of insured housing (35% and 38% respectively). In contrast, provinces with higher percentage of insured housing have suffered slight damage. It is significant to note that in Bingöl province, which was severely affected in 2003 by an earthquake with Mw 6.4 and maximum IX_{MM}, the percentage of insured buildings is one of the highest in Eastern Turkey.

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BUILDING DAMAGE
IN THE MOST AFFECTED CITIES OF EASTERN TURKEY

AFAD

SITUATION	ELAZIĞ	MALATYA	TOTAL
Undamaged	229	118	347
Small Damage	174	229	503
Medium Damage	37	1	38
Heavily Damaged	116	529	645
Collapsed	20	56	76
To be Demolished Urgently	12	-	12
TOTAL	**588**	**933**	**1.521**

As a part of damage detection activities, 1.521 buildings were surveyed.
Results of damage detection activities are written above.
https://en.afad.gov.tr/press-release-17--response-and-rehabilitation-continues-in-the-aftermath-of-earthquake-in-elazig-and-malatya

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DAMAGE IN RC BUILDINGS (1/3)

Close to Elaziğ city, there is a residential complex consisting of about 10 5-storey residential buildings which are identical, based on a uniform horizontal ground. The damage observed was almost identical comprising column damage at a height of about 70 - 80 cm from the ground. This damage is attributed to poor construction quality in combination with the prevailing strong vertical component of the earthquake ground motion.

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DAMAGE IN RC BUILDINGS (2/3)

Light damage comprise detachment of plaster pieces from the brick infill walls and detachment of pieces of concrete from the columns in the corners where the walls meet. The first damage is non-structural, while the second can adversely affect the antiseismic performance of the building by reducing the strength of the columns. The presented damage was generated in the lower parts of the building and more specifically in the ground floor.

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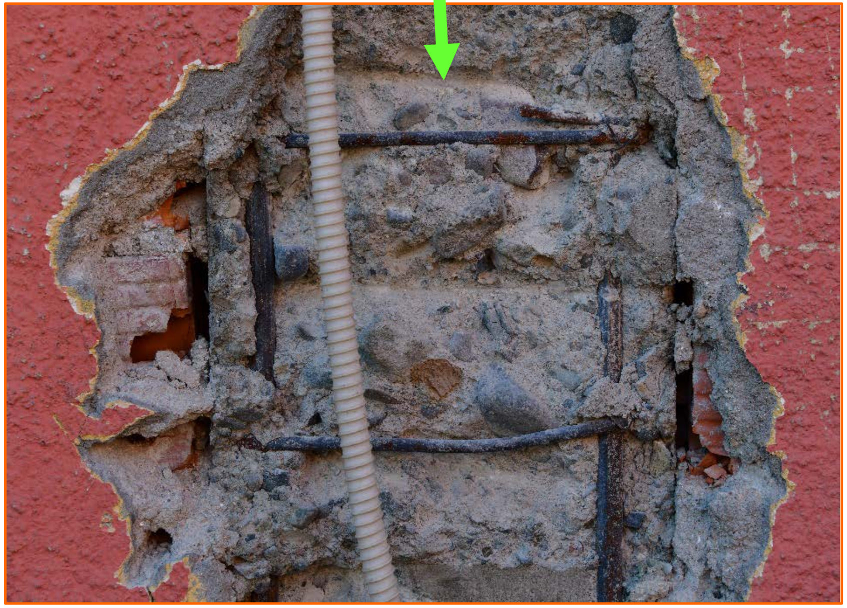
DAMAGE IN RC BUILDINGS (3/3)



Similar non-structural damage in the infill walls and structural damage in the columns in the corners of the ground floor of a reinforced concrete building in Elaziğ city.

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DAMAGE IN MOSQUES

The majority of mosques in the affected area were built with masonry techniques. The mosques generally feature one or more domes, the surrounding masonry walls and the adjacent minarets. In the affected areas of eastern Turkey, mosques suffered damage to the surrounding walls comprising detachment of plasters from the masonry walls, cracking and partial collapse of the masonry walls.

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DAMAGE IN MINARETS

▲ From *Oliveira et al. (2012)*

Based on *Oliveira et al. (2012)*, the basic elements of the minaret are: footing, boot, transition segment, cylindrical or polygonal body, stairs, balcony, upper part of the minaret body, spire/cap and end ornament. They may be built with cut-stone, brick, or a mixture of both. The top is usually a 3-D timber structure covered by 5-mm-thick lead sheets. Iron clamps hold wall blocks together.

The masonry minarets were observed to fail in their upper part of their body, in their spire and in their end ornament. Most minarets in Elaziğ city present failure of the end ornament and collapse of the spire attributed to the action of the vertical component of the earthquake ground motion and the excitation of construction with small amplitude high seismic vibration of several cycles.

▶ Minarets in Elaziğ city

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VERY HEAVY STRUCTURAL DAMAGE IN RC BUILDINGS
PARTIALLY OR TOTALLY COLLAPSED BUILDINGS IN ELAZIĞ CITY

A partially collapsed building in Elaziğ city. It appears to be identical in construction to adjacent buildings. The adjacent buildings remained almost intact by the earthquake.

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VERY HEAVY STRUCTURAL DAMAGE IN RC BUILDINGS
PARTIALLY OR TOTALLY COLLAPSED BUILDINGS IN ELAZIĞ CITY

This building in Elaziğ city collapsed almost within its foundation plan in the well known form of pancake. This indicates the prevalence of the vertical component of the earthquake ground motion, even in this strike-slip seismic event.

A macroseismic epicenter has been created close to the affected areas due to the adverse local soil conditions.

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VERY HEAVY STRUCTURAL DAMAGE IN RC BUILDINGS
PARTIALLY OR TOTALLY COLLAPSED BUILDINGS IN ELAZIĞ CITY




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VERY HEAVY STRUCTURAL DAMAGE IN RC BUILDINGS
PARTIALLY OR TOTALLY COLLAPSED BUILDINGS IN ELAZIĞ CITY

The presented residential building was among the totally collapsed buildings in Elaziğ city. The destruction was almost complete with debris leaving no gaps and empty spaces between them. The tangled mass of earthquake building debris reflects not only the strong seismic motion, but also the poor construction of buildings and the inadequate quality of construction materials.

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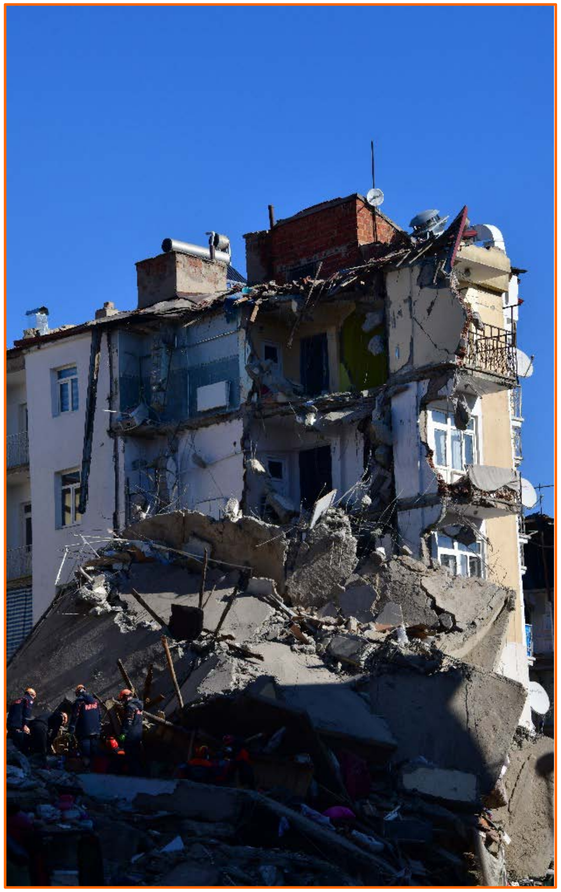
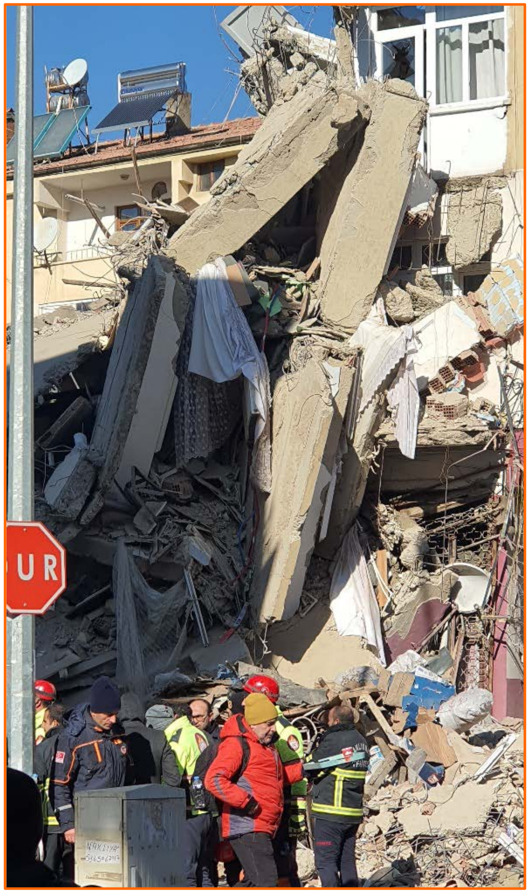
VERY HEAVY STRUCTURAL DAMAGE IN RC BUILDINGS
PARTIALLY OR TOTALLY COLLAPSED BUILDINGS IN ELAZIĞ CITY





This multistorey reinforced concrete building in Elaziğ city suffered partial collapse after the January 24, 2020 earthquake. Its remaining still-standing parts are practically undamaged. Spatial homothetic motions indicated the dominance of the vertical component of the earthquake ground motion.

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VERY HEAVY STRUCTURAL DAMAGE IN RC BUILDINGS
PARTIALLY OR TOTALLY COLLAPSED BUILDINGS IN ELAZIĞ CITY

Details of the damage induced by the January 24, 2020 earthquake on the previously presented building

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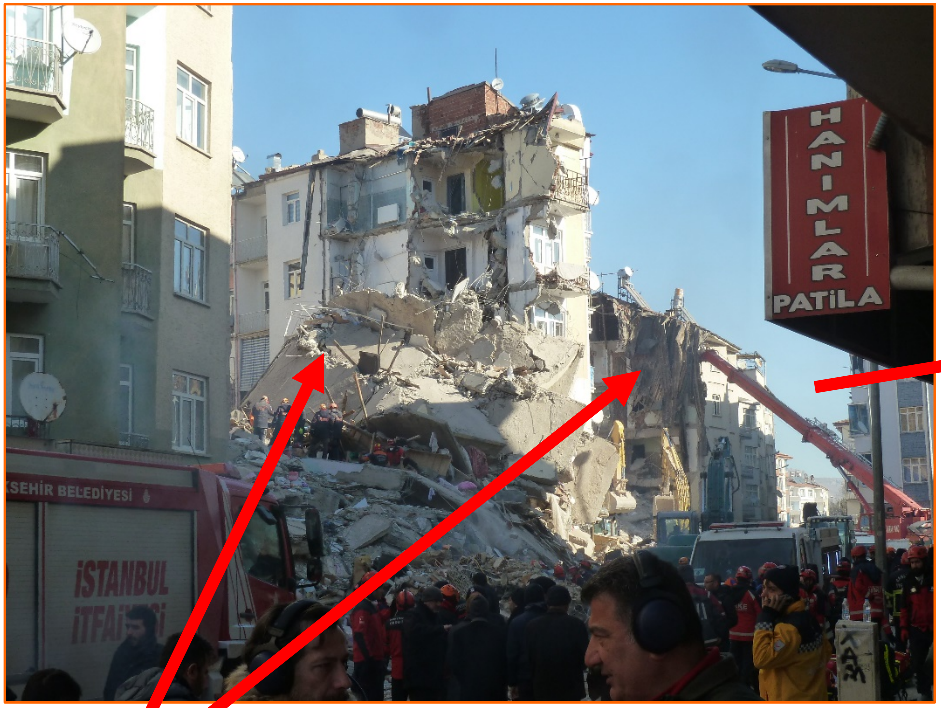
VERY HEAVY STRUCTURAL DAMAGE IN RC BUILDINGS
PARTIALLY COLLAPSED BUILDINGS IN ELAZIĞ CITY



Two buildings in the same neighborhood in Elazig city has suffered collapse of their southwestern parts. The direction of the collapse indicates not only the direction of maximum ground velocity and acceleration but also information about the microseismic and macroseismic epicenter.

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CONCLUSIONS

The January 24, 2020 Mw 6.98 earthquake in Eastern Turkey has been generated by the rupture of the Pütürge segment of the Eastern Anatolian Fault, which was considered as a seismic gap.

The affected area of the Eastern Turkey experienced similar destructive earthquakes in the historical past. The 1875 (Ms 6.7) and 1905 (Ms 6.8) earthquakes might have been generated along this segment based on Ambraseys (1988).

The dominant building type in the affected area of the 2020 Elaziğ earthquake is the reinforced concrete (RC) structures with RC frame and infill walls. These structures are built in different periods with the more recent ones designed and constructed according to stringent antiseismic building codes.

The damage was observed in Elaziğ and Malatya provinces in Eastern Turkey, which are located close to the ruptured fault.

More specifically, very heavy structural damage was locally observed in three localities of the aforementioned provinces, while adjacent localities remained almost untouched by the earthquake.

The most affected Elaziğ and Malatya provinces are characterized by low percentage of insured housing (35% and 38% respectively). In contrast, provinces with higher percentage of insured housing have suffered slight damage. It is significant to note that in Bingöl province, which was severely affected in 2003 by an earthquake with Mw 6.4 and maximum IX_{MM}, the percentage of insured buildings is one of the highest in Eastern Turkey.

Damage is attributed to the synergy of several factors comprising poor construction quality, construction defects, inadequate quality of construction materials in combination with the prevailing strong vertical component of the earthquake ground motion.


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Em. Professor Panayotis Carydis
PhD c. Spyridon Mavroulis
The January 24, 2020
Mw 6.8 Elazığ (Turkey)
Earthquake
Elazığ , 2020