FIG Working Week 2016
CHRISTCHURCH, NEW ZEALAND
2–6 May 2016
Recovery from disaster

GPS-constrained estimate of present-day slip rate along major faults of Turkey

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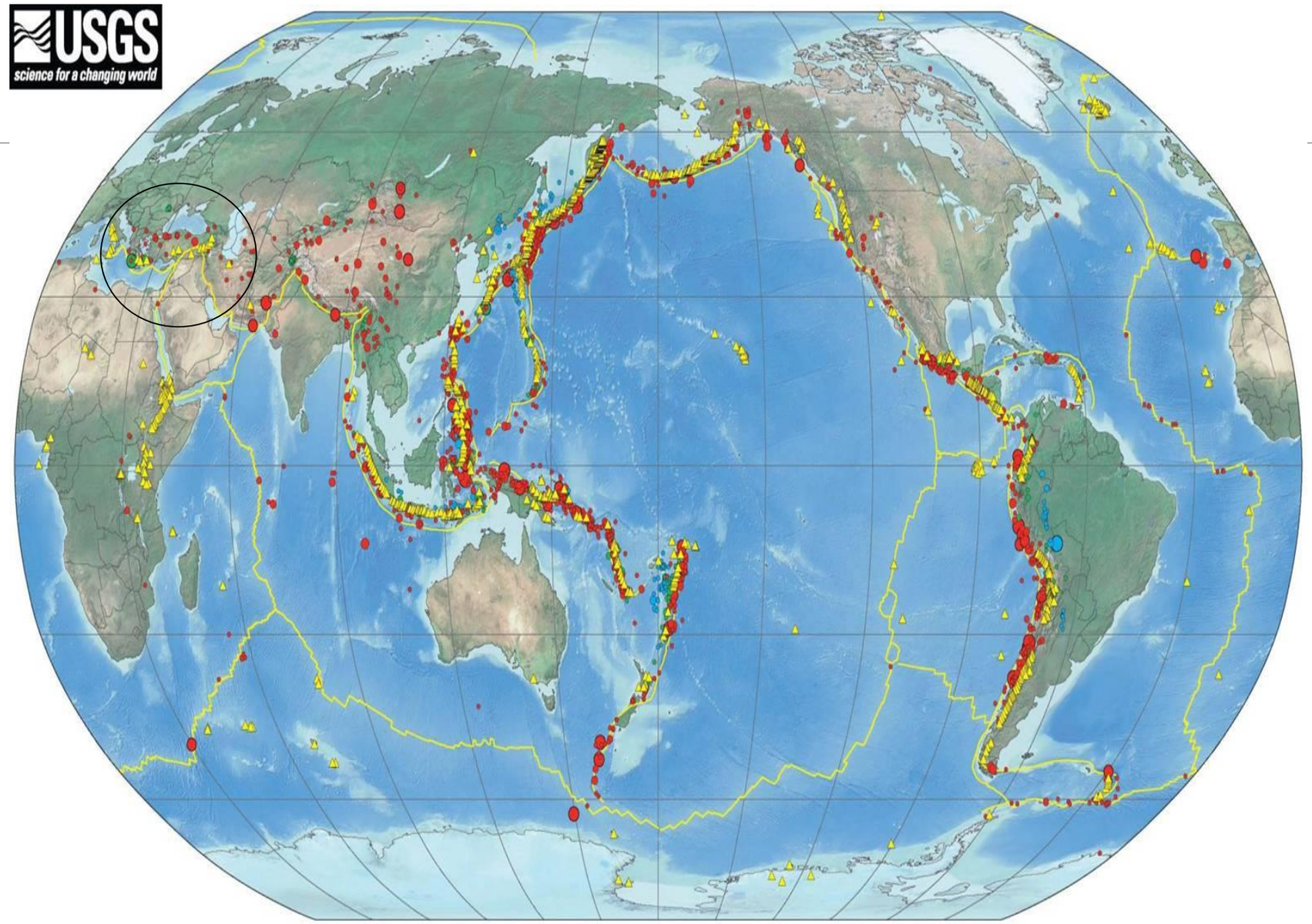
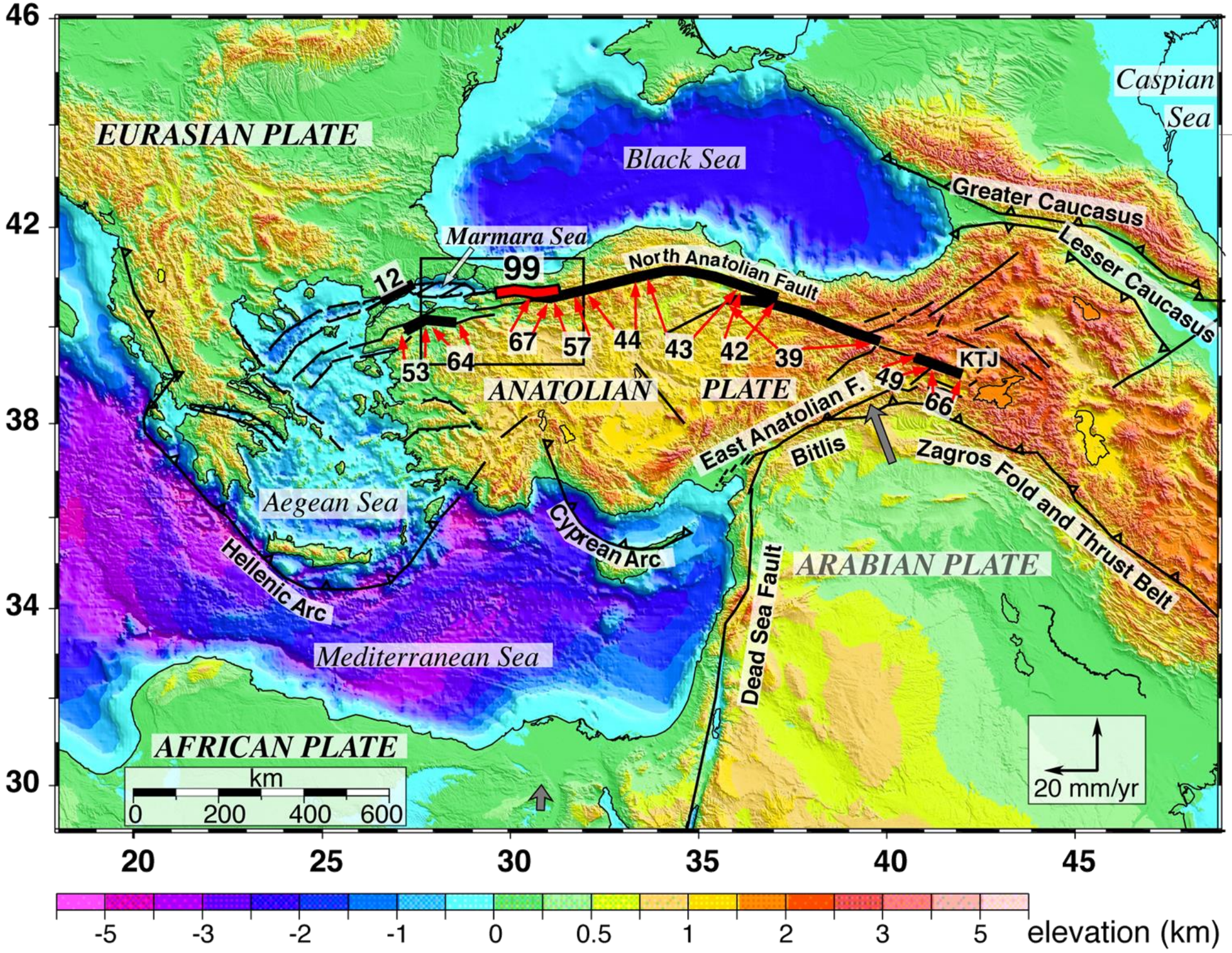
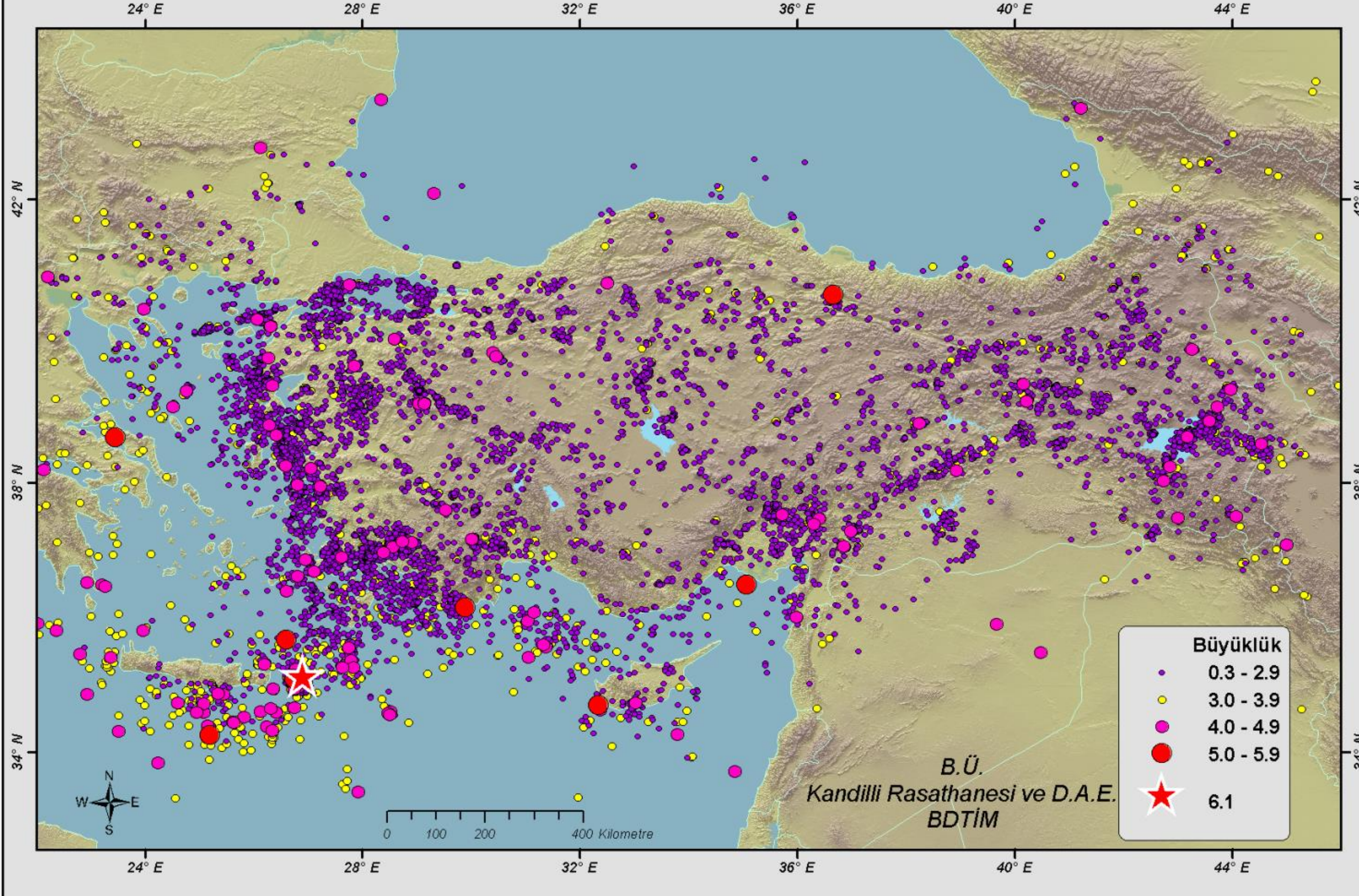

USGS
science for a changing world

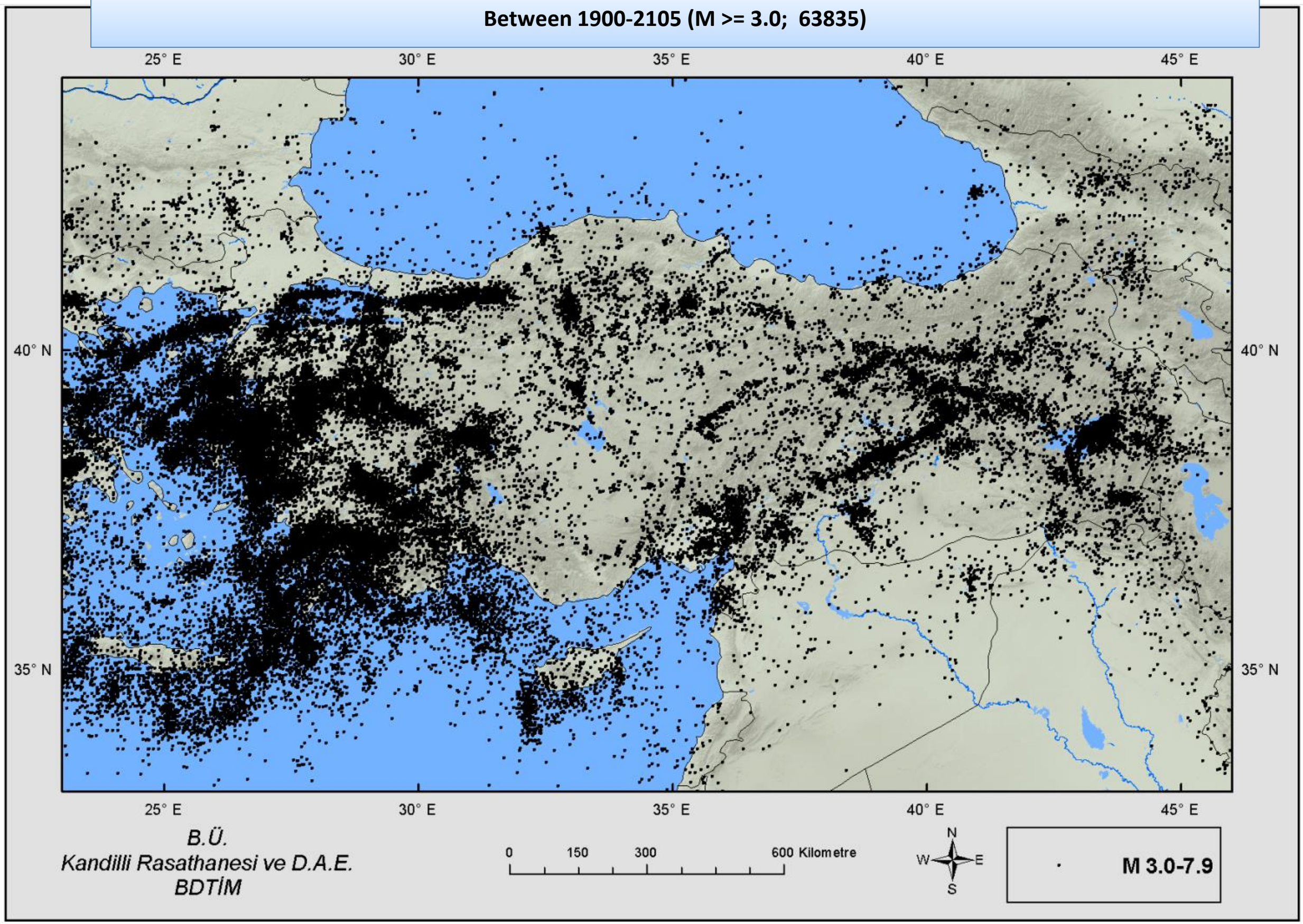
Tectonic Settings of Turkey



Earthquake Activity during 2015Toplam : 12284



Between 1900-2105 (M >= 3.0; 63835)



Motivation:

Revised Active Fault Map of Turkey

about 500 faults can generate earthquakes,

In order to understand the earthquake potential of these faults, it is needed to determine the slip rates,

Although many regional and local studies were performed in the past, the slip rates of the active faults in Turkey have not been determined,

Block modelling, which is the most common method to produce slip rates,

GPS velocities required for block modeling is being compiled from the

published studies and the raw data provided then velocity field is combined.

To form a homogeneous velocity field, different stochastic models used and the optimal velocity field achieved.

In literature, GPS site velocities, which are computed for different purposes and published, are combined globally and this combined velocity field are used in the analysis of strain accumulation.

It is also aimed to develop optimal stochastic models to combine the velocity data.

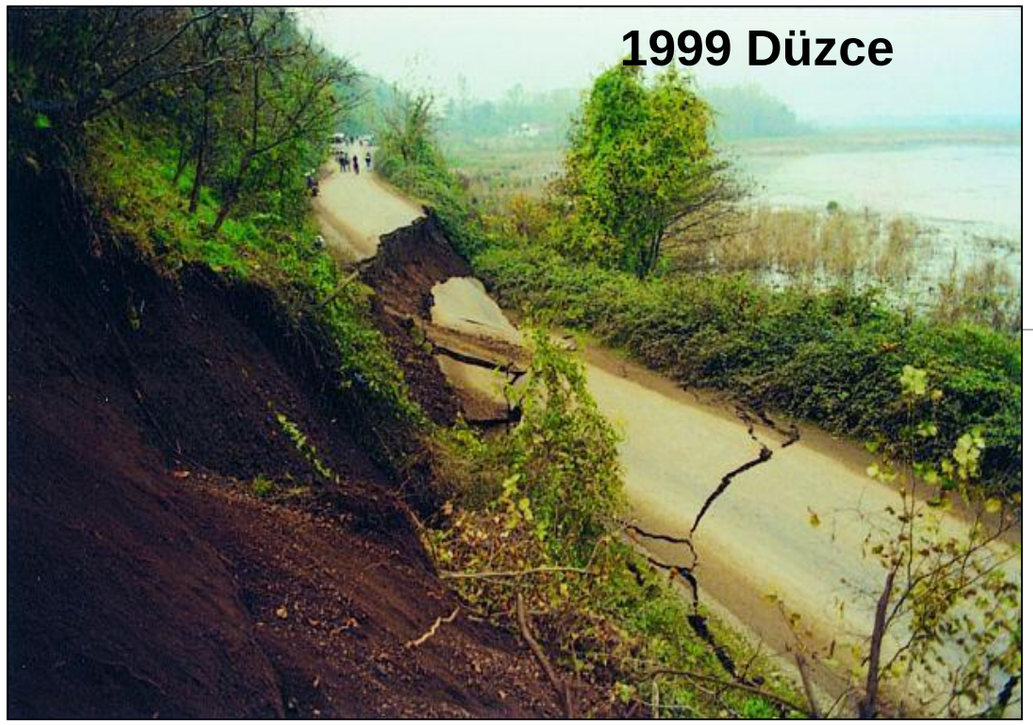
Real time, survey mode and published GPS observations is being combined in this study.

We also perform new GPS observations.

Furthermore, micro blocks and main fault zones from Active Fault Map Turkey will be determined and homogeneous velocity field will be used to infer slip rates of these active faults.

Here, we present the outputs of first two years of the study.

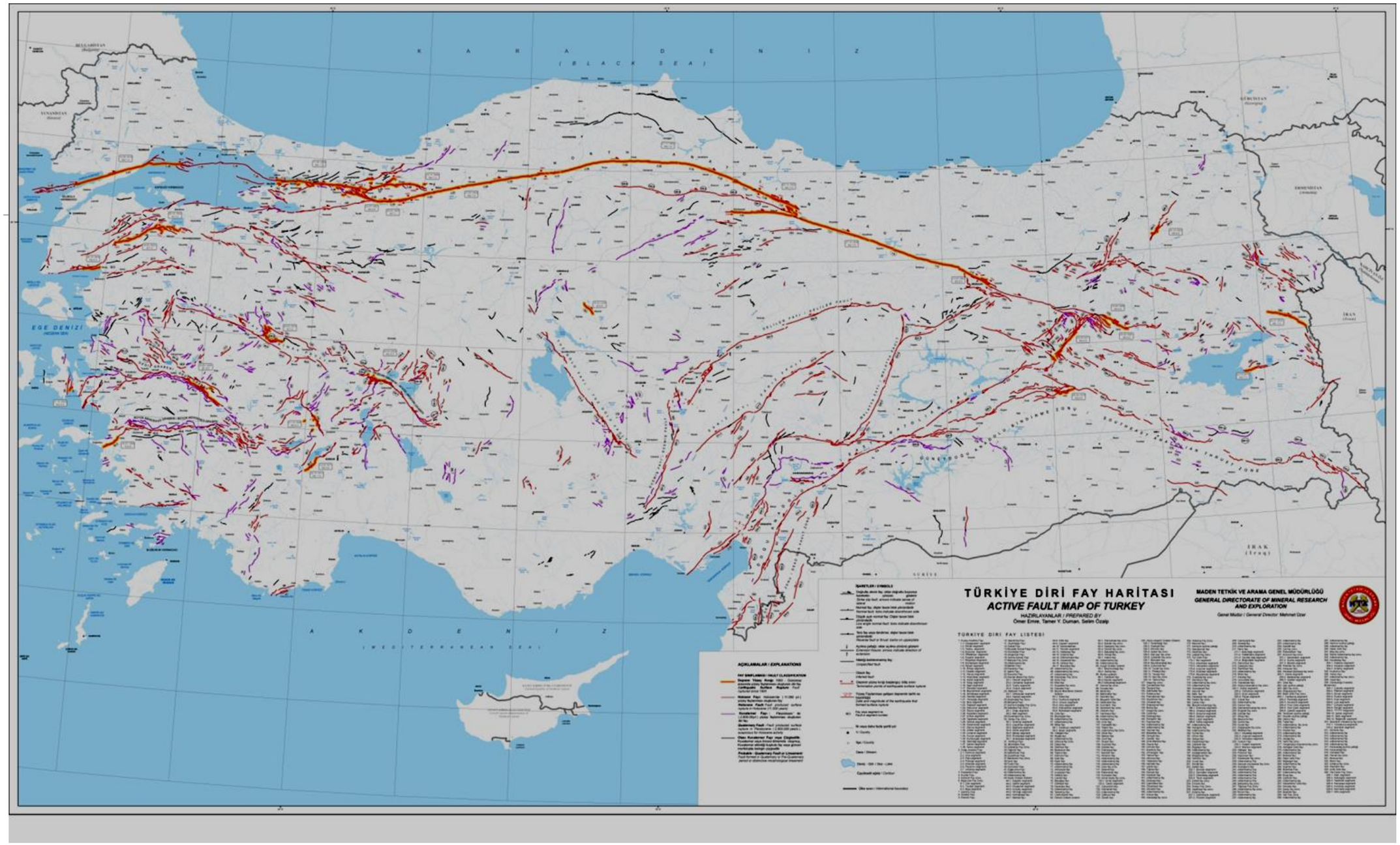
Active Fault Map of Turkey –
General Directorate of Mineral Research and Exploration – (Saroglu et al. 1992)


1999 Düzce

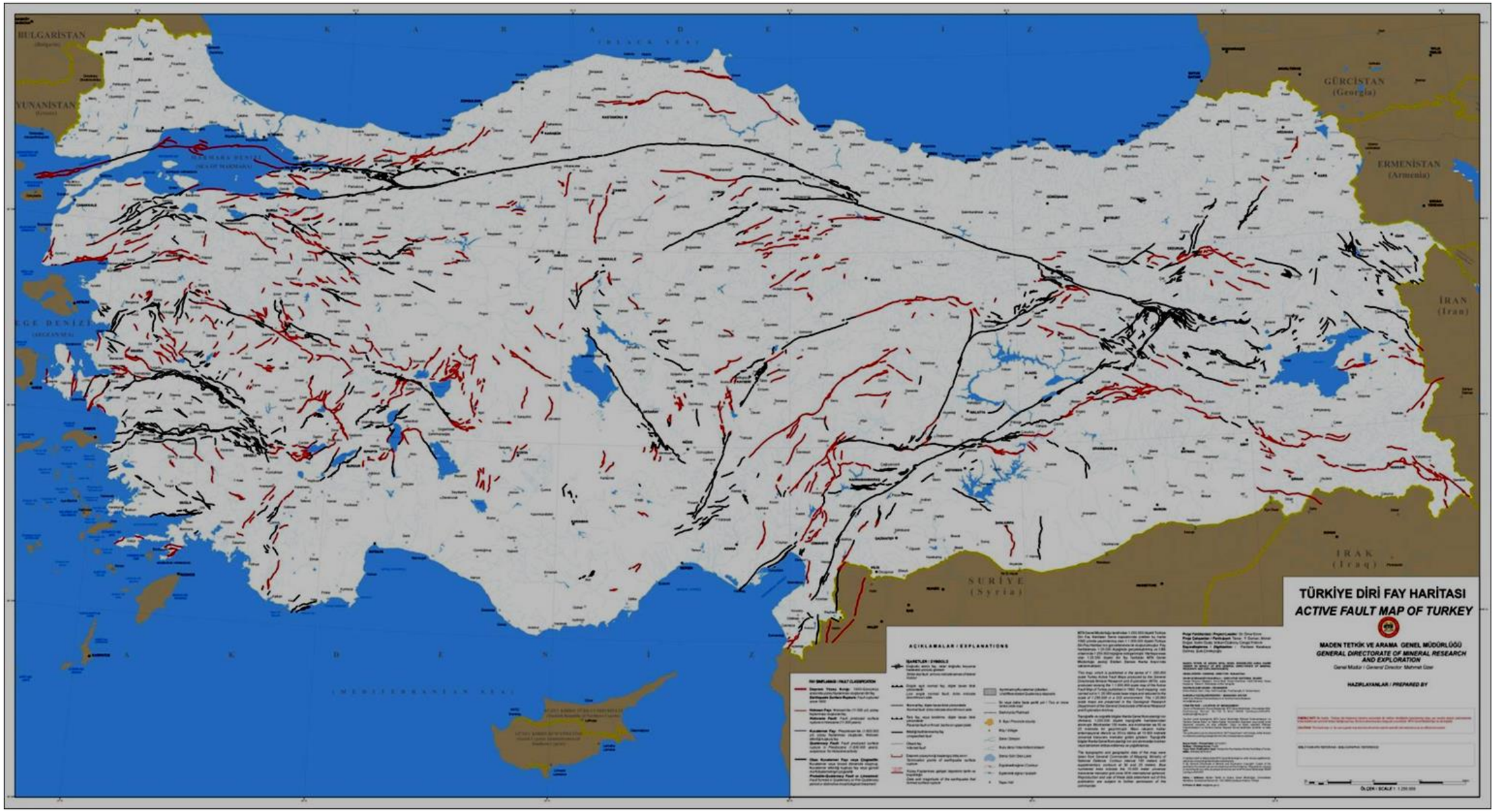

1999 Düzce


1999 İzmit


1995 Dinar



Updated Active Fault Map of Turkey 2012; by General Directorate of Mineral Research and Exploration.



1992 : 150 fault/fault zone

2012: 326 fault/fault zone and 485 fault segment M>5.5

- data from Turkish National Permanent GPS Stations and the data from Turkish National Permanent GPS Stations–Active and Turkish National Fundamental GPS Network were obtained.

- Episodic GPS measurements are being performed at selected points.

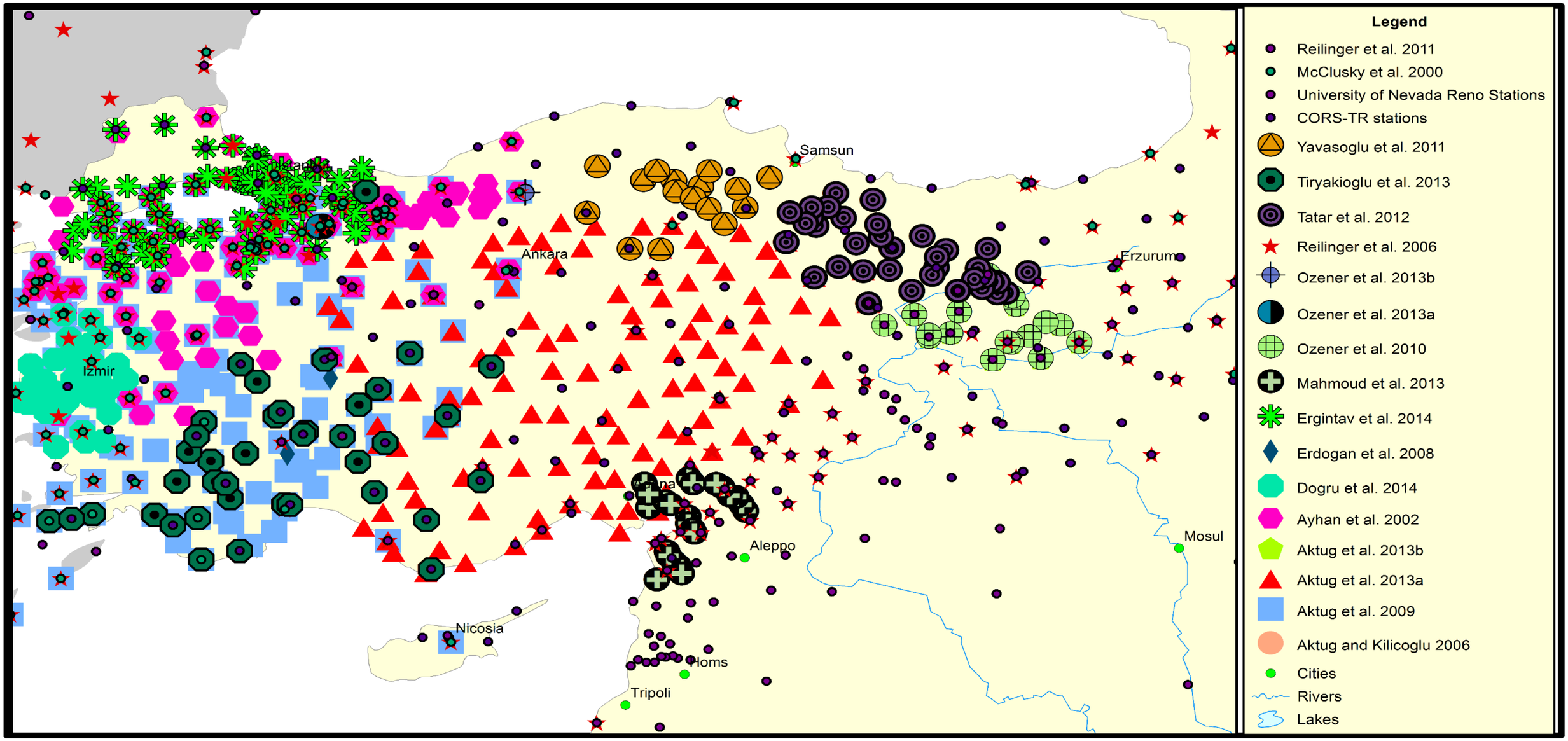
- The GPS data available in the literature compiled.

- new stochastic models are being developed and a homogenous combined velocity field will be produced.

- Additionally, combined velocity will be used to infer the fault slip rates through block modeling.

- The output of the project will be the fault slip rate map of main active faults of Turkey and will be one of the most important inputs of Turkish Seismotectonic Map.

Current Velocity Fields	Number of Stations
Aktug and Kılıcoglu (2006)	53
Aktug et al. (2009)	204
Aktug et al. (2013a)	137
Aktug et al. (2013b)	133
Ayhan et al. (2002)	136
Dogru et al. (2014)	75
Erdogan et al. (2008)	16
Ergintav et al. (2014)	112
Mahmoud et al. (2013)	44
Ozener et al. (2010)	55
Ozener et al. (2013)	35
Ozener et al. (2013b)	28
Reilinger et al. (2006)	433
Reilinger et al. (2011)	227
Tatar et al. (2012)	48
Tiryakioglu et al. (2013)	39
CORS-TR stations	146
Yavasoglu et al. (2011)	16


Legend
Reilinger et al. 2011
McClusky et al. 2000
University of Nevada Reno Stations
CORS-TR stations
Yavasoglu et al. 2011
Tiryakioglu et al. 2013
Tatar et al. 2012
Reilinger et al. 2006
Ozener et al. 2013b
Ozener et al. 2013a
Ozener et al. 2010
Mahmoud et al. 2013
Ergintav et al. 2014
Erdogan et al. 2008
Dogru et al. 2014
Ayhan et al. 2002
Aktug et al. 2013b
Aktug et al. 2013a
Aktug et al. 2009
Aktug and Kilicoglu 2006
Cities
Rivers
Lakes
Samsun
Ankara
Erzurum
İzmir
Aleppo
Mosul
Nicosia
Homs
Tripoli

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	53	24	17	0	0	1	14	43	0	0	0	9	8	8	7	27	0	10	0	0
2	24	208	30	0	0	4	73	19	10	29	0	33	8	19	8	145	6	8	17	0
3	17	30	137	0	22	36	4	7	0	0	0	12	8	8	7	34	12	14	1	1
4	0	0	0	19	6	6	0	0	0	0	0	0	19	0	0	3	10	3	0	0
5	0	0	22	6	137	2	0	0	0	0	0	28	6	0	0	9	6	42	0	19
6	1	4	36	6	2	176	2	1	0	0	1	46	6	0	0	57	66	0	0	0
7	14	73	4	0	0	2	160	14	0	38	0	8	0	0	0	78	3	0	0	0
8	43	19	7	0	0	1	14	77	0	0	0	6	24	12	13	19	0	4	0	0
9	0	10	0	0	0	0	0	0	16	0	0	0	0	0	0	6	0	0	14	0
10	0	29	0	0	0	0	38	0	0	150	0	34	0	17	0	37	0	0	1	0
11	0	0	0	0	0	1	0	0	0	0	44	0	0	0	0	0	1	0	0	0
12	9	33	12	0	28	46	8	6	0	34	0	250	4	4	4	36	7	9	20	2
13	8	8	8	19	6	6	0	24	0	0	0	4	55	18	18	16	11	8	0	0
14	8	19	8	0	0	0	0	12	0	17	0	4	18	61	18	22	0	5	0	0
15	7	8	7	0	0	0	0	13	0	0	0	4	18	18	48	10	0	4	0	0
16	27	145	34	3	9	57	78	19	6	37	0	36	16	22	10	463	108	14	11	0
17	0	6	12	10	6	66	3	0	0	0	1	7	11	0	0	108	231	2	1	0
18	10	8	14	3	42	0	0	4	0	0	0	9	8	5	4	14	2	48	0	0
19	0	17	1	0	0	0	0	0	14	1	0	20	0	0	0	11	1	0	39	0
20	0	0	1	0	19	0	0	0	0	0	0	2	0	0	0	0	0	0	0	16

Aktug_and_Kilicoglu_2006.gmt

Aktug_etal_2009.gmt

Aktug_etal_2013a.gmt

Aktug_etal_2013b.gmt

Aktug_etal_2015.gmt

Aktug_etal_2016.gmt

Ayhan_etal_2002.gmt

Dogru_etal_2014.gmt

Erdogan_etal_2008.gmt

Ergintav_etal_2014.gmt

Mahmoud_etal_2013.gmt

Ozdemir_TUSAGA_Aktif.gmt

Ozener_etal_2010.gmt

Ozener_etal_2013a.gmt

Ozener_etal_2013b.gmt

Reilinger_etal_2006.gmt

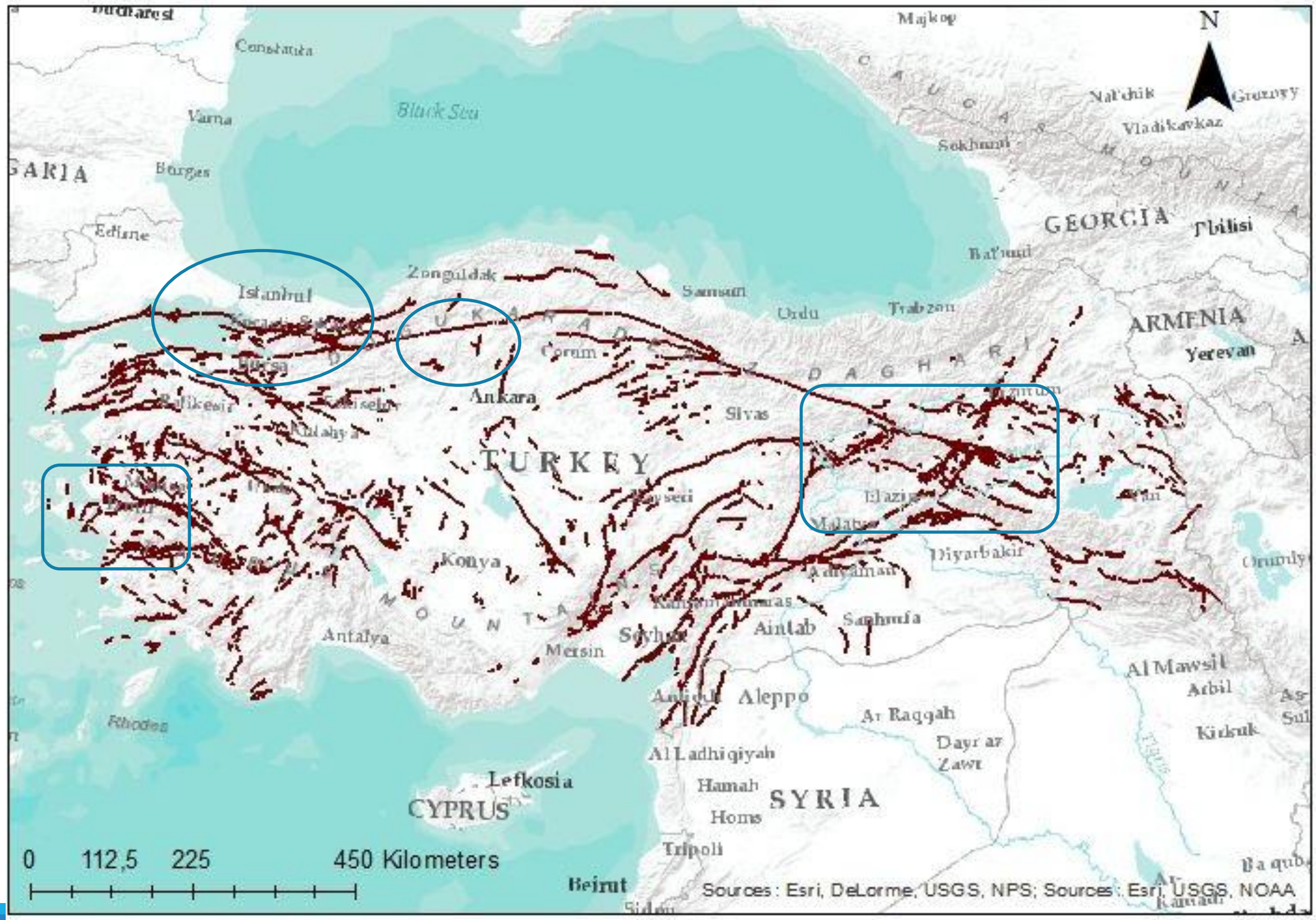
Reilinger_etal_2011.gmt

Tatar_etal_2012.gmt

Tiryakioglu_etal_2013.gmt

Yavasoglu_etal_2011.gmt

Episodic GPS Measurements



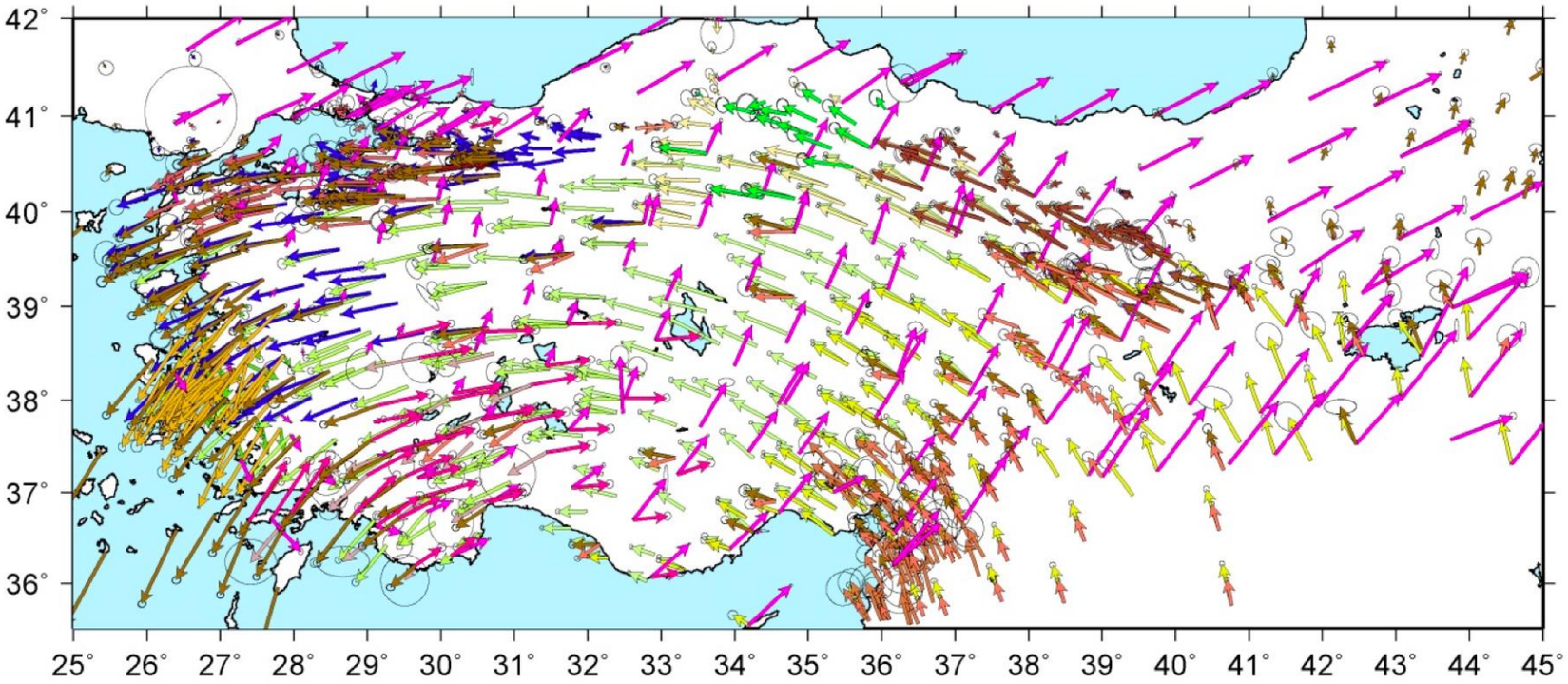
Number of velocity field : 20

Reference velocity field : Aktuğ et al. (2009)

Number of observation : 4280

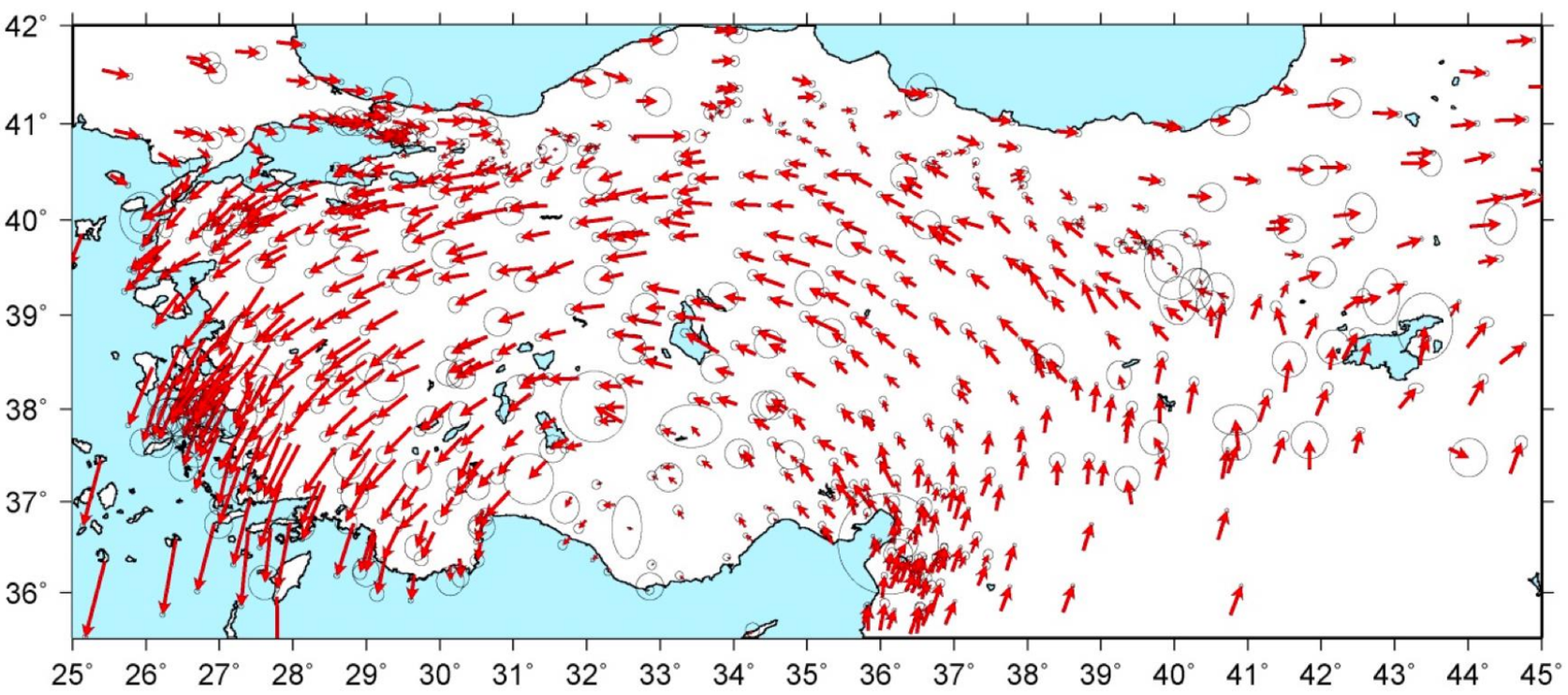
Number of parameters : 2204

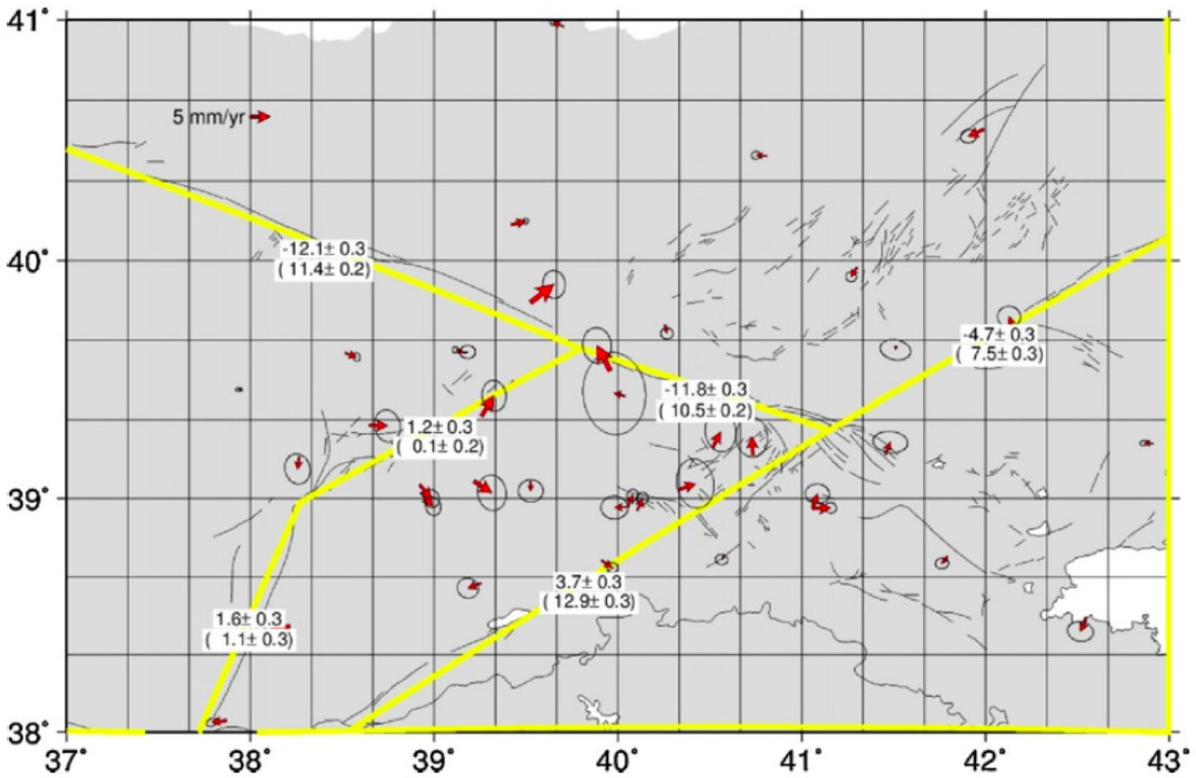
Number of velocity points : 1072



Before

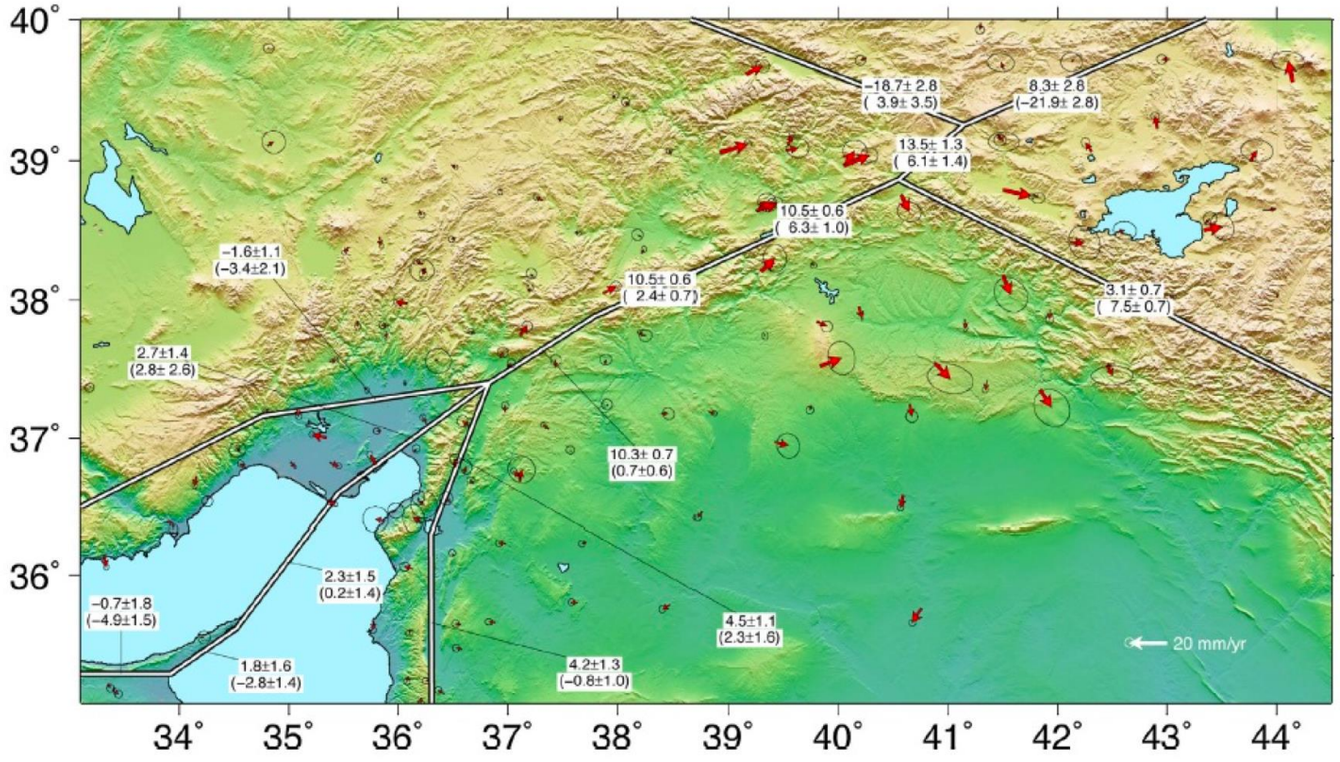
After transformation

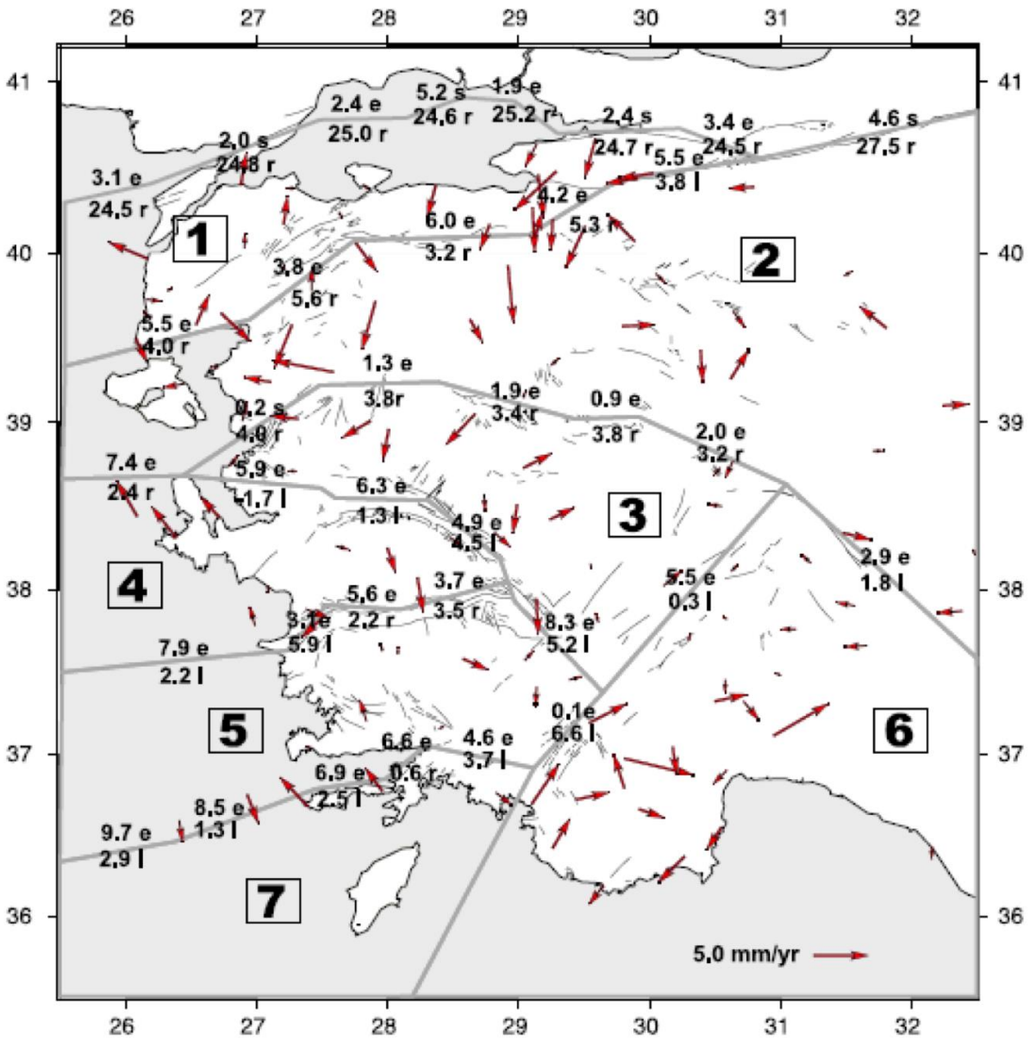




Karliova triple junction

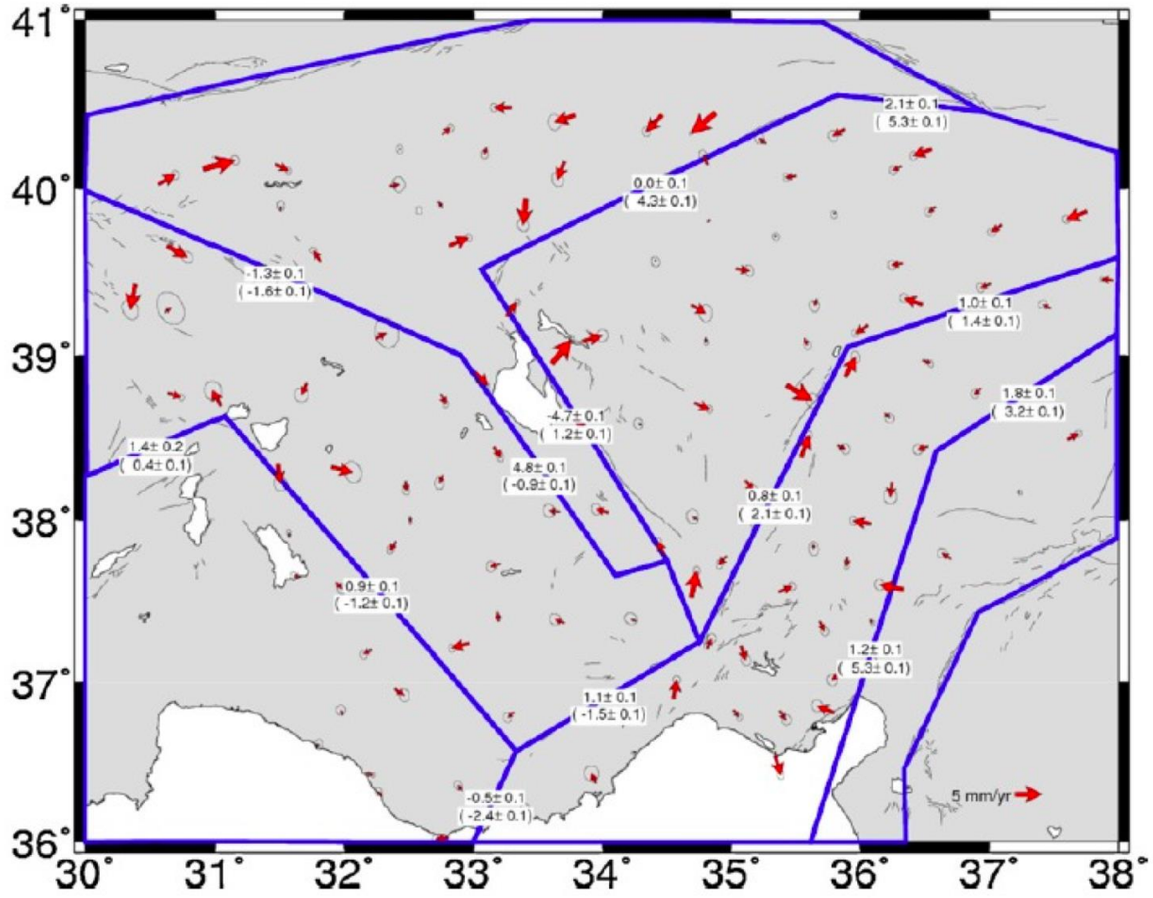
East anatolian fault

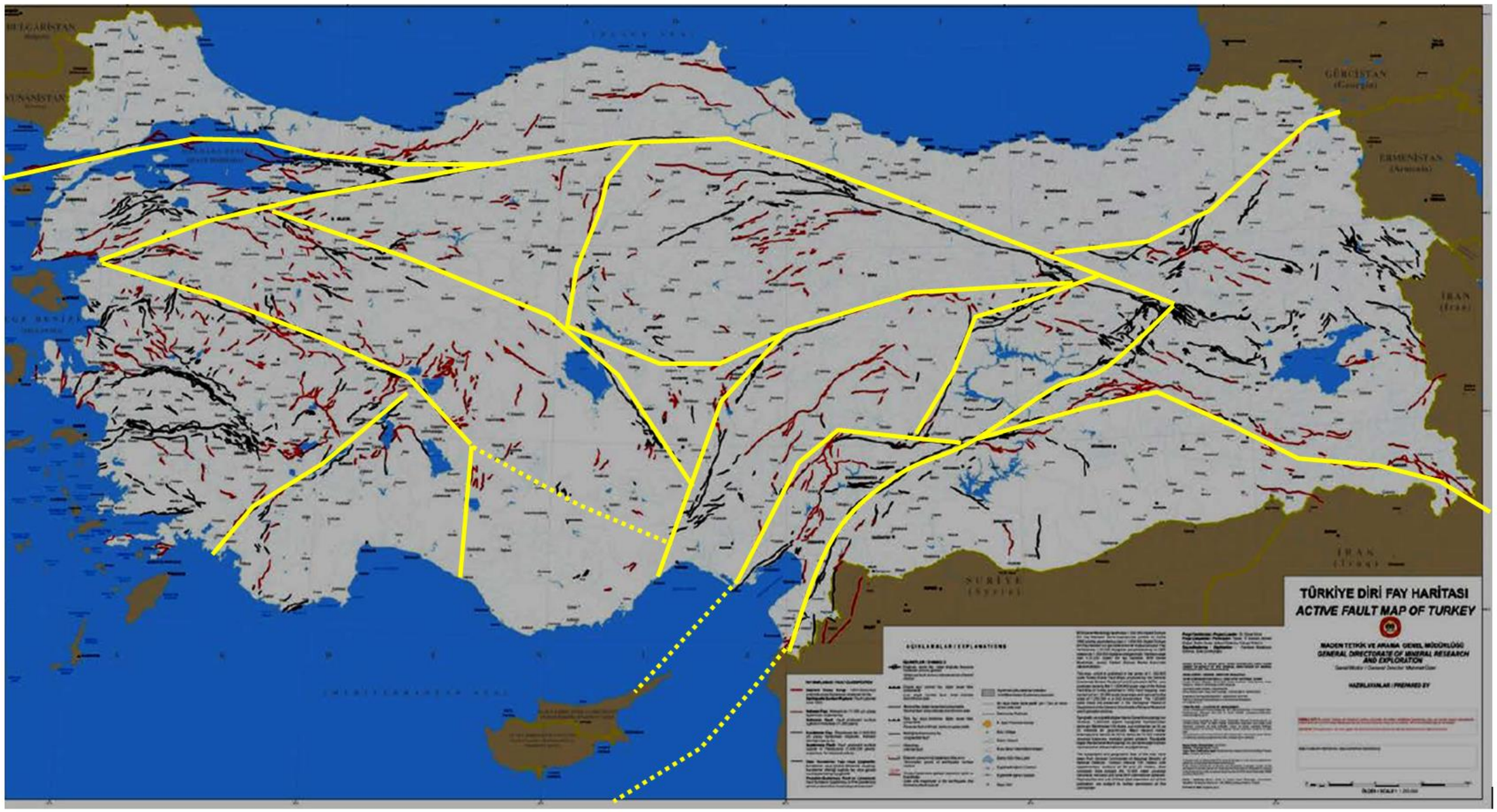




Mid-anatolia

Western anatolia/ eagean region

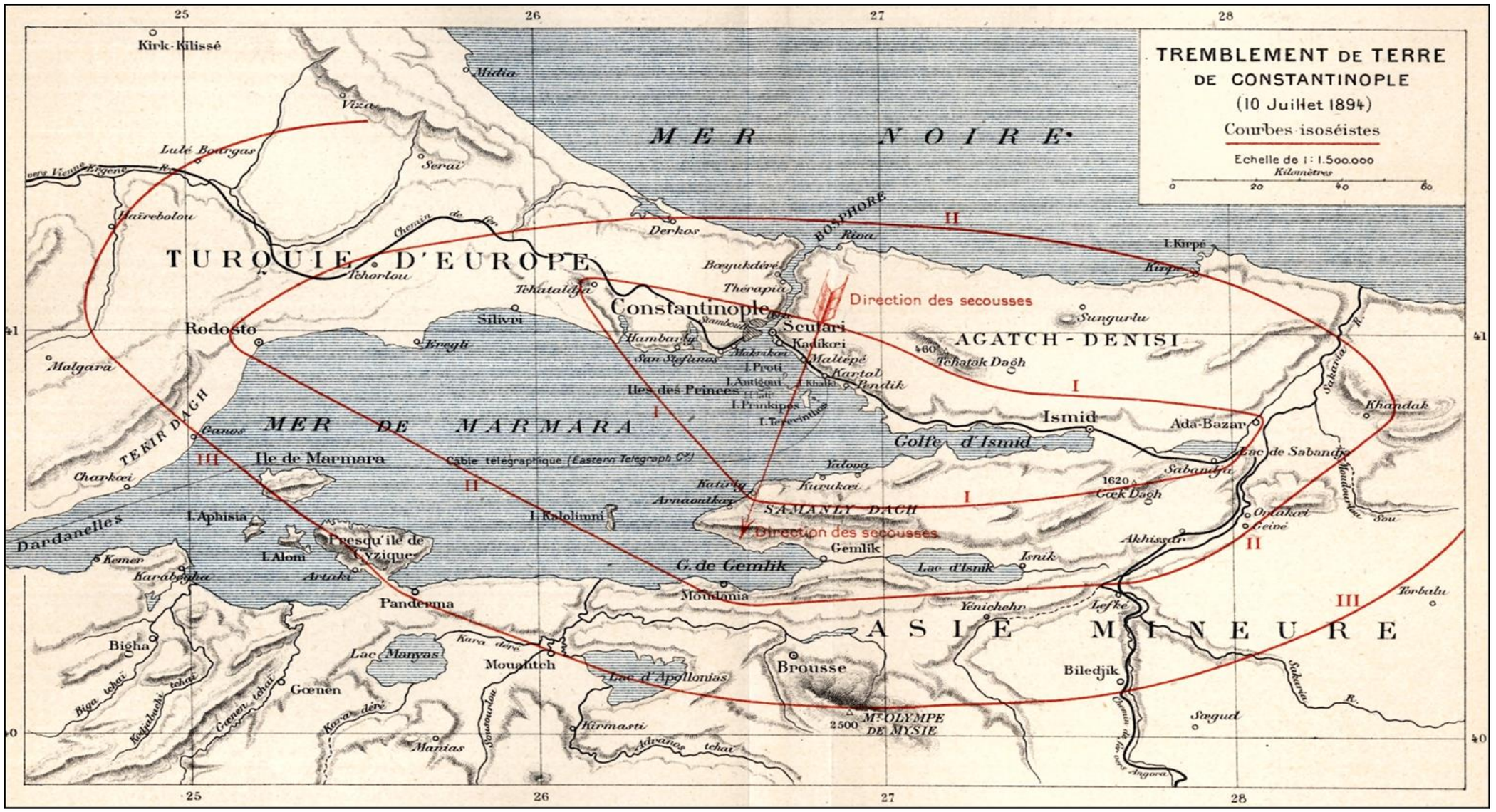




Block boundaries

Early Findings

- Seismic gaps on NAFZ: Marmara sea in the west, Yedisu in the east M_w7.5



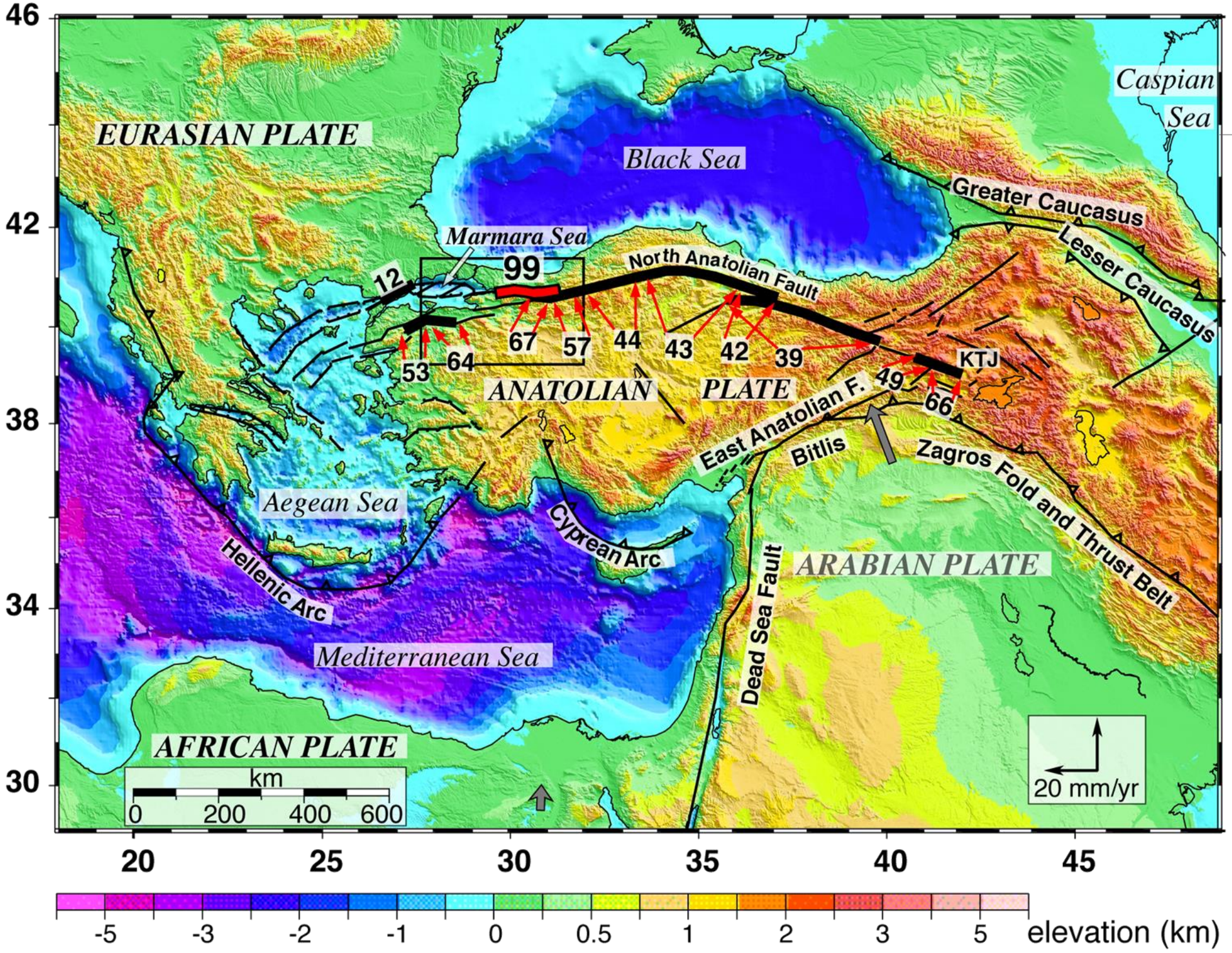
cont.

- Southern branch of western NAF is without the presence of significant tectonic deformation.

- The left-lateral slip along EAFS shows a decreasing gradient at Karlıova 13.1±1.6 mm/yr and at south 4.1±1.2 mm/yr.

- In consideration of the slip rate, there are two seismic gap along EAFS. In Palu-Sincik slip deficit is 1,82 m and has the potential of producing an earthquake of M_w7.5 and Celikhan- Turkoglu slip deficit is 5,16 m and has the potential of producing an earthquake of M_w7.7.

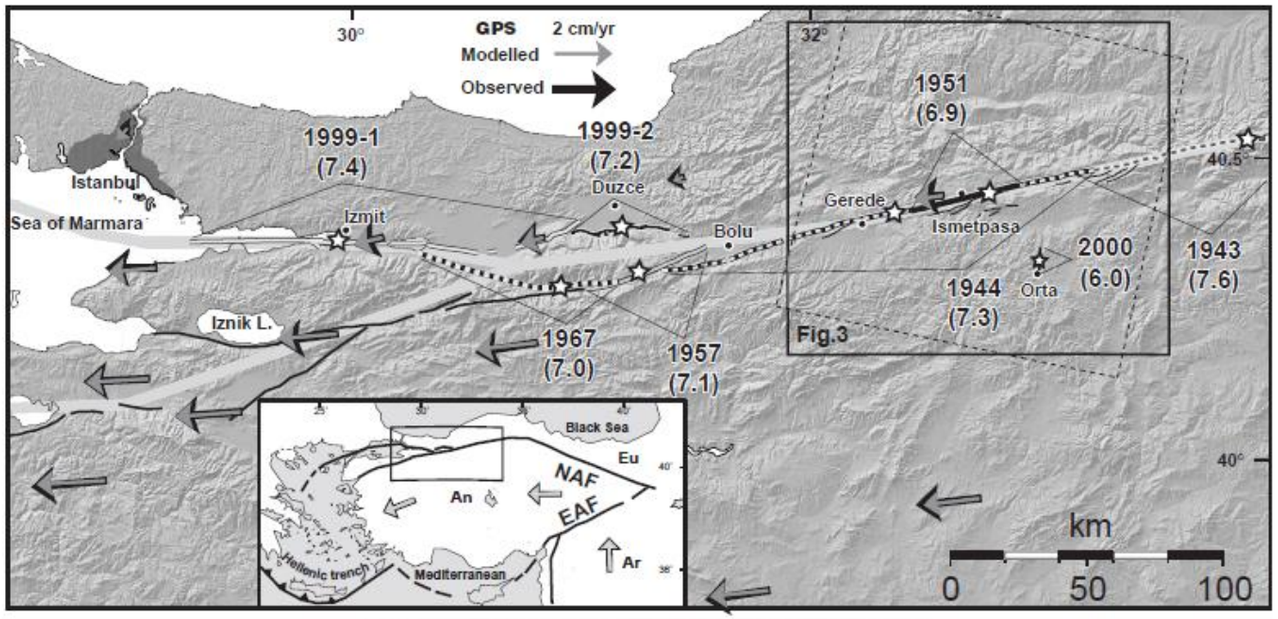
Tectonic Settings of Turkey

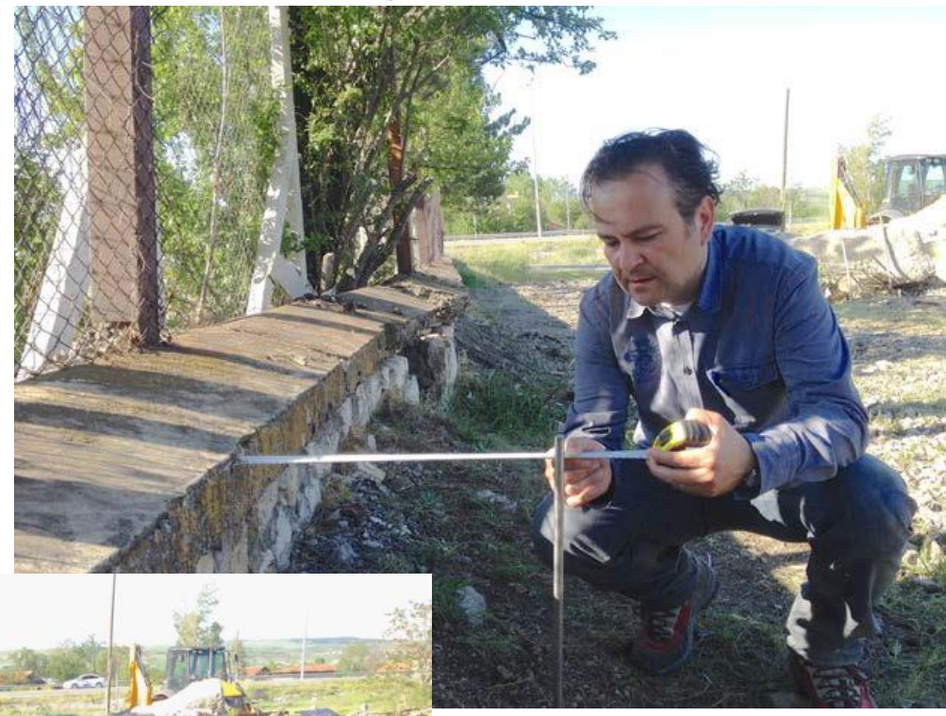


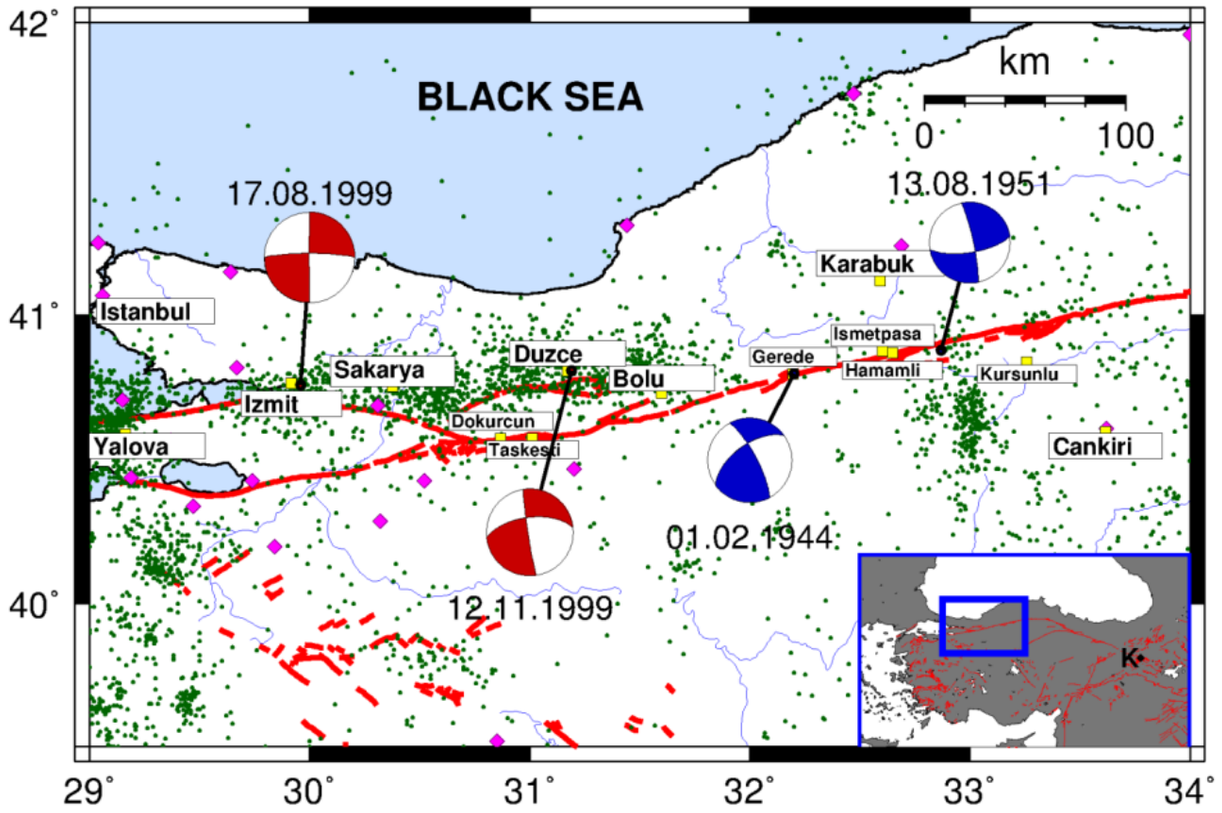
Additional Efforts

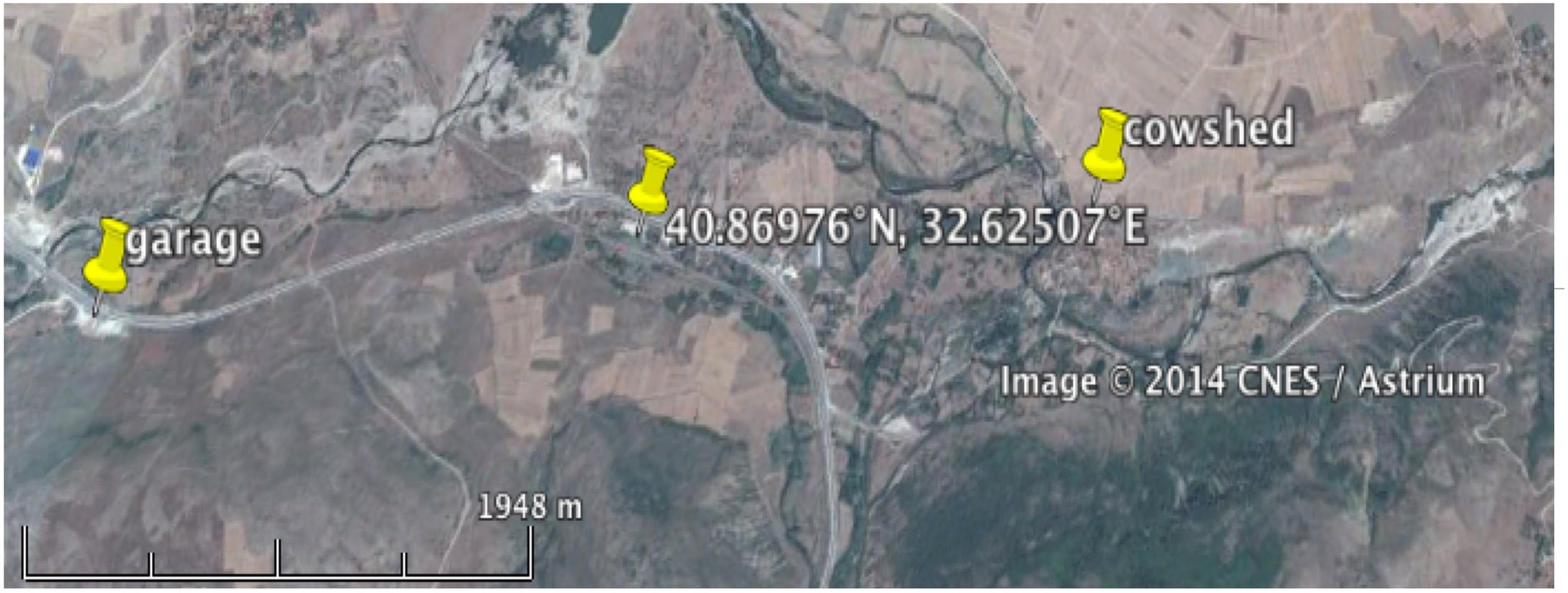
Creepmeter study on North Anatolian Fault Zone

Installed creepmeters will be a powerful tool to search the possibilities of the transient or episodic creep and they can validate the results of on-going monthly InSAR and campaign GPS studies, along NAF.



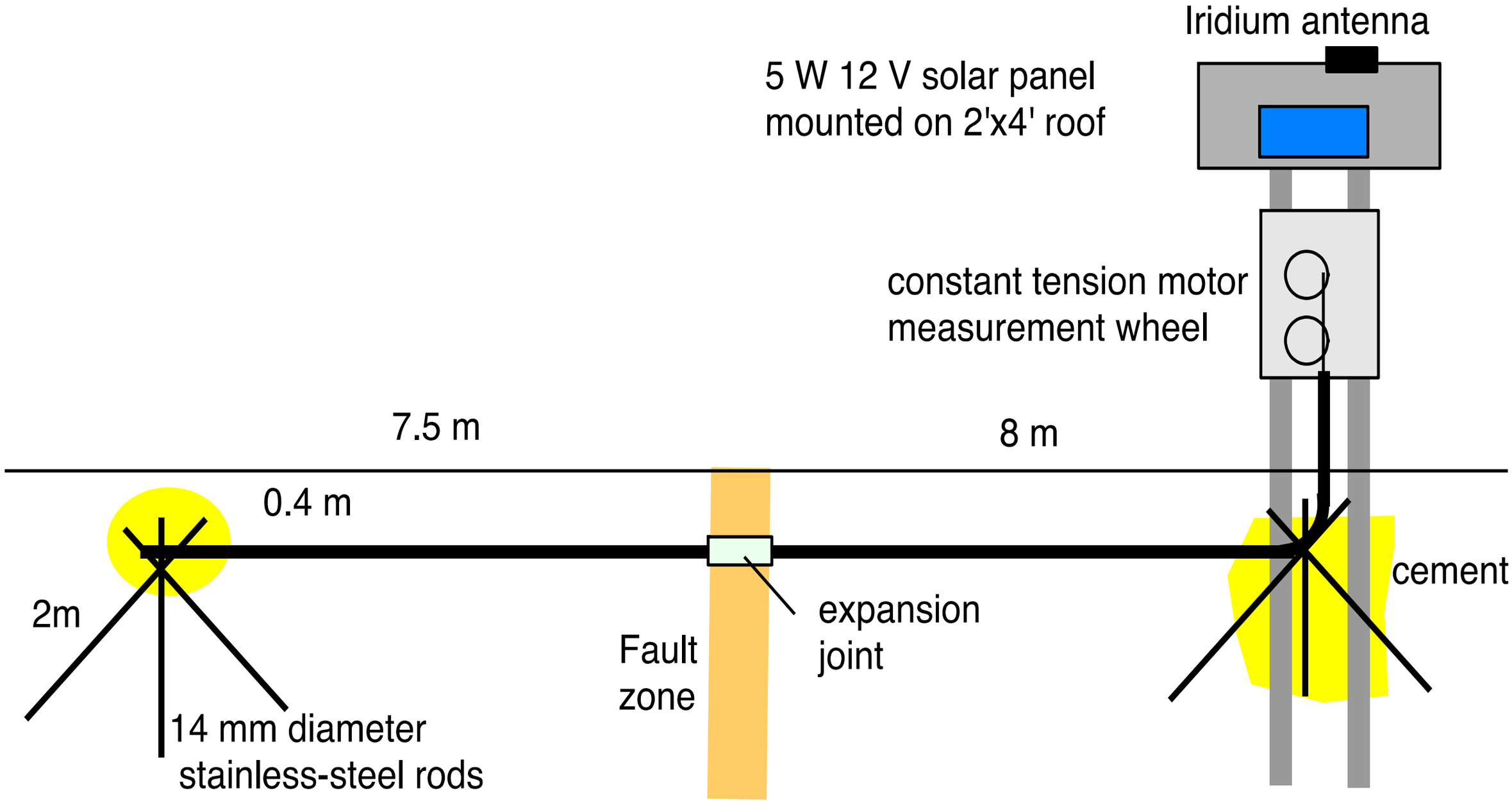





garage
40.86976°N, 32.62507°E
cowshed
Image © 2014 CNES / Astrium
1948 m


Service
Yard
weigh
scale
Alignment
Array
Wall offset
465 mm
21 May '14
40.86976°N, 32.62507°E
hairline
cracks

Creepmeter

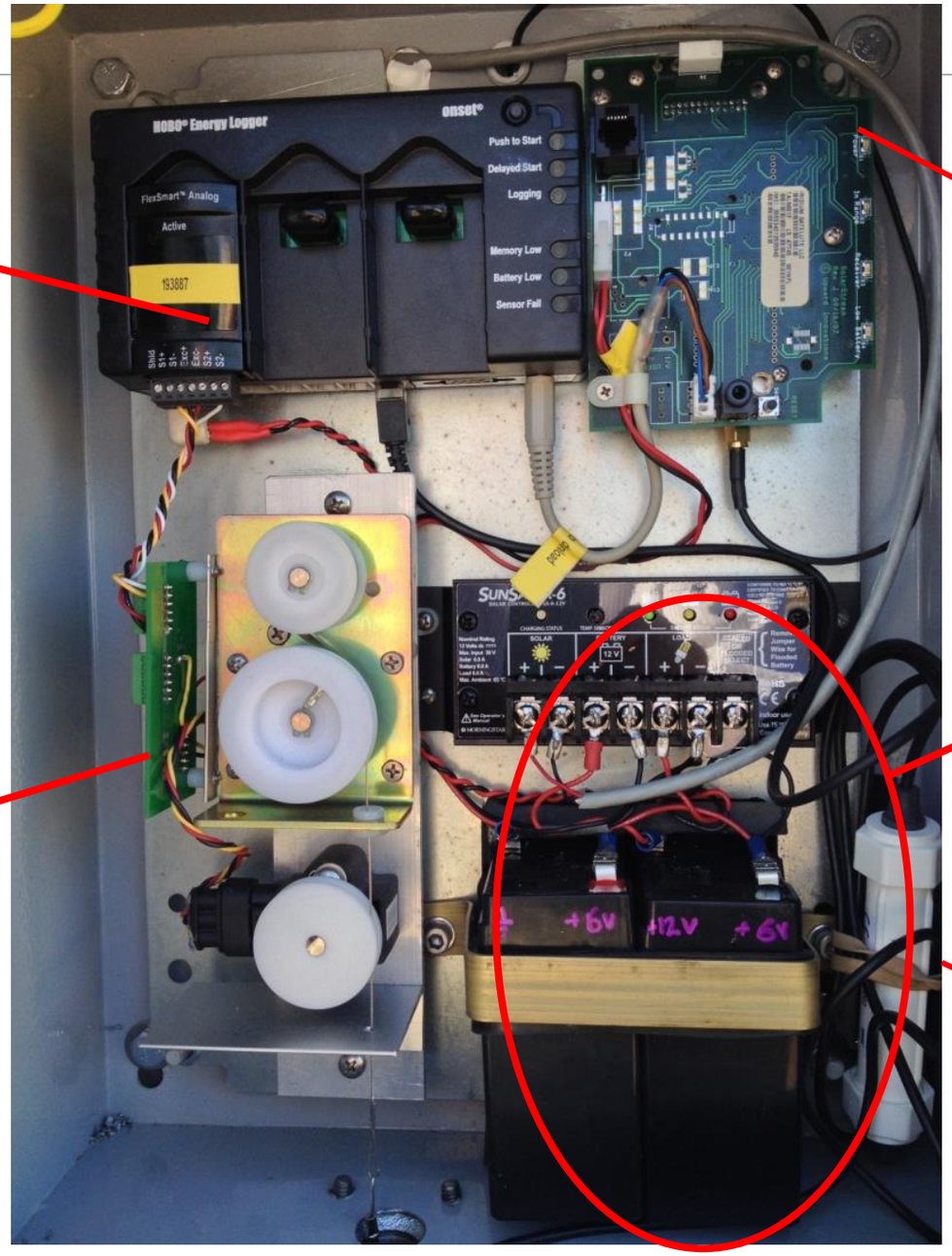

Iridium antenna
5 W 12 V solar panel
mounted on 2'x4' roof
constant tension motor
measurement wheel
7.5 m
8 m
0.4 m
2m
14 mm diameter
stainless-steel rods
Fault
zone
expansion
joint
cement

Creepmeter Specifications

- *The creepmeters have a resolution of 5 µm and a range of 2.2 m.*
- *Each creepmeter uses two sensors- a subsurface LVDT (resolution 5 µm range 2.2 mm) and an above-ground rotary Hall effect sensor (resolution 25 µm and range 2.2 m) and their data are transmitted via the Iridium satellite as 30 minute samples every 2 hours.*
- *Their ability to capture slow slip, coseismic rupture or afterslip has been tested in deployments on the rapidly creeping landslides (1-3 mm/day) in the US.*

Above Ground Hall Effect Sensors

Data logger



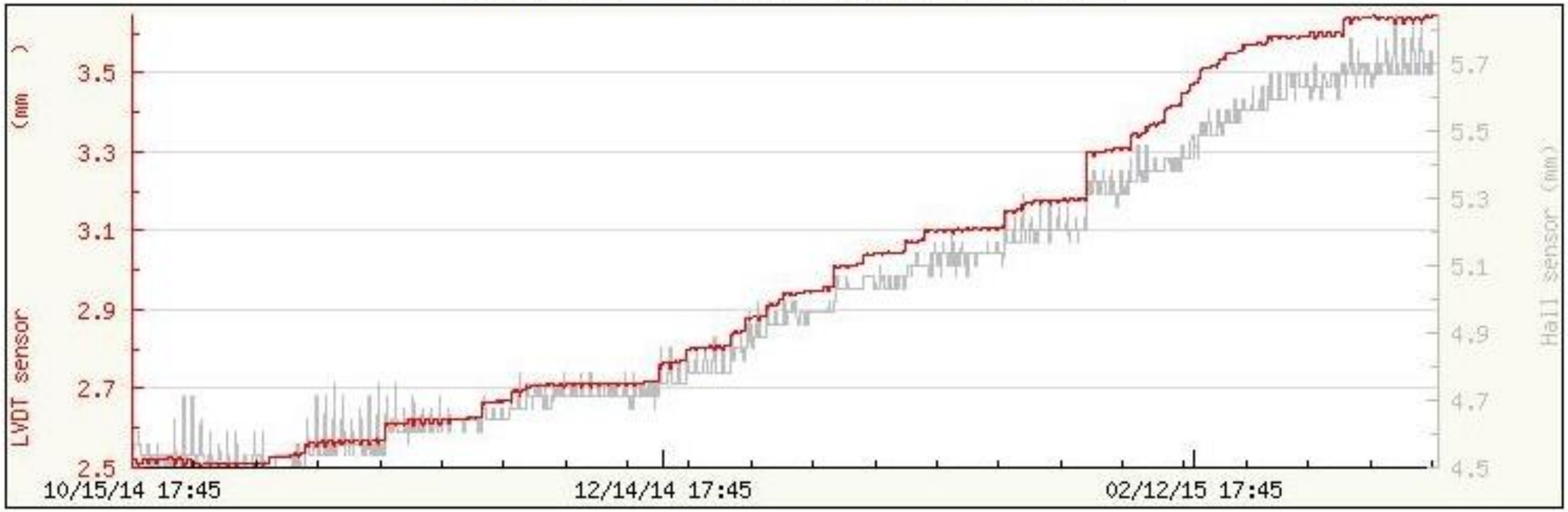
İridium data transfer card

Battery and solar panel unit

Plastik benzeri hassas tel (delrin) makarası ve motoru

Heat measurement probe

All the data of LVDT sensor and Hall sensor



Borehole Strainmeters

in Istanbul

Determination of deformation < 1mm

Slow Earthquake (Slow slip Event/Episodic Tremor Slip)

- It is a new concept for earthquake studies. It is like as aseismic slip and earthquake.
- It is believed that, it trigerres earthquakes and happened before the great earthquake.
- It can not be detected by sismometer and accelerometer.
- It happens in deep and very slow. It takes months and years.

PBO Network

Permanent GPS

Campaign GPS

Borehole Strainmeter

Long Baseline Laser


6350
View
UNAV

This kind of earthquake can be detected just by geodetic techniques.

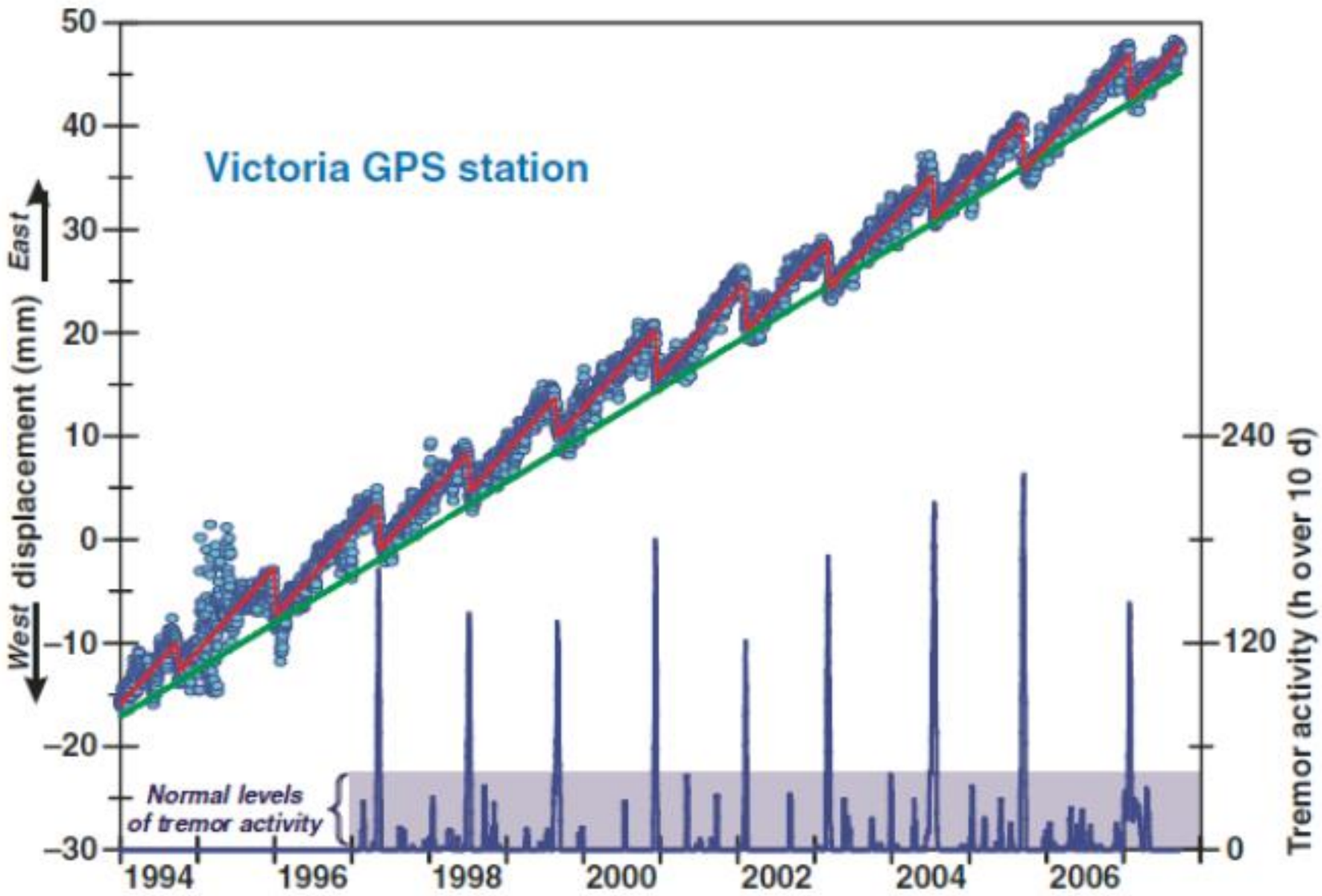
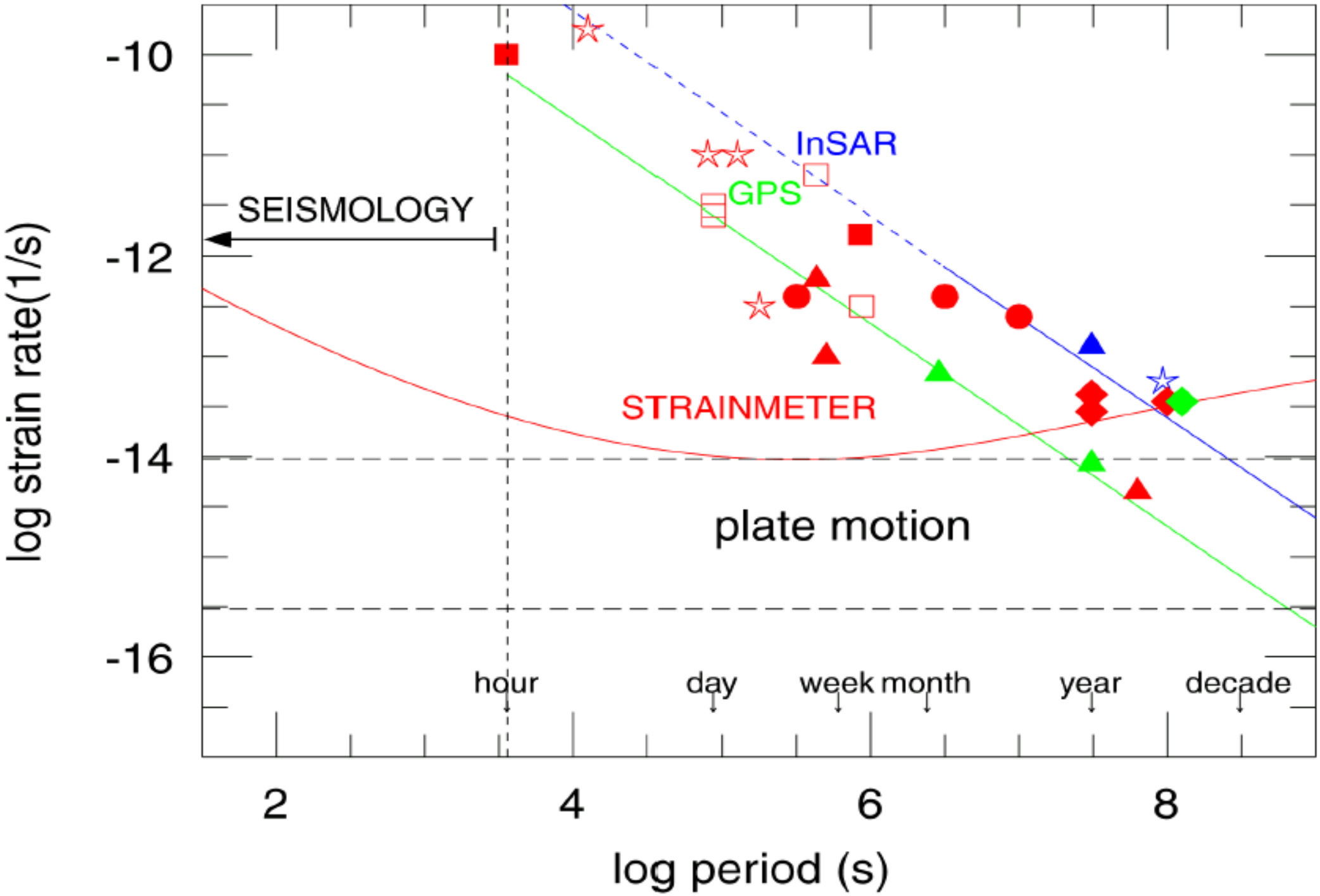


Figure 5. Episodic and Tremor Slip (ETS) (Gomberg, 2010)

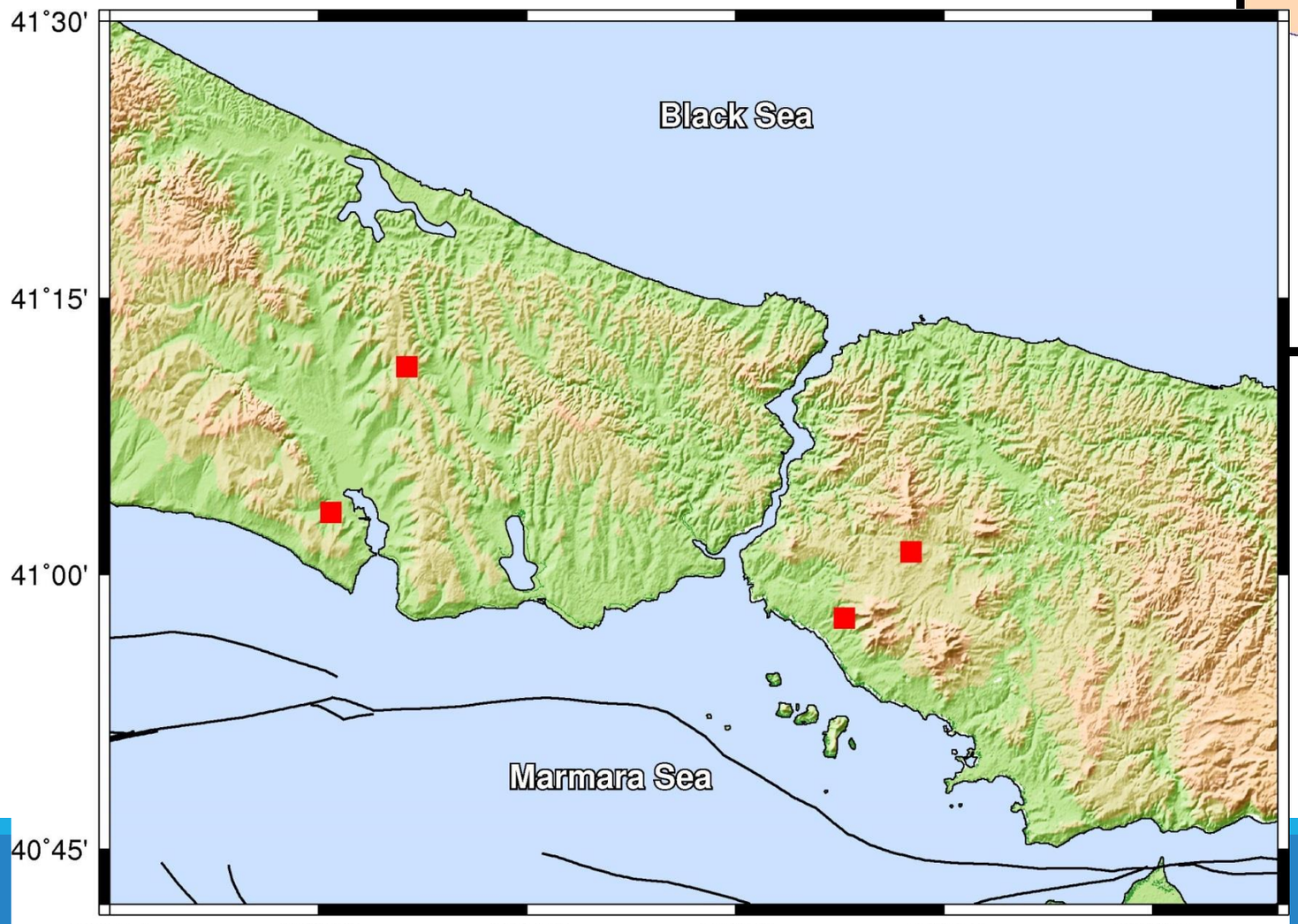
Gomberg, 2010

Why use strainmeter?

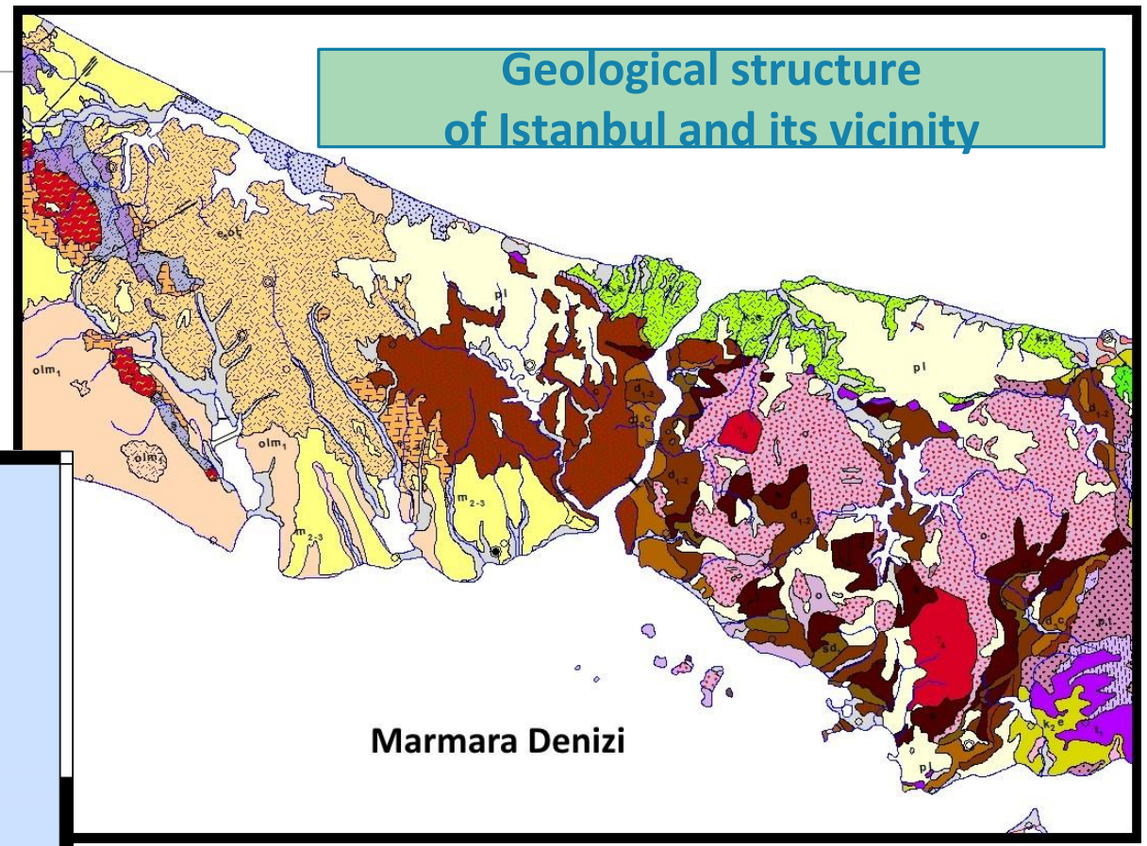


Borehole Geodetic Monitoring in Marmara Region

Selection of sites



Geological structure of Istanbul and its vicinity

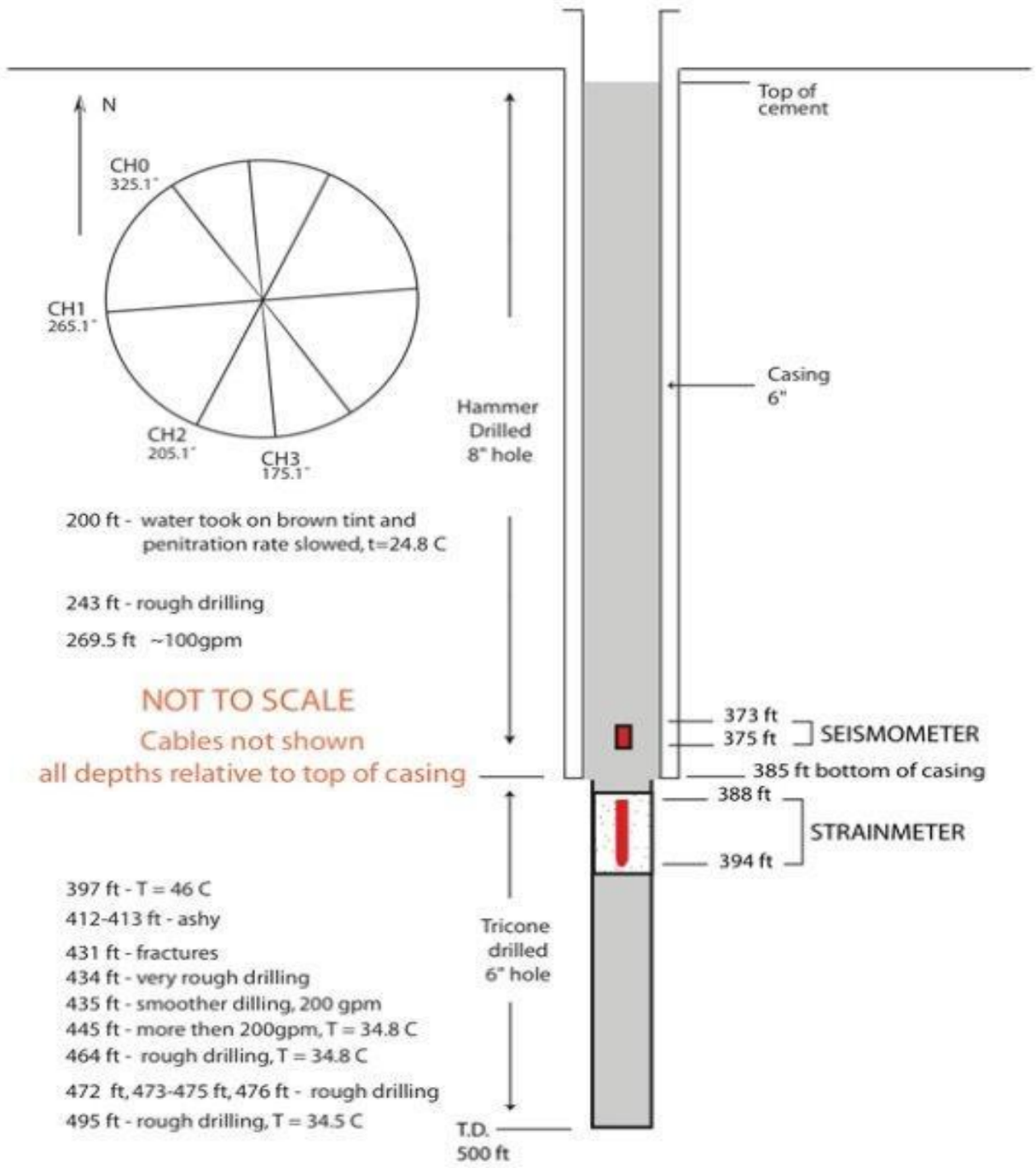


Office and field studies

Our team studied on the geology map of Marmara region to find suitable places for drilling. Then a field trip was carried out to make reconnaissance.

Pictures display the meeting held in UNAVCO office and the preparation to fieldwork for site selection, deployment the instruments in the field in Istanbul.

Borehole equipments



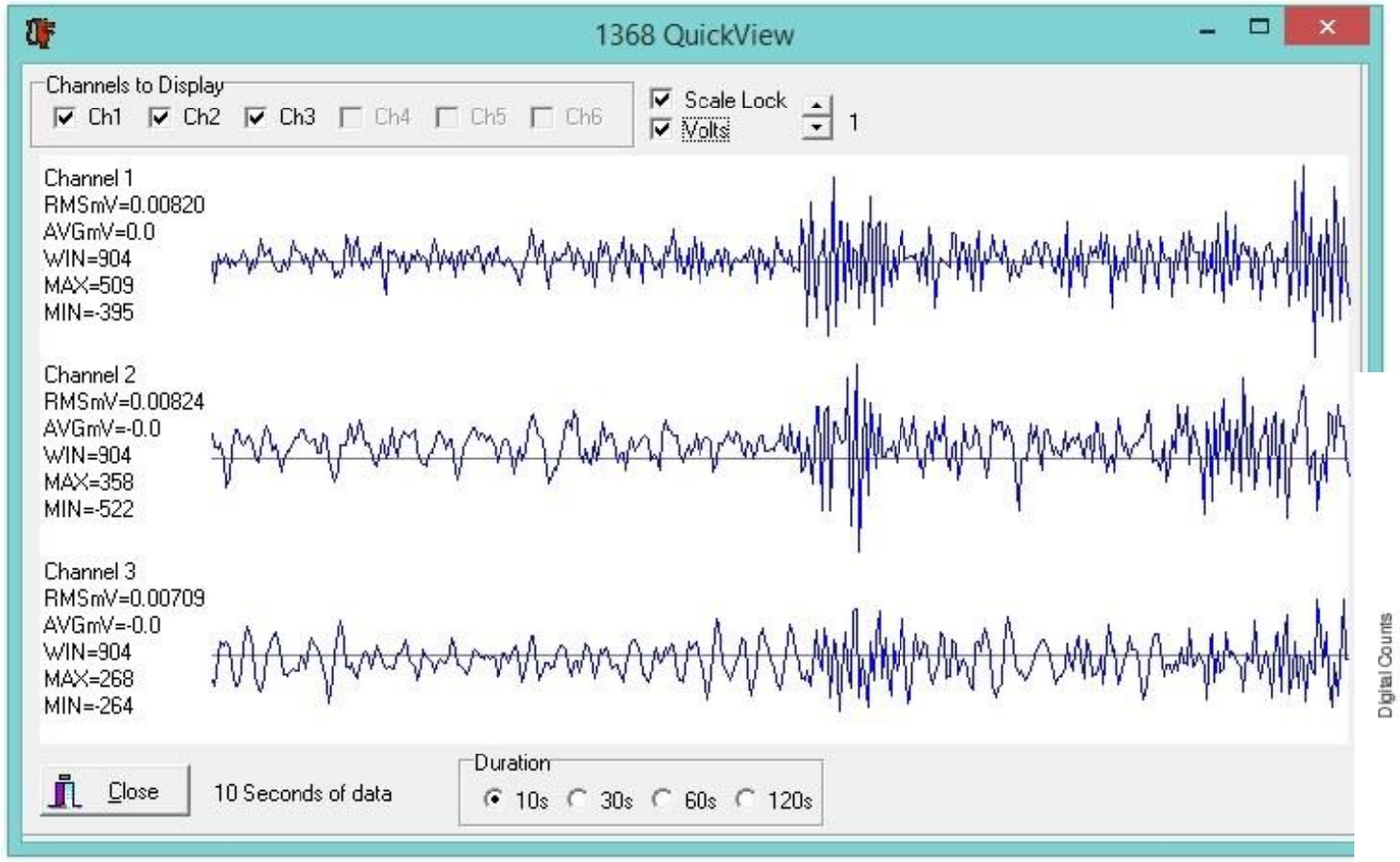
Borehole strain sensitive to deformation in the range of less than a month. With respect to integration with GPS arrays, the system has significant contribution in increasing the resolution of top end differential GPS mapping of earth deformation.

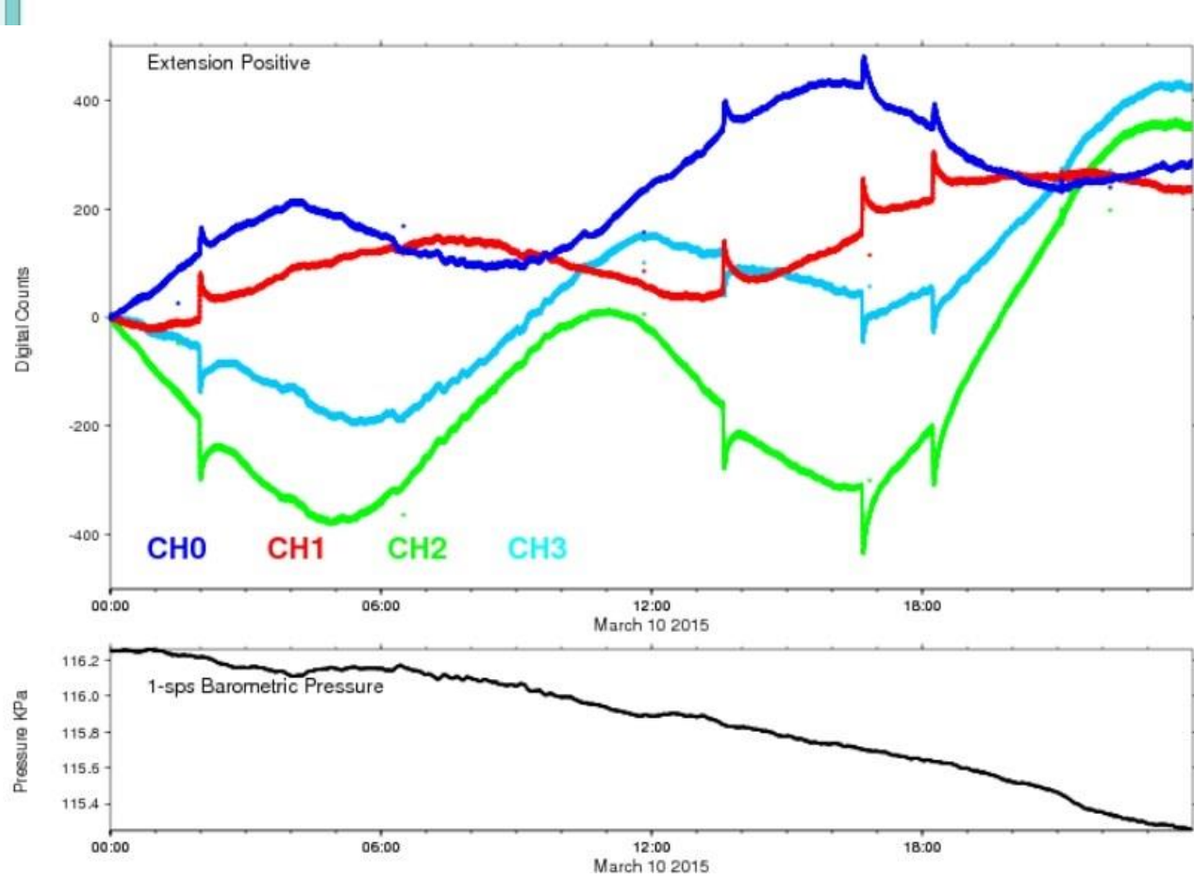
Borehole Installation İstanbul-2014

A typical installation starts with a borehole that is 15 cm in diameter and approximately 200 m deep, the actual depth depends on the location of desirable rock.

Data Transfer

Seismic data are collected by seismometers installed in the boreholes. The figure displays the sample seismic data in Tepekent in Istanbul.





http://strainistanbul.org/

Thank you for your attention

Hoping to see you in ISTANBUL

ozener@boun.edu.tr