FIG Working Week
17 - 21 May, Bulgaria
From the wisdom of the ages to the challenges of modern world
SOFIA 2015

Slip Rates Estimate of Western North Anatolian Fault System in Turkey

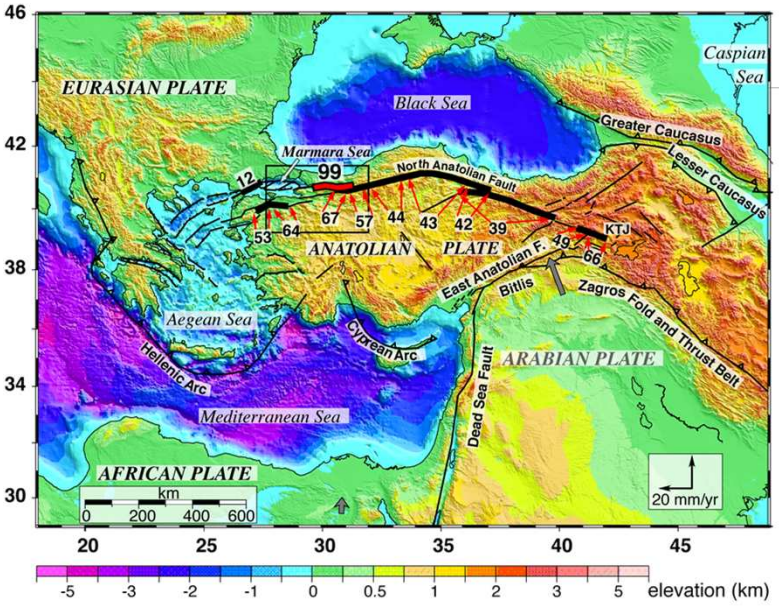
Haluk Ozener, Asli Dogru, Bahadir Aktug, Semih Ergintav, Bulent Turgut, Onur Yilmaz, Kerem Halicioglu, Aslı Sabuncu, Onur Gurkan

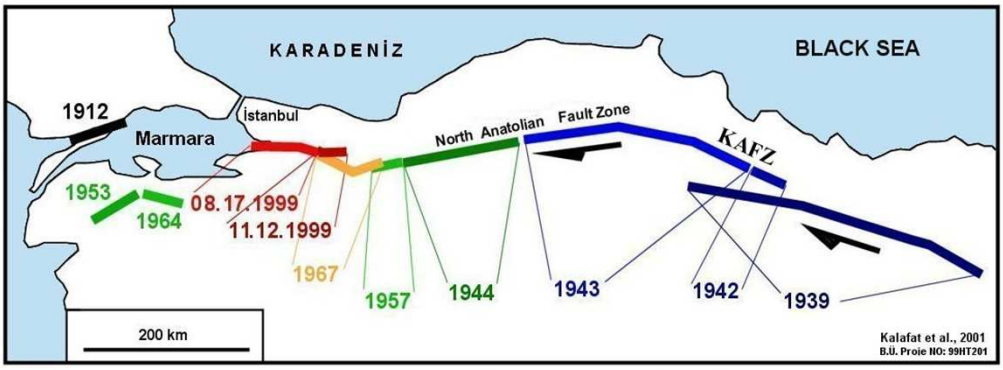
Bogazici University

Kandilli Observatory & Earthquake Research Institute,

Geodesy Department,Turkey

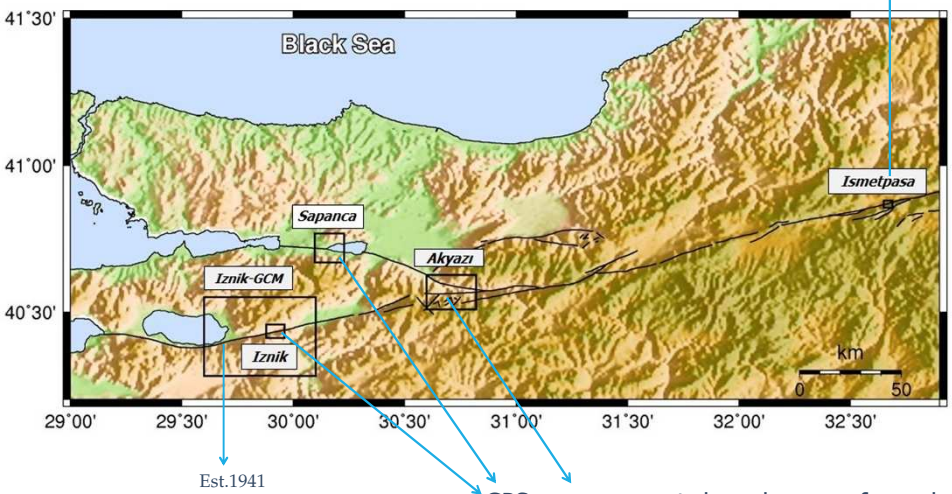
Tectonic Settings of Turkey





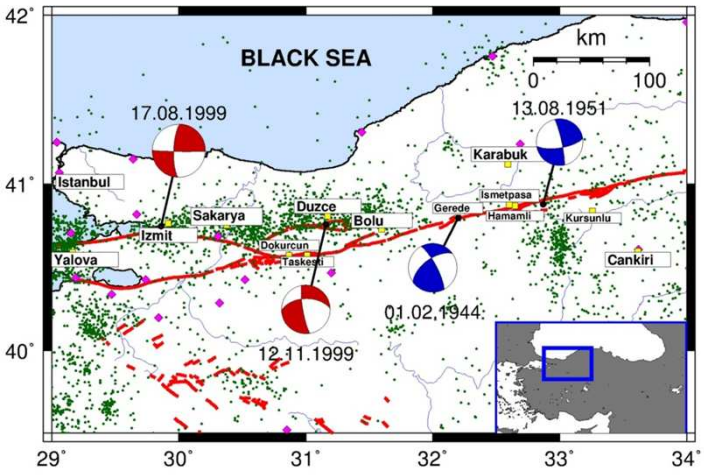
The wesward migration earthquakes since 1939 along the North Anatolian Fault

Geodetic networks on the western NAF



GPS measurements have been performed since 1994.

The map displays the seismicity and the focal mechanisms of devastating earthquakes in the region.



Data Processing and Analysis

Number of stations at each networks

Iznik	Sapanca	Akyazi	Ismetpasa	Iznik-GCM
10	5	10	6	5

Fieldworks at Geodetic Networks

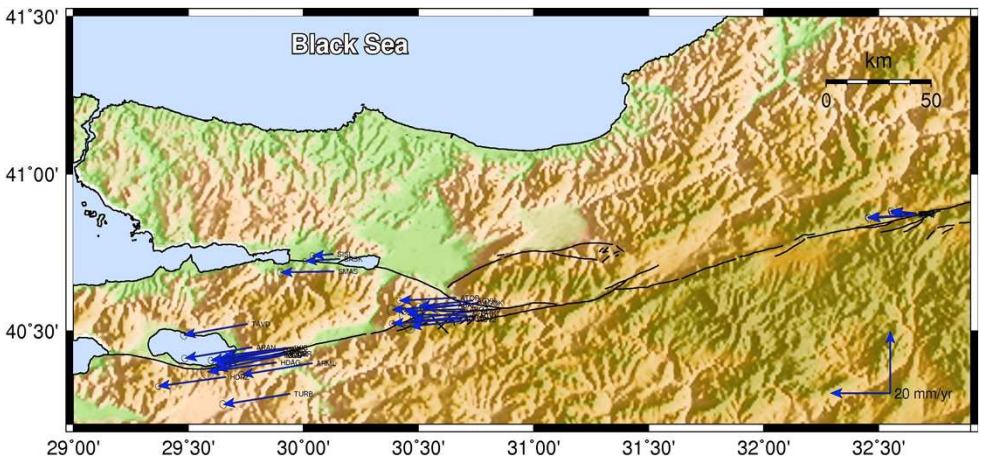
Data Processing and Analysis

Networks \ Years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Iznik	X	X	X	X	X	X	X	X	X	X
Iznik-GCM			X					X	X	X
Sapanca	X	X	X		X	X	X	X	X	X
Akyazı	X						X	X	X	X
Ismetpaşa	X		X		X	X	X	X	X	X

The table displays the observation spans of the networks

Details of measurement and process steps

- Equipment
- 10-hour/day
- The elevation mask 10°
- Logging 15 sec.
- GAMIT/ GLOBK
- ITRF2008.
- Precise orbit, IGS , SP3 (Standard Product 3) from SOPAC
- Earth Rotation Parameters (ERP) came from USNO_bull_b
- 9-parameter Berne model---radiation and the pressure.
- Scherneck model for the ocean tide loading effect.
- Zenith Delay unknowns Saastamoinen a priori standard troposphere model with 2-hour interval.
- Iono-free LC (L3) linear combination of L1&L2 carrier phases
- The model which depended on the height for the phase centers of the antennas.



The map shows the horizontal velocity field of networks in Eurasia-fixed reference frame. (with 95% confidence ellipses). Black line displays the North Anatolian Fault

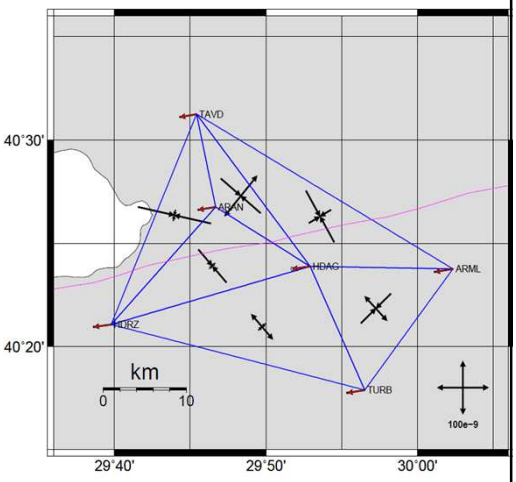
Strain Analysis

- Strain is the key element in order to understand the seismic hazard analysis.
- We analyzed periodic GPS observations of these networks to derive velocity vectors and principal components of crustal strain rates.
- In this study, strain rates are calculated only ***Iznik-GCM*** network.

Strain Analysis

Iznik-GCM

Lon.(o)	Lat.(o)	ε_1 (10^{-9} y^{-1})	ε_2(10^{-9} y^{-1})	Azimuth (o)
29.8057	40.4550	0.989E+02	-1.009E+02	-50.1002
29.7326	40.4393	-0.209E+02	-1.458E+02	-77.7694
29.8928	40.4384	-0.491E+02	-1.110E+00	-29.6059
29.7743	40.3984	-0.159E+02	-0.824E+02	-41.4508
29.8290	40.3491	0.634E+02	-0.187E+02	48.3211
29.9543	40.3640	0.634E+02	-0.802E+02	46.4050



Results

- The Iznik map of horizontal deformation shows that southern branch of western NAF is without the presence of significant tectonic deformation. North and south parts of the fault move toward southwest relative to Eurasia with the same rate.
- Although spatial coverage within Sapanca is relatively low, obtained velocities ranged between 6.70±1 and 17.90±1 mm/y.
- The southern part of this fault branch seems to agree with the expected rate which is higher than the upper part.

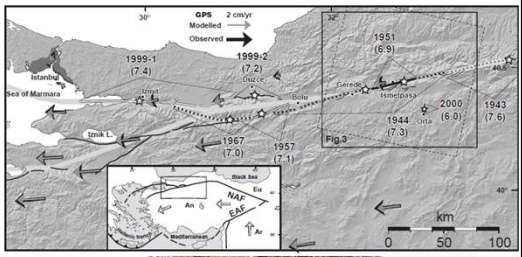
Results

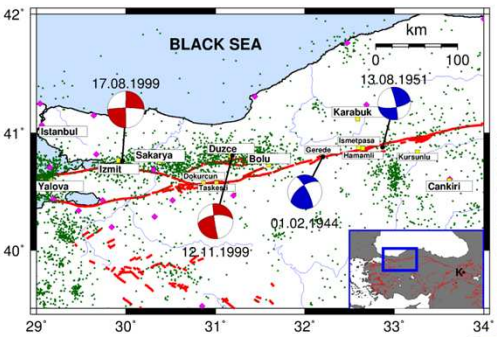
- Site velocities in Akyazi network are consistent with limits of 18.30-22.80±1 mm/y.
- NAF splays into two branches here. Site velocities reflect the movements of different segments.
- For the Iznik-GCM network, velocities varies between 21.60±1 and 24.00±1 mm/y. The maximum strain rate is 98 nstrain/y agreeing with the region tectonics.
- The largest magnitude of horizontal velocities relative to Eurasia detected at GPS sites at western Black Sea (Ismetpasa) is 19.70±1 mm/y and relative to a northern GPS site (ISP2) is 7.83±1 mm/y. So that the creep rate from 2005 is approximately 7 mm/y.

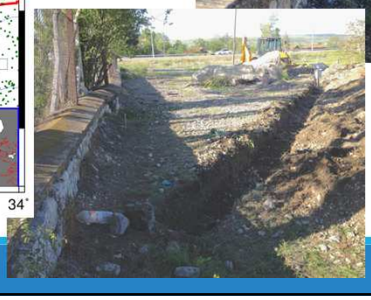
New Studies

Creepmeter
on the
North Anatolian Fault

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.



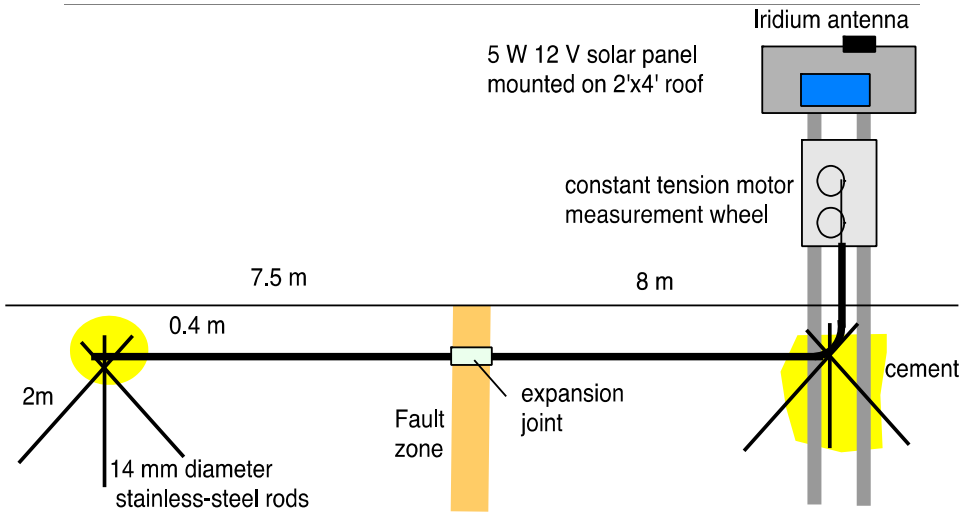





garage
40.86976°N, 32.62507°E
cowshed
Image © 2014 CNES / Astrium
1948 m


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

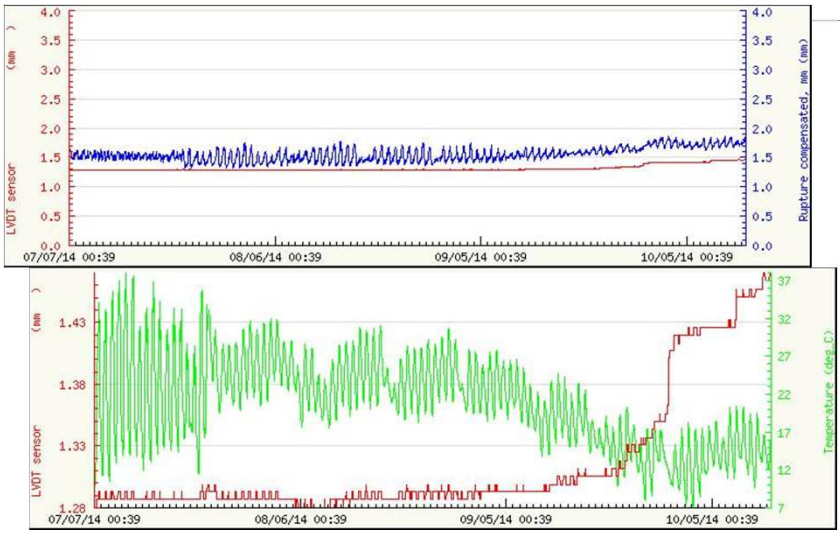
Creepmeter Specifications

- *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.*

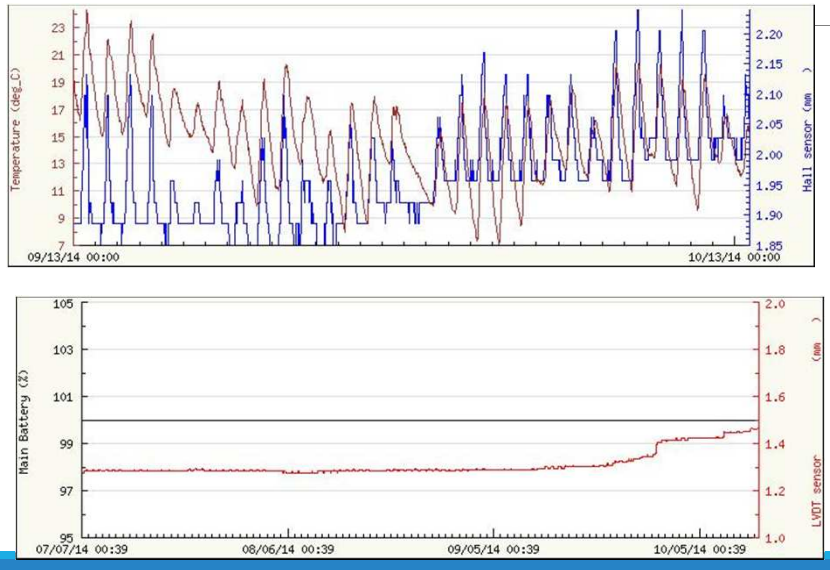
Sensors

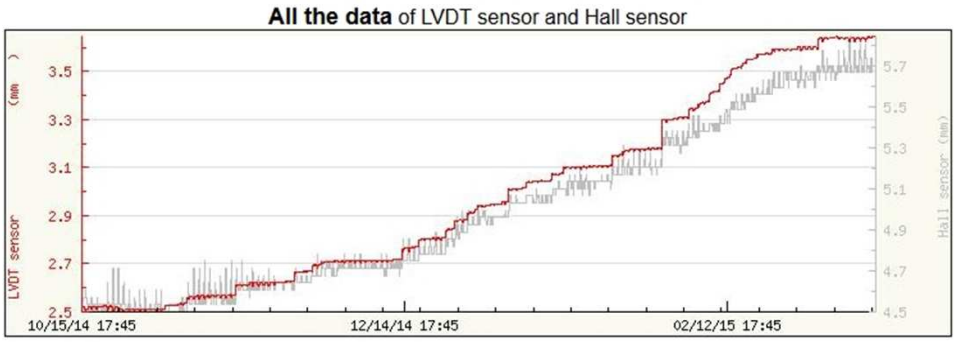
Field studies and maintenance

Data


LVDT sensor (mm)
Rupture compensated, mm (mm)
07/07/14 00:39
08/06/14 00:39
09/05/14 00:39
10/05/14 00:39
Temperature (deg_C)

Data


Temperature (deg_C)
Hall sensor (mm)
09/13/14 00:00
10/13/14 00:00
Main Battery (%)
LVDT sensor (mm)
07/07/14 00:39
08/06/14 00:39
09/05/14 00:39
10/05/14 00:39



Strainmeter

Determination of deformation < 1mm

Slow Earthquake

(Slow slip Event/Episodic Tremor Slip)

- new concept for earthquake studies.
- Between aseismic slip and earthquake.
- It is believed that, it triggers earthquakes and happened before the large events.
- It can not be identified by sismometer and accelerometer.
- It happens in deep and very slowly. months or years.

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

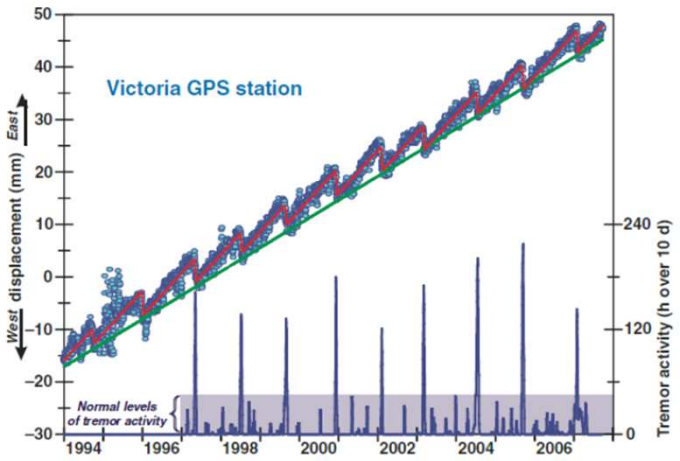
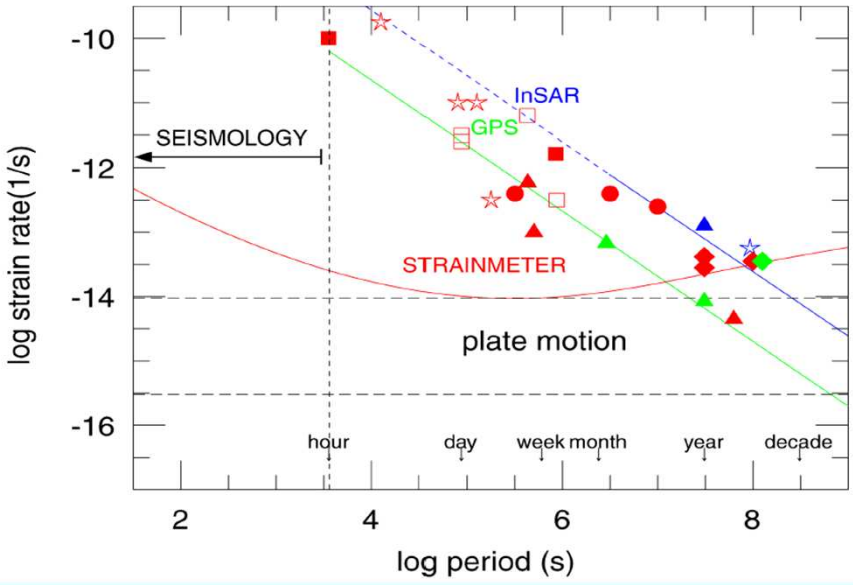
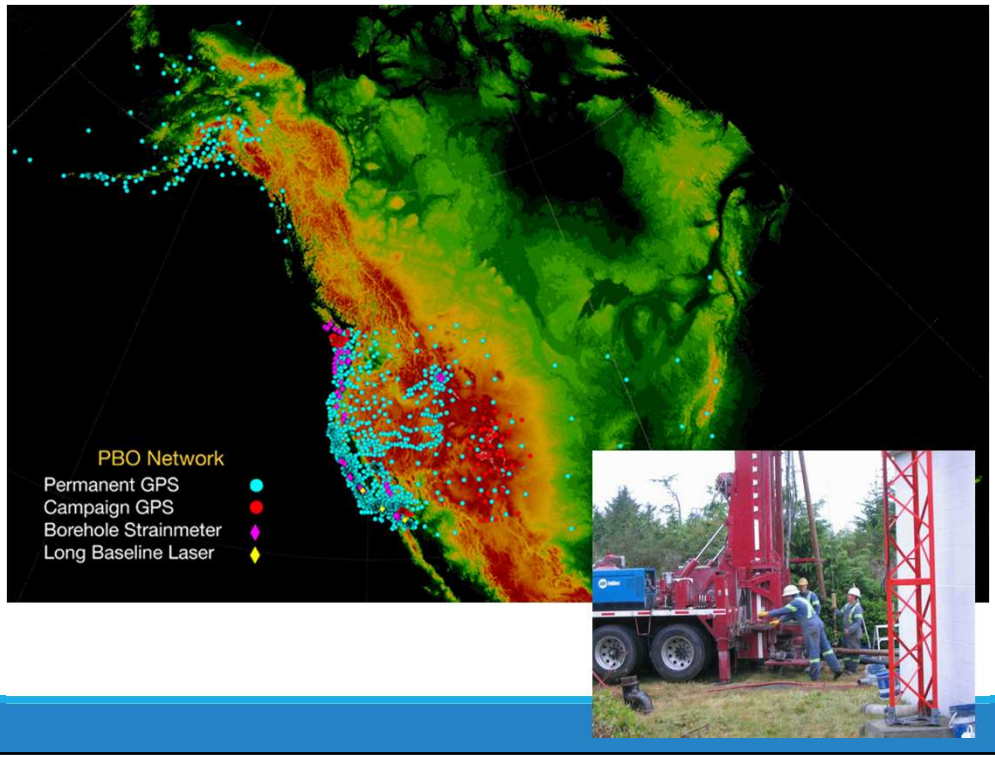


Figure 5. Episodic and Tremor Slip (ETS) (Gomberg, 2010)

Gomberg, 2010

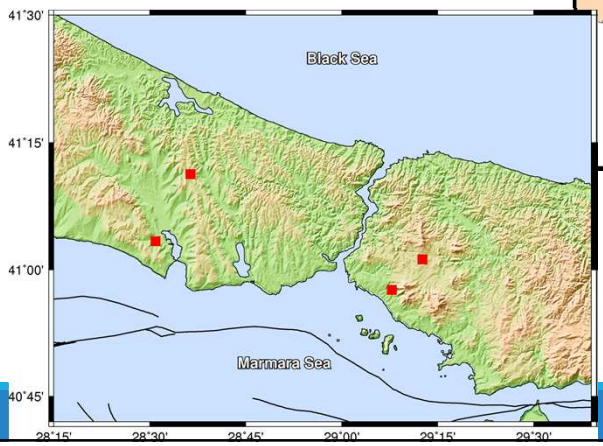
Why use strainmeter?



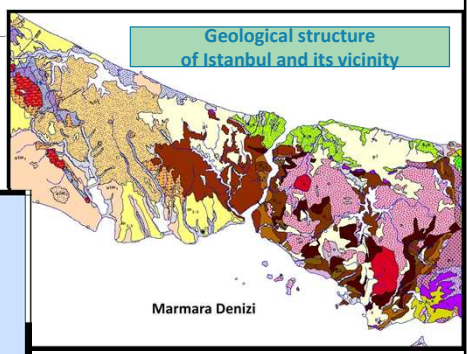


Borehole Geodetic Monitoring in Marmara Region

Selection of sites



Geological structure of Istanbul and its vicinity

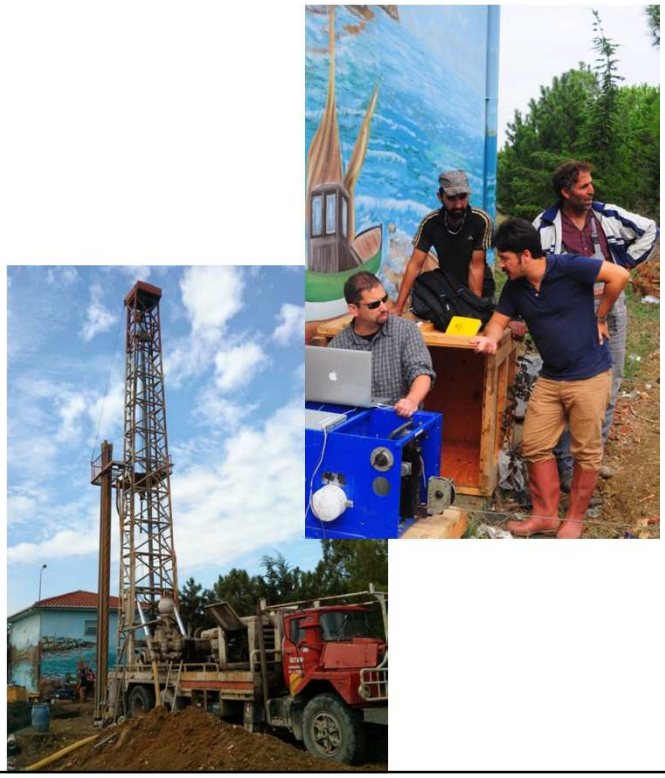


Office and field studies

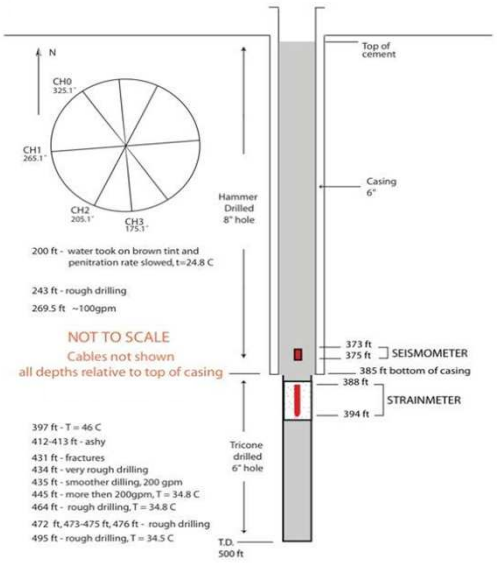
Our team studied on the geology map of Marmara region to find suitable places for drilling. Then a field trip was carried out for reconnaissance.

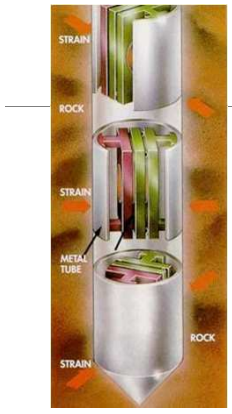
Borehole Installation İstanbul-2014

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.



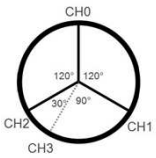
Borehole equipments





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.

Instrument used



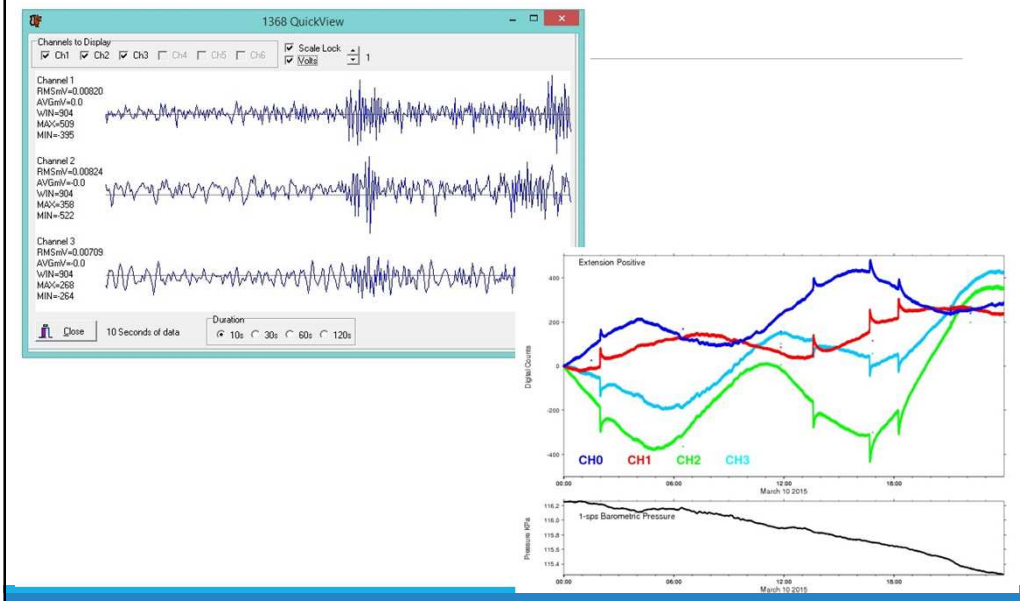
Strainmeter

Seismometer

Pore pressure

Data Transfer

Seismic data are collected by seismometers installed in the boreholes



http://strainistanbul.org/

Thank you for interest and attention

ozener@boun.edu.tr