Contrasting seismogenic behaviors on the North Anatolian Fault in the Sea of Marmara

Pierre Henry, Aix Marseille Univ, CNRS, IRD, INRAE, Coll France, CEREGE, Aix-en-Provence, France (henry@cerege.fr)

Céline Grall*, Valérie Ballu, La Rochelle Univ., CNRS, LIENSS, La Rochelle, France

M Sinan Özeren, Volkan Özbey, Gülseren Uçarkuş, Ziyadin Çakir, Istanbul Technical University, Maslak, Istanbul, Turkey

Louis Géli, IFREMER, Centre de Brest, Géosciences Marines, Plouzané, France

Semih Ergintav, Kandilli Observatory and Earthquake Research Institute, Department of Geodesy, Bogazici University, Istanbul, Turkey

Dietrich Lange, Helmholtz Centre for Ocean Research Kiel GEOMAR, Kiel, Germany

Jean-Yves Royer, Laboratoire Géosciences Océan, Université de Brest and CNRS, Plouzané, France

* Also at Lamont-Doherty Earth Observatory, Columbia University, New York, NY, USA
The Main Marmara Fault and the Splays

- Geodetic Eurasia-Anatolia plate motion 24±1 mm/yr (McClusky, 2000; Meade et al., 2002; Reilinger et al., 2006, 2010)
- 2/3 to 3/4 taken by the MMF
Geological vs Geodetic fault rates

- Trenching (last 1000 yrs; Meghraoui et al., 2012)
- Offset seafloor morphology (since 12 000 yr; Polonia et al., 2004; Gasperini et al., 2011; Grall PhD Thesis, 2013)
- Offset buried morphology (100.000 – 400.000 yr; Grall et al., 2013; Kurt et al., 2013)

Geodetic plate motion 24±1 mm/yr (Mc Clusky, 2000; Meade et al., 2002; Reilinger et al., 2006, 2010)

Geodetic interseismic loading rate 20±2 mm/yr (Ergintav et al., 2014)
Results of seafloor acoustic ranging experiments

Aseismic creep rates at the seafloor
- Central High deployment (EMSO & MARSITE)
  - < 2 mm/yr
  - (Sakic et al. 2016; Lange et al., 2019)
- Western High deployment (Turkish-Japanese project)
  - = 10.7 ± 4.8 mm/yr
  - (Yamamoto et al., 2019)
Inversion of geodetic data

- Inverted slip deficit rates have large uncertainties in the central part of the Sea of Marmara and also depend on assumptions on the southern branch but imply:
  - Low rate of slip deficit between 027.5° and 028°E
  - Asperity on the Istanbul-Silivri segment
Distribution of seismicity along the Main Marmara Fault

Figure 13
Schmittbuhl et al., 2016

Base of seismogenic zone is about 5 km deeper W vs E

Wollin et al., 2018
Historical seismicity and aseismic creep

Fully locked (>10 km depth) segments

Marmara Sea M≥6.8 seismicity 0-2000 AD

Parsons et al. (2004)

Aseismic creep
10 mm/an at seafloor (Yamamoto et al., 2019) and repeaters at crustal depths (Schmittbuhl et al., 2016; Bohnhoff et al., 2017; Uchida, 2019)

No seafloor creep
(Sakic et al., 2016)
(Lange et al., 2019)
Low seismicity
(Bohnhoff et al., 2013; Wollin et al., 2018)

Shallow (10 km) locking depth
(Bohnhoff et al., 2013; Ergintav et al., 2014)

Post-seismic creep
(Ergintav et al., 2009; Çakir et al., 2012; Aslan et al., 2019)

No seafloor creep (Sakic et al., 2016), Low seismicity (Bohnhoff et al., 2013; Wollin et al., 2018), Shallow (10 km) locking depth (Bohnhoff et al., 2013; Ergintav et al., 2014), Post-seismic creep (Ergintav et al., 2009; Çakir et al., 2012; Aslan et al., 2019)

Post-seismic creep
(Ergintav et al., 2009; Çakir et al., 2012; Aslan et al., 2019)
Creeping does not mean safe

Surface aseismic creep on the North Anatolian fault is observed along the surface rupture of large earthquakes


3. Western Sea of Marmara segment: creep rate ≈10 mm/yr (*Yamamoto et al.*, 2019), likely ruptured at least in part during 1912 Earthquake

Seafloor rupture on Western SoM segment

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Influence of crustal heterogeneity

- North Anatolian Fault follows Intra-pontide ophiolitic suture (Şengör et al., 2014)
- Relationship between creeping at the surface and outcropping lithology is complex (e.g. ophiolitic melange, limestone and volcanics on Ismetpaşa segment, Cetin et al., 2014)
- In the Sea of Marmara, presence of a high density, high magnetic body along Prince Island segment (Gholamrezaie et al., 2019)
Possible influence of hydrocarbon gas generation in Thrace basin

- Shallow microseismicity and creep hypothetically related to high fluid pressure and gas migration in fault zone above 6-8 km depth (Géli et al., 2018; Grall et al., 2018; Tary et al., 2019)

July 25, 2011 M₄ 5.1 Earthquake aftershocks relocated with OBSs (Géli et al., 2018)
Heat flow and sediment blanketing effects

**Crustal heat flow**
60-70 mW/m²

**Basin thermal model from Grall et al. (2012)**

**Syn-kinematic Sediment thickness**
From Bayrakci et al. (2013)
Crustal heat flow and tectonic stretching

- Variations in tectonic stretching cannot explain higher crustal heat flow in the Eastern SoM
- Higher crustal heat flow in the Eastern SoM could explain a shallower seismogenic zone as well as a more distributed extension

Beta values from Kende et al. (2017)

Crustal heat flow values are calculated as the heat flow at the top of the crust in the absence of sediment blanketing
Conclusions

• Apparent relationship between crustal thickness variations and seismogenic zone segmentation in the Sea of Marmara
• High fluid pressure caused by gas generation in Thrace Basin may unlock faults down to a maximum depth of 6-8 km
• Crustal heterogeneities may influence creeping and locked zone distribution at crustal level
• Long term post-seismic creep is known to occur after large earthquakes. Ganos 1912 earthquake may thus have caused enhanced aseismic creep at crustal level in the Western Sea of Marmara.
• Variations of seismogenic zone lower limit correlate with variations of thermal regime
Some references


