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

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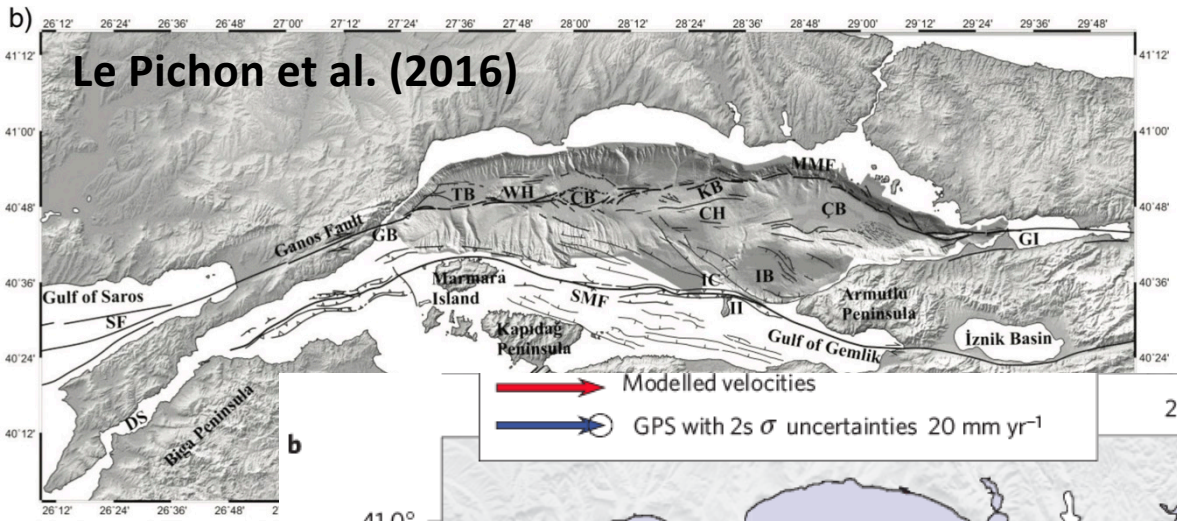
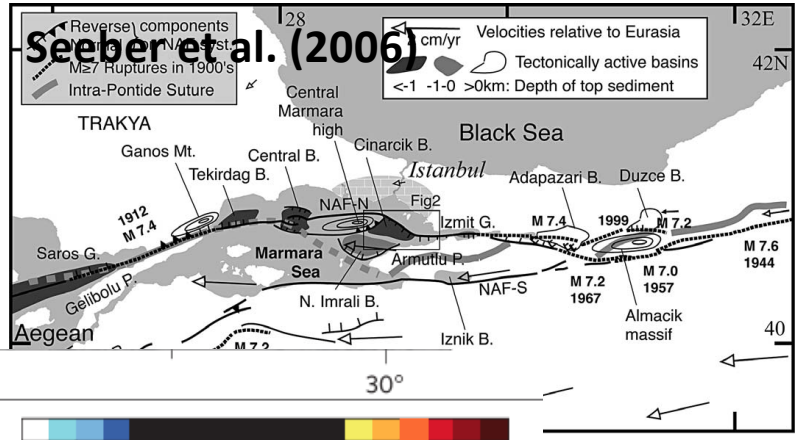
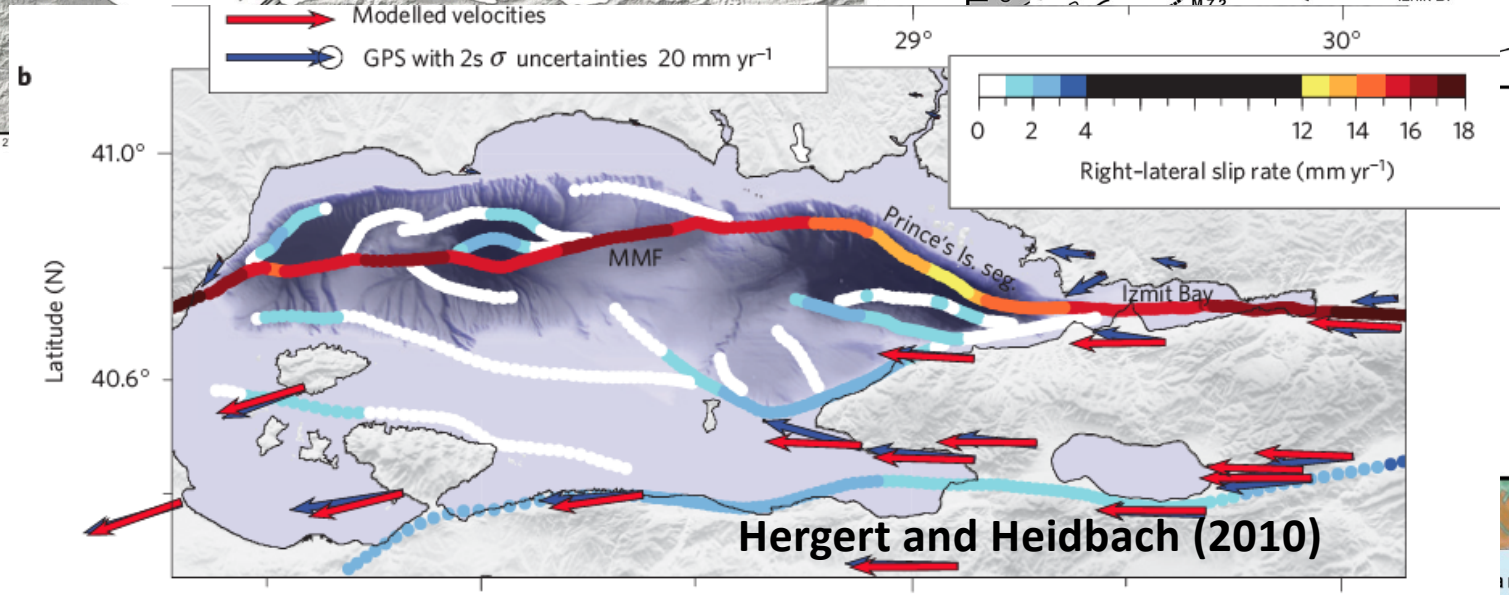
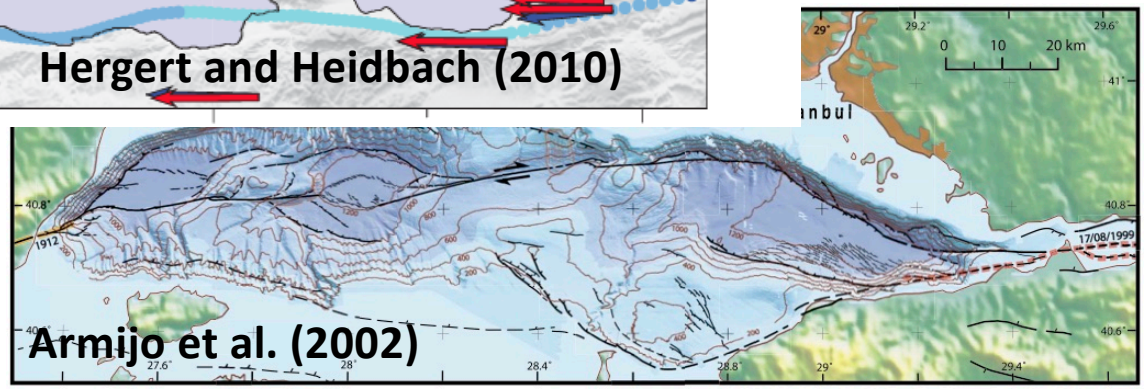
MAREGAMI

The Main Marmara Fault and the Splays



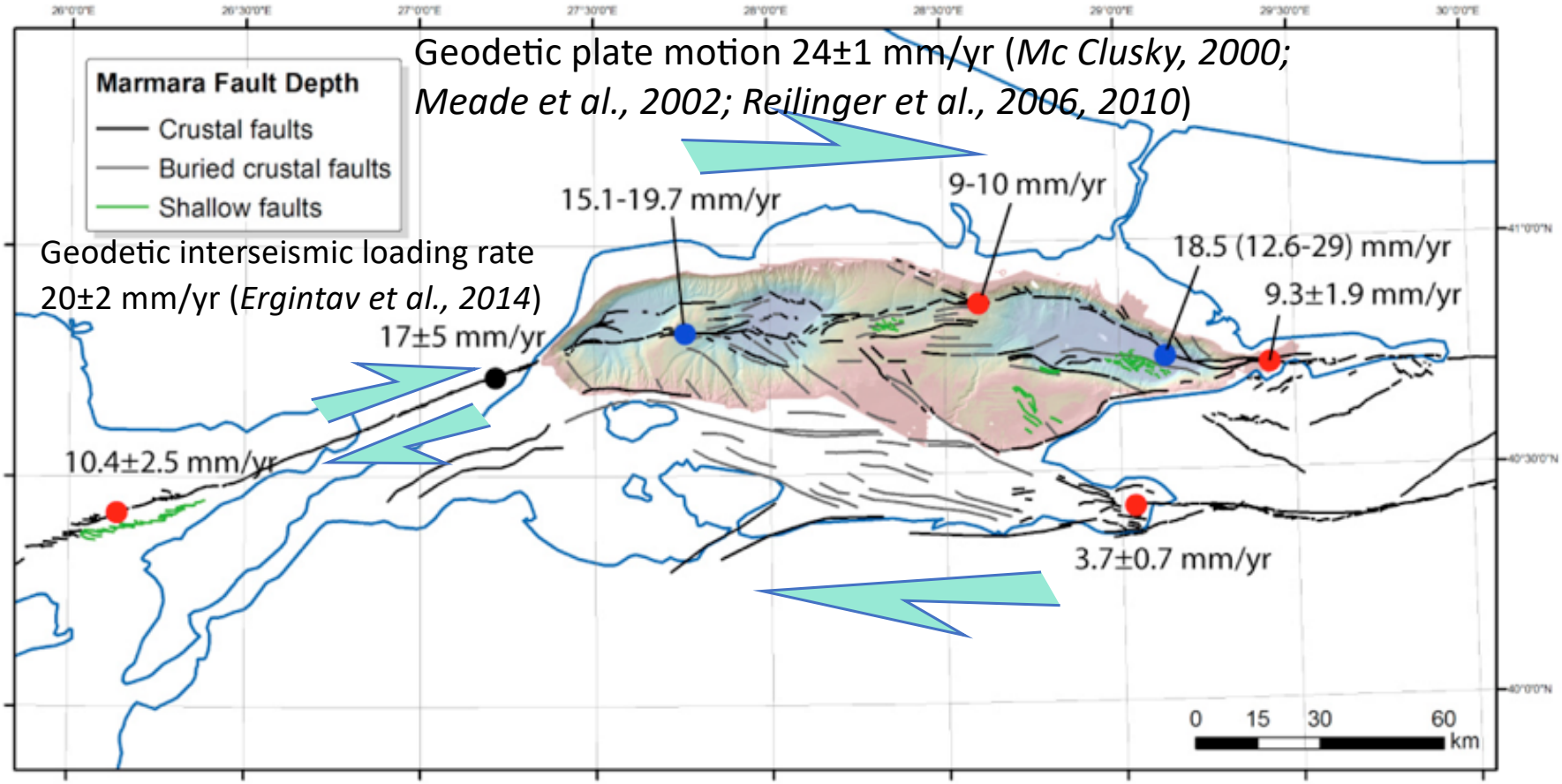






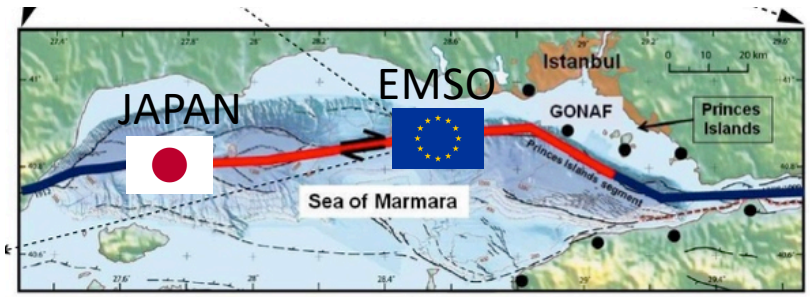
- Geodetic Eurasia-Anatolia plate motion 24±1 mm/yr (*Mc Clusky, 2000; Meade et al., 2002; Reilinger et al., 2006, 2010*)
- 2/3 to 3/4 taken by the MMF

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)

Results of seafloor acoustic ranging experiments



Aseismic creep rates at the seafloor

- Central High deployment (EMSO & MARSITE)

  < 2 mm/ yr

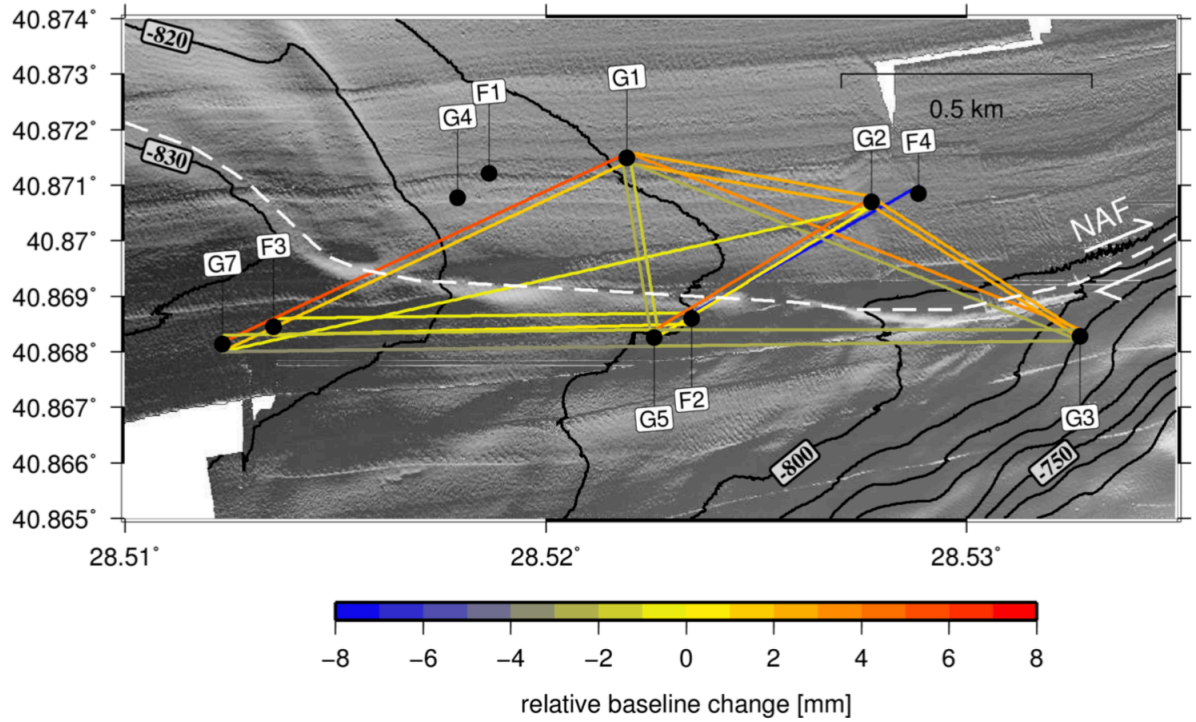
(*Sakic et al. 2016; Lange et al., 2019*)

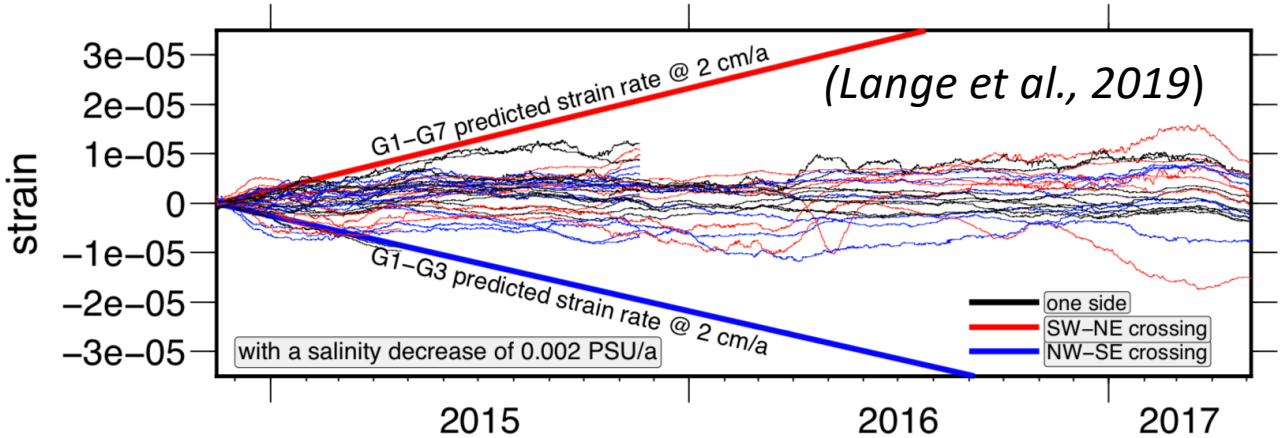
- Western High deployment (Turkish-Japanese project)

  = 10.7 ± 4.8 mm/yr

(*Yamamoto et al., 2019*)

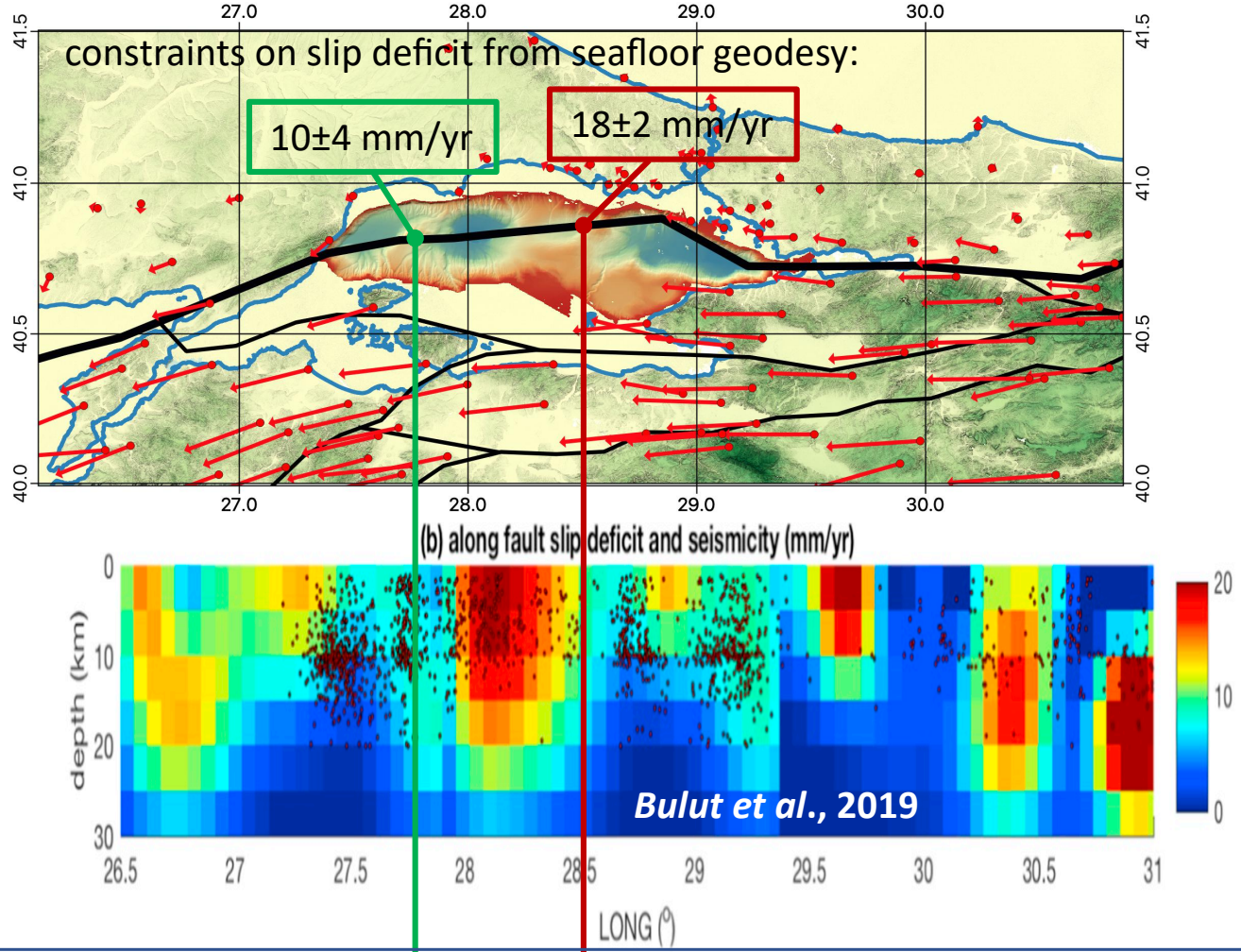
Joint LGO(Brest)/Geomar networks with 4 + 6 Sonardyne beacons



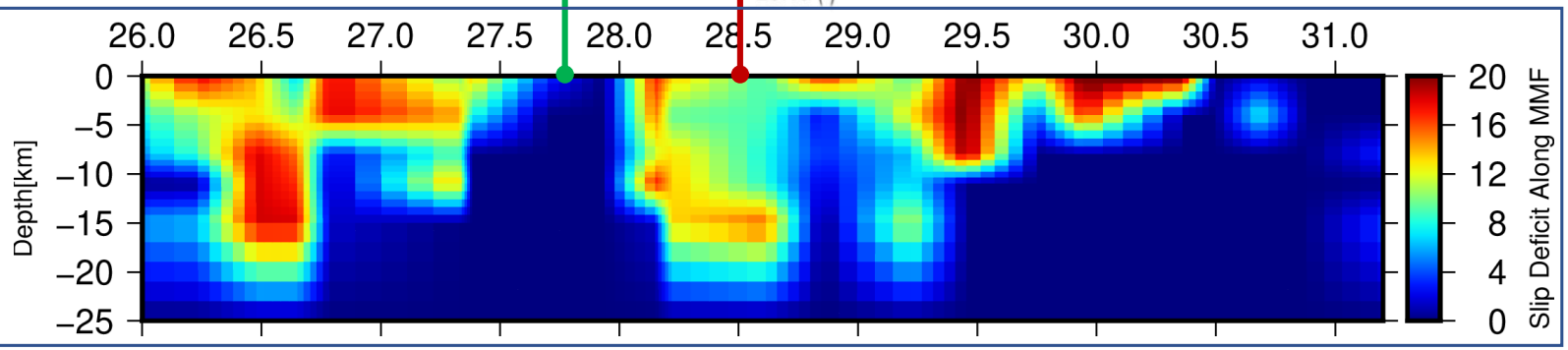


Inversion of geodetic data

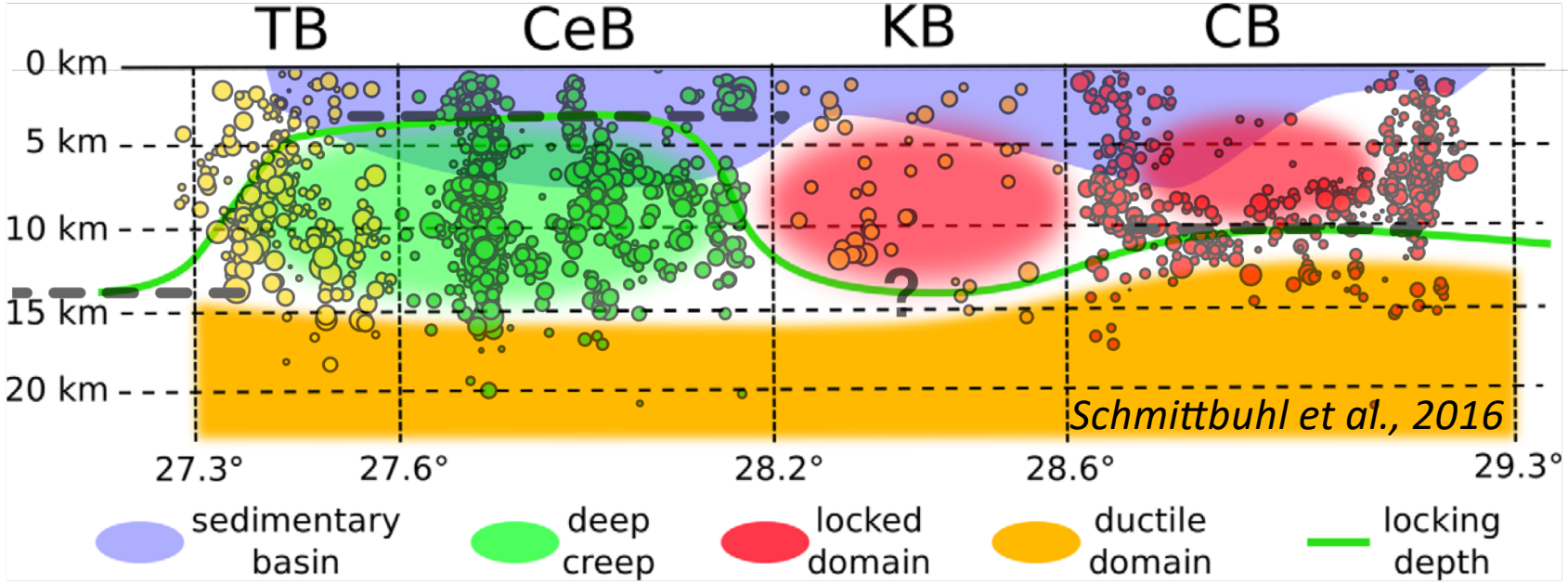
- Inverted slip deficit rates have large uncertainties in the central part of the Sea of Marmara and also depend on assumptions on the southern branch but imply:
- Low rate of slip deficit between 027.5° and 028°E
- Asperity on the Istanbul-Silivri segment



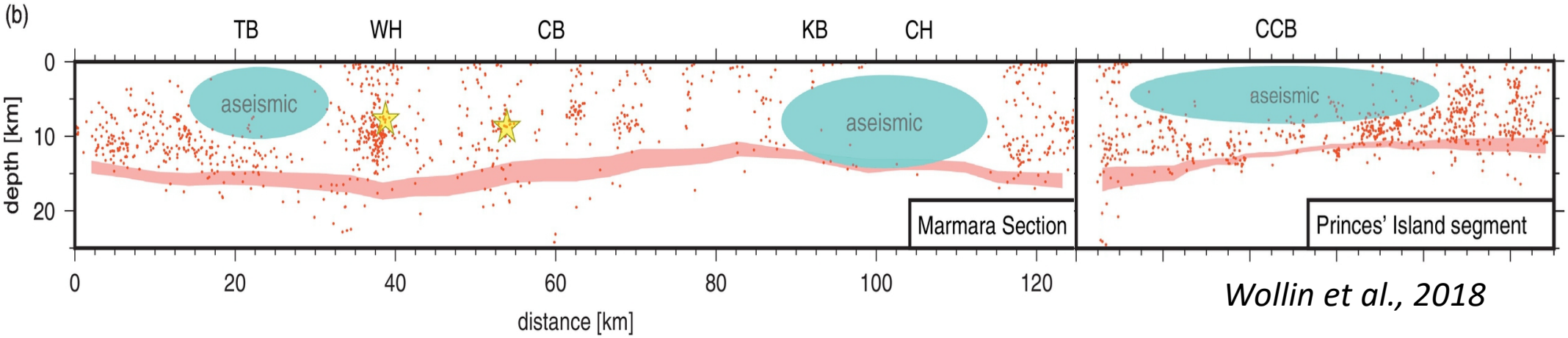
***Özbey et al.*, EGU 2020**
This session



Distribution of seismicity along the Main Marmara Fault



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

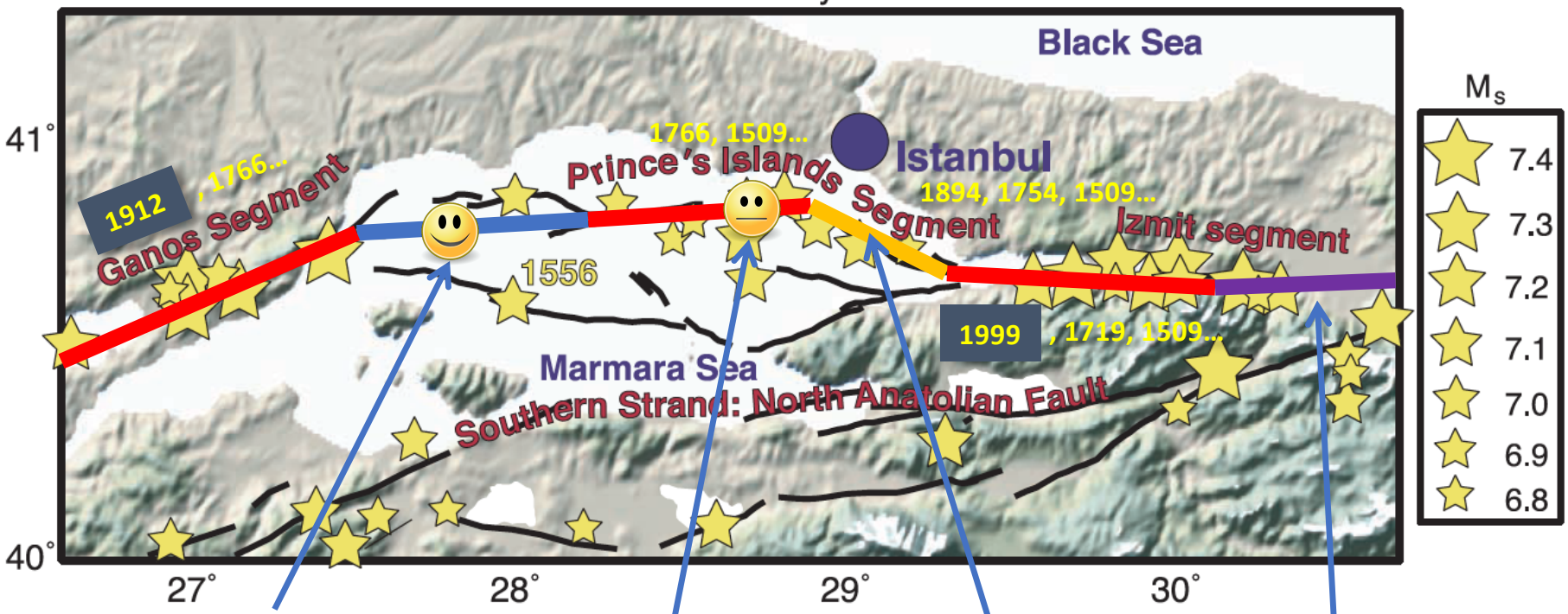


Historical seismicity and aseismic creep

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*)

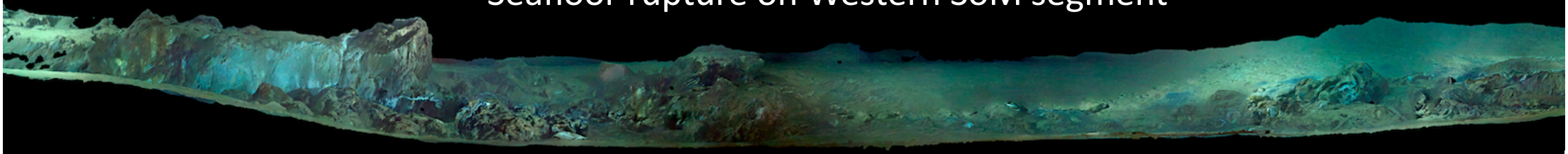
Post-seismic creep
(*Ergintav et al., 2009; Çakir et al., 2012; Aslan et al., 2019*)

Creeping does not mean safe

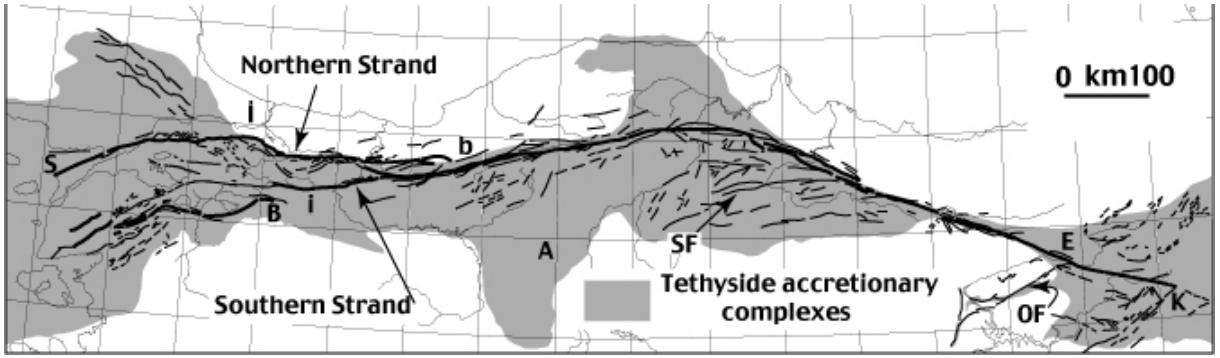
Surface aseismic creep on the North Anatolian fault is observed along the surface rupture of large earthquakes

1. *Ismetpaşa* segment: current maximum creep rate 20 mm/yr in 1944 rupture zone (*Çakir et al.*, 2005; *Setin et al.*, 2014)
2. Izmit segment: current maximum creep rate 8 mm/yr in 1999 supershear rupture zone (*Çakir et al*., 2012; *Aslan et al*., 2019)
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

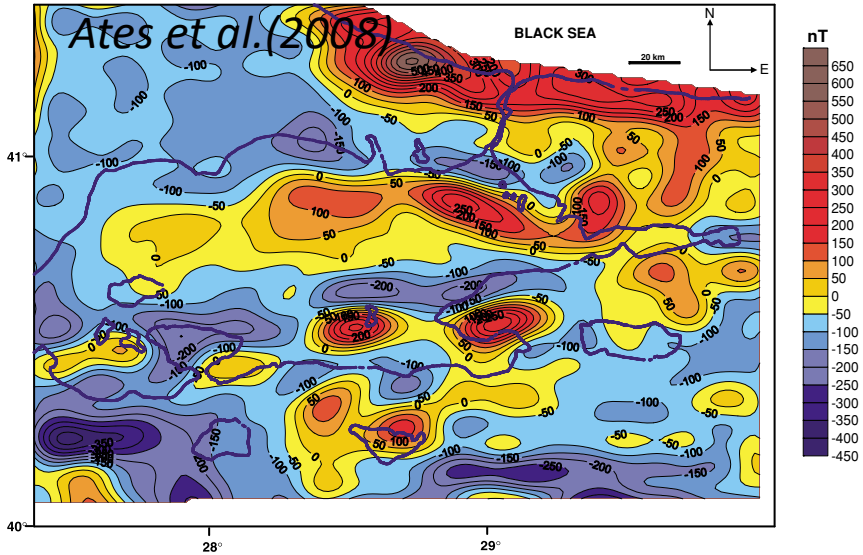


Influence of crustal heterogeneity

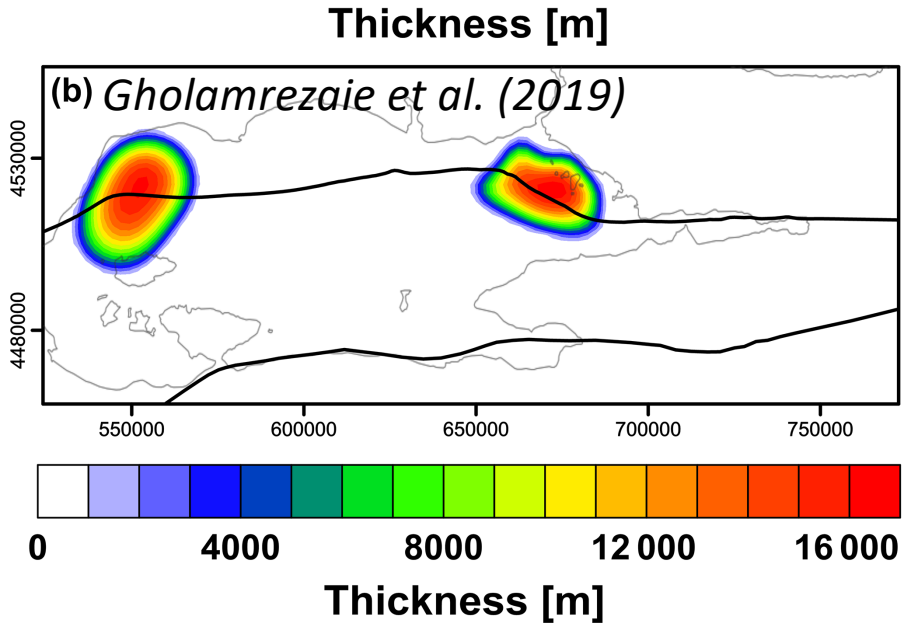


- North Anatolian Fault follows Intra-pontide opholitic suture (*Şengör* et al., 2014)
- Relationship between creeping at the surface and outcroping lithology is complex (e.g. ophiolitic melange, limestone and volcanics on *Ismetpaşa* segment, *Cetin et al*., 2014)
- In the Sea of Marmara, presence of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

Magnetic anomaly map

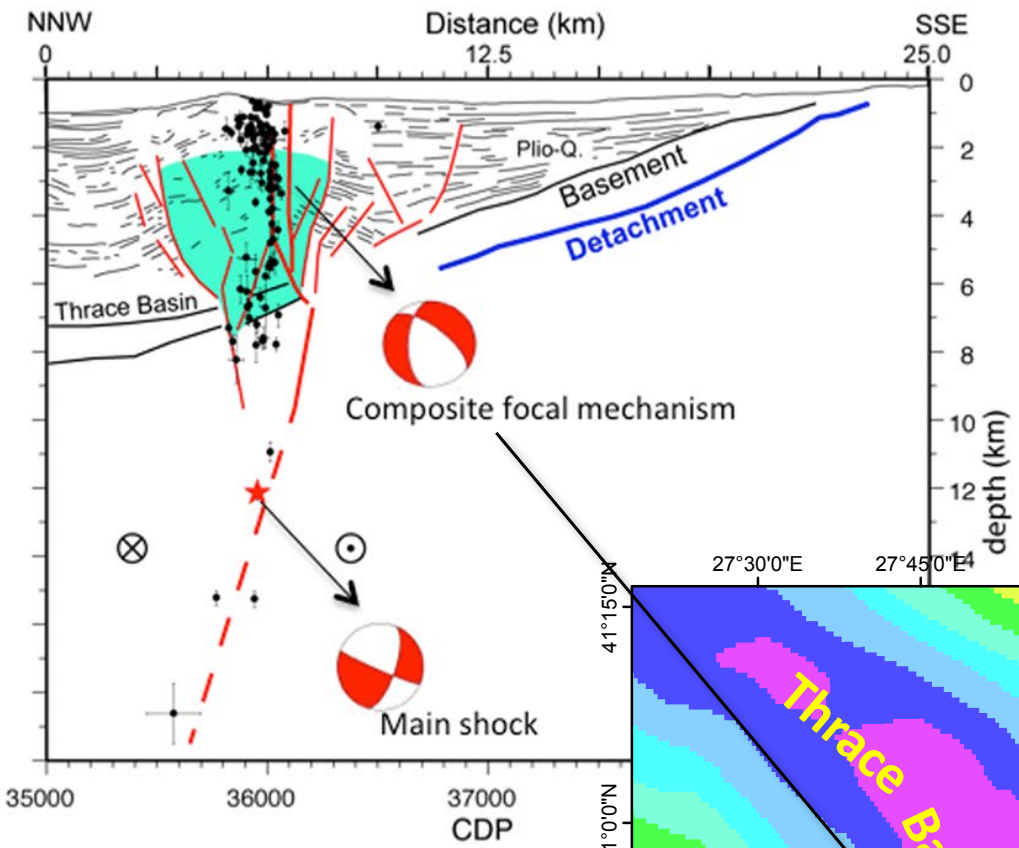


High density bodies within crust

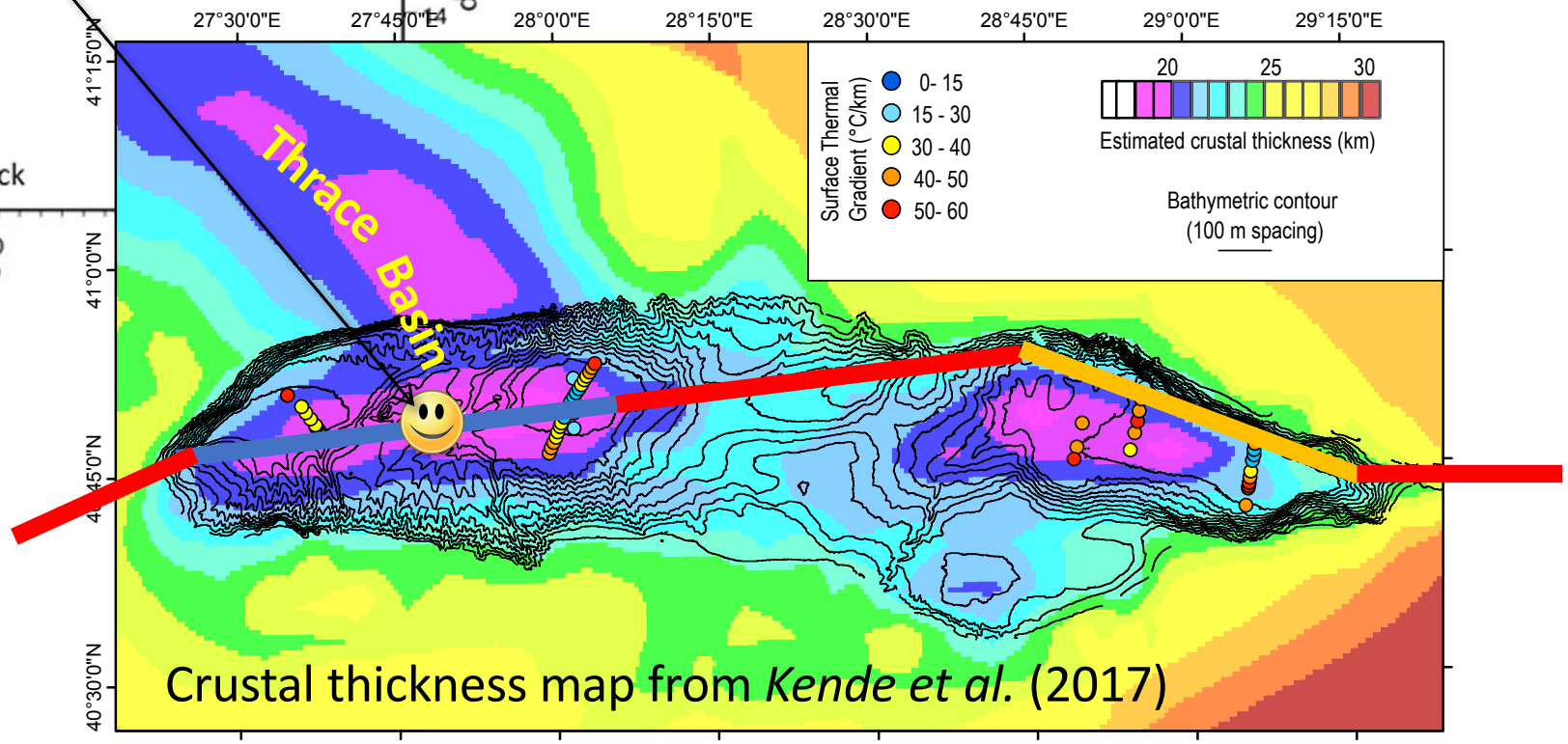


Possible influence of hydrocarbon gas generation in Thrace basin

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



July 25, 2011 M_L 5.1 Earthquake aftershocks relocated with OBSs (*Géli et al.*, 2018)

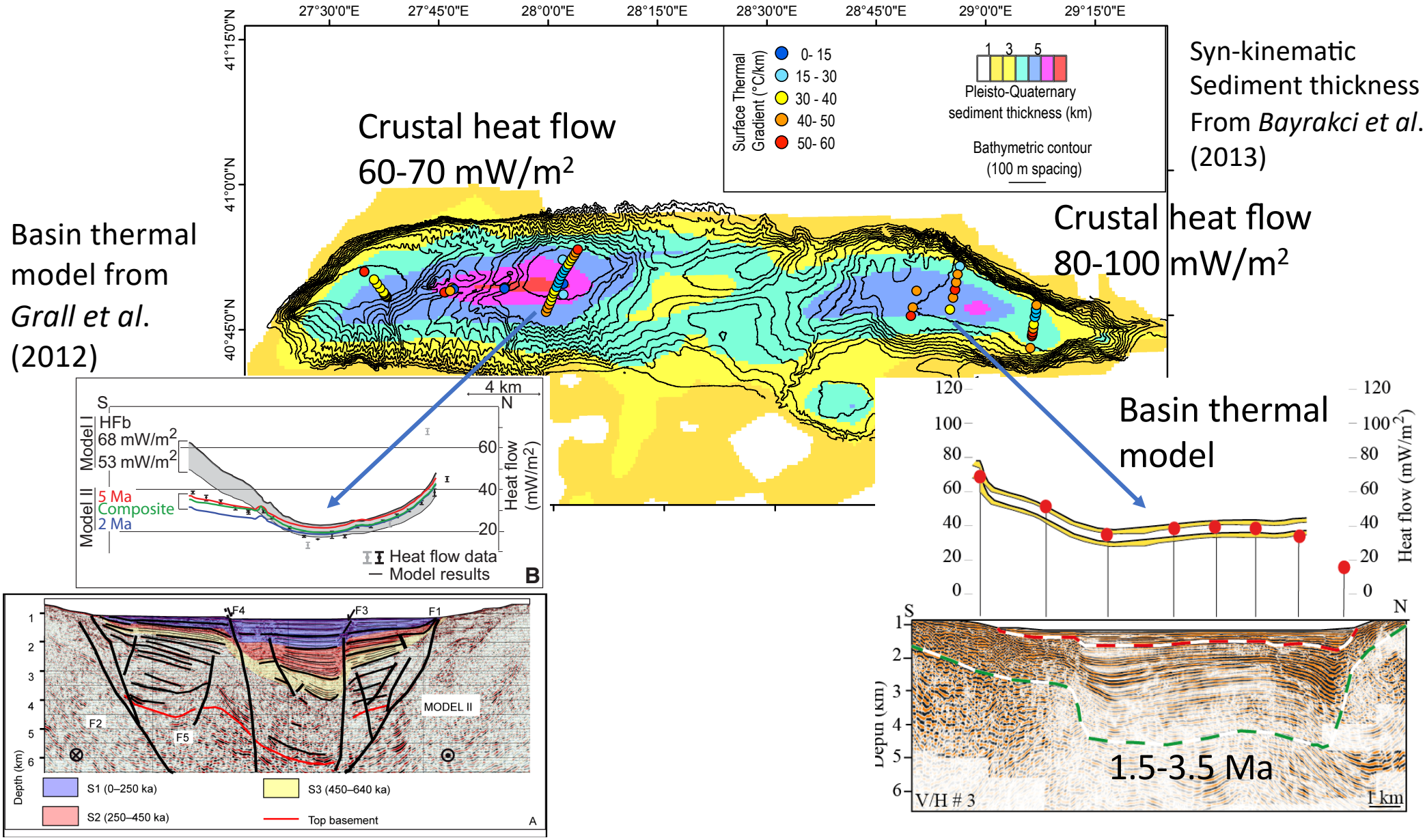


Crustal thickness map from *Kende et al.* (2017)

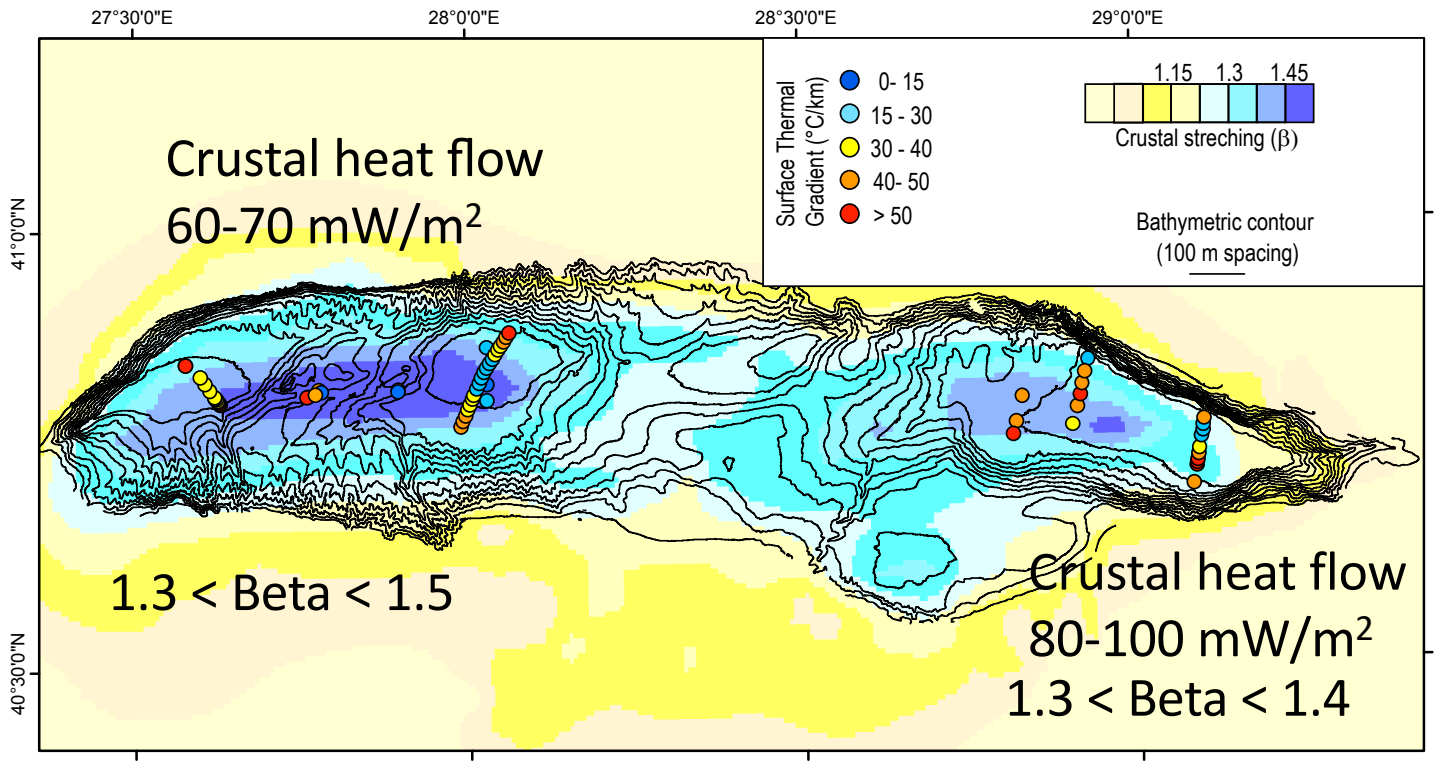
Heat flow and sediment blanketing effects

Syn-kinematic Sediment thickness From *Bayrakci et al.* (2013)

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



Crustal heat flow and tectonic stretching



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

- 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

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 heterogenities 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

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