Drilling the North Anatolian Fault

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An international workshop entitled "GONAF: A deep Geophysical Observatory at the North Anatolian Fault", was held 23–27 April 2007 in Istanbul, Turkey. The aim of this workshop was to refine plans for a deep drilling project at the North Anatolian Fault Zone (NAFZ) in northwestern Turkey. The current drilling target is located in the Marmara Sea offshore the megacity of Istanbul in the direct vicinity of the main branch of the North Anatolian Fault on the Prince Islands (Figs. 1 and 2).

The NAFZ represents a 1600-km-long plate boundary that slips at an average rate of 20–30 $mm \cdot yr^{-1}$ (McClusky et al., 2000). It has developed in the framework of the northward moving Arabian plate and the Hellenic subduction zone where the African lithosphere is subducting below the Aegean. Comparison of long-term slip rates with Holocene and GPS-derived slip rates indicate an increasing westward movement of the Anatolian plate with respect to stable Eurasia. During the twentieth century, the NAFZ has ruptured over 900 km of its length. A series of large earthquakes starting in 1939 near Erzincan in Eastern Anatolia propagated westward towards the Istanbul-Marmara region in northwestern Turkey that today represents a seismic gap along a ≥100-km-long segment below the Sea of Marmara. This segment did not rupture since 1766 and, if locked, may have accumulated a slip deficit of 4–5 m. It is believed being capable of generating two M≥7.4 earthquakes within the next decades (Hubert-Ferrari et al., 2000); however, it could even rupture in a large single event (Le Pichon et al., 1999).

The most recent devastating earthquakes in the region occurred in 1999 near Izmit and Düzce with magnitudes >7.

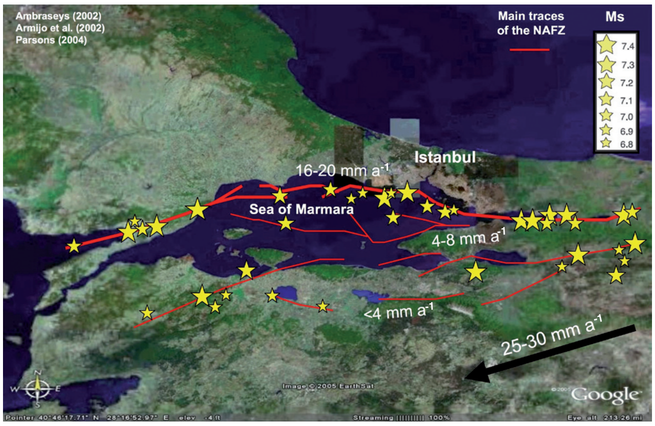

Figure 1. Google Earth view of the Marmara Sea / Istanbul region. Red lines indicate major segments of the North Anatolian Fault Zone (NAFZ). Stars indicate major events that occurred in the last 2000 years.

Their western termination of rupture is located offshore below the eastern Sea of Marmara possibly extending to just south of the Princes Islands (Özalaybey et al., 2002) within ~20 km of Istanbul.

Current seismic activity in the eastern Marmara Sea indicates a complex fault network at the transition between the western end of the Izmit earthquake rupture and the assumed seismic gap south of Istanbul. The majority of focal mechanism solutions indicate dominant strike-slip motion with minor normal faulting activity (Örgülü and Aktar, 2001; Karabulut et al., 2002). However, existing seismic observations lack the spatial and temporal resolution required to accurately distinguish between locked and creeping segments of the NAFZ. This is due to the threshold (magnitude >2) of the existing seismic networks. The knowledge of the stress state at the NAFZ is rudimentary at best. Stress orientation (World Stress Map) with respect to the fault zone is mainly based on a small number of focal mechanisms of larger seismic events (Heidbach et al., 2004) and aftershocks (Bohnhoff et al., 2006). Maximum compressive stress is generally oriented at 35°–45° with respect to the fault trend and in agreement with predictions from Coulomb friction theory. In contrast to other major plate bounding faults, the NAFZ does not appear to be a weak fault. However, no data exist on stress magnitudes and on heat flow close to the NAFZ in the Marmara Sea region.

The GONAF initiative focuses on the installation of a borehole observatory in a deep borehole at the NAFZ. This will conduct long-term monitoring of seismic activity, stress, heat and fluid flow. The target area is located offshore Istanbul in the Marmara Sea close to the main branch of the NAFZ on the outermost island of Sivriada (Fig. 2). The projected observatory is located at the transition between the western end of the 1999 Izmit rupture and the 150-km-long seismic gap along the western NAFZ that may have accumulated a 4–5 m slip deficit within the past 250 years.

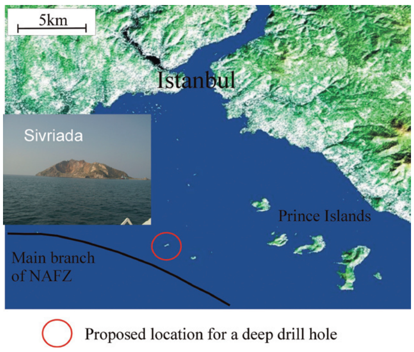

Figure 2. Proposed drilling location on the island of Sivriada that is located in direct vicinity to the main branch of the NAFZ.

Presentations at the workshop included an overview of existing fault drilling projects, a session on seismotectonics, seismology, and the geological setting of western part of the NAFZ and the Marmara Sea region, and deep borehole monitoring results and technology. The potential drill site on Sivriada island was visited during a one-day field trip. A summary of suggested pre-site and drilling-phase studies concluded the workshop. Key scientific and technical aspects of a deep drillhole and long-term geophysical observatory were discussed in order to prepare for a full drilling proposal to be submitted to the International Scientific Continental Drilling Program (ICDP).

Reports on fault mechanics and earthquake processes as well as technical and logistical challenges of a drilling presented included projects in California (San Andreas Fault Observatory at Depth; Hickman, et al., 2007), Taiwan (Taiwan Chelungpu-Fault Drilling Project; Ma and Tanaka, 2007), Japan (Nojima Fault; Ito et al., 2003), and Greece (Corinth Rift Laboratory; Cornet, 2007). All fault drilling projects produced new and ground-breaking results with regards to physics of faulting, slip distribution at hypocentral depth, source mechanisms, and the earthquake energy budget. Other presentations detailed the structure, kinematics, and seismotectonics of the western NAFZ emphasizing recent and partly unpublished field data. Unresolved fault structure and hypocenter locations in the Marmara Sea underscored the need for high-resolution long-term seismological observations and detailed wide-angle seismic profiling close to the planned drill site.

A final series of presentations focussed on state-of-the-art monitoring strategies for a borehole observatory including instrumentation and other technical aspects. In particular, detailed introductions presented new scientific results and technical achievements covering high-resolution earthquake monitoring, strain monitoring, velocity measurements, stress measurements, heat and fluid flow measurements, and borehole logging techniques.

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