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Late glacial-Holocene shelf evolution of the Sea of Marmara west of Istanbul

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ABSTRACT

We present an investigation the Late Quaternary seismic stratigraphy of the shelf area of the northern the Sea of Marmara extending from its northern coast (between Silivri and Kumkapı) to approximately 100 m depth, using shallow high-resolution seismic reflection data along 73 N–S and 15 E–W lines. Seismic sequence analysis is used to identify the depositional systems, associated sedimentation conditions, and relative sea level changes. Seismic stratigraphic interpretations indicate the presence of four distinct seismic units (SU I, II, III and IV) underlying the shelf area. Seismic units are bounded by erosional unconformities overlying an acoustic basement. Seismic unit I constitutes the acoustic basement (AB), which is characterized by chaotic, subparallel, and wavy reflections that out locally off the rocky shorelines and along the crests of the positive structures where the sedimentary cover is absent. Seismic unit II is interpreted to represent the pre-Holocene deposits and exhibits subparallel reflections. Seismic unit II is interpreted to have been subjected to sub-aerial erosion during the Last Glacial Maximum. Seismic unit III–IV are interpreted to have formed during the Holocene (Flandrian) transgression and have parallel/subparallel internal reflection patterns. The top of seismic unit IV forms the present-day sea floor. As a result of the presence of fill, seismic facies within seismic unit IV reflect differences in depositional processes. The bathymetry of the study area has a close relation with sedimentation dynamics, tectonic, wave and flow dynamics and palaeotopograpy. Particularly, sudden dip changes determined at the shelf area might have been due to fault and/or fault systems that control the bottom topography. Seismic activity in the Sea of Marmara region has a key role the northern branch of the North Anatolian Fault Zone (NAFZ) affecting on the tectonic activity of the study area. The last two earthquakes in İzmit and Duzce, Turkey, in 1999 have been originated from NAFZ. The presence of several faults on various scales in the seismic profiles of the study area is identified. The active normal faults in the Holocene units that disturb the seafloor are determined. Most of these faults are intense in the eastern part of research area. The isopach map of Holocene sediment (seismic unit III and IV) indicates that the maximum sediment accumulations (up to 36 m) occur in the offshore areas of Bakırköy and Kumkapı. Young sediment thicknesses are common on the shoreline areas in the investigated area.

1. Introduction

The evolution of shelf deposits during the Late Quaternary was mainly controlled by glacio-eustatic sea level fluctuations. In particular, during the Last Glacial Maximum 18,000 years ago, the global sea level was approximately 120 m lower than at present (Fairbanks, 1989). At this time, the Sea of Marmara was isolated from both the Black Sea and the Aegean Sea (e.g., Aksu et al., 2002; Smith et al., 1995). The Sea of Marmara is approximately 280 km long and nearly 80 km wide. It has a surface area of approximately 115,000 km^2 and an average depth of 494 m, reaching of 1355 m in its center (Barka, 1992). As shown Fig. 1A, the Sea of Marmara is connected to the Mediterranean Sea via the Dardanelles and to the Black Sea via the Bosphorus Strait. Relatively low-salinity, low-density water from the Black Sea flows into the Sea of Marmara via the Bosphorus Strait, while relatively high-salinity, dense Mediterranean water enters the Sea of Marmara via the Dardanelles. This results in a permanent two-layer structure with a halocline at a depth of 20–25 m (Ünlüata et al., 1990). The Sea of Marmara consists of a highly complex morphology including shelves, slopes, basins, sub-basins and ridges. Shelf areas appear at the southern and northern sides of

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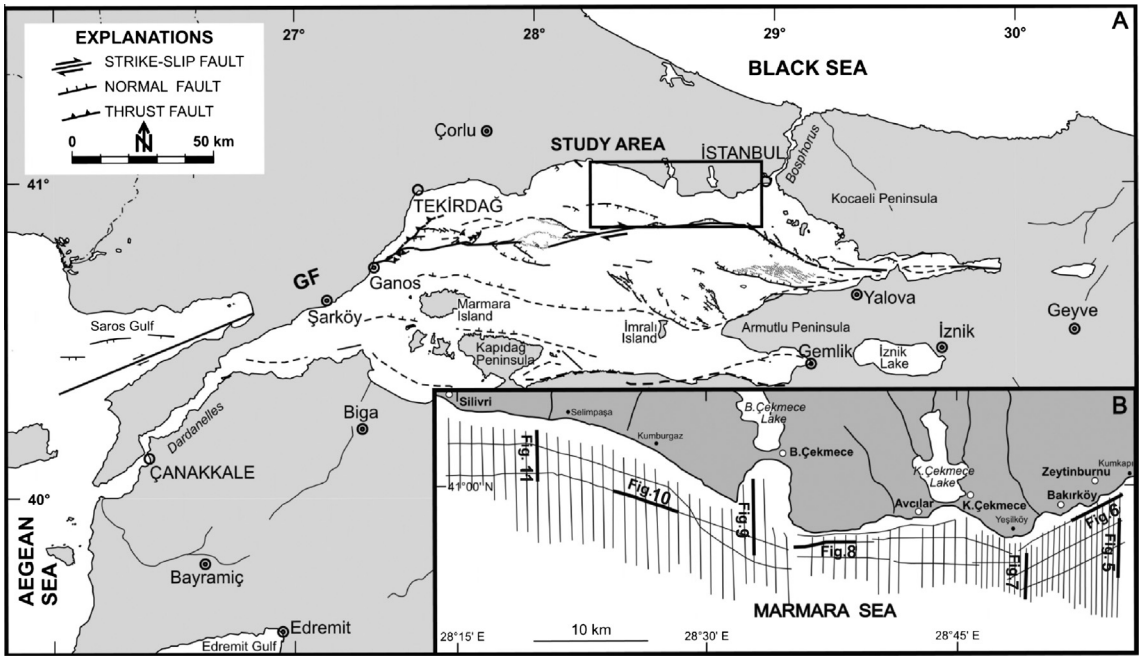

Fig. 1. (A) Tectonic map the Sea of Marmara (compiled from Armijo et al., 1999, 2002; modified from Okyar et al., 2008). (B) Locations of the seismic lines.

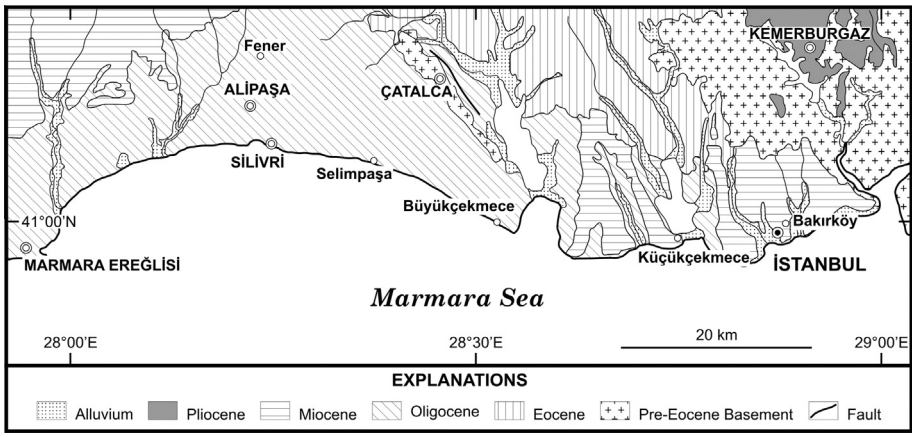

Fig. 2. Geological map of the coast surrounding the study area on the northwestern shelf of the Sea of Marmara (compiled from Turgut and Eseller, 2000; Türkecan and Yurtsever, 2002; Siyako, 2006).

the Sea of Marmara. This very complicated basin-ridge system is called as Marmara Trough indicating that this very complicated morphology of the Sea of Marmara is strongly related with the E–W oriented northern segment of the North Anatolian Fault Zone (NAFZ) in the Sea of Marmara. East–west trending active faults on seismic sections in the study area have been identified (Figs. 5–7). An east–west trending active fault in the Sea of Marmara was first mentioned by Pınar (1942). Later studies revealed that this fault is the possible extension of the North Anatolian Fault Zone (NAFZ). This recent variation of the tectonic regime in the northern shelf of the Sea of Marmara may indicate a significant change in the development of the NAFZ through the Sea of Marmara. The NAFZ is the main tectonic element controlling the present-day tectonic regime in the Marmara region.

To accurately map and interpret the fault geometry in the Sea of Marmara, intensive seismic reflection surveys (e.g., Aksu et al., 2000; Okay et al., 2000; İmren et al., 2001; Le Pichon et al., 2001, 2003; Demirbağ et al., 2003; Gökaşan et al., 2003; Armijo et al., 2005) have been carried out following the 17 August 1999 İzmit Earthquake. Okay et al. (2000) showed that the North Anatolian Fault in the Sea of Marmara consists of a main strand and a few subsidiary branches; the main strand is comprised of the Ganos Fault and the Central Marmara and North Boundary Fault segments. İmren et al. (2001), Le Pichon et al. (2001, 2003) and Demirbağ et al. (2003) concluded that the northern Marmara Basin is cut by a single strike-slip fault system (the Marmara Fault) that links the İzmit Fault in the east to the Ganos Fault in the west. Gökaşan et al. (2003) renamed the Main Marmara Fault as the New Marmara Fault because it represents the new rupture of the North Anatolia Fault Zone (NAFZ) in the Sea of Marmara. They also stated that the New Marmara Fault unconformably cuts older structures that form the Marmara Basin. Armijo et al. (2005) identified fault scarps on the floor of the Sea of Marmara and stated that their geometry is the result of a combination of strike-slip and normal faulting, which is consistent with the segmentation of the pull-apart fault system.

Several seismic surveys have been conducted to understand the Late Quaternary stratigraphy of the Sea of Marmara (e.g., Smith