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Research paper

Interaction between trench retreat and Anatolian escape as recorded by neogene basins in the northern Aegean Sea

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ABSTRACT

The evolution of the North Aegean Sea is studied through the development of three deep basins: the North Aegean Trough, the North Skyros Basin and the Ikaria Basin. Bathymetric data, a 2D seismic dataset and the well-investigated stratigraphic records of the onshore deep basins of northern Greece and Western Turkey were used to make structural and seismic stratigraphic interpretations. The study area shows two sharp unconformities that correspond to the Eocene-Oligocene transition and the Miocene-Pliocene shift. These discontinuities were used as marker horizons for a more detailed structural and seismic stratigraphic interpretation resulting in the identification of several seismic units. A general seismic signature chart was established using onshore basin stratigraphy and well data, which was then used to constrain the ages of the different seismic units. The main features observed in the basins are interpreted as: 1) trans-tensional growth patterns in Pliocene and Quaternary sediments that combine NE–SW trending and steeply dipping fault zones that likely correspond to strike-slip corridors and E-W/WNW-ESE trending normal faults, 2) regional erosional truncations of Miocene sediments, likely related to the Messinian Salinity Crisis (MSC), 3) thick delta-turbidite deposits of Neogene age. Only the North Aegean Trough shows evidence of earlier development and polyphase deformation through inversion structures, and additional seismic units. Extension processes in the Aegean region have been driven by the Hellenic slab rollback since the middle Eocene. The widespread development of Neogene basins at the whole Aegean scale attests to a major tectonic change due to an acceleration of the trench retreat in the middle Miocene. The present study shows that the Neogene basins of the North Aegean Sea developed in dextral transtension with the northward migration of the associated NE-SW trending strike-slip faults. At regional scale, this tectonic pattern indicates that the westward escape of Anatolia started to interact with the trench retreat in the middle Miocene, around 10 Myr before the arrival of the North Anatolian Fault in the North Aegean Sea.

1. Introduction

The first plate kinematic models of the eastern Mediterranean (McKenzie, 1972; Le Pichon and Angelier, 1981) and the present-day displacement field observed by satellite geodesy (McClusky et al., 2000; Hollenstein et al., 2008; Müller et al., 2013) show that the active Aegean extension results from the combined effects of the southwestward retreat of the Hellenic trench and the westward displacement of Anatolia along the North Anatolian Fault (NAF). The geological record shows that this interaction between two strongly oblique components of boundary displacement started in the middle Miocene (Dewey and Sengör, 1979; Şengör et al., 2005; Philippon et al., 2014), around 10 My before the NAF reached the Aegean (Armijo et al., 1999; Hubert-Ferrari et al., 2003; Şengör et al., 2005). On the other hand, the coeval extensional exhumation of high-pressure metamorphic rocks in the southern Hellenides and high-temperature metamorphic rocks in the Southern Rhodope (Brun and Sokoutis, 2007; Brun and Faccenna, 2008) started in the middle Eocene (see review of data in Jolivet and Brun, 2010; Philippon et al., 2012). This brief summary of the Aegean extension

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history, which occurred during a large part of the Tertiary, shows that Aegean extension was not continuous, neither in time nor in space, but that it occurred in two major stages (Philippon et al., 2014; Brun et al., 2015). This is evidenced by a striking difference in the distribution of Paleogene and Neogene sedimentary basins in the Aegean region, suggesting that a major change in the dynamics of Aegean extension happened in the middle Miocene, more than 30 My after its onset.

In the present paper, we first evaluate offshore and onshore stratigraphy in the northern Aegean Sea (Fig. 1) from onshore basins described in the literature, available well logs and published offshore studies. We compare basin infill characteristics with the seismic stratigraphic interpretation of two lines in the Thermaikos and Prinos basins. Then, on this basis and using a 2D seismic data set, we describe the structure and seismic stratigraphy of the North Aegean Trough, the North Skyros Basin and the Ikaria Basin. These data are then used to discuss the regional geodynamic setting and, in particular, the interaction between trench retreat and Anatolian escape.

2. The project database

Only a few seismic reflection studies of the offshore northern Aegean domain have been published. The most extensive structural and stratigraphic work using seismic reflection data was done by Martin (1987) and Mascle and Martin (1990). Brooks and Ferentinos (1980), Lykousis et al. (1995, 2002, 2005) and Lykousis (2009) used shallow seismic reflection data, with a focus on seismic facies and depositional environments of mainly Quaternary deposits. Deep seismic stratigraphic descriptions are not available for the northern Aegean Sea.

The database used for this study is a compilation of 1) a 2D seismic reflection dataset acquired in the 1970s by Texaco, SEISA and ENSPM; 2) published seismic reflection data; 3) GMRT bathymetric data (Ryan et al., 2009); 4) well data provided by TOTAL. The lines cover an area of roughly 70 km^2 with line spacing of between 1 and 20 km. The lines vary in length from 1.5 km to 15 km and run mostly NW-SE and SW-NE. The seismic data have not been reprocessed, leaving mostly low-quality images. As only paper versions were available, lines were scanned before being digitized with MatLab, Mapviewer and Didger for SGY-file creation at the University of Pierre and Marie Curie, Paris 6. They were integrated into Petrel and Kingdom Suite projects. The maximum depth of the lines was 5 s two-way-travel time. In the absence of a velocity model, an average of 2500 m/s for Tertiary deposits was assumed for the time-depth conversion, resulting in a first estimated basin depth of 6.25 km. Published seismic reflection data in the northern Aegean domain (Schuster et al., 1987; Mascle and Martin, 1990; Roussos and Lyssimachou, 1991; Proedrou and Papaconstantinou, 2004; Nunn and Harris, 2007; Sakellariou et al., 2013) were

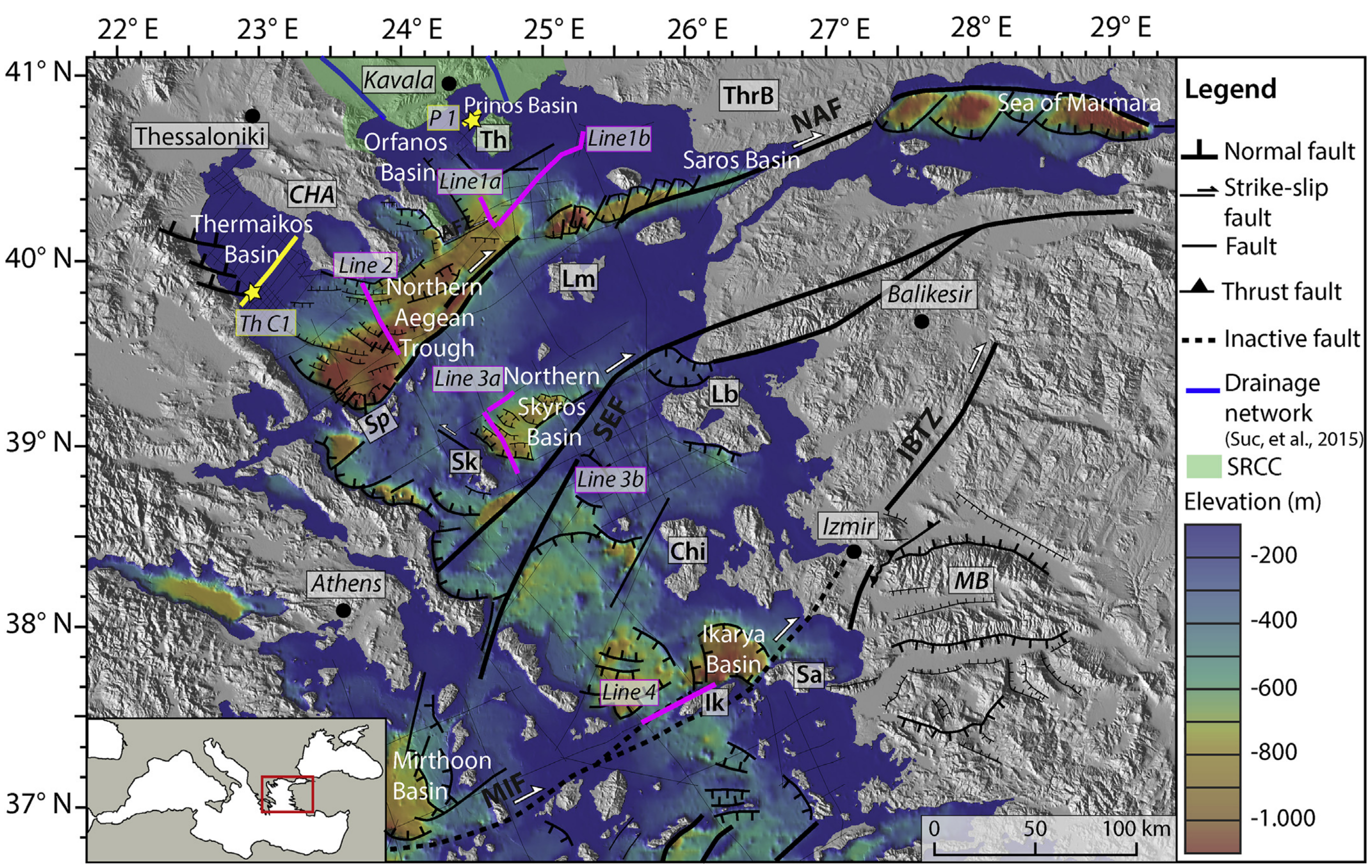

Fig. 1. Regional map of the northern Aegean Sea highlighting the major structures. GMRT bathymetry data (Ryan et al., 2009) highlight the deepest basins. Line locations are provided for the North Aegean Trough (Line 1a, 1b and 2), the Northern Skyros Basin (Line 3) and the Ikaria Basin (Line 4). Well-locations are provided for the Thermaikos Basin (ThC1) and the Prinos Basin (P1). The faults mapped are recovered from previous studies (Mascle and Martin, 1990; Brun et al., 2016) and where possible enhanced with the use of seismic data. Faults that became inactive or that do not display clear evidence of activity are depicted with dashed lines. Abbreviations of basins, islands and geological features: AFZ: Athos Fault Zone; Chi: Chios; IB: Ikaria Basin; IBTZ: Izmir-Balikeshir Transfer Zone; Ik: Ikaria; Lb: Lesbos; Lm: Limnos; MB: Menderes Grabens; MiB: Mirthoon Basin; MIF: Mirthoon-Ikaria Fault; NAF: North Anatolian Fault; NAT: North Aegean Trough; NSB: North Skyros Basin; OB: Orfanos Basin; Pb: Prinos Basin; Sa: Samos; SB: Saros Basin; SEF: Skyros-Eubea fault zone; Sk: Skyros; SM: Sea of Marmara; SRCC: Southern Rhodope Core Complex; Th: Thassos; TheB: Thermaikos Basin; ThrB: Thrace Basin.