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Detrital supply from subduction/accretion complexes to the Eocene–Oligocene post-collisional southern Thrace Basin (NW Turkey and NE Greece)

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ABSTRACT

The Thrace Basin is a large, mostly Eocene–Oligocene post-collisional sedimentary basin which developed following the closure of the Vardar–İzmir–Ankara oceanic domain (latest Cretaceous–Paleocene). Sandstone petrologic data (framework and heavy-mineral analyses) and the synthesis of preexisting and new sedimentological observations along representative stratigraphic sections show that the basin fill of the southern Thrace Basin was mostly derived from the İzmir–Ankara and Biga (?Intra-Pontide) subduction/accretion complexes to the south. Proximal facies consistently show northward paleocurrents whereas most paleocurrent indicators measured downcurrent point to an eastward paleoflow, likely the result of the deflection of primary gravity flows originated along the southern margin of the basin. Detrital contributions from the Rhodopian basement complex to the west are virtually absent within the southern Thrace Basin fill. Conversely, Rhodopes-derived, Eocene proximal facies in northeastern Greece are characterized by a series of coarse-grained fan-deltas prograding eastward and likely feeding the basin–plain turbidites of the depocentral portion of the Thrace basin, now concealed in the subsurface to the north of our study area.

Arenites of the southern Thrace Basin are mostly lithic arkoses and arkosic litharenites. Provenance from the İzmir–Ankara and Biga suture zones to the south is characterized by ophiolitic, granitoid/gneissic, low-grade metamorphic, and extrabasinal carbonate rock fragments, as well as by picotite and glaucophane.

The application of detailed petrographic observations for discriminating paleo- vs. neovolcanic and penecontemporaneous vs. noncoeval terrigenous sands lead to a substantial revision of the geodynamic interpretation of the Thrace Basin, formerly considered a forearc basin. A significant penecontemporaneous volcanic component is common in the Upper Eocene–Lower Oligocene section and can be related to extensive post-collisional volcanism following the closure of the Vardar–İzmir–Ankara ocean. The coexistence of pure neovolcanic layers (crystal tuffs and cinerites) and hybrid arenites rich in penecontemporaneous carbonate grains with sands derived from a continental basement and ophiolitic suites indicates the presence of episutural basins where shallow-water carbonates were deposited on top of the exhuming subduction–accretion prism. These carbonates were mixed with penecontemporaneous neovolcanic and terrigeneous components and redeposited in deeper marine environments.

1. Introduction

Several authors have linked specific plate-tectonic settings to the mineralogical composition of sands and sandstones (e.g., Dickinson, 1970, 1985; Crook, 1974; Dickinson and Suczek, 1979; Ingersoll and Suczek, 1979; Valloni and Maynard, 1981; Dickinson et al., 1983; Mack, 1984; Valloni and Zuffa, 1984; Valloni, 1985; Garzanti et al., 2007). In spite of (i) some limiting factors, like modifications occurring during weathering, sediment transport, deposition, and diagenesis (see, for example, the papers in Basu, 1993 and Zuffa, 1985 and Johnsson), and (ii) other important critical remarks to be taken into consideration (e.g. Zuffa, 1991; Weltje, 2006), these broad correlation schemes have been evaluated extensively, and sandstone detrital modes are now commonly employed to determine, in conjunction with other basin-analysis techniques, the plate-tectonic setting of ancient terrigenous successions (for a review, see Garzanti et al., 2007).

Calibrated procedures for recognizing and classifying sand/sandstone grain types (particularly carbonate and volcanic grains) are critical in reconstructing source/basin paleogeography and assessing evolutionary trends through time. In particular, the analytical procedure for point counting of arenite framework requires fundamental attributes of grains to be taken into account, like composition (carbonate

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versus non-carbonate grains), spatial relationships (intrabasinal versus extrabasinal grains), and time relationships (grains coeval or non-coeval with respect to the basin fill) (e.g. Zuffa, 1980, 1987; Ingersoll et al., 1987; Critelli and Ingersoll, 1995).

Clastic successions characterized by either (i) compositionally hybrid beds or (ii) alternating strata of siliciclastic and penecontemporaneous carbonate-clastic composition may indicate, respectively, (i) the presence of marine shallow-water 'sediment parking areas' where extrabasinal and intrabasinal grains can mix before being resedimented (e.g. Fontana et al., 1989), and (ii) distinct terrigenous and intrabasinal sources playing an independent role in supplying the depocenter (e.g. Gandolfi et al., 1983, 2007). Moreover, the detection of neovolcanic and paleovolcanic grains within the same arenite succession is crucial for a correct interpretation of the geotectonic setting in which sediments were deposited (e.g. De Rosa et al., 1986; Critelli and Ingersoll, 1995; Hathway and Kelley, 2000; Pal et al., 2005). Thus, a thorough knowledge of the composition, origin, and age of arenite grains is critical in unraveling source/basin paleogeography and tracing its evolution through time. As a final point, we must bear in mind that source area reconstructions should not be conducted with gross compositional data alone, but need to be supported by other lines of evidence (heavy minerals, paleocurrents, facies relations, etc.).

This paper illustrates how detailed definition of sandstone detrital modes (including heavy-mineral analysis, paleocurrent analysis, and the study of sedimentological facies relationships) can discriminate not only the overall plate-tectonic setting of terrigenous successions, but also pinpoint significant within-basin provenance variations, thus providing important elements to constrain (i) the sediment dispersal pattern, (ii) the three-dimensional geometry of petrographic lithosomes, and (iii) the overall basin evolution. To this end, we studied the sandstone petrography of the Eocene–Oligocene sedimentary succession of the southern Thrace Basin (northwestern Turkey and northeastern Greece). This portion of the basin was chosen as the study area because recent studies have constrained the paleoenvironmental/paleostructural setting and the chronostratigraphy of the basin fill (Okay et al., 2010; Özcan et al., 2010), thus integrating a large wealth of preexisting data, both from surface and subsurface studies (e.g. Doust and Arikan, 1974; Şengör, 1979; Önal, 1986; Sümengen and Terlemez, 1991; Görür and Okay, 1996; Turgut and Eseller, 2000; Yaltirak and Alpar, 2002; Okay et al., 2004).

2. Geological setting

The Thrace Basin is a complex system of depocenters located between the Rhodope–Strandja Massif to the north and west and the Biga Peninsula to the south (Fig. 1). The southern margin of the basin is now covered by the Marmara Sea and deformed by the North Anatolian Fault. The Thrace Basin is the largest and thickest Tertiary sedimentary basin of the eastern Balkan region and constitutes an important hydrocarbon province (Turgut et al., 1991; Turgut and Eseller, 2000; Siyako and Huvaz, 2007). The older part of the basin fill crops out along the basin margins but it is covered by Plio-Quaternary deposits in the basin center (Siyako, 2006). In this area, subsurface data is abundant as Türkiye Petrolleri Anonim Ortakliği (TPAO) has drilled more than 350 wells and acquired in the 80s and 90s a fairly dense network of seismic lines.

Most Thrace Basin strata range from the Lower Eocene (Ypresian) to the Upper Oligocene. Maximum total thickness, including the Neogene–Quaternary succession, commonly reach 5000 m and goes up to 9000 m in a narrow depocenter bounded by strike–slip faults (Yıldız et al., 1997; Turgut and Eseller, 2000; Siyako and Huvaz, 2007). In terms of volume, most of the Eocene–Oligocene sedimentary succession is made of basin–plain turbidites (Aksoy, 1987; Turgut et al., 1991). Sedimentation along the basin margins was characterized by carbonate deposits during the Eocene and by deltaic bodies prograding towards the basin center in the Oligocene (Sümengen et al., 1987; Sümengen and Terlemez, 1991. The western margin of the basin, in Greek and Bulgarian territory, was characterized already in the Eocene by a series of coarse-grained fan-deltas prograding eastward and feeding the depocentral basin–plain turbidites (Caracciolo et al., 2007a, b).

The Thrace Basin lies across a geodynamically complex area characterized by three juxtaposed lithospheric blocks (terranes) distinguishable as to lithology, structural configuration, and geological evolution: the Rhodope–Strandja crystalline massif, the İstanbul Zone, and the Sakarya Zone (Fig. 1). (1) The Rhodope–Strandja massif has Laurasian affinity and it is composed of Variscan continental crust, Mesozoic metasedimentary rocks, and fragments of oceanic crust (Burg et al., 1996). This assemblage suffered repeated phases of crustal thickening and exhumation during the Cretaceous and early Tertiary (e.g. Krohe and Mposkos, 2002). The main phase of deformation occurred in the Maastrichtian–early Paleogene following the closure of the Vardar Ocean (Stampfli and Borel, 2004). A widespread extensional regime active from mid-Eocene time induced the exhumation of the Rhodopian core complexes (e.g. Bonev and Beccaletto, 2007). (2) Located at the southwestern margin of the Black Sea, the İstanbul Zone is a continental fragment about 400 km long and 70 km wide. It comprises a Precambrian crystalline basement and a fairly complete Ordovician–Carboniferous sedimentary cover which was deformed during the Variscan orogeny (Görür et al., 1997; Okay et al., 2011). Its stratigraphic, paleobiogeographic, and paleomagnetic characters show a marked Laurasian affinity. It was proposed that this continental fragment rifted off the Odessa shelf and drifted southward during the opening of the western Black Sea backarc basin in the Cretaceous (Görür and Okay, 1996). (3) The Sakarya Zone, approximately 1500 km long and 120 km wide, is a continental block separated from the Rhodope–Strandja crystalline massif and the İstanbul Zone by the so-called Intra-Pontide suture (Şengör and Yilmaz, 1981). The basement of this terrane is made of amphibolite-facies metamorphic rocks visible in a few tectonic windows of limited areal extent (e.g. Okay et al., 2008; Cavazza et al., 2009). In the Paleogene, the Sakarya Zone collided with the Anatolide–Tauride terrane of African affinity to the south following the closure of the İzmir–Ankara ocean (Okay and Tüysüz, 1999; Stampfli and Borel, 2004).

Juxtaposition of the İstanbul and Sakarya Zones along the Intra-Pontide suture occurred in pre-Cenozoic time, although the exact timing has not been yet clearly defined. The westward continuation of the Intra-Pontide suture into the Marmara Sea is controversial. Scattered outcrops of the ophiolitic Çetmi mélange in the Biga peninsula have been interpreted as marking the Intra-Pontide suture between the Sakarya Zone to the southeast and terrains of Rhodopian affinity to the northwest (Siyako et al., 1989; Okay and Tüysüz, 1999; Beccaletto et al., 2005). Stampfli and Hochard (2009) date the formation of the suture in the Biga peninsula at 200–180 Ma (Late Triassic–Early Jurassic) despite the fact that the blocks and the matrix composing the mélange reach up to the Early Cretaceous (Beccaletto, 2004).

Juxtaposition of the Sakarya and Anatolide–Tauride terranes occurred between the Late Cretaceous and the Paleogene following northward subduction and closure of the Vardar Ocean and its continuation to the east, the İzmir–Ankara ocean (Okay and Tüysüz, 1999; Stampfli and Hochard, 2009). The transition between the collisional tectonic regime following the closure of these oceanic realms and the extensional regime characterizing the Neogene evolution of the Aegean and periAegean regions is complex and relatively poorly known (e.g. Burchfiel et al., 2000; Bonev, 2006; Bonev and Beccaletto, 2007;). The Thrace Basin developed during this transitional tectonic regime.

Contrasting hypotheses have been put forward to explain the origin and the evolution of the Thrace Basin. (1) Keskin (1984) and Perinçek (1991) considered this basin as intramontane in nature. (2) Turgut et al. (1991) and Tüysüz et al. (1998) proposed a transtensional post-collisional origin following the closure of the Intra-Pontide Ocean. (3)