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Late Cenozoic stress states around the Bolu Basin along the North Anatolian Fault, NW Turkey

Suha Ozden[a,*], Semir Over[b], Kaan Sevki Kavak[c], Serife Sevinc Inal[d]

[a] Department of Geological Engineering, Canakkale Onsekiz Mart University, 17020 Canakkale, Turkey
[b] Department of Geophysical Engineering, Mustafa Kemal University, 31040 Antakya, Turkey
[c] Department of Geological Engineering, Cumhuriyet University, 58140 Sivas, Turkey
[d] Dil Devrimi Caddesi, Akkonaklar Sitesi, B8-88, No. 28, Eryaman Evleri, Etimesgut, Ankara, Turkey

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ABSTRACT

This study defines the Late Cenozoic stress regimes acting around the Bolu Basin along the North Anatolian Fault in northwestern Turkey. The inferred regional stress regime, obtained from the inversion of measured fault-slip vectors as well as focal mechanism solutions, is significant and induces the right-lateral displacement of the North Anatolian Fault. The field observations have also revealed extensional structures in and around the Bolu Basin. These extensional structures can be interpreted as either a local effect of the regional transtensional stress regime or as the result of the interaction of the fault geometries of the dextral Duzce Fault and the southern escarpment of the North Anatolian Fault, bordering the Bolu Basin in the north and in the south, respectively.

The inversion of slip vectors measured on fault planes indicates that a strike-slip stress regime with consistent NW- and NE-trending $\sigma_{H_{max}}(\sigma_1)$ and $\sigma_{H_{min}}(\sigma_3)$ axes is dominant. Stress ratio (R) values provided by inversion of slip vectors measured on both major and minor faults and field observations show significant variations of principal stress magnitudes within the strike-slip stress regime resulting in older transpression to younger transtension. These two stress states, producing dextral displacement along NAF, are coaxial with a consistent NE-trending σ_3 axis. The earthquake focal mechanism inversions confirm that the transtensional stress regime has continued into recent times, having identical horizontal stress axis directions, characterized by NW and NE-trending σ_1 and σ_3 axes, respectively. A locally consistent NE-trending extensional, normal faulting regime is also seen in the Bolu Basin. The stress-tensor change within the strike-slip stress regime can be explained by variations in horizontal stress magnitudes that probably occurred in Quaternary times as a result of the westward extrusion of the Anatolian block.

1. Introduction

The Alpine-Himalayan orogenic system incorporates many structural lineaments including plate boundaries such as along the border of the Anatolian block where three major plates – the Eurasian, African and Arabian – are juxtaposed (Fig. 1). The collision of the Arabian plate with the Eurasian plate in eastern Turkey during the late Miocene (Sengor and Yilmaz, 1981) induced two major strike-slip faults: the North Anatolian Fault (NAF; Ketin, 1948, 1957, 1969) and the East Anatolian Fault (EAF), bounding the Anatolian block in the north and in the east of Turkey, respectively. Both the NAF and EAF have been ascribed to the westward extrusion of the Anatolian block from the Eurasian–Arabian continental collision zone (Sengor and Yilmaz, 1981) and both contribute to the geodynamic evolution of the Aegean region to the west-southwest of Anatolia (Le Pichon and Angelier, 1981). In the same way, the northward convergence of Arabia produces important strike-slip faults within the Zagros fold and thrust belting in SE Iran (Jackson et al., 2006; Authemayou et al., 2005, 2006). This convergence has an oblique character (Jackson et al., 2006; Regard et al., 2004) with a rate of 10–17 mm/year (Talebian and Jackson, 2002).

The active fault trace of the NAF runs about 1400 km from Karliova in the east to the Northern Aegean extensional regime in the west (Sengor, 1979; Barka, 1984; Andrieux et al., 1995; Kiratzi, 2002; Ganas et al., 2005) and includes numerous sedimentary basins related to the development and segmentation of the fault zone (Barka and Hancock, 1984) (Fig. 1). The NAF is clearly a long and wide right-lateral shear zone (Sengor et al., 2004) and can be separated into three main segments along its trace: an eastern part with N 110° trend, a central northern convex part, and a western part with N 075° trend (Barka, 1992). The western segment, which lies in the Marmara Sea region, splays initially into two branches

* Corresponding author.
E-mail address: ozden@comu.edu.tr (S. Ozden).

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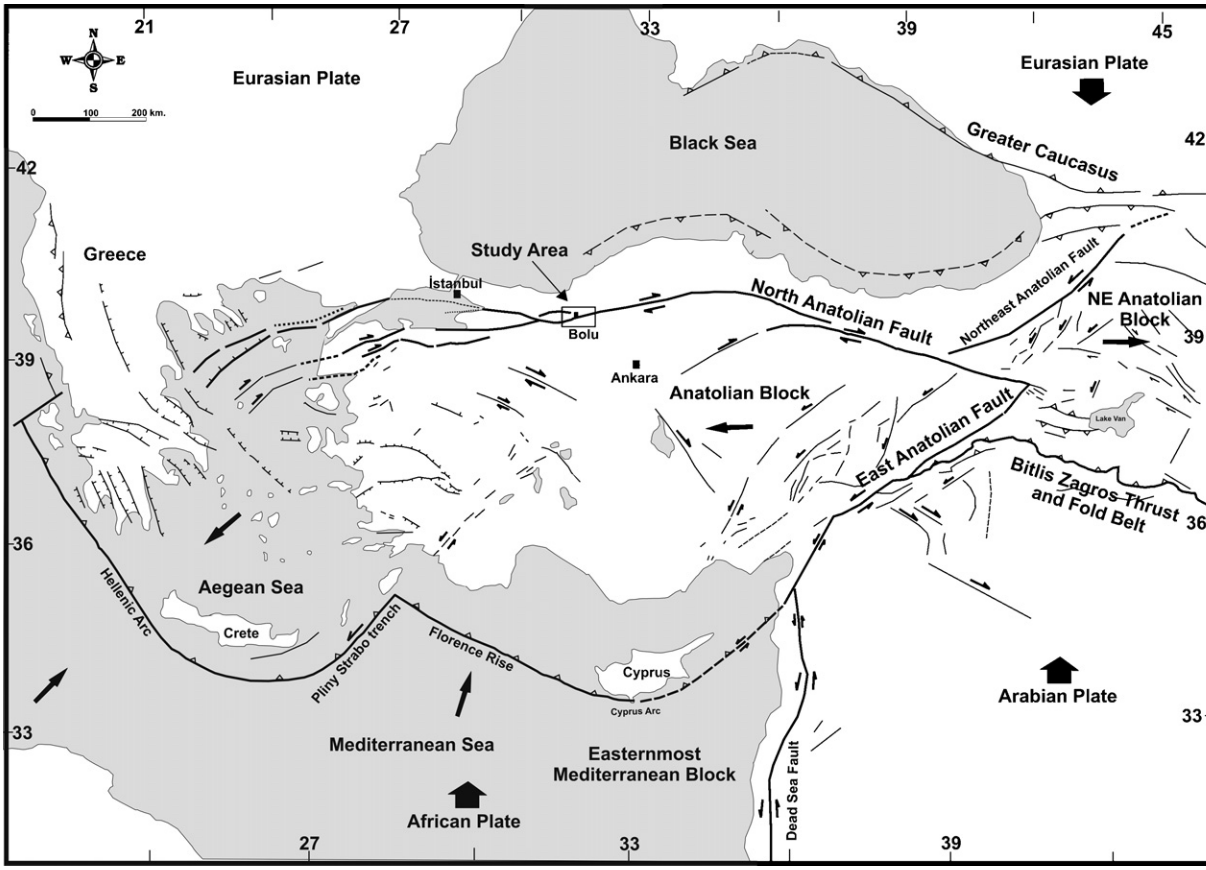

Fig. 1. Location of the study area on a sketch map of the eastern Mediterranean tectonic framework (modified from Sengor, 1979 and Barka, 1992).

(Fig. 2) that continue as separate northern and southern faults to the east of the Marmara Sea (Barka, 1992).

GPS measurements (Kiratzi, 1993; Oral et al., 1993; Reilinger et al., 1997; McClusky et al., 2000; Hubert-Ferrari et al., 2002) have previously indicated that the present-day right-lateral displacement on the NAF is between 16 and 30 ± 2 mm/year. Recently, Reilinger et al. (2006) calculated a displacement rate of 24.2 mm/year in the vicinity of the Bolu region. There are also numerous other large-scale studies of the behaviour of the Anatolian block in the vicinity of the western and central part of the NAF and the westward extrusion of Turkey (Barka, 1984; Dewey et al., 1986; Sengor et al., 1985; Piper et al., 1997; Chorowicz et al., 1999; Barka et al., 2000).

In the present study, we have focused on the Bolu Basin (Ardel, 1965) and its surroundings, in particular the link between the western and central segments of the NAF (Figs. 1–3). The control of seismotectonic features around the Bolu Basin is based mainly on earthquake activity in easternmost Marmara Sea part of the western segment of the NAF. Recently, the 17 August 1999 (M_s = 7.4) Izmit and 12 November 1999 (M_s = 7.2) Duzce earth-

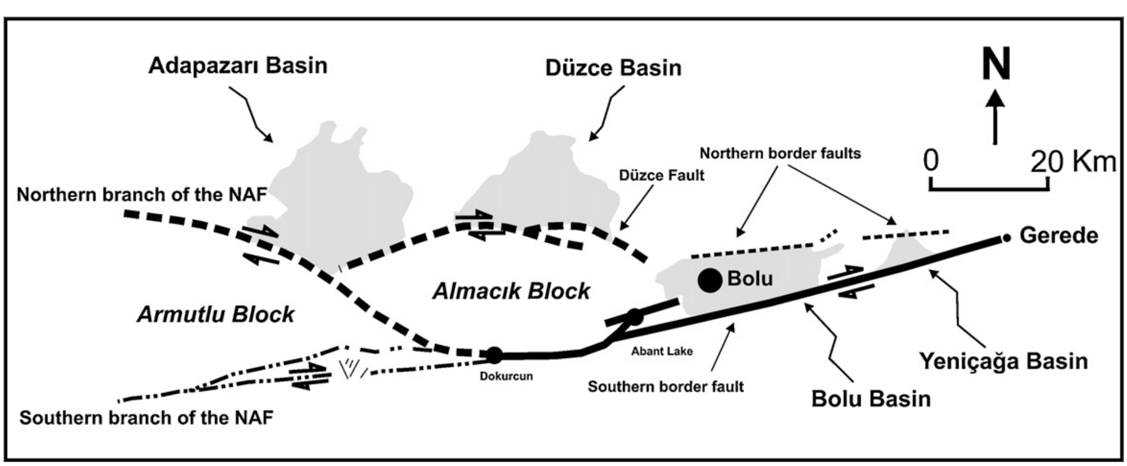

Fig. 2. Main active structural lineaments around the Bolu Basin (modified from Saroglu et al., 1992).