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New paleomagnetic results from Ordovician sedimentary rocks from NW Anatolia: Tectonic implications for the paleolatitudinal position of the Istanbul Terrane

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ABSTRACT

The Istanbul terrane, classically known as the "Paleozoic of Istanbul", is geologically one of the important continental components of NW Turkey. The terrane comprises an Early Ordovician to Early Carboniferous transgressive sedimentary sequence and appears as an exotic unit with respect to its present surroundings.
The paleogeographical position of the Ordovician rocks is unknown. We have therefore conducted a paleomagnetic study from a total of 56 sites in red fluvial clastics of the Kurtkoy formation and shallow marine quartzites of the Aydos formation to determine the paleolatitude of the Istanbul terrane during the Ordovician. The Lower Ordovician group mean direction calculated from 17 reliable sites provides a mean inclination of $I = 19.4°$, ($\alpha_{95} = 2.3°$, $k = 146.0$) accepting only inclination data. A paleolatitude of 16.4° is obtained after considering an inclination correction factor of $f = 0.6$ due to the E/I results. The Early Ordovician paleolatitude of the Istanbul terrane shows a lower paleolatitudinal position closer to the equatorial zone than previously inferred.

1. Introduction

The northern part of Anatolia comprises a mosaic of several units of oceanic and continental origin which was amalgamated by strike-slip and collision tectonics during the Cretaceous (Okay and Tüysüz, 1999). The Istanbul terrane (Ustaömer et al., 2011), formerly referred to as the Istanbul Zone (Okay, 1989; Okay et al., 1994), Istanbul fragment (Ustaömer and Robertson, 1993), Istanbul-Zonguldak Unit (Yiğitbaş and Yılmaz, 1999; Yılmaz et al., 1997) or the Istanbul Nappe (Şengör and Yılmaz, 1981), is situated along the southern coast of the Black Sea (Fig. 1). This terrane is one of the major continental components of Anatolia and has a strike length of 400 km. A well-developed Paleozoic succession of the Istanbul terrane ranges from the Early Ordovician to Late Carboniferous in age (Haas, 1968; Özgül, 2012; Tokay, 1962). This terrane presents a distinctive stratigraphic sequence and appears as an exotic unit with respect to its present surroundings (Okay et al., 1994). The tectonic evolution is considered in geological terms to have been a part of Eurasia, with a peri-Gondwanan origin. By the Carboniferous, this terrane was a component of Eurasia, while the Menderes and Bitlis Massifs further south in Anatolia were parts of Gondwana (Gürsu and Göncüoğlu, 2005; Gürsu et al., 2004; Kröner and Şengör, 1990; Loos and Reischmann, 1999, 2001; Ustaömer et al., 2009) in the Late Paleozoic and accreted to the South Eurasian margin during Tertiary times (Ustaömer et al., 2011). The original position of the Istanbul terrane within the Early Paleozoic era is still currently a matter of debate. Based on zircon age associations, Chen et al. (2002) proposed a NE African affinity, whereas Ustaömer et al. (2005) suggested a location in NW Africa. The recent study of Ustaömer et al. (2011) concluded that the Istanbul terrane was a former peri-Gondwanan block located at the northwestern margin of Gondwana close to Amazonia. In addition, based on stratigraphic and faunal correlations, the Istanbul terrane has been considered to be an extension of the east Avalonian terrane (Bozkurt et al., 2008; Kalvoda, 2001; Kalvoda et al., 2003; Oczlon et al., 2007; Okay et al., 2008), although it has also been correlated with the Armorican terranes (Yanev et al., 2006). These suggested correlations imply close stratigraphic similarities to the Paleozoic rocks of the southern margin of Laurasia (Görür et al., 1997; Okay et al., 1994). Some authors have further suggested that the Istanbul terrane is a part of the South Laurasian platform margin, showing similar stratigraphic sequences to Moesia, until the Late Mesozoic (e.g., Okay et al., 1994). These authors consider that this terrane reached its present position due to southward movement during the Late Cretaceous–Paleocene along two transform faults (Finetti et al., 1988) as a result of the opening of the western Black Sea basin (e.g., Okay and Tüysüz, 1999; Okay et al., 1994). Although the Istanbul terrane has been placed in a higher paleolatitudinal location in the Early Paleozoic era by most previous authors (e.g., Gahagan and Ross, 1988; Ziegler et al., 1977), Sayar and Cocks (2013) recently argued that the western Pontides were sited

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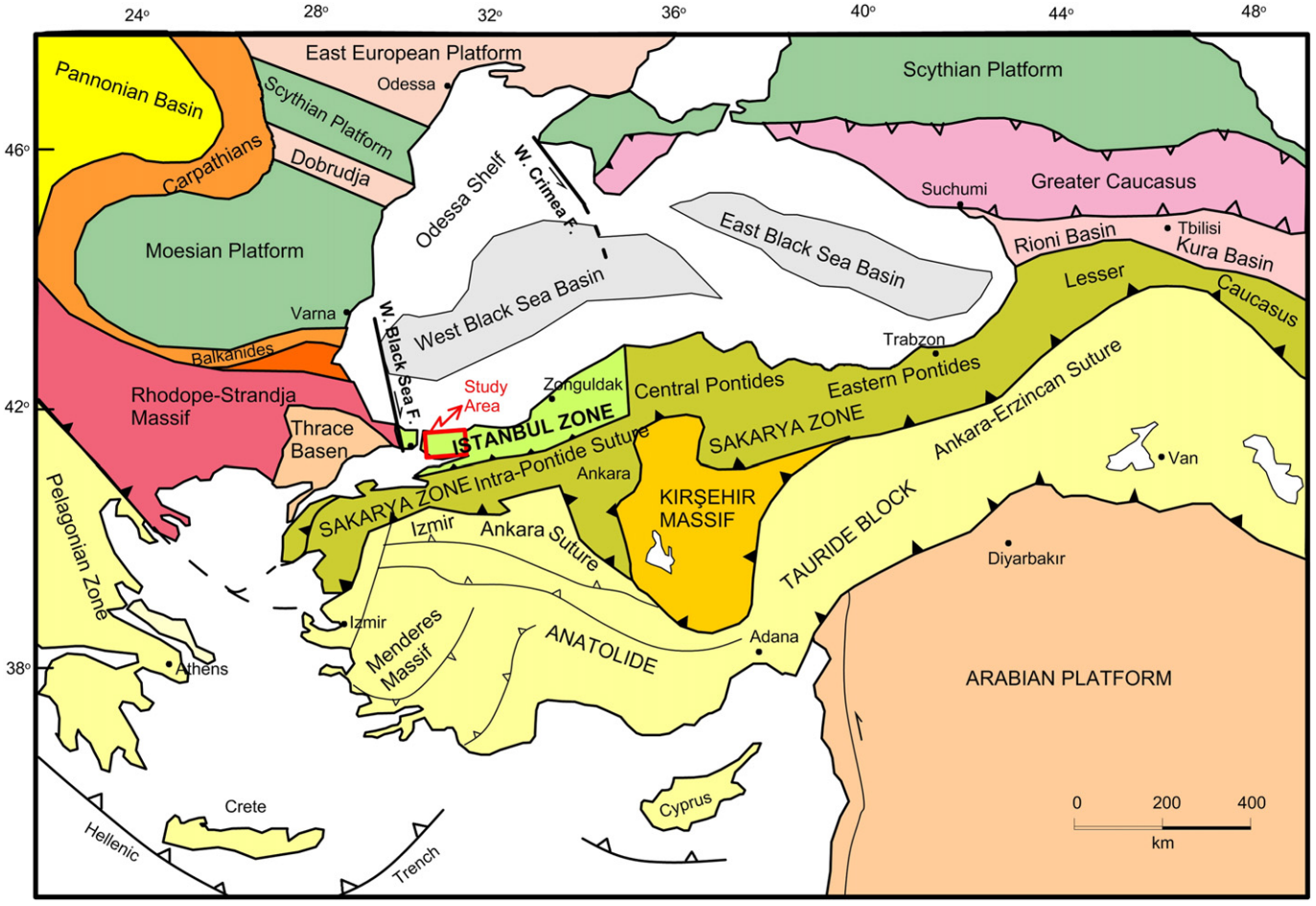

Fig. 1. Tectonic units of Turkey (modified from Okay and Tüysüz, 1999) indicating the study area in the Istanbul Zone.

at a significantly lower paleolatitude of approximately 40° S during the latest Ordovician.

Further investigation is merited because only a limited number of studies have focused on the paleomagnetic signature of the Istanbul terrane during the Paleozoic. The first paleomagnetic study was carried out at 18 sites from Permian red sediments in the Amasra region by Gregor and Zijderveld (1964). According to their mean direction (D/I = 292°/−14.8°), the authors stated that the Istanbul terrane was close to Laurasia in the Permian. The study covering a total of 12 sampling sites from the Silurian-Carboniferous age of Evans et al. (1991) reported paleolatitudes generally lower than 15° for the Istanbul terrane and compatible with Laurasia. The paleolatitude of the Istanbul terrane in the Ordovician has been investigated paleomagnetically by Lauer (1981) from just two sites reporting a mean paleomagnetic direction of D/I = 313°/43°.

None of these paleomagnetic studies has investigated the effect of inclination flattening in sedimentary rocks used to determine these paleolatitudes. Therefore, we have carried out a paleomagnetic study from the lower part of the Paleozoic sequence of the Istanbul terrane with the aim of constraining the paleolatitudinal position of this exotic unit in Ordovician era and thereby the origin of this terrane within Gondwana. The new paleomagnetic results are discussed in the light of previous geological data regarding the paleogeographical position of the Istanbul terrane.

2. Geological setting and paleomagnetic sampling

The Paleozoic of Istanbul (Fig. 1) is dominated by an east-west trending continental unit 100 km wide and 500 km long overlying a Precambrian basement and characterized by a near complete Paleozoic stratigraphic sequence well-exposed in the vicinity of Istanbul (Abdüsselamoğlu, 1977). This area is bordered in the west by the Strandja Zone and in the south by the Sakarya Zone (Fig. 1). Each zone exhibits a distinctive type of Late Jurassic–Early Cretaceous and Late Triassic metamorphism and deformation (Okay et al., 2001; Sunal et al., 2011), respectively, which are not observed in the Istanbul terrane (Özgül, 2012). The Triassic–Early Jurassic oceanic assemblages of the Central Pontides constitute the eastern tectonic contact of the Istanbul terrane (Ustaömer and Robertson, 1993, 1994). The Black Sea, which is believed to have opened as a marginal basin in Cretaceous times (Görür, 1988; Okay et al., 1994; Ustaömer and Robertson, 1993), forms the northern margin of the Istanbul terrane.

The westerly area of the Istanbul terrane passes through marine sedimentation comprising an Early Ordovician to Early Carboniferous transgressive sequence. There are no pre-Ordovician outcrops in the Istanbul region, but Neoproterozoic granitic and metamorphic rocks have been described from the Bolu Massif (Okay et al., 2008; Ustaömer et al., 2005). Further east, the basement units of the Paleozoic of Istanbul crop out in small inliers in the Karadere-Zirze area (Arpat et al., 1978; Chen et al., 2002; Dean et al., 1997, 2000).

In the Istanbul terrane, the Paleozoic succession (Fig. 2) starts with a thick (>3000 m) sequence of the Lower Ordovician red fluvial and lacustrine deposits (Kocatöngel Formation; Gedik and Aksay, 2002; Kaya, 1982; Yazman and Çokuğraş, 1983: Kurtköy Formation; Haas, 1968; Kaya, 1978; Önalan, 1981). The red clastics are overlain by 50- to 200-m-thick (Gedik et al., 2005) quartz conglomerates and quartzites deposited in a tide-dominated shore environment (Aydos Formation: Önalan, 1981). The basin became progressively deeper and more stable