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Jurassic arc volcanism on Crimea (Ukraine): Implications for the paleo-subduction zone configuration of the Black Sea region

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ABSTRACT

The early Cretaceous and younger opening of the Black Sea has obliterated much of the older record of Tethyan subduction below southeastern Europe. The earlier Mesozoic evolution was dominated by opening and closure of Tethyan oceans between Gondwana and Laurasia with their consumption, at least in part, accommodated along the southern Eurasian margin. Crimea (Ukraine), a peninsula in the northern Black Sea, represents the northernmost region of southeastern Europe that exposes a record of a pre-Cretaceous Tethyan active margin. To shed new light on the paleosubduction zone configuration of the southeastern European margin in the Jurassic, we report $^{40}Ar/^{39}Ar$ isotope dating on 10 samples and whole rock geochemistry on 31 samples from supposedly Jurassic magmatic rocks from the Crimean peninsula. The samples can be subdivided into two age groups: middle Jurassic (~172–158 Ma) and uppermost Jurassic to lowermost Cretaceous (~151–142 Ma), that both have a subduction-related geochemical signature. The ages of the younger group are in conflict with previously assigned biostratigraphic ages of the units under- and overlying the volcanic complex. This might suggest a scenario where the latter were juxtaposed by faulting. We argue that the Crimean volcanics represent a fragment of a volcanic arc overlying the southeastern European continental margin. These data therefore provide evidence for Jurassic northwards subduction below the Eurasian margin, preceding the opening of the Black Sea as a back-arc basin. We argue that the corresponding Jurassic trench was already positioned south of the Turkish Pontides and the Caucasus belt, implying a very shallow slab angle in the Jurassic.

1. Introduction

Much remains to be understood about the Mesozoic configuration of subduction zones in the present-day Black Sea region. Fundamentally different views on the number, as well as the location and polarity of subduction zones in this region in Jurassic times prevail in literature (Barrier and Vrielynck, 2008; Dercourt et al., 2000; Kazmin et al., 1987; Kent and May, 1987; Moix et al., 2008; Robertson and Dixon, 1984; Şengör and Yilmaz, 1981; Stampfli and Borel, 2002). Geodynamic reconstructions display a complex subduction zone configuration in the present-day eastern Mediterranean region (Figs. 1 and 2), resulting from two simultaneously interacting large-scale plate tectonic processes: 1) the early stages of Pangea break-up by the opening up of the central Atlantic ocean, imposing a widely dispersed sinistral strike-slip movement of Laurasia to the north relative to Gondwana to the south (Favre and Stampfli, 1992; Stampfli and Borel, 2004), and 2) south-to-north motion of blocks rifting away from Africa, accommodated by subduction of the (Paleo- and Neo-) Tethys oceans beneath the southern Eurasian margin (Fig. 2) (Şengör and Yilmaz, 1981). The Jurassic paleo-position of the subduction zones and continental blocks along the southern Eurasian margin in the present-day Black Sea region, however, is poorly constrained, because opening of the Black Sea since the early Cretaceous has obscured much of the geological record. A key area in the present-day Black Sea region is the Crimean peninsula. Here, heavily deformed Triassic–lower Jurassic turbiditic sediments are covered by an upper Jurassic carbonate platform (Mileyev et al., 1997; Voznesensky et al., 1998). Magmatic intrusions that are observed within the Triassic–lower Jurassic sequence are of unknown geochemical composition. Whether these magmatic intrusions and associated extrusive volcanism along the southern European margin relate to rifting in a back-arc setting or locate the volcanic arc of a Jurassic subduction zone is a

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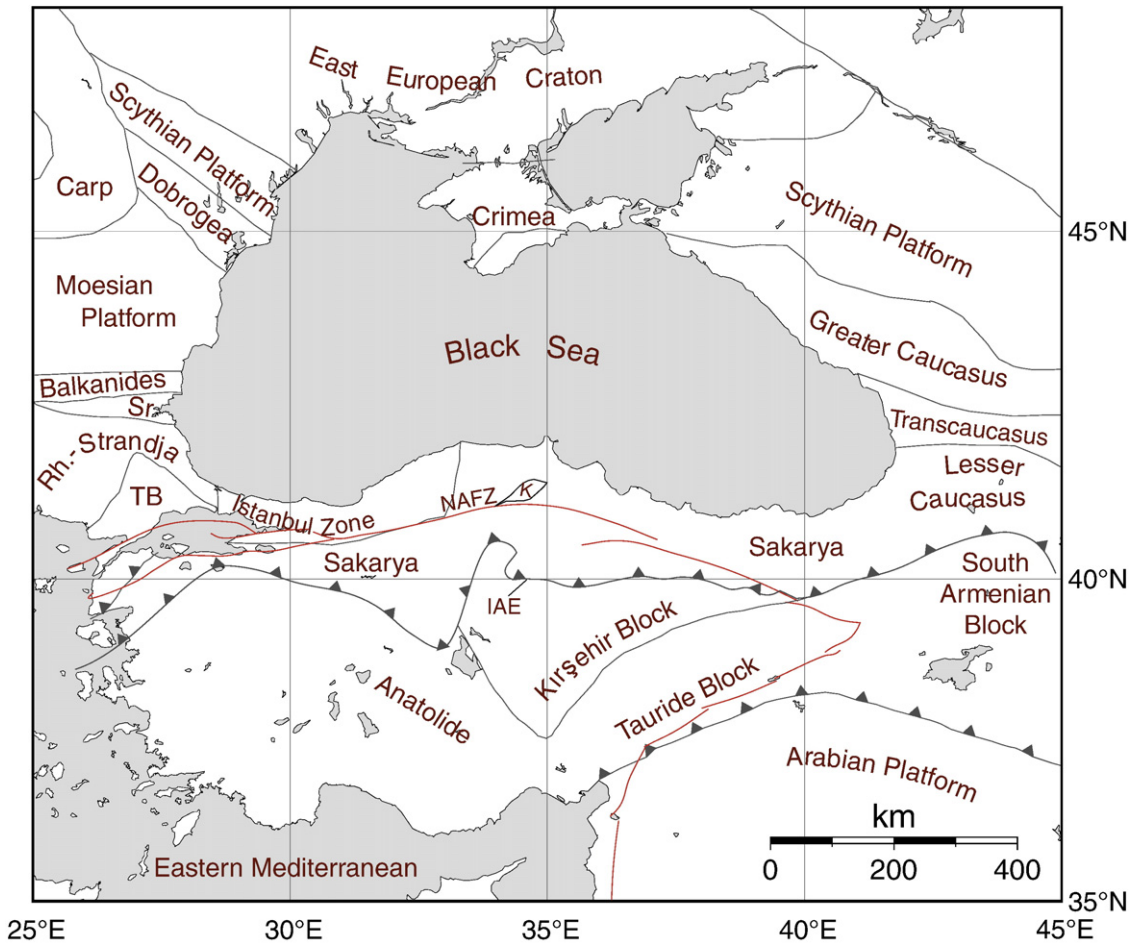

Fig. 1. Map showing the most important tectonic blocks and sutures in a present-day geographical map. Carp = Carpathians, IAE = İzmir–Ankara–Erzincan suture, K = Kargı Massif, NAFZ = North Anatolian Fault Zone, Rh. = Rhodope, Sr = Srednogorie, TB = Thrace basin.

matter of debate (Nikishin et al., 2001; Saintot et al., 2006b, 2007). Here, we provide critical constraints on the genesis of Jurassic magmatism on Crimea. To this end, we carried out $^{40}Ar/^{39}Ar$ isotope dating and major and trace element X-ray fluorescence (XRF) analysis on supposedly Jurassic Crimean volcanics. The results will be used to infer the plate tectonic setting for Crimea during volcanism, and we place this interpretation in context with respect to the Greater Caucasus and Turkish Pontides.

2. Geological setting

2.1. Main geological units in the circum-Black Sea region

The circum-Black Sea region contains a number of continental terranes and oceanic units, which are briefly reviewed here.

In northern Turkey, three continental units are combined into the *Pontides* belt. This belt comprises the Strandja Massif and the İstanbul Zone in the west, the bulk is represented by the Sakarya Zone (Fig. 1) (Okay et al., 1996). The Pontides are bounded in the north by the Black Sea and in the south by the İzmir–Ankara–Erzincan ophiolitic suture zone. The İstanbul Zone is structurally the highest zone, and the Sakarya Zone is structurally the lowest zone (Okay et al., 2001a). For the purpose of this study, we will only describe the İstanbul and Sakarya Zones.

The *İstanbul Zone* comprises non-metamorphic Paleozoic, Mesozoic and Cenozoic sedimentary sequences overlying pan-African/Cadomian crystalline basement (Chen et al., 2002; Ustaömer et al., 2005). The Paleozoic affinity of the İstanbul zone is debated (Chen et al., 2002), but there is a general consensus based on its stratigraphy and lack of metamorphism — that in Mesozoic times it can be considered as a fragment of Moesia that rifted southward during the opening of the western Black Sea basin in the late Cretaceous (Okay et al., 1994; Üstaömer and Robertson, 1993).

The *Sakarya Zone* has a crystalline basement with Carboniferous metamorphic ages (Bozkurt et al., 2008; Okay et al., 2008; Topuz and Altherr, 2004; Topuz et al., 2004, 2007) and is overlain by the locally metamorphosed Karakaya Complex of Triassic to earliest Jurassic age, and a younger discordant Mesozoic to Cenozoic (volcano-)sedimentary cover (Chen et al., 2002; Ustaömer et al., 2005). Blueschists and eclogites have been recovered from the Karakaya complex, marking its affinity with a latest Triassic subduction zone (Okay and Monié, 1997; Okay et al., 2002). Triassic deposits present in the Karakaya Complex are either interpreted as an inverted (back-arc) rift basin or as a subduction accretion complex (Genç and Yilmaz, 1995; Okay and Göncüoğlu, 2004; Pickett and Robertson, 2004).

The Sakarya and İstanbul zones share a post-Triassic volcano-sedimentary cover. In the western and central Pontides lower Jurassic continental to shallow marine clastic rocks, intercalated with ammonitico-rosso levels are exposed (Altıner et al., 1991).The eastern part of the Sakarya Zone (i.e. the eastern Pontides) however, has a different lower to middle Jurassic stratigraphy, consisting of volcanics and volcano-sedimentary units (Yılmaz and Kandemir, 2006; Yılmaz et al., 2003), interpreted as related to a volcanic arc (Şen, 2007). The Mudurnu Formation that can be traced from the western to the eastern Pontides comprises turbidites and magmatic rocks of roughly