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A review of the plate convergence history of the East Anatolia-Transcaucasus region during the Variscan: Insights from the Georgian basement and its connection to the Eastern Pontides

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ABSTRACT

This article summarizes the geodynamic evolution of the Variscan to Mesozoic Tethyan subduction history, based on a review of geochronological data from Eastern Anatolia and the Lesser Caucasus, and new isotopic ages for the Georgian crystalline basements. The geological history of the basements of Georgia (Transcaucasus) and NE Turkey (eastern Pontides) appears to be similar and provides evidence for a continuously active continental margin above a north-dipping subduction since at least the Lower Jurassic. New La-ICPMS U-Pb ages from the Georgian basement provide further evidence for the derivation of the Transcaucasus and its western continuation (the eastern Pontides) from Gondwana. A migmatized granodiorite provides preserved magmatic zircon cores with an age of 474 ± 3 Ma, while the age of migmatization is constrained by its 343 ± 2 Ma metamorphic rims. Metamorphism is synchronous with widespread I-type granites that were emplaced at 335 ± 8 Ma in the neighbouring Dzirula massif, and in the eastern Pontides. These U-Pb ages are in close agreement with recently obtained Ar/Ar ages from biotites and muscovites from metamorphic schists and U-Pb ages ranging from 340 to 330 Ma in the Georgian basement. The narrow range of ages suggests that the Variscan LP-HT metamorphic event in the eastern Pontides and Georgia was of short duration and likely related to mantle-derived intrusives. Furthermore, we suggest that (1) rifting of the Pontides-Transcaucasus block (PTB) from Gondwana at 450–350 Ma could have been driven by roll-back of the south-dipping Rheic slab, (2) that the main metamorphic and coeval magmatic events are related to the accretion of the PTB to the Eurasian margin at c. 350 Ma, while the source of magmatism is ascribed to slab detachment of the south-dipping slab at 340 Ma and that (3) three subduction zones may have been contemporaneously active in the Tethyan domain during the Jurassic: (i) the Lesser Caucasus South Armenian Block (SAB) shares a similar Gondwana affinity, but bears younger ages for its MP-MT metamorphic evolution and calc-alkaline magmatism bracketed from 160 to 123 Ma; (ii) north-dipping subduction below the PTB from c. 210 Ma to 150 Ma; (iii) northward intra-oceanic subduction bracketed from 180 to 90 Ma between the SAB and the PTB.

1. Introduction

The crystalline basements of the NE Anatolia – Caucasus region are largely unaffected by Africa-Arabia-Anatolia collision. Their relative pristine condition allows us to study the tectonic history of these Gondwana-derived tectonic blocks that were dislocated in the Early Paleozoic, until their accretion to the Eurasian margin

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from the Late Paleozoic to Cenozoic. The main questions posed in this paper concern (1) what is the origin of the metamorphic basements currently exposed in the Transcaucasus, Pontides and Lesser Caucasus (Georgia, NE Turkey and Armenia), (2) what are the lateral correlations between these three distinct geographic and political zones, and (3) what was their position with respect to the Gondwanan and Eurasian margins in Late Paleozoic to Mid-Mesozoic times? These questions still arise due to lack of accurate geochronological data, in Georgia especially, of reliable paleomagnetic data and as a result of the scarcity of crystalline basements outcrops, which are covered by thick sequences of Cenozoic volcanic rocks. In addition, there is no review at hand that compiles the ages that were recently obtained in the study region.

The Caucasus and Transcaucasus basements (Fig. 1A) have undergone numerous thermal events, resulting from their formation in the Neoproterozoic, their dislocation from Gondwana (Fig. 1B) and subsequent accretion to the Eurasian margins in Paleozoic to Mesozoic times. The highly deformed İstanbul and the Sakarya Zone in the Turkish Pontides display varying lithologies of different ages. The occurrence of numerous superposed tectonic events from Proterozoic to Cenozoic times therefore renders the interpretation of geochronological data difficult to address, resulting in various spatio-temporal models of their accretion to Eurasia (Okay and Tüysüz, 1999; Göncüoğlu et al., 2000; Ustaömer et al., 2011, 2012, 2013; Aysal et al., 2012; Moritz et al., 2015).

Here, we present a synthesis of recently acquired, well-constrained, geochronological data obtained from NE Anatolian, Armenian and Georgian metamorphic and magmatic basement rocks, supplemented by new U-Pb ages from the Georgian Transcaucasus basements. The combination of results leads us to propose correlations of basements between the aforementioned geographic areas, as well as lateral correlations to W Turkey and the Balkans. Furthermore, we interpret the geochronological data with respect to main basement structures and other magmatic and metamorphic evidences in terms of subduction polarity and orogenic events since the Early Paleozoic.

2. General overview of Eastern Anatolia and Transcaucasus crystalline basements

The study area covers the Eurasian crystalline basements of the Pontides, Lesser Caucasus and Transcaucasus domains in Eastern Turkey, South Georgia and Armenia (Fig. 1A; Fig. 2). Further south, the Eurasian basement is separated by the Sevan-Akera suture zone (Adamia et al., 1981, 1990a,b, 2011a,b; Dercourt et al., 1986; Zonenshain and Le Pichon, 1987; Galoyan et al., 2009; Rolland et al., 2009a,b, 2010; Sosson et al., 2010) from the Daralagöz or the South Armenian Block (SAB) (Zonenshain and Le Pichon, 1987). We will only refer to the term of SAB. The SAB is a Gondwana-derived terrane that was accreted to the Eurasian margin during the Late Mesozoic to Early Cenozoic (Rolland et al., 2012; Hässig et al., 2015a,b, 2016a,b,c; Meijers et al., 2015a). The origin of the Eurasian basement of Georgia is still unclear and may be derived from Laurussia, as well as from Gondwana (e.g., Kröner and Romer, 2013; and references therein). Recently published data provide evidence for the following succession of events in the crystalline basements (see for syntheses: Sosson et al., 2010; Ustaömer and Robertson, 2010; Ustaömer et al., 2012; Mayringer et al., 2011; Adamia et al., 2011a,b; Topuz et al., 2007; Dokuz et al., 2011; Rolland et al., 2012; Moritz et al., 2015):

(1) Neoproterozoic to Lower Cambrian ages for the magmatic calc-alkaline protoliths of the Pontides, the SAB and the Transcaucasus in South Georgia. In NE Turkey, detrital zircon ages from two meta-sedimentary units yield populations of 900–1000 Ma and 500–650 Ma, which suggests a NE Africa Gondwana origin (Ustaömer et al., 2012). In Georgia, the protolith of crystalline basements is formed by calc-alkaline plutons, which ages are bracketed between 750 and 400 Ma, with large uncertainties (Sm-Nd, Rb-Sr and K-Ar on whole-rock, Shengelia and Okrostsvaridze, 1998; Okrostsvaridze et al., 2002; Zakariadze et al., 2007) and ~540 Ma by U-Pb on zircon (Mayringer et al., 2011). In the SAB, protolith ages of ~610 ± 36 Ma were obtained using the Rb-Sr isochron method (Baghdasarian and Ghukasian, 1983), but these are considered unreliable.

(2) Variscan (345–310 Ma) high Temperature (HT) magmatism and metamorphism occurred in the NE Turkish Pontides (Topuz et al., 2007; Dokuz, 2011) as well as in Trans-Caucasian South Georgia (Mayringer et al., 2011; Shengelia et al., 2012).

(3) In the Lesser Caucasus and Pontides, the Transcaucasus and Sakarya basements are cross-cut by widespread magmatic suites related to northward subduction of the Tethys ocean in the Jurassic (200–150 Ma) and in the late Early Cretaceous (120–110 Ma, Adamia, 1984; Yılmaz et al., 2000; Ustaömer et al., 2012; Shengelia et al., 2012; Meijers et al., 2010c; Okay et al., 2014). In contrast, the Lesser Caucasus basement of the SAB is largely overprinted by 160–123 Ma medium Pressure – medium Temperature (MP-MT) metamorphism and subduction-related magmatism (U-Pb on zircon and Ar–Ar on biotite and muscovite, Hässig et al., 2015a,b). The age of this MP-MT metamorphic and magmatic event thus partly overlaps with Jurassic magmatism in the Pontides and Transcaucasus. Contemporaneously, the Sevan-Akera ophiolite formed in a back-arc environment between the SAB and Transcaucasus (Galoyan et al., 2009; Rolland et al., 2009b). Ophiolite formation occurred in the Middle to Late Jurassic, which is based on 178–155 Ma Ar/Ar ages (on amphibole) for gabbros within the ophiolite (Galoyan et al., 2009; Rolland et al., 2010; Hässig et al., 2013a) and biostratigraphic ages from radiolaria (Danelian et al., 2007, 2008, 2010, 2012, 2014; Asatryan et al., 2010, 2012). The Middle to Late Jurassic ages are similar to those obtained by Çelik et al. (2011) and Topuz et al. (2013a,b) along the western continuation of the Sevan-Akera suture (i.e. the Izmir-Ankara-Erzincan suture), which suggests that the ophiolites that are exposed along the Sevan-Akera and Izmir-Ankara-Erzincan suture form part of the same ophiolitic belt. We suggest that the Ar/Ar ages from the gabbro reflect the initial oceanic crust emplacement age, rather than the obduction age, which would explain why they are similar to oceanic crust ages such as zircon U-Pb ages (see Topuz et al., 2013a,b). The foliation in the gabbros is most likely related to intra-oceanic ductile deformation ('flaser-gabbros', Mevel et al., 1978), and might be mistaken for a true metamorphic foliation resulting from obduction. Blue amphibole-bearing greenschists, garnet amphibolite and eclogites from Refaiye (Izmir-Ankara-Erzincan suture) have been dated with U-Pb on rutile and Ar–Ar on phengite by Topuz et al. (2013a) at 172–176 Ma. The age of the blueschists and eclogites, as well as their tectonic position, suggest a similar intra-oceanic setting for their formation between the Taurides and the Pontides, as for the gabbros from the Sevan-Akera ophiolite.

(4) The intra-oceanic ophiolite that formed from ~178 to 155 Ma between the SAB and the Transcaucasus was obducted onto the SAB at c. 90 Ma (Sosson et al., 2010; Hässig et al., 2013a,b; Hässig et al., 2015b; Hässig et al., 2016a,b,c, this issue a-b; Topuz et al., 2013b). Obduction preceded the accretion of the SAB–Taurides-Anatolides to the Pontides Transcaucasus block (PTB) in the Late Mesozoic to Early Cenozoic (Adamia et al., 2011a,b; Rolland et al., 2012; Ustaömer et al., 2012).