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Cordierite-bearing strongly peraluminous Cebre Rhyolite from the eastern Sakarya Zone, NE Turkey: Constraints on the Variscan Orogeny

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ABSTRACT

The Cebre Rhyolite with an outcropping area up to 12 km^2 is one of the rare extrusions in the Variscan basement of the Sakarya Zone. The unit consists of high-K calc alkaline rhyolites ($SiO_2 = 74–82$ wt.%). Abundant phenocrysts of quartz and K-feldspar are accompanied by subordinate cordierite phenocrysts, rare muscovite microphenocrysts and biotite microcrysts set in a fine-grained groundmass. Three types of rock fragments (xenoliths) have been recognized; (i) porphyritic, (ii) equigranular hypabyssal and (iii) hypocrystalline fragments. Zircon U–Pb dating indicates that the Cebre Rhyolite was extruded at 332.8 ± 4.38 Ma, which post-dates the Variscan low temperature metamorphism and pre-dates the emplacement of I-type granitic intrusions (325–303 Ma).The samples are strongly peraluminous with A/CNK values ranging from 1.48 to 2.95 and A/NK from 1.49 to 2.99. They have very high K_2O (3.72–7.42 wt.%) and Al_2O_3 (10.77–14.11 wt.%) contents, but very low CaO (0.02–0.21 wt.%), Na_2O (0.05–0.78 wt.%) and MgO (0.3–0.21 wt.%) contents. The samples show geochemical affinity with the upper continental crust, e.g., enrichment of large ion lithophile elements (LILEs; K, Rb, U, Th, Pb), depletion of high field strength elements (HFSEs; Nb, Ta, Ti), Sr, P and Eu, but $\varepsilon Nd_{(t)}$ values (−3.06 to −8.75) and isotope ratios of $Sr_{(t)}$($^{87}Sr/^{86}Sr = 0.70499–0.70915$) and $Pb_{(t)}$ ($^{206}Pb/^{204}Pb = 16.41–17.570$, $^{207}Pb/^{204}Pb = 15.54–15.59$, $^{208}Pb/^{204}Pb = 36.20–37.22$) are similar to those of the lower crust. Geochemical and isotope data indicate that the Cebre Rhyolite was generated by melting of metapelitic rocks with some addition of intermediate metaigneous derived magma. As a geodynamic model, we propose that the Variscan Orogeny in Turkey was occurred by collision of Gondwana with an arc/terrane separated from the southern margin of Laurussia. This collision was followed shortly after by splitting of oceanic lithosphere into two pieces and sinking down into asthenosphere. Rapid upwelling of asthenosphere to space emptied by previous oceanic lithosphere provided heat for high temperature metamorphism and anatexis of metasedimentary rocks in the crust.

1. Introduction

Variscan Orogeny, a major tectonic event in the Early Carboniferous in Central Europe, was recorded only in the Sakarya Zone among the tectonic units of Turkey (Okay and Tüysüz, 1999) (Fig. 1 inset). Similar to the European Variscides, this event is documented by high temperature metamorphism (Topuz et al., 2004a, 2007) and related anatexis, followed by the emplacement of numerous, I-type granitic plutons (Dokuz, 2011; Kaygusuz et al., 2012; Topuz et al., 2010). I-type granitoids form about 50% of the rocks in the Variscan basement of the Sakarya Zone. Compared to I-type equivalents, S-type granites are rare in the Variscan basement. Apart from this study, only one has so far been reported from the Yusufeli, lay 200 km to the northeast (Ustaömer et al., 2012).

Unlike I-type granites, S-type granites include some mineral phases like cordierite, sillimanite, muscovite, and garnet, which are also typical for metapelites and metagreywackes. Because of the broad overlap of stability fields of these phases and felsic melt, they can be crystallized from granitic melts. The origin of these crystals in granitic magmas whether phenocrysts (Clemens and Wall, 1984; Erdmann et al., 2005), xenocrysts (Fourcade et al., 2001; Gottesmann and Förster, 2004), restite (Chappell et al., 1987; Dahlquist et al., 2005), or secondary reaction products (Kontak and Corey, 1988; Stevens et al., 2007) remains a widely debated topic in granite petrogenesis. Such granites/rhyolites with their strongly peraluminous character are so-called S-type and

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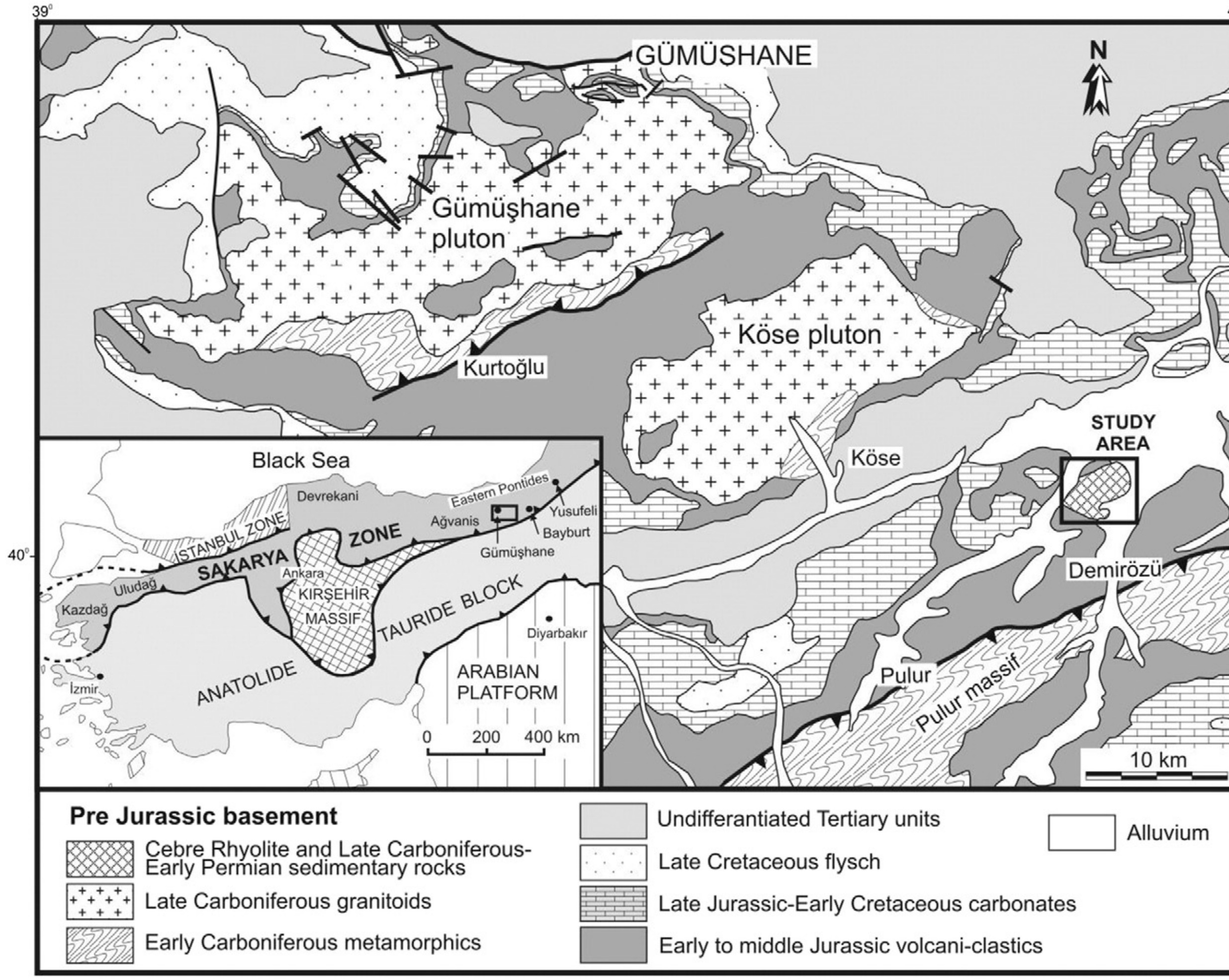

Fig. 1. Simplified geological map of the Gümüşhane region, North Eastern Turkey, showing the distribution of Variscan basement and Mesozoic–Cenozoic cover units. Inset shows the main tectonic units of Turkey, modified from Okay and Tüysüz (1999).

universal in orogenic belts. They are considered as a consequence of melting of metasedimentary rocks during crustal thickening in response to thickening or some types of regional extension (Chappell and White, 2001; Clemens, 2003; Collins, 1998; Gardien et al., 1995; McCulloch and Chappell, 1982; Miller, 1985; Montel and Vielzeuf, 1997). However, recent studies show that strongly peraluminous character, although rare, is also a feature of rocks from subduction-related environments (Collins and Richards, 2008; Gorczyk et al., 2007; Healy et al., 2004; Lucassen et al., 2004). Similar to their collisional equivalents, they were also derived from crustal sources including metasedimentary rocks (Chen et al., 2014) or from mixed melts derived from subducted sediments and mantle (Cai et al., 2011). Compared with subduction-related peraluminous granitoids, collision-related equivalents display a more evolved and narrow range of SiO_2, lower $FeO + MgO + TiO_2$ contents (<3–4%), radiogenic isotopes similar to crustal sources and never include mafic magmatic enclaves (Champion and Baltitude, 2013; Gray, 1984; Keay et al., 1997). Many petrologists suggest that I- and S-type granitoids are not used as a geodynamic indicator, but only in association with structural data (Barbarin, 1999; Bonin, 1990; Roberts and Clemens, 1993).

The Early Carboniferous Cebre Rhyolite is located in the eastern Sakarya Zone (Okay and Tüysüz, 1999), NE Turkey, the type location of the Variscan rocks in Turkey (Fig. 1). In this study, we present LA-ICP-MS U–Pb zircon ages as well as whole-rock geochemistry and Sr–Nd–Pb isotopes to constrain possible source rocks and petrogenetic processes involved in their genesis. Strongly peraluminous rhyolites of this study are also evaluated together with the other Variscan basement rocks (i. e., metamorphics, I-type granitic plutons and Late Paleozoic cover rocks) to supply a contribution to our understanding of the Late Paleozoic tectonic events in the Sakarya Zone.

1.1. Pre-Jurassic basement rocks of the Sakarya Zone

The pre-Jurassic basement of the Sakarya Zone can be subdivided into two tectonic assemblages that were juxtaposed during the Late Triassic: a lower assemblage of Carboniferous metamorphic, granitic and Late Carboniferous to Permian sedimentary rocks (Fig. 1); and an upper assemblage of subduction–accretion units of Paleotethys called the Karakaya–Küre cComplex (Okay and Göncüoğlu, 2004).

Medium- to high-grade gneiss, schist, amphibolite, marble, and scarce metaperidotite with Early to Middle Carboniferous metamorphic ages are the oldest rocks in the lower assemblage and are exposed in the small inliers of Kazdağ, Devrekani, Kurtoğlu, Pulur, and Yusufeli (Dokuz, 2000; Nzegge et al., 2006; Okay et al., 2006; Topuz et al., 2004a, 2007). Numerous small granitoids with Middle Carboniferous to Early Permian crystallization ages are situated in these metamorphic rocks throughout the Sakarya Zone (Delaloye and Bingol, 2000; Dokuz, 2011; Kaygusuz et al., 2012; Topuz et al., 2010; Karslı et al., 2016; Şengün and Koralay, 2017). However, recent studies (e.g., Aysal et al., 2012; Sunal, 2012) show that there are some metagranitoid bodies in the westernmost end of the Sakarya Zone with crystallization ages of 389–401 Ma (Early to Middle Devonian), which have escaped from intensive Variscan deformations. The tectonic significance of this plutonism and the relationships between these metagranitoid bodies and other