Tectonophysics 664 (2015) 225–243

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

# A review for genesis of continental arc magmas: U, Th, K and radiogenic heat production data from the Gümüşhane Pluton in the Eastern Pontides (NE Türkiye)

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ARTICLE INFO

*Article history:*
Received 6 May 2015
Received in revised form 31 July 2015
Accepted 6 September 2015
Available online 3 October 2015

*Keywords:*
Radiogenic heat production
Gamma ray spectrometer
Gümüşhane Pluton
Eastern Pontides

ABSTRACT

In this study, in situ radioelemental ($^{238}$U, $^{232}$Th and $^{40}$K) measurements and heat production rate evaluation have been conducted at 132 sites in the Gümüşhane Pluton of the Eastern Pontides Orogenic Belt (EPOG) of Northern Türkiye. The average K, U and Th values for granites are 4.35 ± 0.71%, 5.85 ± 2.74 ppm, 22.13 ± 5.55 ppm, respectively; micrograntes 4.33 ± 1.37%, 7.12 ± 2.23 ppm, 24.11 ± 9.59 ppm; metagranite 3.93 ± 0.68%, 6.24 ± 2.75 ppm, 12.87 ± 3.92 ppm; andesite/basalt 1.75 ± 0.74%, 3.22 ± 1.07 ppm, 9.01 ± 5.14 ppm. Based on the abundances of K, U and Th, the radiogenic heat production (RHP) values, which is a reflection of the geological rock types, are estimated as 3.52 ± 1.03 $\mu Wm^{-3}$, 3.86 ± 1.31 $\mu Wm^{-3}$, 2.93 ± 0.89 $\mu Wm^{-3}$, and 1.68 ± 0.63 $\mu Wm^{-3}$ for granites, micrograntes, metagranites and andesite/basalt, respectively. The average heat production value for the study area is estimated as 2.83 ± 1.39 $\mu Wm^{-3}$, which is closer to the upper continental crustal value; contrary to the highest heat production value of granitic basement and the lowest heat production values of the sedimentary rocks.

The study region is depicted with very high level of Th/U value ranging from 0.11 to 23.19 with mean value of 3.53 ± 2.5, which is comparatively close to the upper continental crustal estimate of 3.8. The numerical results verify that mantle-derived magmas are subjected to contamination with both middle and lower crustal material constituted by fragments of southerly dipping subduction of Tethys Ocean during the late Mesozoic–Cenozoic.



## 1. Introduction

The Eastern Pontides Orogenic Belt, which includes the Gümüşhane Pluton, essentially formed as a result of the left lateral movement of the Arabian–African plates with respect to Eurasian Plate and opening of the Atlantic Ocean within the Alpine–Himalayan system (Masson and Miles, 1986). The Meso-Cenozoic geodynamic evolution of the Eastern Pontides Orogenic Belt is still a controversial issue due to lack of systematic geological, geophysical, geochemical and chronological data. The common assessment is that geodynamic evolution of this belt is associated with northward subduction of oceanic lithosphere and characterizes the southern margin of Eurasia during the Mesozoic (Okay and Şahintürk, 1997; Topuz et al., 2005; Arslan and Aslan, 2006; Dilek et al., 2010; Karslı et al., 2010a). However, some researchers present that the late Cretaceous volcanic activity is related to southward subduction of oceanic lithosphere (Bektaş et al., 1999; Eyüboğlu et al., 2011; Maden, 2013; Maden and Öztürk, 2015).

The most intense geological processes such as magmatism, metamorphism, crust–mantle interaction and related tectonics are occurred at the convergent plate margins (Eyüboğlu, 2015). The distribution of $^{238}$U, $^{232}$Th and $^{40}$K elements and RHP values contributes a significant knowledge on deep thermal structure, crustal evolution, convective mechanism in the mantle and the thermal history of the Earth (Mareschal et al., 2000; Singh and Manglik, 2000; Ray et al., 2003; Kumar and Reddy, 2004; Perry et al., 2006; Kumar et al., 2007; Ray et al., 2008; Mareschal and Jaupart, 2013). RHP is fairly related to lithological and geochemical properties of the rocks (Kirti and Singh, 2006). In general, granites produce large amounts of radiogenic heat, whereas basalts and peridotites produce almost no radiogenic heat (Fowler, 1990).

Gamma-ray spectrometers are used for estimating the U, Th and K radioelemental concentrations of rocks. The radioelemental concentrations of granite are in the order of 1 to 2 magnitude, which is greater than those of basaltic–ultrabasic rocks. Zhang et al. (2007) demonstrated that the RHP in a granitic melt has crucial impact on the cooling-crystallization period of the melt. Also, the analysis of Th/U, K/U, and K/Th ratios may also permit us to determine the metamorphic history of a rock caused by the enrichment/depletion processes (Chiozzi et al., 2002). The K/U ratios do not change significantly during melting (Jochum et al., 1983, 1993; Hofmann et al., 1986; Jochum and Hofmann, 1997; Hofmann, 2003; Sun et al., 2008). According to the

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http://dx.doi.org/10.1016/j.tecto.2015.09.023
0040-1951/

Williams et al. (1996), Rubatto and Gebauer (2000), Rubatto (2002), Eyüboğlu et al. (2011), the high Th/U ratios of the cores are consistent with a magmatic origin. Furthermore, Karslı et al. (2011) and Kaygusuz et al. (2014) evaluated the origin of volcanic rock as lower continental crustal melts rather than the N-MORB-derived melts, based on the Th/U values in the Seme adakite and Camiboğazı samples, respectively.

In this study, we present new data of $^{238}U$, $^{232}Th$ and $^{40}K$ concentrations and their ratios for the Gümüşhane Pluton to explain the geodynamic evolution of the Eastern Pontides in terms of the subduction polarity. Our objectives are to represent the genesis of continental arc magmas and to delineate the geodynamic evolution of the Eastern Pontides during the late Mesozoic–Cenozoic.

## 2. General geology and tectonic settings

The Eastern Pontides Orogenic Belt (Fig. 1), in NE Turkey, delineates a Late Cretaceous magmatic arc built on a pre-Liassic basement (Şengör and Yılmaz, 1981; Yılmaz et al., 1997; Okay and Şahintürk, 1997; Okay and Tüysüz, 1999; Topuz et al., 2004a, 2004b, 2007). This magmatic belt is subdivided into three sub-tectonic units from north to south as Northern, Southern and Axial zones depending on their lithological and facies changes and tectonic characteristics (Bektaş et al., 1995; Eyüboğlu et al., 2006). The Northern zone is represented by Mesozoic–Cenozoic aged tholeiitic and calc-alkaline bimodal volcanic rocks and granitic intrusions. The southern zone consists of numerous rock associations such as Paleozoic metamorphic massifs (Pulur, Ağvanis, and Tokat Massifs) and granitic intrusions (Gümüşhane and Köse Granites) possessing Hercynian basement of the Eastern Pontides (Eyüboğlu et al., 2006). The axial zone is represented by a Middle-to-Upper Cretaceous olistostromal mélange, Upper Cretaceous high-K volcanics (shoshonitic and ultrapotassic) and serpentinized Alpine-type peridotites (Eyüboğlu et al., 2007).

The Meso-Cenozoic geologic evolution of the Eastern Pontides has still been obscure due to lack of structural, geochemical, geophysical and geochronological data (Eyüboğlu, 2010). There are three different theories about geodynamic evolution of the Eastern Pontides Orogenic Belt.

According to Dewey et al. (1973), Chorowicz et al. (1998), Bektaş et al. (1999), Eyüboğlu et al. (2006) and Eyüboğlu (2010), the Eastern Pontides magmatic arc, which is the active northern margin of Gondwana from the Paleozoic to the Cenozoic, developed as a result of a southward subduction zone of Paleotethys continued incessant from the Paleozoic until the end of Eocene (Bektaş et al., 1995, 2001). Also, Görür et al. (1983) stated that tectonic evolution of the Pontides, the northern margin of Gondwana, was dominated by south dipping subduction of the Paleo-Tethys Ocean at the end of Liassic. The paleomagnetic studies are quite satisfactory and implied that the Eastern Pontides Orogenic Belt was placed at 23° (Van der Voo, 1968; Lauer, 1981; Sarıbudak, 1989), 25.5 ± 4.5° (Channell et al., 1996), 20.0 ± 2.5° (Çinku et al., 2010), and 26.6° (Hisarlı, 2011) north latitude, south of Eurasia during the Cretaceous. The Pontides have moved northwards to their present position of 42° north, which can be explained by southward subduction of the Tethys oceanic lithosphere (Bektaş et al., 1999).

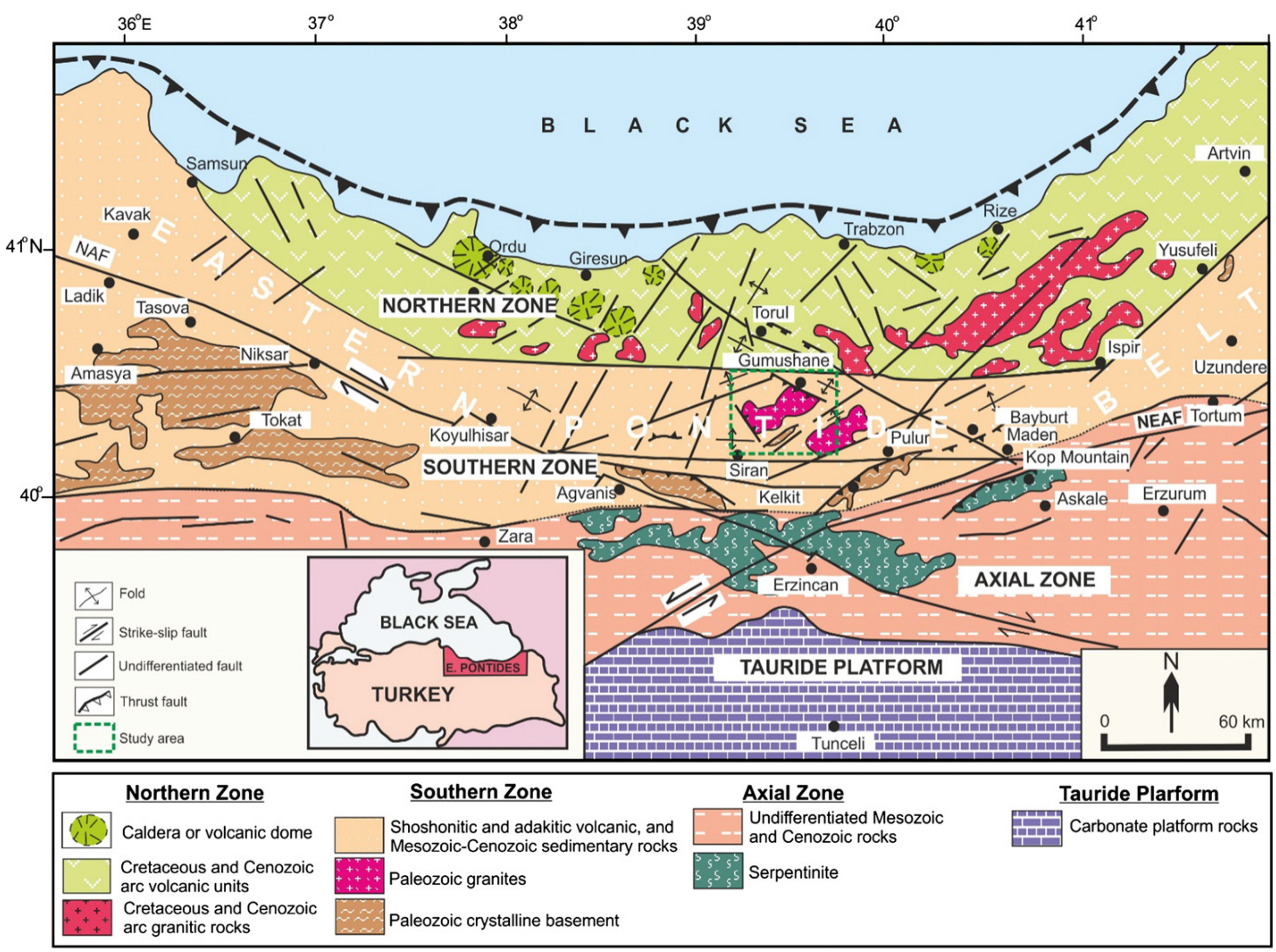


**Fig. 1.** Tectonic map showing the main lithological units and zones of the Eastern Pontides Orogenic Belt (Eyüboğlu et al., 2006).