

Reply to comment by Erkül and Erkül on “Al-in-hornblende thermobarometry and Sr-Nd-O-Pb isotopic compositions of the Early Miocene Alaçam granite in NW Anatolia (Turkey)”

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We appreciate Erkül and Erkül's comment on our paper entitled “Al-in-hornblende thermobarometry and Sr-Nd-O-Pb isotopic compositions of the Early Miocene Alaçam granite in NW Anatolia (Turkey)”. Their reply gives us the possibility to address and clarify some points about the Alaçam granite (AG) and related magmatic rocks along the Northern Menderes Massif (NMM).

Hasözbeke et al. (2012) dealt with geological, geochemical, and geochronological data obtained from different projects (Erdoğan et al., 2003, 2007, 2010) on the Oligo-Miocene granites (Eğrigöz, Koyunoba, Alaçam) along the northern border of the Menderes Massif (MM) in western Anatolia (Turkey). The points made by Erkül and Erkül (2013) are addressed as follows:

1. Erkül and Erkül stated that the AG and its related stocks exhibit 2 distinct facies (Erkül, 2010, 2012; Erkül and Erkül, 2010, 2013). AG presents petrographic features similar to those of the Eğrigöz and Koyunoba granites in the NMM as well as granites of similar age in northwestern Anatolia (Akay, 2009). Textural differences between the periphery and the center of the AG were observed and already reported by Hasözbeke et al. (2011). The main granitic body and the accompanying stocks cropping out in Alaçam Mountain differ from each other only in terms of size, except for slight differences in the emplacement depth and crystal sizes (Hasözbeke et al., 2011, 2012). Fine to coarse holocrystalline texture from the periphery to the central parts in the AG and accompanying stocks is clearly observed, as expected in any shallow-seated plutonic body. Besides the textural characteristics, our previous U-Pb zircon crystallization age data (c. 20–23

Ma) and Rb-Sr cooling mica ages (c. 18–20 Ma) indicate rapid cooling of the granitic bodies (Hasözbeke et al., 2011). Their geochemical and isotopic signatures do not represent significant trends to separate the AG and accompanying stocks as different facies. It is clear that not only the granitic masses in the Alaçam Mountain but also the several other granitic plutons (e.g., Eğrigöz, Koyunoba, Kozak, Ezine, Evciler granites) are compatible in terms of their geological, geochemical, and geochronological characteristics as reported by Akay (2009) and the currently discussed paper.

Our data presented in this reply and in a previous paper (Hasözbeke et al., 2011) are not in agreement with the observation of Erkül and Erkül (2013) that western and eastern Alaçam stocks represent widespread extensional ductile shear zones and detachment faults. In our generalized columnar section of the Alaçam region, lithological differences exist compared to the papers of Erkül (2010) and Erkül and Erkül (2013). As indicated in our geological map (Hasözbeke et al., 2011), the AG and its related stocks cross-cut the metadetrital unit that is interlayered with the metarhyolites. In the papers of Erkül (2010) and Erkül and Erkül (2012), the rocks observed in “skarn zone” or “mylonitic shear zone” of ‘Stock A’ are actually metarhyolites and they are part of the host rock association of the AG. Embayed quartz phenocrystals in recrystallized low-grade metamorphosed glassy matrix are observed (Figure) and were also previously reported in the literature (Akay et al., 2011; Akal, 2012; Özdamar et al., 2013). In western Anatolia, the thick, high-pressure metadetrital rocks cropping out along the northern part of the MM were named by Okay et al. (1996, 1998, 2005)

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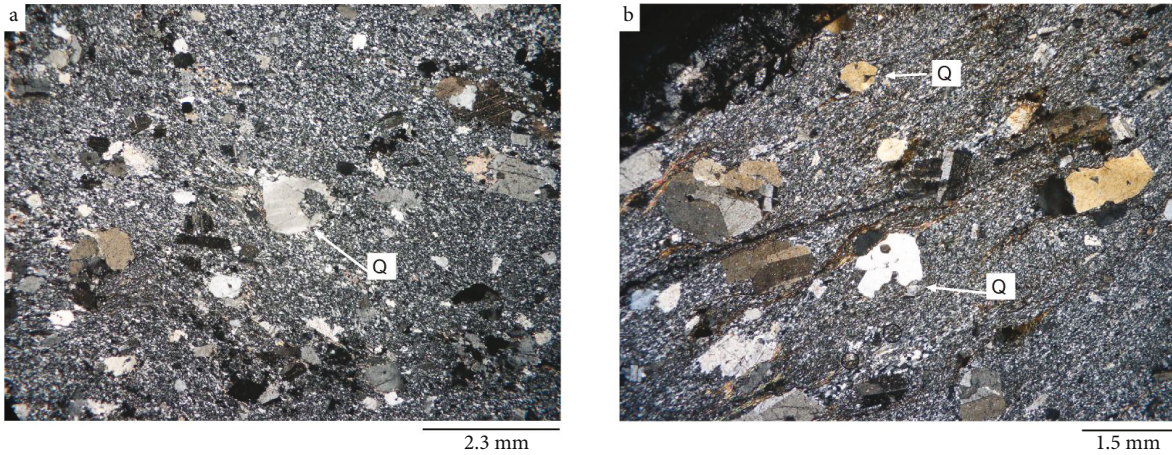


Figure. Photomicrographs showing the low-grade metamorphosed volcanic textural features of metarhyolites in the Afyon Zone where the intrusive boundary of the Alaçam granite stock is observed with metarhyolites. **a, b)** Slightly deformed volcanic texture with subhedral embayed quartz phenocrystals (Q) in recrystallized glassy matrix is characteristic for the metarhyolites of the Afyon Zone.

as the Afyon Zone. Eastward, the lateral continuation of the Afyon Zone forms a part of the Kütahya-Bolkardağ Belt (Özcan et al., 1988; Göncüoğlu et al., 2003). In the thick metadetrital associations metarhyolite intervals have been mapped and c. 230–250 Ma ages were obtained by paleontological and geochronological methods by several authors (Akay et al., 2011; Akal, 2012; Özdamar et al., 2013). The U-Pb zircon age of the gneissic granites (314.9 ± 2.7 Ma; Hasözbeke et al., 2011) from the lowermost parts of the Afyon Zone is also in agreement with the age determinations for the metarhyolites in the Afyon Zone and the Kütahya-Bolkardağ Belt. In addition to the cross-cutting contact relationship, a wide age difference between the undeformed granite (Alaçam stock, 20.3 ± 1.4 Ma; Hasözbeke et al., 2011) and the hosting gneissic granites (314.9 ± 2.7 Ma; Hasözbeke et al., 2011) with metarhyolites intervals (c. 230–250 Ma; Akay et al., 2011; Akal, 2012; Özdamar et al., 2013) is not in line with the observation by Erkül (2010) that these rocks are the “syn-tectonic mylonitic upper parts of the Alaçam granite”.

2. Although the descriptions of the symbols including Al-in-hornblende barometry and analyzed isotope samples were marked in the legend of the geological map of the Alaçam Region (Hasözbeke et al., 2012), for some reason, they were missing from the maps. From the north edge to the south center of the AG, sample locations of the Al-in-hornblende barometry are given as respectively, sample numbers: 550, 424, 552 - UTMs: 0655300;4285505, 0623656;4362433, 0646935;4358090.

3. One of the major conflicts of the previously suggested syn-extensional emplacement model of the Early Miocene granites in the northern part of the MM is related to their emplacement depths. In addition to all field characteristics indicating a shallow-seated nature

(existence of roof pendants, rapid cooling textures, skarn zones, and transition from the plutonic rocks to volcanic counterparts), Al-in-hornblende barometry from the main granitic body yields a depth of 4.7 ± 1.6 km (Hasözbeke et al., 2012). Shallow-type emplacement models cannot be explained by detachment mechanism for the following reasons (Hasözbeke et al., 2012, p. 44): “The extension model led to a deduction of an intrusion depth between the brittle-ductile transition zones. In general, these types of fault zones can form and evolve in the middle to lower crust (Ramsay, 1980; Coward, 1984). The location of the transition zone between elasto-frictional (ductile) and quasi-plastic (brittle) behavior defines an emplacement depth of these granitoids between ca. 15–20 km (Sibson, 1977; Brichau et al., 2007, 2008; Tirel et al., 2009), inconsistent with our new Al-in-hornblende thermobarometry calculations”.

The low-angle fault system in the region is not only considered to be associated with syn-tectonic mylonites but also responsible for the exhumation of the ultrahigh to high pressure metamorphic rocks of the Afyon Zone and the MM. Therefore, it is not only the formation of mylonite, as stated by Erkül and Erkül (2013), but also the exhumation of the very high pressure metamorphic rocks that must be explained in the suggested models. Furthermore, the depth of the low-angle fault zone, along which these shallow-seated granites are suggested to be emplaced, would be too shallow to exhume high pressure/low temperature metamorphic rocks of the Afyon Zone (Candan et al., 2005) and the high-P MM (Candan et al., 2001). Furthermore, Ring et al. (1999) noted that the crustal material of the MM, 35–40 km thick, cannot be exhumed by only the so-called shallow dipping low-angle faults.

In NW Anatolia, all the Oligo-Miocene granites (Evciler, Ezine, Kozak, Alaçam, Eğrigöz, Koyunoba, and Baklan) bear similar geological, petrographic, geochemical, and geochronological characteristics and cross-cut the MM, Karakaya Complex, Sakarya Zone, Bornova Flysch Zone, and/or Afyon Zone (Akay, 2009). Therefore, if these granites emplaced syn-tectonically along detachment faults, then the low-angle tectonic contacts between these different tectonic belts must have been considered as low-angle detachment faults, which is not the case. Besides, it has to be explained how all these detachment-related syn-tectonically emplaced granites, almost in every location, cut both the footwall and hanging wall rock associations of these so-called detachment faults.

Erdoğan et al. (2013) recently discussed the metamorphism and exhumation history of the Kazdağı Massif and concluded that the exhumation of the Kazdağı metamorphic sequence took place stepwise: (i) by tectonic imbrication, (ii) by deep erosion after the emplacement of the young granites, and (iii) by uplifting along normal faults during Pleistocene time but not related to any kind of detachment faults.

4. Based on mol $Al_2O_3/mol (Na_2O + K_2O)$ vs. mol $Al_2O_3/mol (CaO + Na_2O + K_2O)$ values, samples of the AG cluster together along the peraluminous and metaaluminous dividing line, except for 3 outliers that are slightly on the metaaluminous side (Hasözbeke et al., 2011). Geochemical data presented in this paper are also compatible with the previous papers of Yılmaz et al. (2001), Dilek and Altunkaynak (2007), Akay (2009), and Hasözbeke et al. (2010).

5. When Erkül and Erkül (2013) refer to 'a widely accepted lithospheric delamination model', this by itself does not make our model unacceptable. We have already discussed the main limitations of this controversial model in light of our new analytical and geological findings in the original paper.

As Erkül and Erkül (2013) pointed out, in a previous study (Hasözbeke et al., 2011), the AG was interpreted as upper crustal derived melt based on REE patterns. Whole-

rock geochemical and isotopic analysis gives additional information about the origin of the AG. Based on such data, we concluded a middle-crustal source as the origin of the AG and its stocks (Hasözbeke et al., 2011, 2012).

As Erkül and Erkül (2013) stated, they published data on geological, mineralogical, and geochemical features of the mafic microgranular enclaves (MMEs) from the AG. Our paper on the AG emplacement depth was published online on 20 April 2011 in the Turkish Journal of Earth Sciences; however, the paper by Erkül and Erkül (2012) on MMEs was available online from 18 February 2012 in Lithos. Therefore, it was impossible to refer to or discuss their data in our paper. The scope of our paper was to manifest the source and emplacement depth of the AG with the support of isotopic data. A generalized comparison of the Miocene granites with its geological, mineralogical, and geochemical features was already put forward by Akay (2009).

Erkül and Erkül (2013) made a statement on the crustal source evidence concluded from the U-Pb ages of Hasözbeke et al. (2011). Regarded supportive conclusions from the zircon CL images and U-Pb discordia data were only considered in the Alaçam region by Erkül and Erkül (2013). However, in our paper, we demonstrated clear evidence for the presence of zircon cores in the AG (Hasözbeke et al., 2011, p. 13, Figure 11b), and similar upper intercept ages of 556 ± 93 and 562 ± 72 Ma (core ages) were also observed in the early Miocene Eğrigöz and Koyunoba granites, respectively (Hasözbeke et al., 2010). The source of these granites could be the older basement of the northern MM.

Summarizing, our implications from the age, isotope, and Al-in-hornblende results from the AG and its related stocks are not in line with the results presented by Erkül (2010, 2012) or Erkül and Erkül (2010, 2012). Overall, our interpretation mainly relies on analytical data collected from Al-in-hornblende barometry and isotopic data of the AG. Different approaches within the same geological framework may shed further light on this issue.

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