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Comment 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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Hasözbek *et al.* (2012, Turkish Journal of Earth Sciences 21, 37-52) published Al-in-hornblende thermobarometry and new Sr-Nd-O-Pb isotope data and discussed the emplacement depth and the petrogenesis of the Alaçam granites. In this paper, they mainly concluded that these granitoids were emplaced at shallow crustal levels (4.7±1.6 km) and were not deformed in a ductile manner as the brittle-ductile boundary of an extended continental crust is much deeper (15-20 km). They also suggested that the Sr-Nd-Pb-O isotopic compositions of the Alaçam granite are consistent with derivation from an older middle crustal source rather than a mantle source. In our work on the geological, geochronological, geochemical and isotopic characteristics of the Alaçamdağ granitoids, together with other syn-extensional granitoids, we carefully examined the results of Hasözbek *et al.* Inconsistencies in interpretation lead us to comment on some points in this paper.

1. In their petrography, geochemistry and isotopic data section, Hasözbek *et al.* stated that the Alaçamdağ granites have more or less equigranular, fine to coarse grained holocrystalline textures. However, our field and petrographic observations revealed that the Alaçamdağ granitoids are not as unique as published and can be divided into two distinct facies: western (Musalar granitoids) and eastern (Alaçam granitoids) stocks (Erkül 2010, 2012; Erkül & Erkül 2010). In Figure 2 of Hasözbek *et al.*, the western stocks correspond to the stocks labelled AS-1 and AS-3, while the eastern stock is a single body extending NW-SE. The western stocks consist of holocrystalline equigranular granites and granodiorites with intruding aplitic equivalents while the eastern stocks are characterised by abundant K-feldspar megacrysts within the holocrystalline matrix (Erkül 2012). These two facies are mineralogically similar to each other and include large amounts of mafic microgranular enclaves (MME), which are quite important in explaining the petrogenesis of these granitoids.

The western and eastern stocks contain extensional ductile shear zones that consist of widespread ultramylonites and protomylonites, which were not mentioned by Hasözbek *et al.* Further information about these shear zones can be found in Erkül (2010). Erkül (2010) also reported systematic Ar-Ar biotite cooling ages from the Alaçamdağ granitoids and associated mylonitic rocks (e.g., western and eastern stocks) in the Alaçamdağ region. These Ar-Ar ages, ranging from 20.5 to 19.5 Ma, clearly demonstrate that the cooling of eastern stocks was coeval with the formation of mylonitic rocks in the shear zones that provide clear evidence for Early Miocene extensional ductile deformation in the region. Therefore, the ductilely deformed Alaçamdağ granitoids are not genetically related to an older metagranitoid of the Afyon Zone or Menderes Massif, as suggested by Hasözbek *et al.* Ductile shear zones in the Alaçamdağ granitoids are also characterised by asymmetric structures in shear bands, sigma-type quartz and feldspar porphyroclasts, oblique-grain-shape foliation, asymmetric boudins and mica fish (Erkül 2010; Erkül & Erkül 2010). These structures in low-grade mylonitic rocks can be used as good shear sense indicators that may provide insights into the development of the extensional regime in the northern Menderes Massif. Kinematic analysis of the Simav detachment and associated low/high-angle shear zones in the northern Menderes Massif has already been presented in many papers (Işık & Tekeli 2001; Işık *et al.* 2004; Seyitoğlu *et al.* 2004; Purvis & Robertson 2004, 2005; Ring & Collins 2005; Çemen *et al.* 2006; Thomson & Ring 2006; Erkül 2010; Erkül & Erkül 2010). They provide detailed evidence that the granitoid rocks and associated basement units underwent low-grade mylonitic ductile deformation and the overprinting brittle deformation in the region was due to progressive uplift of footwall rocks in the region, which is a typical exhumation process in an extended crust (Işık & Tekeli 2001; Thomson & Ring 2006; Erkül 2010). These studies confirm that the

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Menderes Massif and associated granitoid intrusions were locally deformed into low-grade mylonitic rocks due to extensional detachments and shear zones.

2. In the mineral chemistry section, systematic sample locations chosen for Al-in hornblende thermobarometry evaluations were neither shown in the figure nor indicated as geographic coordinates. This also fails to explain the argument that the emplacement depth of the Alaçamdağ granitoids increases from east to west.

3. In the discussion section, Hasözbek *et al.* argue that the Alaçamdağ granitoids, together with other Aegean and NW Anatolian granitoids, were emplaced at shallow crustal levels. They reported estimated emplacement depths averaging 4.7±1.6 km for the Alaçamdağ granitoids and denied the presence of extensional ductile deformation (e.g., detachment faults and shear zones) as the ductile-brittle transition zone occurs at deeper levels (about 15-20 km). Although the emplacement depth of each stock forming the Alaçamdağ granitoids is not clear due to missing location data, their estimated average emplacement depth confirms the shallow emplacement of syn-extensional granitoids in the northern Menderes Massif (Akay 2009; Erkül 2010, 2012). Increasing emplacement depth of granitoids from east to west in the Alaçamdağ region is also consistent with previous assumptions (Erkül 2010). However, the absence or presence of ductile deformation based on depth parameters alone appears unlikely as low-grade mylonite formation can be controlled by many other factors as well as depth. Other factors include lithology (e.g., contrasting behaviours of minerals), temperature, deviatoric stress, fluid content, fluid pressure and fluid compositions (Lister & Davis 1989; Blenkinsop 2002; Passchier & Trouw 2005; Trouw *et al.* 2010 and references therein). The temperature range for low-grade mylonites is widely accepted as occurring between 250 and 500 °C (Trouw *et al.* 2010), and each mineral has a different behaviour at constant temperature. For instance, thermodynamic estimations in low-grade mylonitic rocks suggest that plastic deformation in quartz and mica usually occurs at temperatures greater than 200 °C and plastic deformation of feldspars is widely accepted to begin at about 450 °C. Amphiboles, common mafic minerals, begin to deform plastically above 500 °C (Blenkinsop 2002). However, quartz can deform ductilely at e.g. 300 °C while feldspars behave in a brittle manner at the same temperatures. Therefore, variation in behaviour of different minerals means that no unique depth or temperature can be proposed for brittle-ductile transitions. In the Alaçamdağ region, the mylonitised eastern stocks include retrograde mineral assemblages defined by an alteration of biotite to chlorite. This alteration process suggests that the western stocks were heated at temperatures above 250 °C. Local skarn mineralisation along the contact of the Alaçamdağ granitoids with host rocks also indicate that the fluid-related parameters mentioned above can be other controlling factors during the formation of low-grade mylonitic rocks in the Alaçamdağ region. Adjacent metamorphic core complexes (e.g., Kazdağ, Rhodope and Cycladic Core Complexes), even the footwall of central Menderes Massif, was also intruded by shallow-seated, syn-extensional granitoids emplaced on the footwall of a detachment or cut by shear zones; therefore shallow emplacement of syn-extensional granitoids is a common event in the extended continental crust of the Aegean region.

4. In the isotopic compositions of the Alaçam granite section, authors indicate that the Miocene granitoids in northwestern Turkey have mainly peraluminous and minor metaluminous characters. However, this is not correct, as Eocene to Middle Miocene granitoid rocks have I-type, mostly metaluminous and a slightly to mildly peraluminous character (Aydoğan *et al.* 2008; Karacık *et al.* 2008; Boztuğ *et al.* 2009; Erkül & Erkül 2010; Erkül 2012). Their A/CNK values and mineralogical composition is characterised by the presence of hornblende and biotite as the main mafic phases and the absence of sillimanite and garnets as restite minerals, which is compatible with a metaluminous rather than peraluminous character.

5. In the section "isotopic compositions of the Alaçam granite", Hasözbek *et al.* cited that Aldanmaz *et al.* (2000), Dilek & Altunkaynak (2007, 2009) and Aydoğan *et al.* (2008) claimed a slab break-off model for the origin of the Miocene granitoids. However, Dilek & Altunkaynak (2007, 2009) only suggested this model for Eocene granitoids in north-western Turkey. Lithospheric delamination is a widely accepted model for the origin of Miocene magmatism that has been proposed in many papers (Aldanmaz *et al.* 2000; Köprübaşı & Aldanmaz 2004; Dilek & Altunkaynak 2007, 2009; Ersoy *et al.* 2010, 2012). It is claimed that the Miocene granitoids were derived from hybrid magmas formed by mixing of crust and mantle (Aydoğan *et al.* 2008; Boztuğ *et al.* 2009; Dilek & Altunkaynak 2009, 2010; Öner *et al.* 2010; Erkül & Erkül 2010; Erkül 2012).

Hasözbek *et al.* suggest in their Figure 9 that the Alaçamdağ granitoid samples plot in the field corresponding to middle crust composition, which is different from those of the Central Aegean granitoid samples (e.g., Ikaria and Tinos granitoids). However, this figure does not show any field defining middle crustal compositions. Hasözbek *et al.* (2011) had already suggested an upper crustal origin for the same Alaçamdağ granitoid samples, based on normalising values of Rudnick & Gao (2003). Finally, the origin of the Alaçamdağ granitoids explained in this paper clearly contradicts the suggestions of Hasözbek *et al.* (2011).

Hasözbek *et al.* argued that the Alaçamdağ granitoids were derived from an older crustal source (e.g., Menderes Massif or Afyon Zone) based on Sr-Nd-O-Pb isotopic data. However, our recent research indicates the presence of a mantle contribution into the crustal components during the formation of the Alaçamdağ granitoids (Erkül & Erkül

2012). Compiled $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ data from the Aegean granitoids reveal that the Alaçamdağ granitoids have $\delta^{18}O$ values between 8 and 10.5‰ and therefore plot on the mixed field, corresponding to mixed magmas (Whalen *et al.* 1996) (Figure). MMEs bear critical mineralogical and geochemical information that may highlight the petrogenesis of the Alaçamdağ granitoids. Oligocene and Miocene granitoids in western Turkey have abundant MMEs up to metres across that are circular to ovoid (Erkül 2012). The MMEs are monzonitic, monzodioritic and dioritic in composition and their sharp contacts with host rock are commonly attributed to the undercooling and mingling of hybrid mafic microgranular globules formed by the mixture of mafic and felsic magmas (Perugini *et al.* 2004). On a microscopic scale, disequibilirium textures (spongy cellular plagioclase, antirapakivi mantling, blade shaped biotite and acicular apatite) suggest chemical, thermal and mechanical equilibrium conditions (Eichelberger 1980; Barbarin & Didier 1991, Hibbard 1991, 1995; Boztuğ *et al.* 2009; Erkül & Erkül 2010, 2012; Erkül 2012). Lower SiO_2 contents than the host rock, and higher MgO and Mg numbers of MMEs requires the presence of a mafic component, rather than pure crustal material. A hybrid origin for the granitoids in western Turkey is not a new idea and has been suggested by many authors (Aydoğan *et al.* 2008; Akay 2009; Boztuğ *et al.* 2009; Dilek & Altunkaynak 2009; Erkül & Erkül 2010; Erkül 2012). Geological, mineralogical and geochemical features of the MMEs appear to have been neglected by Hasözbek *et al.* in revealing the petrogenesis of the Alaçamdağ granitoids.

Hasözbek *et al.* also support an older purely crustal source with U-Pb ages of 500-550 Ma obtained from inherited zircon grains in the Alaçamdağ granitoids. However, U-Pb dating from inherited zircon grains requires more systematic study to reveal the protolith of the granitoids. The granitoid rocks were generated by partial melting with crustal contamination, crystal fractionation and magma mixing processes that affect primary melts. Therefore, older ages from inherited zircon grains may also derive from various processes such as crustal contamination by host meta-sedimentary or igneous rocks and by partial melting of source protoliths at deeper crustal levels. The limited number of U-Pb ages (e.g., 500-550 Ma) from the Alaçamdağ granitoids is insufficient to support an old crustal protolith for the Alaçamdağ granitoids.

In conclusion, the Alaçamdağ granitoids are not as unique as suggested in the paper by Hasözbek *et al.* and they include rather complex lithological and structural features that need careful examination to highlight their emplacement mode and to evaluate petrogenetic models. To relate the emplacement depth of granitoids with brittle and ductile deformation conditions may lead to erroneous assumptions, due to various parameters that must be taken into account. Mineralogical, geochemical and isotopic features of the MMEs, which were omitted by Hasözbek *et al.*, appear to have a crucial importance in the understanding of the magmatic origin of the Alaçamdağ granitoids. Therefore, the older crustal origin for the Alaçamdağ granitoids suggested by Hasözbek *et al.* must be considered with caution.

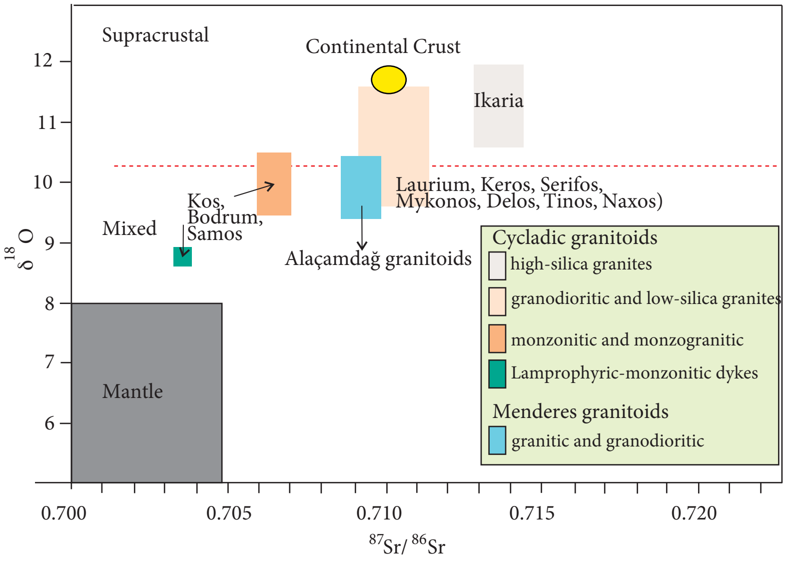

Figure. Comparison of the $^{87}Sr/^{86}Sr$ versus oxygen isotopic composition of the Aegean and Northwestern Anatolian (NW) granitoids and lamprophyric rocks. Oxygen and $^{87}Sr/^{86}Sr$ data are taken from Altherr *et al.* (1998), Altherr & Siebel (2002), Hasözbek *et al.* (2012) and Erkül (2012). Mantle, mixed and supracrustal rock values are from Whalen *et al.* (1996).

References

Akay, E. 2009. Geology and petrology of the Simav Magmatic Complex (NW Anatolia) and its comparison with the Oligo-Miocene granitoids in NW Anatolia: implications on Tertiary tectonic evolution of the region. *International Journal of Earth Sciences* **98**, 1655-1675.

Aldanmaz, E., Pearce, J.A., Thirlwall, M.F. & Mitchell, J.G. 2000. Petrogenetic evolution of Late Cenozoic, post-collision volcanism in western Anatolia, Turkey. *Journal of Volcanology and Geothermal Research* **102**, 67-95.

Altherr, R., Henjes-Kunst, F., Mathews, A., Friedrichsen, H. & Hansen, B.T. 1988. O–Sr isotopic variations in Miocene granitoids from the Aegean: evidence for an origin by combined assimilation and fractional crystallization. *Contributions to Mineralogy and Petrology* **100**, 528-541.

Altherr, R. & Siebel, W. 2002. I-type plutonism in a continental back-arc setting: Miocene granitoids and monzonites from the central Aegean Sea, Greece. *Contributions to Mineralogy and Petrology* **143**, 397-415.

Aydoğan, M.S., Çoban, H., Bozcu, M. & Akıncı, Ö. 2008. Geochemical and mantle-like isotopic (Nd, Sr) composition of the Baklan Granite from the Muratdağı Region (Banaz, Uşak), western Turkey: Implications for input of juvenile magmas in the source domains of western Anatolia Eocene-Miocene granites. *Journal of Asian Earth Sciences* **33**, 155-176.

Barbarin, B. & Didier, J. 1991. Conclusions: enclaves and granite petrology. *In*: Didier J. & Barbarin B. (eds), *Enclaves and Granite Petrology*. Elsevier, 545-549.

Blenkinsop, T.G. 2002. *Deformation Microstructures and Mechanisms in Minerals and Rocks*. Kluwer Academic Publishers, Dordrecht, Boston.

Boztuğ, D., Harlavan, Y., Jonckheere, R., Can, İ. & Sarı, R. 2009. Geochemistry and K-Ar cooling ages of the Ilıca, Çataldağ (Balıkesir) and Kozak (İzmir) granitoids, west Anatolia, Turkey. *Geological Journal* **44**, 79-103.

Çemen, İ., Catlos, E.J., Göğüş, O. & Özerdem, C. 2006. Postcollisional extensional tectonics and exhumation of the Menderes Massif in the Western Anatolia extended terrane, Turkey. *In*: Dilek, Y. & Pavlides, S. (eds), *Postcollisional Tectonics and Magmatism in the Mediterranean Region and Asia*. Geological Society of America Special Publications **409**, 353-379.

Dilek, Y. & Altunkaynak, Ş. 2007. Cenozoic crustal evolution and mantle dynamics of post-collisional magmatism in western Anatolia. *International Geology Review* **49**, 431-453.

Dilek, Y. & Altunkaynak, Ş. 2009. Geochemical and temporal evolution of Cenozoic magmatism in western Turkey: mantle response to collision, slab break-off, and lithospheric tearing in an orogenic belt. *In*: Van Hinsbergen, D.J.J, Edwards, M.A. & Govers, R. (eds), *Collision and Collapse at the Africa-Arabia-Eurasia Subduction Zone*. Geological Society, London, Special Publications **311**, 213-233.

Dilek, Y. & Altunkaynak, Ş. 2010. Geochemistry of Neogene-Quaternary alkaline volcanism in western Anatolia, Turkey, and implications for the Aegean mantle. *International Geology Review* **52**, 631-655.

Eichelberger, J.C. 1980. Vesiculation of mafic magmas during replenishment of silicic magma reservoirs. *Nature* **288**, 446-450.

Erkül, F. 2010. Tectonic significance of synextensional ductile shear zones within the Early Miocene Alaçamdağ granites, northwestern Turkey. *Geological Magazine* **147**, 611-637.

Erkül, F. & Erkül, S.T. 2010. Geology of the Early Miocene Alaçamdağ magmatic complex and implications for the western Anatolian extensional tectonics. *Bulletin of the Mineral Research and Exploration Institute of Turkey (MTA)* **141**, 1-25.

Erkül, S.T. 2012. Petrogenetic evolution of the Early Miocene Alaçamdağ volcano-plutonic complex, northwestern Turkey: implications for the geodynamic framework of the Aegean region. *International Journal of Earth Sciences* **101**, 197-219.

Erkül, S.T. & Erkül, F. 2012. Magma interaction processes in syn-extensional granitoids: The Tertiary Menderes Metamorphic Core Complex, western Turkey. *Lithos*, **142-143**, 16-33.

Ersoy, Y., Helvacı, C. & Palmer, M.R. 2010. Mantle source characteristics and melting models for the Early-Middle Miocene mafic volcanism in Western Anatolia: Implications for enrichment processes of mantle lithosphere and origin of K-rich volcanism in post-collisional settings. *Journal of Volcanology and Geothermal Research* **198**, 112-128.

Ersoy, Y., Helvacı, C. & Palmer, M.R. 2012. Petrogenesis of the Neogene volcanic units in the NE–SW-trending basins in western Anatolia, Turkey. *Contributions to Mineralogy and Petrology* **163**, 379-401.

Hasözbek, A., Erdoğan, B., Satır, M., Siebel, W., Akay, E., Doğan, G.D. & Taubald, H. 2012. Al-in-Hornblende Thermobarometry and Sr-Nd-O-Pb Isotopic Compositions of Early Miocene Alaçam Granite in NW Anatolia (Turkey). *Turkish Journal of Earth Sciences* **21**, 37-57.

Hasözbek, A., Satir, M., Erdoğan, B., Akay, E. & Siebel, W. 2011. Early Miocene post-collisional magmatism in NW Turkey: geochemical and geochronological constraints. *International Geology Review* **53**, 1098-1119.

Hibbard, M.J. 1991. Textural anatomy of twelve magma-mixed granitoid systems. *In*: Didier J. & Barbarin B. (eds), *Enclaves and Granite Petrology. Developments in Petrology*. Elsevier, **13**, 431-444.

Hibbard, M.J. 1995. *Petrography to Petrogenesis*. Prentice Hall, New Jersey.

Işık, V. & Tekeli, O. 2001. Late orogenic crustal extension in the northern Menderes Massif (western Turkey): evidence for metamorphic core complex formation. *International Journal of Earth Sciences*, **89/4**, 757-765.

Işık, V., Tekeli, O. & Seyitoğlu, G. 2004. The $^{40}Ar/^{39}Ar$ age of extensional ductile deformation and granitoid intrusion in the northern Menderes core complex: implications for the initiation of extensional tectonics in western Turkey. *Journal of Asian Earth Sciences* **23**, 555-566.

Karacık, Z., Yılmaz, Y., Pearce, J. & Ece, Ö. 2008. Petrochemistry of the south Marmara granitoids, northwest Anatolia, Turkey. *International Journal of Earth Sciences* **97**, 1181-1200.

Köprübaşı, N. & Aldanmaz, E. 2004. Geochemical constraints on the petrogenesis of Cenozoic I-type granitoids in northwest Anatolia, Turkey: Evidence for magma generation by lithospheric delamination in a post-collisional setting. *International Geology Review* **46**, 705-729.

Lister, G.S. & Davis, G.A. 1989. The origin of metamorphic core complex and detachment faults formed during Tertiary continental extension in the northern Colorado River region, USA. *Journal of Structural Geology* **12**, 65-94.

Öner, Z., Dilek, Y. & Kadıoğlu, Y.K. 2010. Geology and geochemistry of the synextensional Salihli granitoid in the Menderes core complex, western Anatolia, Turkey. *International Geology Review* **52**, 336-368.

Passchier, C.N. & Trouw, R.A.J. 2005. *Microtectonics*. Springer-Verlag, Berlin.

Perugini, D., Poli, G., Christofides, G., Eleftheriadis, G., Koroneos, A. & Soldatos, T. 2004. Mantle-derived and crustal melts dichotomy in northern Greece: spatiotemporal and geodynamic implications. *Geological Journal* **39**, 63-80.

Purvis, M. & Robertson, A. 2004. A pulsed extension model for the Neogene–Recent E–W-trending Alaşehir Graben and the NE–SW-trending Selendi and Gördes Basins, western Turkey. *Tectonophysics* **391**, 171-201.

Purvis, M. & Robertson, A. 2005. Miocene sedimentary evolution of the NE-SW-trending Selendi and Gordes basins, W Turkey: Implications for extensional processes. *Sedimentary Geology* **174**, 31-62.

Ring, U. & Collins, A.S. 2005. U-Pb SIMS dating of synkinematic granites: timing of core-complex formation in the northern Anatolide belt of western Turkey. *Journal of the Geological Society, London* **162**, 289-298.

Rudnick, R.L. & Gao, S. 2003. Composition of the continental crust. *In*: Rudnick, R.L. (ed), Treatise on Geochemistry, Elsevier **3**, 1-64.

Seyitoğlu, G., Işık, V. & Çemen, İ. 2004. Complete Tertiary exhumation history of the Menderes massif, western Turkey: an alternative working hypothesis. *Terra Nova* **16**, 358-364.

Thomson, S.N. & Ring, U. 2006. Thermochronologic evaluation of postcollision extension in the Anatolide orogen, western Turkey. *Tectonics* **25**/3, TC3005.

Trouw, R.A.J., Passchier, C.W. & Wiersma, D.J. 2010. *Atlas of mylonites and related microstructures*. Springer.

Whalen, J.B., Jenner, G.A., Longstaffe, F.J., Robert, F. & Gariepy, C. 1996. Geochemical and isotopic (O, Nd, Pb and Sr) constraints on A-type granite petrogenesis based on the Topsails igneous suite, Newfoundland Appalachians. *Journal of Petrology* **376**, 7-60.