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"Petrogenesis of gabbroic rocks from the Malayer plutonic complex (Sanandaj-Sirjan zone, west Iran)": Discussion

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Esna-Ashari and Tiepolo (2020) provide new mineral chemistry data for some samples from the previously reported outcrop of mafic plutonic rocks from the northwestern part of the Malayer-Boroujerd Plutonic complex (MBPC in Deevsalar et al., 2017), which they referred to as MPC. In this paper, they proposed an oversimplified petrogenetic model, in which a quartz-dioritic parent magma with sanukitoid-like high-Mg andesite (HMA) signature – similar to that suggested by Esna-Ashari et al. (2016) for the Aligudarz Plutonic complex (APC), assumed to be generated by the reaction between boninitic ultramafic cumulates and a felsic melt – has produced the MPC gabbros.

This comment is not about the new data represented by the authors but, rather, refers to the data interpretation and the origin considered for these mafic rocks. We encountered several contradictions and oversimplifications in their interpretations in an attempt to force their data to support the petrogenetic model suggested for the APC.

The primary issue with their approach is that the limited number of nameless cumulate sample/s from the small outcrops of the Tangsaran hill (Figure 1a) have been used to explain the mafic magmatism in the MPC. We believe that, any interpretation and related conclusions in Esna-Ashari and Tiepolo (2020) must be limited to the cumulate rocks from the Tangsaran hill, not to the entire MPC.

Based upon our field and microscopic observations, three kinds of cumulate rocks have been identified in the Tangsaran hill (Deevsalar et al., 2017), which can be classified into two groups of olivine-bearing and olivine-free samples. Cumulus plagioclase is the dominant mineral phase that crystallized with either hornblende or hornblende + olivine ± clinopyroxene. Hornblende is present as cumulus (granular) phase and post-cumulate oikocrysts which the later one is a common interstitial phase in Tangsaran cumulates. The gradual transition between the plagioclase-dominated and Plagioclase + Olivine-dominated cumulate gabbros (Figure 1b) suggest the mineral accumulation and precipitation happened in the same magma chamber from a common parental melt. This is supported by similar major and trace element compositions of plagioclase and hornblende as common mineral phases in these rocks. However, limited outcrops in the Tangsaran hill hinder access to the entire cumulate layers but in comparison with other cumulate and non-cumulate gabbros across the MPC it may provide a screenshot of the magma chamber event.

The recalculation the compositions of melt in equilibrium with hornblende and clinopyroxene for the broader range of trace elements and using almost similar solid/liquid partition coefficients ($D_{s/l}$) to those of Esna-Ashari and Tiepolo (2020) on primitive mantle normalized plot reveals some meaningful compositional discrepancies (Figure 1c). It includes clear discrepancies among mineral equilibrium melts and their host rocks (i.e. Tangsaran cumulate gabbros) in addition to that of APC quartz diorites. Werts et al. (2020) reported several examples of hornblendes from different host plutonic

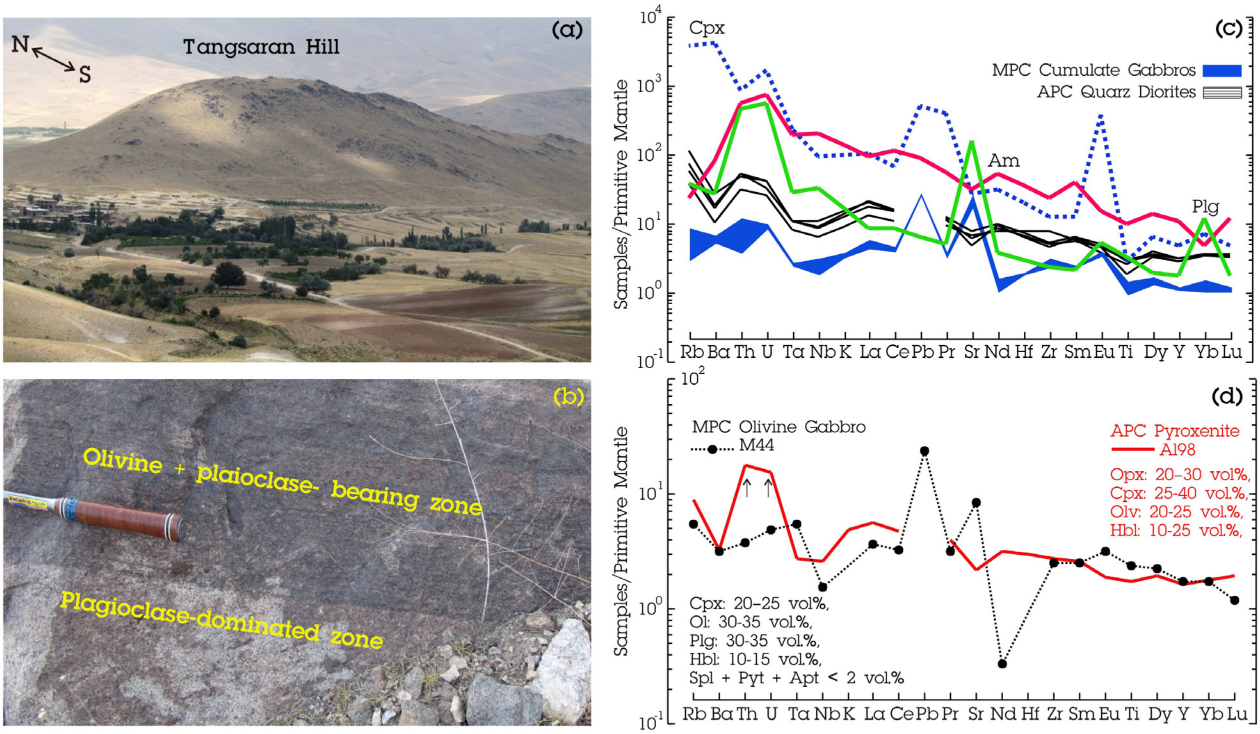

Figure 1. a) Tangsaran southern hillside, b) Cumulate layering, Primitive-mantle normalized trace element pattern of c) Tangsaran mafic cumulates in comparison with APC quartz diorites and melts in equilibrium to clinopyroxene, hornblende and plagioclase, and d) APC ultramafic xenolith (Al98) in comparison with MPC olivine gabbro cumulate (M_{44}). Mineral phases for each cumulate are given on the plot for comparison. Normalizing values is from Sun and McDonough, 1989. $D_{S/L}$-values for trace element modeling are from Shimizu et al., 2017 (for Pr, Eu and Gd), others from Ersoy et al., 2010.

rocks of high SiO_2 variability (42-78 wt%), which are out of equilibrium with their host bulk-rock compositions. Most of the analyzed plutonic hornblendes in this study are in equilibrium with melts typically more silicic than host-rock compositions ascribed to the crystal accumulation and/or melt loss processes within the middle- to upper-crustal reservoirs. The composition of the residual melt in equilibrium with hornblende from the Tangsaran cumulates also approximates to that of highly evolved felsic magmas where SiO_2 in calculated equilibrium melt varies between 63 to 73 wt% (±3.6 wt%, T: 950 ℃, R^2=0.86, Table 1; Putirka et al., 2016; Zhang et al., 2017). In contrast to what is argued in Esna-Ashari and Tiepolo (2020), the fluid-assisted metamorphic or magmatic reaction rim between olivine and plagioclase (i.e. corona) is a common feature in many gabbroic cumulates in arc settings and supports the magmatic evolution in the hydrous magma chamber rather than the interaction between evolved magma and cumulate assemblage (e.g., Whitney and McLelland, 1983; Joesten, 1986). The lack of textural and geochemical evidence of interaction between precipitated cumulate minerals and an evolved residual melt indicates melt extraction from the hydrous magma chamber during the open-system fractional crystallization process. In addition, the compositional discrepancies among hornblende equilibrium melt and host cumulate gabbro (Figure 1c) in Tangsaran hill is consistent with the segregation and accumulation of solid phases including clinopyroxene + plagioclase (+ olivine) ± ilmenite and apatite along with hornblende from the residual melt.

PETROGENETIC MODEL

According to the model suggested by Esna-Ashari and Tiepolo (2020), the significant assimilation of a pre-existed boninitic ultramafic assemblage of Late Triassic to Early Jurassic age in an evolved felsic magma (R: 0.5, equivalent to the high degree of melting (f_M): 0.5; where R is the ratio of mass assimilated to mass crystallized), accompanied with high degree of fractional crystallization (f_C: 0.66) could produce the assumed quartz dioritic parent magma for the MPC gabbros. We argue against this model and believe that it arises from the insufficient knowledge about the MPC mafic rocks – because of the limited number of collected samples which are not representative of the entire magmatic complex – misdescription of the samples and ignoring the tectono-magmatic situation of the MPC during the Middle Jurassic by the authors as discussed more below.

Similar to the adakites, HMA sanukitoid magmas are products of equilibrium reaction between a silicic melt derived from partial melting of a young and/or hot subducting oceanic slab and mantle peridotite (e.g., Shimoda et al., 1998; Kamei et al., 2004), but in the higher contribution of the latter component which needs higher thermal gradients. The assumed HMA melts should display geochemical and even textural evidence of interaction with mantle materials, which is not the case for the MPC gabbros (e.g., Kameia et al., 2004). According to the published U-Pb zircon data (Deevsalar et al., 2017), the oldest MPC cumulate and non-cumulate gabbros belong to the Middle Jurassic (including M_{44} which considered as Late Triassic to Early Jurassic age ultramafic assimilant in the AFC model of Esna-Ashari and Tiepolo, 2020), coeval with granitoids and diorites intrusions. The relatively small outcrops of mafic plutons in the MPC [like other parts of the Sanandaj-Sirjan Zone (SaSiZ)] are presumably indicative of the large volume mafic melts which were trapped behind a barrier of contemporaneous viscous, less dense and colder felsic melts. The small batches of mafic melts that ascended through the SaSiZ crust do not record any field, mineralogical, textural and geochemical interaction with other dominant magmatic phases in contrast to the APC ultramafic cumulates of Esna-Ashari et al. (2016). Therefore, the same scenario as for the APC ultramafic xenoliths, which have different origin (most likely lower crustal ultramafic cumulates), occurrence, mineralogy and geochemical/isotopic signatures compared to the olivine gabbro cumulate from the MPC (considered as “ultramafic rocks” in Esna-Ashari and Tiepolo, 2020) does not help to respond the questions about the mafic magmatism in the study area (Figure 1d).

The lack of a unified classification scheme for boninites allows misdescription of the magmatic rocks which do not satisfy all necessary criteria as “boninite-like” (Pearce and Reagan, 2019). The MPC olivine-rich cumulate sample cannot be classified as boninite or boninite-like according to the International Union of Geological Sciences (IUGS) criteria (Le Bas, 2000). Likewise, the MPC gabbros neither non-cumulate types nor cumulates show sanukitiod affinity in terms of major element content, compatible element concentrations and even rock type.

The middle Jurassic is the peak of arc calc-alkaline magmatism in SaSiZ which indicates heat production in the subduction zone was too low to allow for slab melting, but dehydration of the subducted slab could have facilitated melting of the metasomatised mantle wedge peridotite, thereby triggering the widespread granitic magmatism (Deevsalar et al., 2018b). The produced ultrapotassic magmas with high H_2O solubility could trigger partial melting of mafic lower crust to generate high-K felsic magmas like those huge I-type granitoids occurred in the SaSiZ (Deevsalar et al., 2018b). The entrained lower crustal ultramafic xenoliths in APC quartz diorites could also support this statement.

There are two stages of possible asthenosphere upwelling in N-SaSiZ in which higher thermal gradient at subduction zone allows slab melting as much as expected for the triggering the boninitic magmatism. The first one might have occurred during Neo-Tethys slab segmentation into components of differing dip (cf. the segmented Laramide slab of Saleeby, 2003) which was associated with a long period of low-angle subduction and lack of magmatic activities in large parts of the N-SaSiZ (including the MBPC, Hamadan and Qorveh regions and further south in APC) during Late Jurassic-Paleocene along with much steeper angle subduction resulted in Late Cretaceous magmatic activity in Sanandaj and N Iran (Deevsalar et al., 2017). The second one could happen during the late Eocene slab roll-back and lateral tearing event following the Cretaceous slab flattening (Verdel et al., 2011; Deevsalar et al., 2017, 2018a). Therefore, the boninitic magmatism is unlikely to occur in the N-SaSiZ, including NW-MBPC (i.e. MPC) during the peak of arc-like magmatic activities in the Middle Jurassic.

For all these reasons, the Esna-Ashari and Tiepolo’s model has neither succeeded in explaining the petrogenesis of Tangsaran cumulates nor other cumulate- and non-cumulate gabbros from the MPC and it would be much closer to the reality for the APC if be reevaluated by considering a lower crustal origin for the ultramafic cumulate xenoliths.

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