Investigation the role of geochemical characteristics in the magmatic evolution Jebal-e-Barez plutonic complex, SE Iran

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Introduction: Jebale-Barez Plutonic Complex (JBPC) is composed of many intrusive bodies and is located in the southeastern province of Kerman on the longitude of the 57° 45 ' east to 58° 00' and Northern latitudes 28° 30' to 29° 00'. The petrologic composition composed of granodiorite, quartzdiorite, and granite, alkali-granite, and trace amounts tonalite by dominant granodiorite composition. JBPC located at Uromia-Dokhtar magmatic arc (UDMA). UDMA continued northward subduction of Neotethyan crust beneath Central Iran Block (CIB) induced a continental collision and produced the Andean-type Urmia-Dokhtar magmatic arc (Dewey et al., 1973). There is no firmed reason for dating collision between Arabia and Eurasia (McQuarrie et al., 2013); however, Agard et al (2011) report a resorption of the oceanic domain and collision after 35 Ma and before 25 Ma, respectively. The continuous calc–alkaline magmatism in the UDMA lasts from Eocene to present (e.g., Berberian and King, 1981; Bina et al., 1986) with peaks of Eocene and Upper Miocene to Plio-Quaternary (Agard et al., 2011). Despite of distribution of voluminous magmatic rocks in the UMDA, their tectono-magmatism characteristics' remained poorly understood. Also field observations revealed that more than 98% of the known copper mineralization occurs within the interpreted alteration areas (Shahabpour, 2007). Based on Cu mineralization and Tertiary magmatic activity in the southeastern part of UDMA, so-called Kerman Cenozoic magmatic arc (KCM), Shafiei et al (2009) reported two types of igneous rocks: a) Barren rocks of Pre-collisional Eocene–Oligocene arc diorites, quartzdiorites, granodiorites, and their volcanic equivalents, b) Collisional middle-late Miocene adakite-like porphyritic granodiorites without volcanic equivalents that are fertile and host some large copper ore deposits in Iran. They ascribe Cu mineralisation to the underplating of Cu and sulfur-rich melts from fertile peridotite. The igneous rocks of UMDA are mostly volcanic and, however, plutonic rocks gradually increase eastward across the zone. In this paper, based on the combined data from field mapping, petrographic and geochemical whole rock features, we focused on the Oligo-Miocene rocks of Jebal-e-Barez plutonic complex (JBPC) in the southeastern of UMDA to establish tighter constrains on the petrogenetic processes, determine tectonomagmatic evolution of the JBPC and subduction geometry and its relationship to arc magmatism at the UMDA to depict better constraints of the Neotethyan oceanic slab subduction underneath Central Iran and its related magmatism.

Analytical methods: A total of two hundred samples of the various granitoids have been selected for common thin section study. Among them, 44 representative samples from the different granitic rocks were petrographically selected for whole rock chemical analysis. After agate mortar crushing, analysis of both major and trace elements were performed at the Department of Earth Sciences, University of Perugia, Italy. The analysis for major elements was carried out by an X-ray fluorescence spectrometry (XRF). The concentration of trace elements in the on selected samples has been performed by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The uncertainty is <10% for trace element contents higher than 2 ppm (except for Pb, <15%) and <15% for all the other trace elements.

Geological Setting and Field observations: The Jebal-e-Barez plutonic complex (JBPC) is the largest pluton (~ 500 km2) in the UMDA that morphologically is a NW-SE trend high mountains and streams of this area have cut deep valleys (Aale-Taha, 2003). It is located at the E-NE of Jiroft (Fig. 1).

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Previously, the JBPC were separated into tree plutonic phases by Ghorbani (2014). The first plutonic phase is the main body of complex with composition of quartz-diorite to granodiorite. After differentiation of magma with the process of magmatic differentiation by fractional crystallization in the magmatic chamber, the porphyric and not fully consolidated magmas have been intruded into the main body. Their composition was dominantly granodorite and granite in composition that are defined as the second plutonic phase. Finally, the last phase is started by an intrusion of the holo- leucogranite into the previous bodies. The contacts between igneous bodies and their country rocks are mainly sharp although somewhere the continuous contacts were seen. The crystallization of magma released heat and passed into the country rock where it partially melted and become incorporated into the evolving magma. The metamorphic haloes are local and not widespread in the study area.
Field and petrographic studies indicate that the JBPC is consists of four distinct petrographic groups: quartz-diorite (Qd), granodiorite (Gd), granite (G), and syenogranite (Sg). The enclaves of JBPC occur as both felsic and mafic types. The igneous rocks are frequently cut by mafic and felsic dykes, dominantly of doleritic and aplitic compositions, respectively. In contrast, the oval-shaped mafic microgranular enclaves (MME) display sharp contacts. They are dioritic and monzodioritic in composition and plagioclase, amphibole and pyroxene are their dominant minerals. Locally, the MMEs show dimensional preferred orientations that may indicate magmatic flow. Their petrofabrics do not display evidence of plastic deformation. The granitic rocks show cliff morphology and a weak lineation appears in their outcrops.

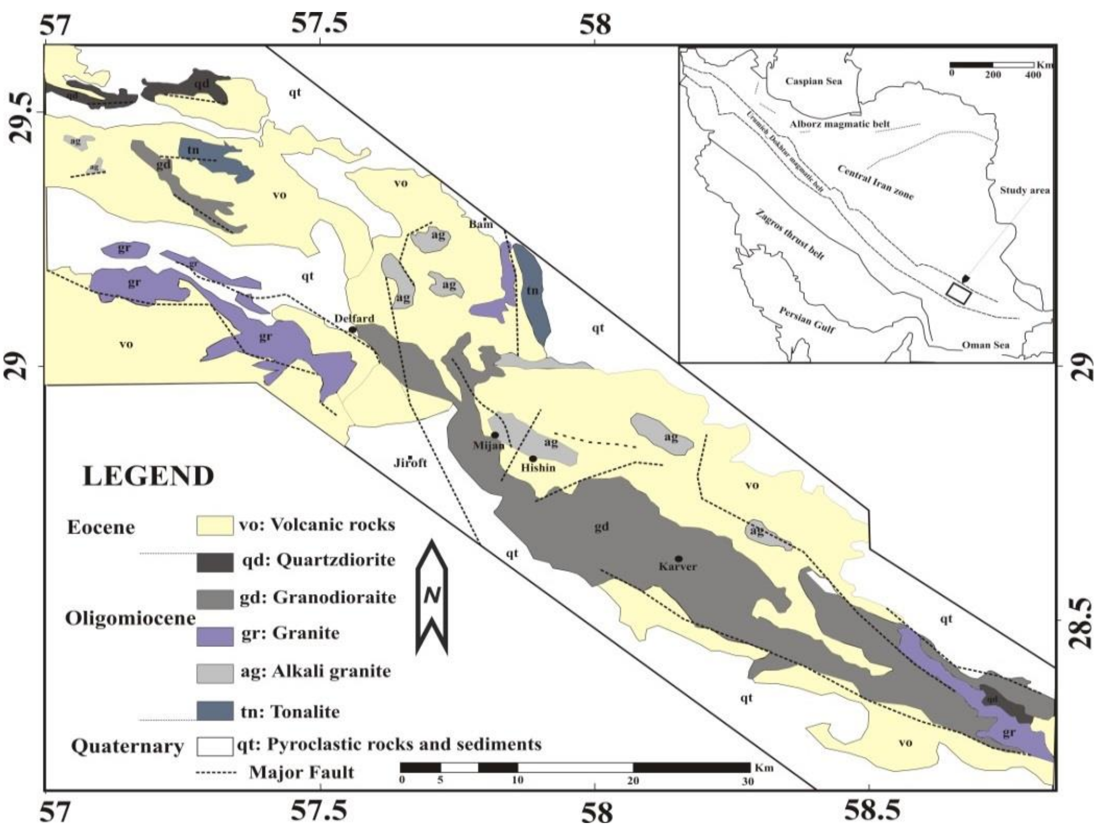

Figure 1: The distribution of Cenozoic volcanic and plutonic rocks of UDMA in relation to the Sanandaj-Sirjan arc and Central Iran. Modified after Alavi, 1994, simplified geological map of the studied area.

Discussion: The JBPC is one of the largest plutons in the UDMA that kept intruding into the calc-alkaline volcanic rocks at the same time. These granitic rocks are calc-alkaline, high-K to low-K subalkaline and mostly metaluminous except granite and alkali-granite units which are slightly peraluminous and I-type in character. It is concordant with radiogenic Sr isotope values of $^{87}Sr/^{86}Sr$-0.7053–0.7075 reported by Rasouli et al (2015) for JBPC. These geochemical properties of the studied granitoids suggest subduction-related arc magmatism. The geochemical data syntectonic granite complex and quartz-diorite-granodiorite suit are continuous in major and trace element abundances versus SiO_2 suggest that these two suites are petrogenetically related and their main petrogenetic process is partial melting or crystal fractionation. The systematic variation for the major elements implies involvement of fractional crystallization in the evolution of JBPC. The trends are consistent with the fractionation of plagioclase feldspar and ferromagnesian minerals as indicated by decreasing MgO, CaO, FeO^t and TiO_2 with increasing SiO_2. Although, the content of (K_2O+Na_2O) vs. SiO_2 displays a linear increasing trend, the Na_2O show different trends with respect to SiO_2. It is generally increases with increasing SiO_2 for intermediate compositions (67 wt% SiO_2 ≤) and then decreases for more felsic granitic rocks, may indicating that sodic feldspar involved in fractionating phases for more felsic granitoids (Fig. 2a). In the Rb vs. Sr (Fig. 2b) diagram of Arth (1976), the trend confirms feldspar fractionation crystallization during the evolution of the studied rocks. Overall REE abundances slightly decrease with increasing SiO_2 consistent with plagioclase fractionation. This feature is confirmed by Eu decreasing during evolution of rocks. Decreasing Sr content from quratz-diorite to granite indicating their evolution from the same source by fractional crystallization.

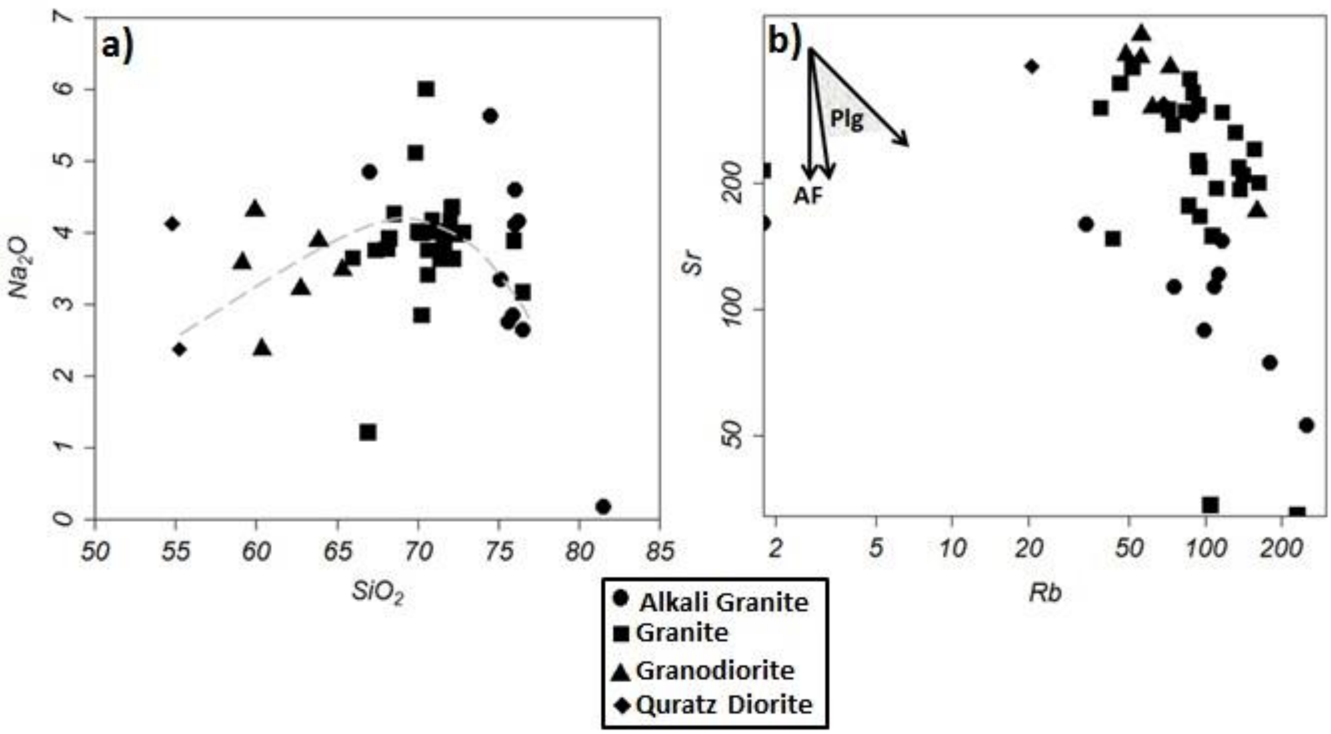

Figure 2: a) Na_2O vs. SiO_2 variation diagram showing alkali-feldspar role in fractionation process; b) The fractional evolution of the plagioclase and alkali feldspar in Rb vs Sr diagram (after Arth, 1976).

In the Rb versus K/Rb diagram rock types show a distinct trend fractional crystallization (Fig. 3a). In the Y/Nb versus Zr/Nb diagram, the trend show no or slight crustal contamination (Fig. 3b). The granodioritic rocks may also formed by the gabbroic magma with silicic material. In these conditions, because the LIL may also be indicator of crustal contamination, as these elements are concentrated in the continental crust, they should have a positive trend with increasing SiO_2 from quartz-diorite to granodiorite. Such correlations are absent or poor which imply a minor role for crustal contamination processes in the evolution of the mafic types of the JBPC granitoids. The JBPG have some gochemical characteristics (e.g. medium- to high-K, calc-alkaline, enrichment of LILEs with respect to the HFSE, depletion of Ti and Nb) which can attribute them to subduction-related granitoids (Floyd and Winchester, 1975). On the tectonic discrimination diagrams of Rb vs. Y+Nb and R_1-R_2, the distributions of JBPC granitoids suggest magmatism that is compatible with the granite series were generated in volcanic arc environments. The distribution of voluminous intermediate to acidic volcanic rocks in the studied area, presence of hornblende phenocrysts, relatively high La/Yb (~12) and Sr/Y (~20) ratios, high Sr (> 230 ppm) and Nd (> 15 ppm) imply a long-lived mature arc setting for JBPC. The field, petrography and geochemical studies indicated that the JPBC originated from both crustal and mantle derived magmas. Some field and petrographic features such as the occurrence of MME, anti-rapakivi and cumulative textures, presence of green hornblende, magnetite, intergranular K-feldspar, automorph sphene, apatite inclusions in the amphibole and biotite crystals and absence of metamorphic minerals (e.g. garnet and andalusite) indicates involvement of upper mantle originated magma in formation of the studied rocks.

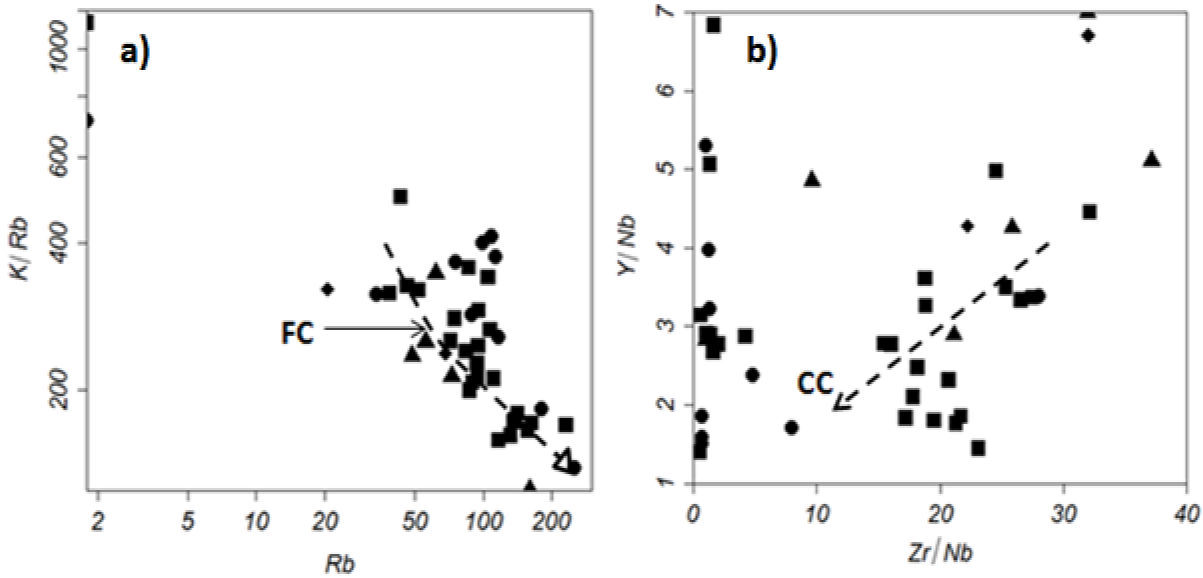

Figure 3: a) The K/Rb vs. Rb; b) Zr/Nb vs. Y/Nb for evaluating degree of crustal contamination (After Wilson, 1989). FC, fractional crystallization; CC, Crustal contamination. Symbols as in Fig. 2.

The increase in temperature and excess fluid pressure caused by subduction trigged melting of mantle edge and formation of basaltic magma and its ascending and introducing into crust followed by partial melting. The juxtaposed series of mafic-felsic pulses formed a mixed magma. Finally this magma is emplaced at broad, shallow magma chamber (9-12 km) (Rasouli et al, 2015), where the differentiation took place by fractional crystallization and produced a wide variety rocks form quartz-diorite to alkali granite. In such shallow magma reservoirs, the emplacement of magma took place as sill.

Conclusions: Based on a combined petrographic, field, whole rock geochemical investigation of the Jebal-e-Barez plutonic complex (JBPC), we propose the following evolutionary model:

1) The JBPC is a calk-alkaline complex that located on the SE of the Uromia-Dokhtar magmatic arc (UDMA). This arc is formed by oblique subduction of Neotethys underneath the Central Iran and contains voluminous volcanic and plutonic rocks. The geochemical signatures of studied rocks (e.g. high-K calk-alkaline) characteristic of mature island arc that have been evolved into active continental margin.

2) The basaltic magma produced by partial melting of mantle wedge materials segregated and ascend to the base of the crust. The conductive heating from the underplating magma triggered of the melting and generation of granitic magma. At the same time, the crystallization occurred in the convicting interior produced rocks ranging in composition from intermediate (quartz-diorite) through felsic (granite) at the study area.

3) The progressive heating of the country rocks melts and incorporates surrounding country rock into crystallizing magma. The shape and size of microgranular enclaves may indicate contemporaneous flow and mingling of partly crystalline felsic-mafic magmas. Furthermore, the elongated shapes of enclaves at the margins of igneous bodies may also imply magmatic flow.

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