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Petrological constraints on the origin of the plutonic massif of the Ghaleh Yaghmesh area, Urumieh–Dokhtar magmatic arc, Iran

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ABSTRACT

The Oligocene Ghaleh Yaghmesh plutonic massif (GYPM) consists of diorite, quartz-diorite, tonalite and granodiorite and evolving from metaluminous nature. All the samples are predominantly medium-K calc-alkaline series, having typical characteristics of I-type granitoids. A significant geochemical criteria of the GYPM is the impoverishment of high-field-strength elements (HFSE) (e.i. Zr, Nb, Ti and Hf) and the overabundance of large-ion-lithophile elements (LILE) (e.i. K, Sr, U, Ba and Cs), with respect to the light rare elements (LREE) as compared to chondritic concentration. These geochemical criteria suggest the involvement of sedimentary components in the generation of rocks studied. Furthermore, variable Pb/Ce amounts, linear trend of all rocks studied on Ti/Zr vs. Yb/Hf diagram, as well as some characteristics petrographic features (e.i. acicular apatite, corroded margin of the plagioclases, the amphiboles and some of the pyroxenes, oscillatory zoning of plagioclases) and the presence of mafic microgranular enclave (MME) indicate that the Ghaleh Yaghmesh parental magma was likely generated by the partial melting of a mixed source dominantly composed of amphibolite and possibly meta-sedimentary source. The overall geochemical and petrographic features are consistent with the interpretation of the Urumieh–Dokhtar Magmatic Arc as an active continental margin during subduction of the Neo-Tethyan oceanic crust underneath the Central Iranian microcontinent.

1. Introduction

Granitoids are the major components of the continental crust and are of prime importance in understanding the geodynamic evolution of the Earth's crust. The diversity of the origin of these rocks stressed by Read (1957) had led different authors to propose that granitoids are not simple in their origin and might be produced in more ways than one. On this account, for the past several years, many petrologists used a variety of characteristics to subdivide the granitoid rocks. Such proposals have been put forward by Chappell and White (1974) for the granitoids of southeastern Australia. They divided these rocks into two distinct types, S- type granites which are interpreted as being derived from partial melting of meta-sedimentary source rocks and are always of peraluminous nature and contain excess Aluminum hosted in Al-rich biotite, cordierite, or muscovite. I-type granites are produced either directly by fractional crystallization of mantle-derived liquids, direct partial melting of mantle-derived source rocks in the crust, or melting of mantle modified by silicic melts. Therefore, basaltic to andesitic rocks are invoked as the source materials for I-type granites (Chappell and White, 1992; Pitcher, 1993). These granitic rocks are classified into low-and high-temperature I-type granites (Chappell and White, 1984, 1992; Chappell et al., 1998). The "low temperature" (Caledonian I-type granites) generated by partial melting of quartzo-feldspathic crust at temperatures of ~700–800 °C. These rocks are characterized by the presence of inherited zircons and are commonly associated with S-type granites (Pitcher, 1993).

The "high-temperature" I-type granites are the most primitive and originated by partial melting of mafic rocks in the deep crust, or possibly in subduction-modified mantle at magmatic temperatures higher than 1000 °C (Chappell et al., 1998) These granites, called

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Cordilleran I-type, occur in younger subduction-related continental margins (Pitcher, 1993) and are dominated by high-Ca tonalitic to low-K granodioritic rocks and the absence of inherited zircons.

Classification, generation and geodynamic environments of granitic rocks have been the subjects of studies of some other researches (e.i. Loiselle and Wones, 1979; Pearce et al., 1984; Maniar and Piccoli, 1989; Atherton, 1993; Barbarin, 1999; Frost et al., 2001; Chappell et al., 2004).

2. Geological setting

The Zagros orogenic belt, a segment of the large Alpine-Himalayan orogenic system of western Asia, developed as a result of subduction of Tethyan oceanic crust and subsequent ongoing convergence between the Arabian (Gondwana) and the Eurasian (Turan) plates which initiated in the Late Cretaceous (Berberian and King, 1981), and ended Early to Middle Eocene (Ghasemi and Talbot, 2006), Late Eocene (Allen and Armstrong, 2008; Allen, 2009), Late Eocene–Oligocene (Agard et al., 2005), Early to Middle Miocene (Mcquarrie et al., 2003), Miocene (Mohajjel et al., 2003) and Tertiary (Berberian et al., 1982). The Zagros Ranges, extending from the northwest to the southeast of Iran, consisting of three major tectonic units (Alavi, 1994): the Urumieh–Dokhtar magmatic arc (UDMA) or Sahand-Bazman, the Sanandaj-Sirjan Zone (SSZ) and the Zagros Fold-Thrust Belt (ZFTB). The UDMA with an approximately 2000 km length and 100–150 km width, parallel to the entire length of the Zagros belt, formed a linear belt and extended from Sahand in the northwest to Bazman in the southeast (Fig. 1a).

The great magmatic activity swept across the country from the Late-Cretaceous to the Tertiary. This activity had a climax in the Eocene and is traceable to the Neogene and the Quaternary (Omrani et al., 2008; Azizi and Moinevaziri, 2009). As a result, many basaltic, andesitic, dacitic, rhyolitic and plutonic (e.i. Ghaleh Yaghmesh plutonic massive) with minor subvolcanic rocks (Amidi, 1989) are distributed over vast parts of Iran particularly in the Urumieh–Dokhtar magmatic arc (UDMA) (Fig. 1). The overall geochemical character of these rocks is calc-alkaline with all features of a continental margin.

The UDMA is dominated by andesite with minor volumes of basalt to rhyolite. A variable association of gabbro to granite and abundant bodies of tonalite-granodiorite comprise the bulk of plutonic rocks of this belt. According to a number of workers (e.i. Pourhosseini, 1981; Hassanzadeh et al., 2002; Ghasemi et al., 2008; Sepahi and Malvandi, 2008; Nasr-Esfahani and ShoJaei, 2011; Rezaei-Kahkhaei et al., 2011; Sadeghian and Ghaffary, 2011; Honarmand et al., 2013; Panahi et al., 2013; Abbasi et al., 2014; Honarmand et al., 2014; Kananian et al., 2014) all these bodies are mainly of Upper Eocene-Lower Oligocene in age and are predominantly calc-alkaline, metaluminous and I-type granite. Most, if not all, magmatic rocks of the UDMA share many geochemical and petrological features with those of the Andean-type magmatism (Berberian et al., 1982).

3. Geology of the Ghaleh Yaghmesh area

The lithostratigraphy of the Ghaleh Yaghmesh area was initially laid out in the context of the geologic quadrangle map of Sarv-e-Bala (Amidi, 1989) published by the Geological Survey of Iran. The nomenclature used in this study is predominantly that established by this worker, along with some revisions, modifications and additions that resulted from this study. The Ghaleh Yaghmesh area lies in the westernmost part of the Yazd province and the central portion of the UDMA, covering an area of approximately 50 km^2. From the structural standpoint, the GYPM is located in vicinity of

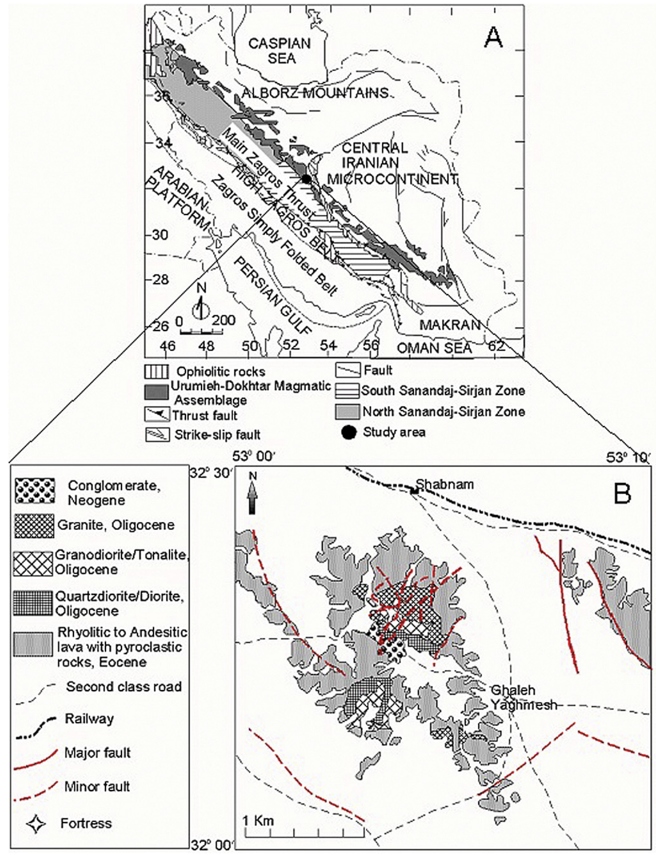

Fig. 1. (a) Structural division map of Iran (Ghasemi and Talbot, 2006) and (b) simplified geological map of Ghaleh Yaghmesh based on the Sarv-e-Bala 1: 100000 geological map (Amidi, 1989) with some changes (after Nadimi, personal communication).

the Naein-Surak fault zone which is considered as a part of the Nain-Dehshir large fault zone. Three main and minor fault systems are identified within the Galeh Yaghmesh region: north-south system, northeast-southwest trending system and northwest-southeast trending system (Nadimi, personal communication) (Fig. 1b). The main north-south trending system dominates the eastern portions of the area where the volcanic rocks are widespread. The movements associated with these faults resulted in separation of the rock types from the surrounding plains. Diorite, quartz-diorite, tonalite and granodiorite comprises the bulk of the Oligocene plutonic rocks intruded the Eocene pyroclastic and volcanic rocks including rhyolite, rhyodacite, andesitic, rhyodacitic and rhyolitic tuff (Figs. 1 and 2a). The plutonic rocks are mostly exposed at the center of the area and surrounded by the volcanic and the pyroclastic rocks forming a caldera-shaped structure (Fig. 1b). Mafic microgranular enclaves (MME) particularly rich in amphibole and biotite are common throughout the granitoids. They display sharp boundaries with their hosts and vary in size from 5 to 12 cm. These rocks are circular or ellipsoidal in shape, fine grained and darker than their host rocks (Fig. 2b). They are quartz-diorite in composition.

Among the previous studies that were undertaken on the magmatic rocks of the Galeh Yaghmesh and its immediate vicinity, the work of Amidi (1975) is worth mentioning. He has defined three types of magmatism at the Natanz-Naein-Surak area (about 12 km E of the study area) consisting of early Turonian tholeiitic, basaltic magmatism, and calc-alkaline volcanism (Eocene to Pliocene and Quaternary). The basaltic volcanism took place during one stage and the rocks of other compositional varieties are possibly