Geochemical and Geodynamic Study of the Precambrian Ag Kand Gneisses, Zanjan

Adel Saki

Department of Geology, Shahid Chamran University of Ahvaz, Ahvaz
adel_saki@scu.ac. iror adel_saki@yahoo.com

Abstract

The Precambrian gneiss rocks crop out in association with a variety of metamorphic rocks including amphibolites, pelitic schists, meta-ultramafic and calc-silicate rocks in the northwest Iran. Petrography and geochemical studies indicate that the gneisses protolith of Ag Kand and Daveh Yataghi have slightly peraluminous chemical compositions belong to medium to high potassic, calc-alkaline series and have I-type characteristics which emplaced in volcanic arc tectonic setting. In the other word, the source of these rocks is igneous (ortho). The intrusion age of the gneisses protolith in the Takab Metamorphic Complex (~ 560 Ma; U-Pb zircon) suggest that these rocks have a Neoproterozoic-Early Cambrian age and experienced the Pan-African Orogeny.

1. Introduction

The Takab Complex is a part of the Zanjan and Azarbaijan province in the northwest Iran. The Iran continental crust was metamorphosed, granitized, folded and faulted during the late Precambrian by the Pan African Orogeny (Stocklin 1974). Precambrian terranes are exposed in many places of Iran such as Central Iran, Zanjan (Takab Complex), Gorgan, Golpayegan and etc (Fig. 1; Nadimi 2007, Saki 2010). Metamorphosed rocks, which are scarcely exposed, from the basement of the region (Nabavi 1976; Berberian 1976) and this orogenic phase, considered by many authors to be an episode of plate collision, terminated between 600 and 550 Ma in Arabia (Brown and Coleman 1972; Frisch & Al- Shanti 1977).

2. Geological setting

The Takab Precambrian Complex has been assigned to the Central Iran Zone by Berberian & King (1981), in its geological and lithological characteristics it seems to have more affinities to the Central Iran zone. Recently Nadimi (2007) has included the study area in the Central Iran Zone. The study area is located in the northwestern Zanjan province of Iran. The area is limited to geographical latitude 47 ° 07´ to 47 ° 45´ E and longitude36 ° 30´ to 37 ° 00´N in terms of Fig. 1b and 2. K–Ar dating of carbonaceous schists in the Zarshuran area (Mehrabi et al. 1999), apatite U-Th/He data from the Takab area (Stockli et al. 2004), and 40Ar–39Ar dating of muscovite schists (Gilg et al. 2006) constrain the timing of rapid exhumation of the basement rocks to the Early Miocene (20 Ma). The intrusion age of the studied gneisses in the Takab Metamorphic Complex ~560 Ma (U/Pb zircon; Stockli et al. 2004) is similar to U/Pb dates from basement rocks of the Saghand area in the Central Iran Zone (Ramezani and Tucker 2003). Lithologically, the Takab Complex is composed of main metamorphic rocks including granulites, amphibolites, meta-ultramafites, gneisses, granitic gneisses, metapelic and different igneous rocks (Hajalioghli et al. 2007; Saki 2010, 2088a and 2008b), which are intruded by granitoid intrusions. Gneisses crop out mainly in the south and northern part of the complex whereas amphibolites are dominant in the northern (Fig. 2a and b). Meta-ultramafic rocks crop out as thin and elongated layers and discontinuous small bodies within amphibolite and in association with retrogressed granulites and calc-silicates. Contacts between gneisses rocks and surrounding rocks are tectonic.

3. Petrography

3.1. Aq Kand gneiss

Aq Kand gneiss consists mainly of pink and grey massive, augen-textured gneiss with a dark quartz-biotite-amphibole matrix in which are set light-coloured porphyroblasts, generally of feldspars (alkali feldspars and plagioclase, Fig. 3a, b). Large "eyes" of plagioclase and/or K feldspar up to 10mm can be seen, small flakes of mica where present wrap the eyes (Fig. 3a, d). Based on mineralogy the rocks are orthogneisses.
The average percentage composition (by volume) of the gneiss is approximately as follows: quartz 30-40%, alkali feldspars 40-50%, biotite 10%, plagioclase 5-10%, amphibole 3 % and accessories 2-5%. The accessory phases are titanite (Fig. 3c), apatite and zircon. The association of quartz, plagioclase, hornblende, biotite and garnet in this ensemble indicates metamorphism in the amphibolite facies.

4. Analytical methods

Petrographic observation of 70 thin-sections was made. Selected samples were analysed for whole rock major and trace element by using XRF and ICP-Mass spectrometry using natural rock standards as reference samples for calibration at Laboratories of Potsdam University, Germany (Table 1 and 2).

5. Discussion

5.1. Whole-rock composition and classification

Representative chemical analyses of Aq Kand and Daveh Yataghi gneiss samples are listed in Table 1 and 2. Major and trace element variations are illustrated in Harker diagram (Fig. 4). In Harker variation plots (Fig. 4), studied samples exhibit a linear-like trend for most major elements. In all rocks, Al_2O_3, Fe_2O_3, MgO, CaO, P_2O_5 and TiO_2 show negative correlations with silica, whereas K_2O are positively correlated and Na_2O constant. The trace elements (Fig. 4k, i) exhibits considerably more scatter then the major elements, Particular Ba and Rb. However, Sr shows a negative linear trend with increasing SiO_2 contents. These chemical variations indicate the importance of fractional crystallisation in the magmatic evolation of these rocks.
The chemical compositions of the rocks are plotted on the SiO_2 versus K_2O+Na_2O classification after Middlemost (1994) in Figure 5a. The samples plot in the granite and granodiorite fields of this diagram. Using AFM diagram of Rickwood (1989) and TAS diagrams of Irvine and Baragar (1971) All rock samples represent a subalkaline composition and the calc alkaline field (Figure 5b and c). The SiO_2 versus K_2O+Na_2O-CaO after Frost et al. (2001) plot yield an apparent medium to high-potassic calc-alkaline fields (Fig. 5d). The Zr vs. SiO_2 plot Whalen et al. (1987) shows almost all samples to be I-type characteristics (Fig. 5e). The K_2O vs. Na_2O plot of white & Chappell (1983); Chappell and white (2001) shows that almost the samples are of I-type rock characteristics (Figure 5f). Based on the Alumina saturation index (ASI) of Shand (1947); Chappell & white (1974) the Takab gniesses are slightly peraluminous (Fig. 5f) and has I-type tendencies.

Clarke (1992) has proposed that high K/Rb ratios in the igneous rocks are typical of magmatic processes and lower values can only be reached by fluid interaction and possibly crustal contribution. Takab gneiss show moderate K/Rb ratios (Table 1) and reflecting crustal contribution and possible fluid interaction in their genesis.

5.2. Fractional crystallization

Samples from the Takab Complex show similar behaviors for most of the incompatible trace elements. The slight negative correlation in the Sr versus SiO_2 diagram may suggest plagioclase fractionation in these suites (Fig. 6). Depletion in Y in the Takab gneisses (Table 2) can be interpreted as hornblende fractionation, which has significantly high partition coefficient values for Y in granitic melts (${}^{Y}Kd_{amph/melt}$= ~6.0; Pearce & Norry 1979). The major element versus silica variation diagrams (Fig. 4) of the Takab gneisses show that the different bodies seem to have derived from a single magma source via a fractional crystallization (FC) process in which the Aq Kand gneisses crystallized first and the other crystallized later. The Takab gneisses form a coherent fractionation trend in element variation diagrams such as Sr and Ba versus SiO_2, and are interpreted as a result of increasing fractionation of plagioclase and K-feldspar, accompanied possibly by amphibole, biotite, and accessory phases (such as titanite, apatite and zircon) (Fig. 6a, b). In particular, strong depletion in Ba and Sr concentrations with increasing silica in relatively high silica gneisses indicating evolution by fractional crystallization of plagioclase and alkali feldspar. Fractionation of these major phases is also consistent with negative correlations of Al_2O_3 and CaO with SiO_2 (Fig. 4b, d). Furthermore, fractional crystallisation is also indicated by the behaviour of Ba and Zr with respect to K_2O, because Ba and Zr behave incompatibly during crystallisation of magmatic liquid, so they are enriched in late stage liquids.

5.3. Tectonic setting

Discrimination diagram for distinguishing tectonic setting of the granitoid rocks after Batchelor and Bowden (1985) were used to conclude the tectonical setting for the Takab gneisses. The R2 [6Ca+2Mg+Al] vs. R1 [4Si-11 (Na+K)-2(Fe+Ti)] diagram in Figure 7d indicates that the Takab gneisses is a pre-plate to syn collision granites. Furthermore, these gneisses in the geotectonic classification of Pearce et al. (1984, 1996) are classified as volcanic arc granite collisional granites (Figure 7a, b, c), similar to those of recent VAG collision granite (high-Rb, low-Zr, -Hf , -Sr contents).

5.4. Source material

Chemically the crustal source of the investigated granitoids is deduced from their Nb/Y vs. Rb/Y data. The granitoids in the study area have predominantly low Rb/Nb values (0.3–3.0) and plot close to the lower crust values (Rudnick & Fountain, 1995). To constrain the source material for the metaluminous intrusions, they were plotted on the molar CaO/(MgO+FeOt) vs. Al2O3/(MgO+FeOt) diagram (Gerdes et al. 2000). The compositions of the granitoids plot in the field of partial melts from metabasaltic to metatonalitic sources. According to Altherr and Siebel (2002), high concentrations of CaO, MgO and FeOt and low K2O/Na2O values, classify the source of investigated rocks as metabasites. The ternary plot of CaO–ASI/30-2K2O (molar) (Christofides et al. 2007; where ASI is Al2O3/(Na2O+K2O+CaO) verifies the results. Basalts, amphibolites and rarely greywackes are protoliths for the magma generation in the Takab area.

6. Conclusion

Petrography and geochemical studies indicate that protolith of Ag Kand and Daveh Yataghi gneisses (orthogneiss) have slightly peraluminous chemical compositions belong to medium to high potassic, calc-alkaline series and have I-type characteristics which emplaced in volcanic arc tectonic setting. These rocks are interpreted as a result of increasing fractionation of plagioclase and K-feldspar, accompanied possibly by amphibole, biotite and accessory phases (such as titanite, apatite and zircon).

The intrusion age of the gneisses protolith in the Takab Metamorphic Complex (~ 560 Ma; U/Pb zircon) suggest that the Takab Complex has a Neoproterozoic-Early Cambrian age and experienced the Pan-African Orogeny. The geochemical features and intrusion age of the gneisses rocks show that intrusion of gneisses protolith is related to a broad-scale magmatic arc that developed along the Proto-Tethyan margin of the Gondwanaland super continent, then during compressional tectonic activity of Pan African Orogeny, the metamorphism of the Precambrian formations (such as the protolith interusion of the gneisses and metapelitic rocks) occurs under amphibolite facies and produced metamorphic rocks as orthogneisses and metapelites in the Takab Complex.

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Fig.1.

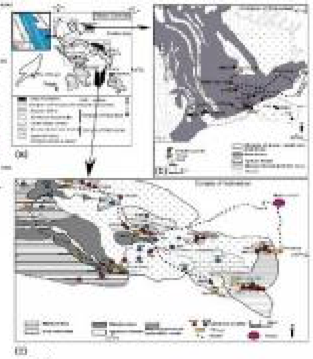

Fig 2.

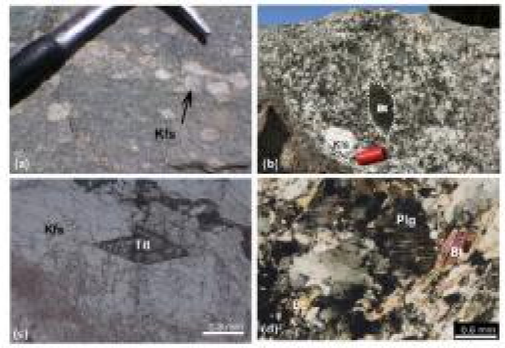

Fig. 3

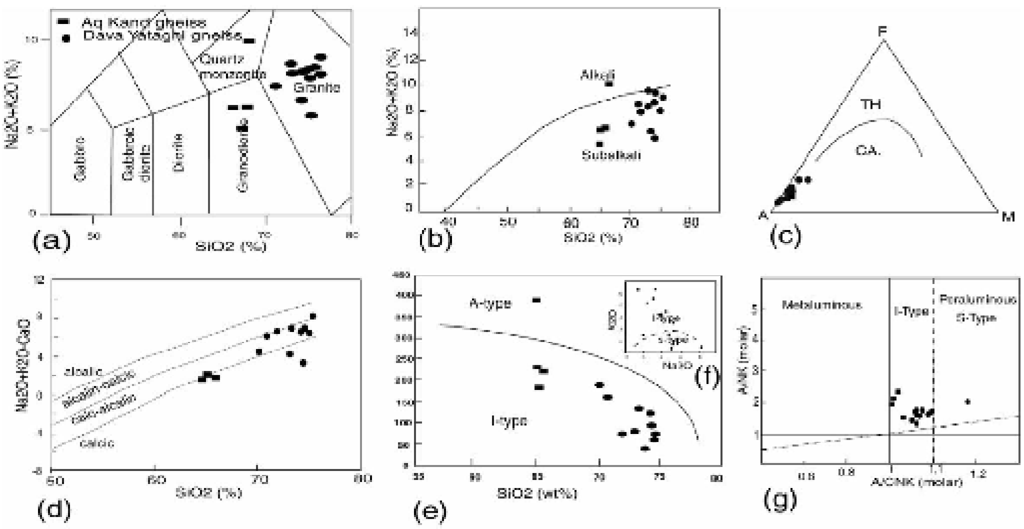

Fig. 4.

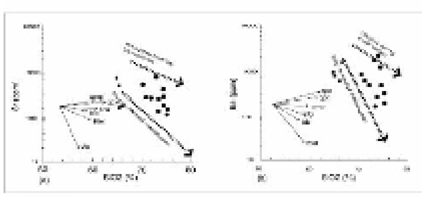

Fig. 5.

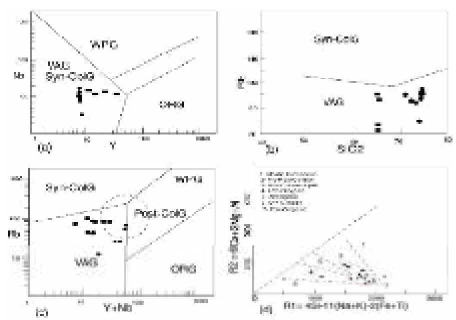

Fig. 6.