Petrology of Gosheh- Nelkhast Intrusions in the region NE of Borujerd, Iran

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Abstract

Different outcrops of granitic rocks in the Gosheh- Nelkhast area, NE of Borujerd, have been studied in order to investigate the magmatic evolution and related events. Three granitoid bodies were intruded into sedimentary and metamorphic rocks of Precamberian, Triassic and Jurassic ages in Senandaj-Sirjan metamorphic belt of Iran. Optical observations and XRF analyses show that the majority of the plutonic rocks are granites and granodiorites. Considering the geochemical diagrams and textural evidences such as micro perthite, granophyre and micrographic textures, maximum temperature at which granitoids were formed is estimated in the range of 700 to 850˚C and maximum H_2O pressure is estimated about 5 Kbar. The Granitoides are calc-alkaline and metaluminous types. All plutons have both I-type and S-type characteristics, although some evidences, such as low normative corundum, indicate an I-type characteristic for the Gosheh granites. From the tectonic setting point of view, the granitoid bodies are of the collisional type and they formed as syn-tectonic to post-tectonic intrusions.

Keyword**:** Granitoide, Calc-alkaline, Collisional, Borujerd, Iran

Introduction

The generation and evolution of large granites are complex processes. The origins of granitic magmas are related to various processes such as melting and assimilation of continental crust, subduction and within-plate magma generation, magma mixing and hybridization. [1-3] Models based on trace element and radiogenic isotope evidence invoke a complex mixture of processes to produce evolved granitic compositions, often accompanied by the generation of mafic to intermediate and acidic magmas. [4]

In this study, the optical examination and geochemical fetures of the plutonic rocks have been applied to evaluate the evolution of plutonic rocks in the Gosheh-Nelkhast area, Northern part of Sanandaj –Sirjan metamorphic belt of Iran.

Geological setting

Gosheh, Tavandasht and Nelkhast intrusive bodies are located in the region NE of Borujerd in western part of Iran (Figure 1). The granitic rocks consist of three separate outcrops with an elongate northwest-southeast trend. The study area is a small part of the Sanandaj -Sirjan metamorphic belt in Iran.

Berthier et al.[5] studied the stratigraphy, petrology and structural geology of the region. The Geological Survey of Iran has published a geological quadrangle map of the Khorramabad area at a scale of 1:250,000 0n 1999. The distribution and mineralogical aspects of intrusions

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in the area have been described by Masoudi [6] and Sarikhani.[7]

The oldest known exposed rocks in the area are Precambrian in age. They are dominantly metarhyolite and amphibolite with minor crystallized dolomite. Their outcrops are separated from other units by faults, so Precambrian rocks occur as minor exposures among the younger rocks. The surrounding units consist of Jurassic metamorphic rocks, Triassic metavolcanic and granitic rocks (Figure 1). Triassic series contain sequence of metavolcanics & tuff with other volcanosedimentary rocks near the base, followed by volcanosedimentary rocks with some marble and metaquartzite. The Jurassic series mainly consist of shale, sandstone and phyllite which in some places are followed by metasandstone. Regional metamorphism has reached a peak in the greenschist facies, but further thermal metamorphism has occurred locally, associated with granitoid emplacement.

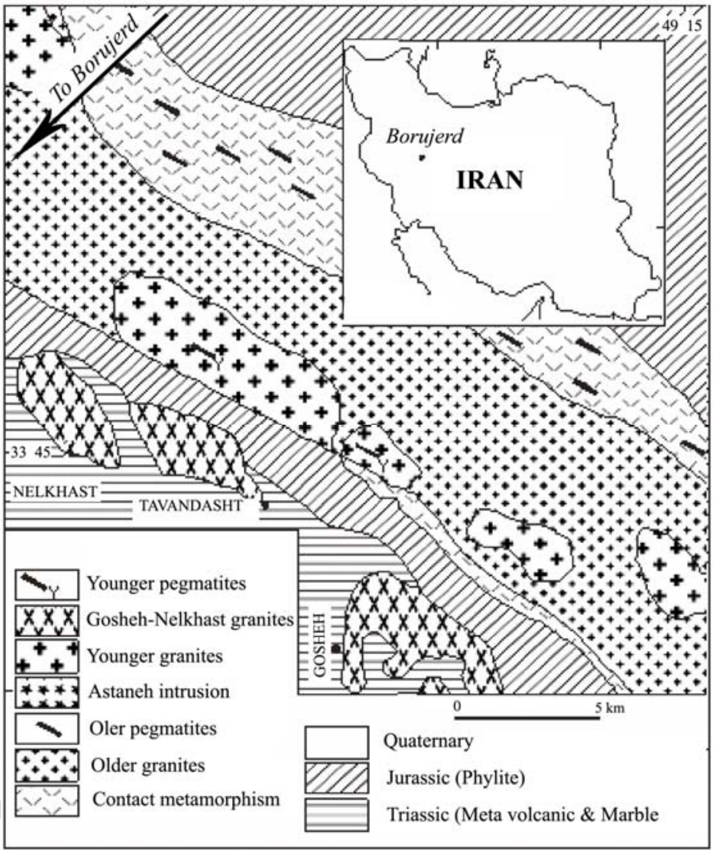

Figure 1 - Simplified geological map of the area, showing Gosheh – Nelkhast granites and related granitoids and country rocks.

Gosheh-Nelkhast intrusions

Intrusions in the Gosheh-Nelkhast area consist of three separate outcrops, Tavandasht, Gosheh and Nelkhast and they have been affected by the tectonic activities during their emplacement (Figure 1). The largest intrusion is located in the northern part of Gosheh (Gosheh granite). Each body appears relatively homogeneous at outcrop scale, although microscopic studies show that the intrusive rocks consist of alkali granite, granite and granodiorite. Granites have been affected by the widespread hydrothermal alteration. Low topography is common and intrusions are covered by Quaternary loose sediments in most places. Intrusions are intersected by veins of quartz and aplite. Xenoliths are also common, especially near the margins. These xenoliths are schists and hornfels types.

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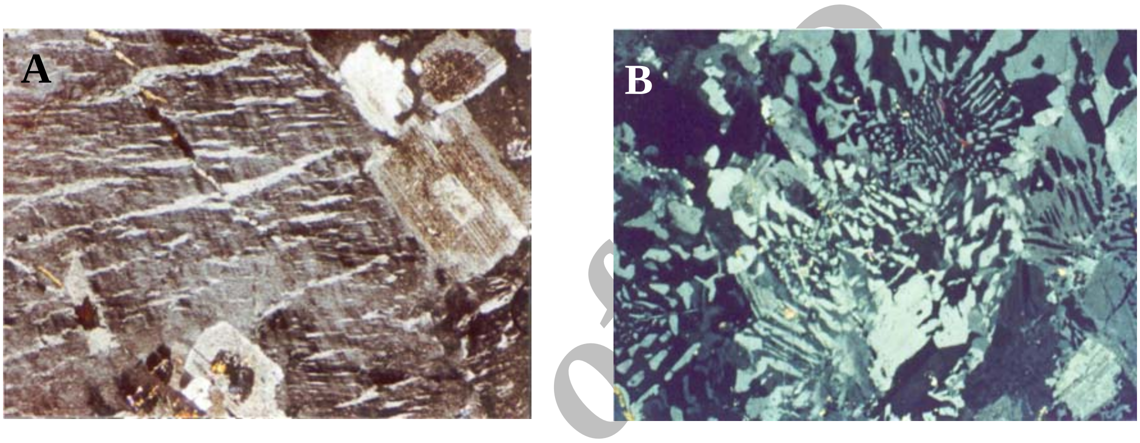
Petrography

Granitoids consist of alkali granite, granite and granodiorite. The granite makes up a great volume of intrusions. Granitoids are medium-grained (2-5 mm) rocks and are mainly composed of quartz, alkali feldspar (mostly microcline) plagioclase, biotite and muscovite. There is no major mineralogical difference between intrusions. Alteration has changed most of the biotite to chlorite and plagioclase to sericite. Furthermore, alteration to clay minerals is common in alkali feldspar.

Texturally, rocks are granular, and grains vary from euhedral to anhedral. Euhedral feldspar porphyroids are significant in some outcrops. Perthite, granophyre and graphic textures are common (Figure 2). Based on these textures, temperature of 700 to 850˚C is estimated for the formation of granitoides and maximum H_2O pressure is estimated about 5 Kbar. [8]



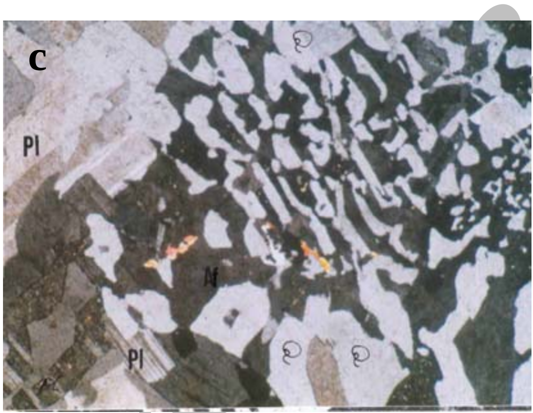


Figure 2- (A) perthite, (B) granophyre and (C) graphic textures

Analytical method and results

X-ray fluorescence spectroscopy (XRF) was used to analyze 20 rock samples for the major elements (Si, Al, Fe, Mn, Mg, Ca, Na, K and P) and the selected trace elements (V, Co, Zn, Rb, Sr, Y, Zr, Nb, Ba, Th, U, Pb, La, Mo and Ce). The determinations were carried out on a Phillips PW 1420 X-ray spectrometer fitted with a rhodium tube at Tarbiat Moallem University. Results of the major and analyzed trace elements are listed in Tables 1 and 2, respectively.

Results and discussion

Geochemistry

In Harker diagrams, some major and trace elements are plotted vs. SiO_2 (Figures 3 and 4). It is observed that, Fe_2O_3, Al_2O_3, TiO_2, MgO, CaO, MnO & P_2O_5 have a negative trend with increasing SiO_2. The decrease of MgO, Fe_2O_3 and TiO_2 is expected due to crystallization

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of ferromagnesian minerals. Because of lower mobility Ti is a good indicator, so it usually has a sharp trend.

Table 1. Chemical analyses of representative major elements of intrusive rocks (percentage)

		SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	MgO	CaO	TiO_2	MnO	P_2O_5	L.O.I	Total
1	Gosheh Granitoid	73.89	12.21	2.7	3.38	3.82	0.64	1.07	0.24	0.04	0.07	0.46	98.52
2		74.21	12.2	2.64	3.44	3.82	0.61	2.02	0.24	0.04	0.06	0.42	99.7
3		79.69	10.5	1.45	3.54	3.97	0.01	0.5	0.02	0.03	0.01	0.01	99.73
4		63.28	15.78	6.47	2.85	3.86	1.16	5.09	0.57	0.09	0.12	0.44	99.71
5		74.55	12.09	2.95	3.54	3.94	0.43	1.75	0.22	0.06	0.07	0.28	99.88
6		63.29	13.3	7.38	1.77	2.43	4.46	5.46	0.69	0.13	0.12	0.92	99.95
7		79.68	10.6	1.26	3.59	4.26	0.02	0.26	0.01	0.02	0.01	0.03	99.74
8		76.6	14.28	1.83	2.81	4.62	0.19	0.78	0.12	0.04	0.14	0.43	101.84
9		79.64	10.77	1.07	3.54	4.22	0.03	0.55	0.03	0.01	0.01	0.1	99.97
10		75.47	11.78	2.59	3.57	3.8	0.29	1.56	0.16	0.04	0.05	0.49	99.8
11	Gosheh Aplite	78.47	10.86	1.52	3.44	4.57	0.01	0.49	0.02	0.05	0.02	0.19	99.64
12		78.97	10.82	1.47	3.39	4.34	0.06	0.37	0.03	0.03	0.01	0.11	99.6
13		79.37	11.55	1.95	3.45	0.31	0.02	3.01	0.02	0.05	0.06	0.35	100.1
14	Tavandasht Granitoid	75.38	11.56	2.51	3.17	4.68	0.46	1.03	0.29	0.04	0.11	0.65	99.88
15		70.24	12.99	4.8	2.42	3.42	1.32	3.15	0.45	0.09	0.12	0.9	99.9
16		79.96	10.38	1.33	3.59	4.2	0.03	0.14	0.05	0.01	0.01	0.08	99.78
17		75.98	11.17	2.24	3.13	4.38	0.44	1.21	0.24	0.04	0.09	0.61	99.53
18	Nelkhast Granitoid	79.4	10.53	1.24	3.17	4.79	0.02	0.51	0.05	0.01	0.01	0.16	99.89
19		76.37	11.42	2	3.44	4.43	0.25	1.02	0.18	0.03	0.07	0.42	99.63
20		75.89	11.53	2.45	3.39	3.9	0.44	1.07	0.25	0.04	0.09	0.72	99.77

Table 2. Chemical analyses of some trace elements of intrusive rocks (ppm)

		Rb	*Sr*	*Ba*	*Pb*	*La*	*Nb*	*V*	*Y*	*Zr*	*Zn*	*U*	*Th*	*Mo*	*Co*	*Ce*
1	Gosheh Granitoid	122	157	275	23	12	88	30	20	152	59	1	5	7	9	1
2		121	157	321	29	1	86	33	21	148	55	5	6	7	10	8
3		263	10	2	49	2	95	19	43	81	49	9	38	9	7	10
4		104	483	1441	17	82	86	56	23	322	68	1	18	9	10	100
5		161	124	266	28	1	91	28	28	142	53	7	7	9	5	1
6		95	252	319	21	26	81	126	21	140	89	1	3	11	28	31
7		303	9	3	47	3	101	19	55	56	19	11	4	11	7	2
8		255	151	324	42	11	103	24	29	72	68	4	11	10	8	1
9		192	28	2	44	1	84	21	26	28	29	8	23	8	6	16
10		170	115	230	29	5	90	28	28	126	46	4	7	10	8	19

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Table 2 continued…

11	Gosheh Aplite	197	14	13	50	2	86	18	29	78	47	1	14	5	8	2
12		246	47	89	35	7	91	19	39	56	41	5	18	9	6	1
13		19	246	19	13	1	87	18	11	34	58	3	1	9	3	2
14	Tavandasht Granitoid	141	188	617	22	37	111	36	24	230	38	1	22	1	6	32
15		145	176	352	30	17	87	59	22	147	70	6	5	9	11	10
16		185	37	112	20	1	134	22	36	74	18	11	22	9	8	1
17		174	181	487	24	23	107	28	30	188	34	12	26	6	7	18
18	Nelkhast Granitoid	235	27	1	25	1	121	19	34	89	26	10	33	6	5	1
19		171	178	383	17	35	108	30	27	140	58	5	19	5	8	31
20		167	248	602	19	46	109	32	27	202	202	7	25	5	5	48

Some trace elements such as Sr, Rb & Ba are concentrated in the silicate phase rather than in accessory minerals. Therefore, Sr and Ba vs. SiO_2 have negative trends. Conversely, Rb shows a positive trend, because Rb can easily enter biotite and K feldspar. Ba and Sr replace Ca and Na in plagioclase and alkali feldspar, respectively.

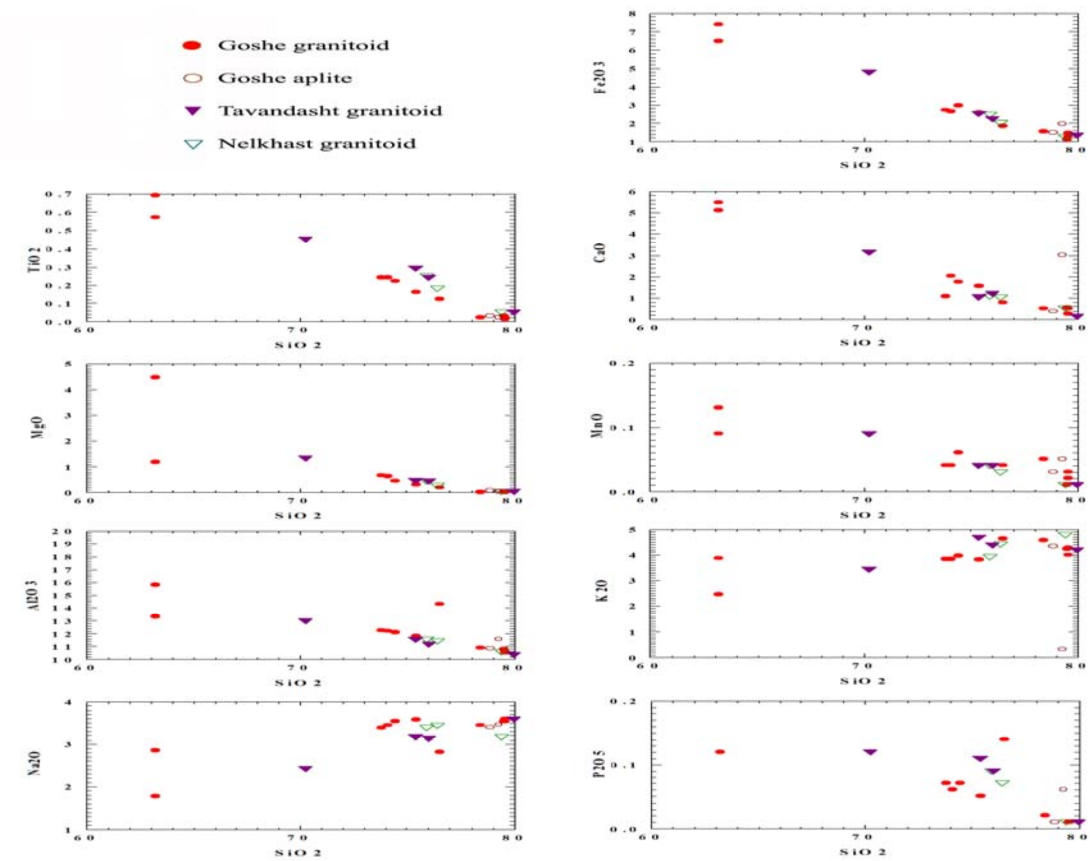

Figure 3 - Variation of major elements vs. SiO_2

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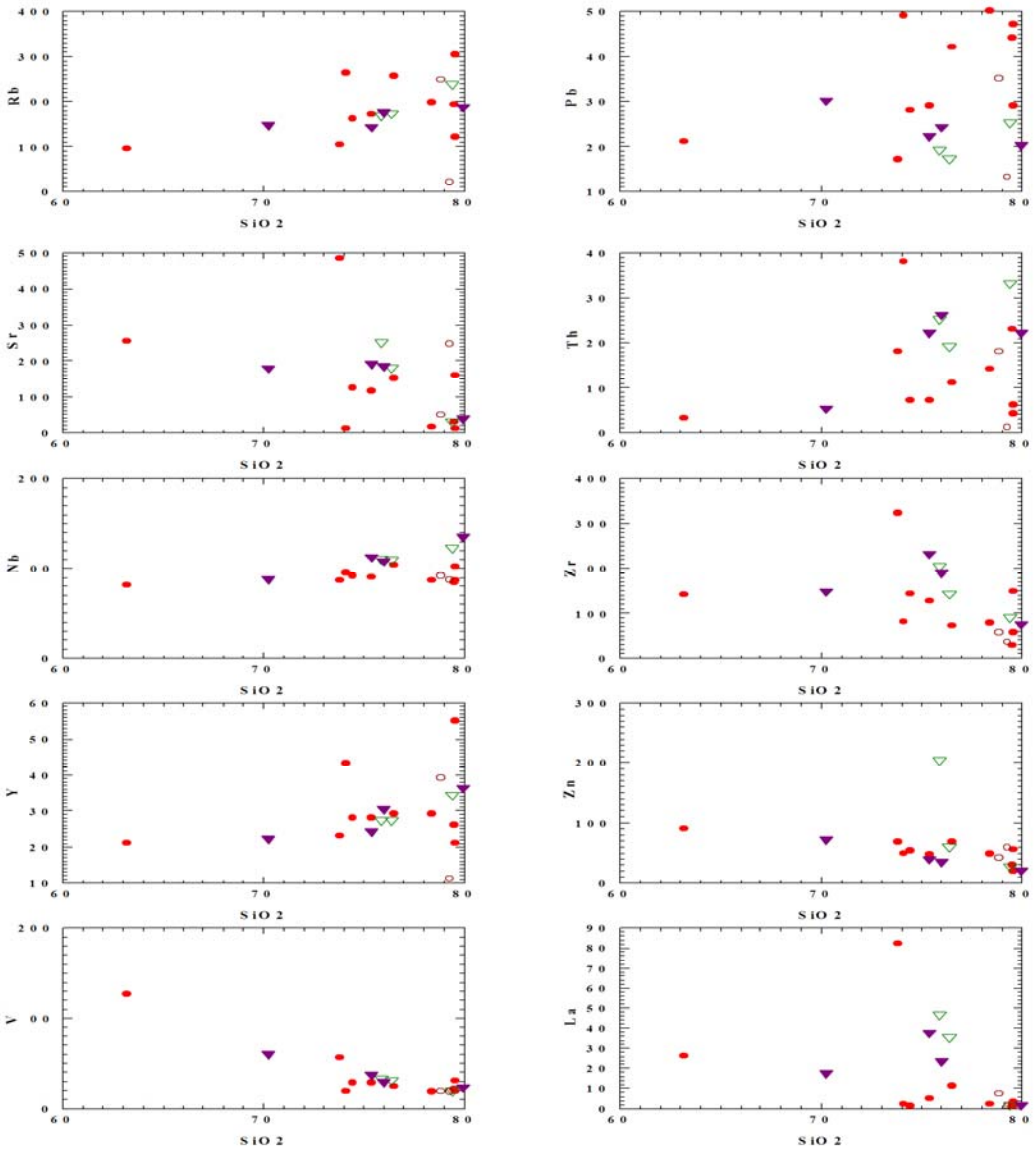

Figure 4 - Variation of some trace elements vs.SiO_2 (Symbols as in Figure 3)

Arc

According to $(Na_2O+K_2O)/SiO_2$ and AFM diagrams [9] a majority of the granitic rocks in the area fall in the subalkaline field and are calc-alkaline type (Figures 5 and 6).

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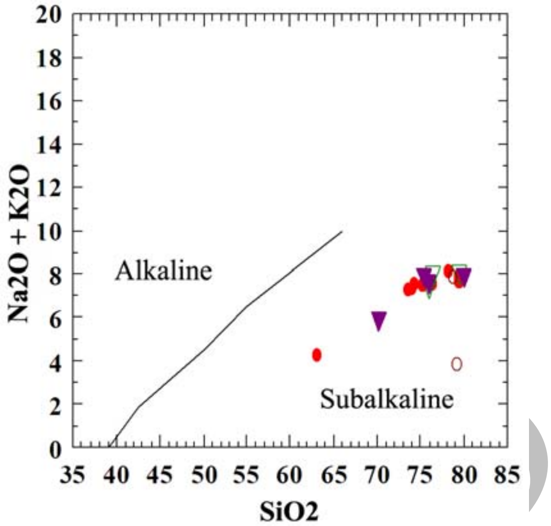

Figure 5 - Granitoid samples in Na2O+K2O/SiO2 diagram (9). (Symbols as in Figure 3).

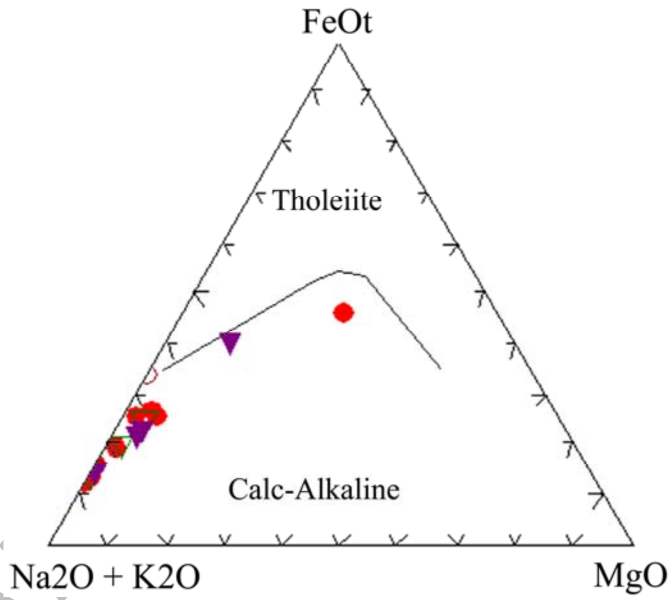

Figure 6 - Granitoid samples in AFM diagram (9). (Symbols as in Figure 3).

Source Rocks of Granites

The subdivision of granites into S-type and I-type [10] has been extended from its initial genetic concept to a tectonic indicator in which S-type granites are believed to be the product of continent collision while I-type granites are the product of cordilleran and post-orogenic uplift regimes [11]. In accordance with this suggestion, A-type [12] and M-type [13] granites were defined to encompass the granites of anorogenic and oceanic arc setting, respectively.

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However, Pearce et al. [14] believe that this classification is difficult to apply, because there are no well-defined boundaries between the granite types; moreover, there are no meaningful correlations between these granitic types and tectonic setting. The results of the analyzed samples confirm this conclusion and there is no simple correlation between analyzed samples and the Australian examples on which the classification is based. All plutons have both I-type and S-type characteristics, although some evidences, such as low normative corundum, indicate an I-type characteristic for the Gosheh granites (Table 3, Figure 7).

According to the classifications of Pupin [15] and Castro et al. [16], analyzed granitoids are orogenic.

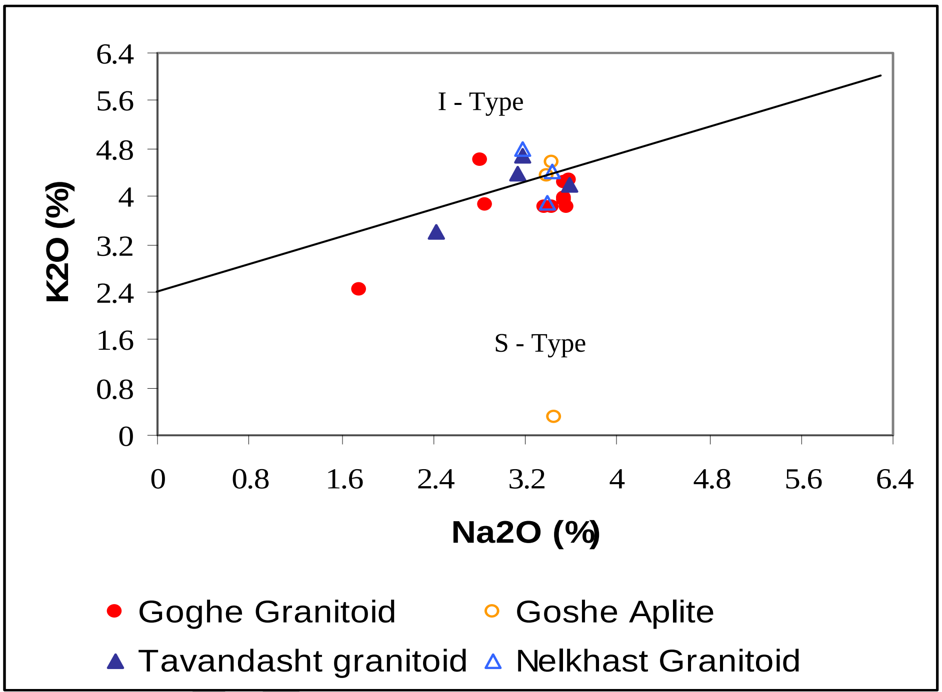

Figure 7 - Studied samples in the subdivision of granites into S-type and I-type (10)

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Table 3 - Characteristics of studied samples based on subdivision of granites into S-type (S) and I-type (I) (10).

	Gosheh Granitoid	Tavandasht Granitoid	Nelkhast Granitoid
Flesic minerals (%)	S, I	S	S
Mafic minerals (%)	I	I	I
SiO2 (%)	I	I	I
Na2O (%)	I, S	I, S	I, S
Na2O/Na2O+K2O+CaO	I	I	I
Normative Corundum	I	I	I
Trace elements	I	I	I
Xenolith	I, S	I, S	I, S

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Tectonic setting of granitoids

Granitoids occur in different environments. There are some methods for the discrimination of environments where granites occur. Diagrams presented by Maniar and Piccoli [17] and Pearce et al. [14] are commonly used to identify the tectonic setting of plutonic rocks.

Based on diagrams of Maniar and Piccoli [17] (Figure 8), the analyzed samples mostly fall in the POG field and they are post orogenic granitoids. In the Nb-Y and Rb-(Y+Nb) diagrams of Pearce et al. [14], all samples fall in the field of within plate granite (Figure 8).

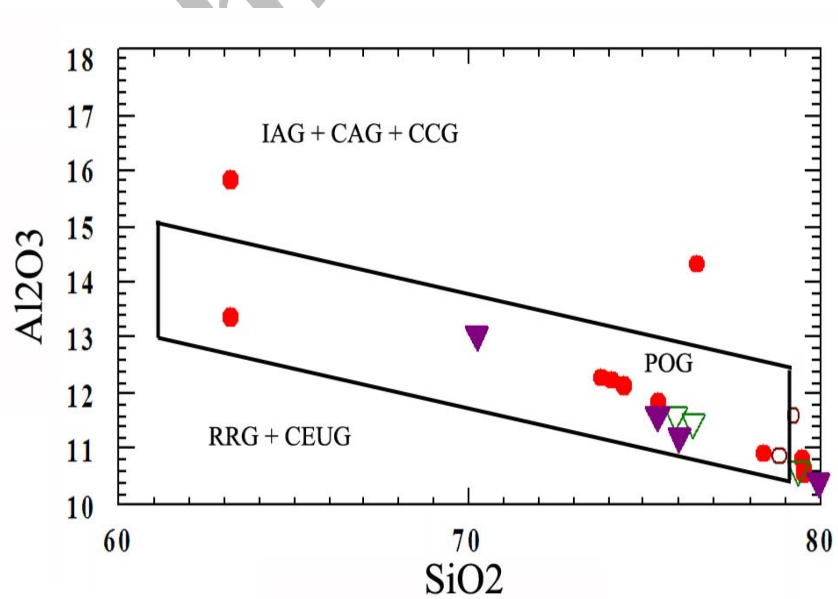

Figure 8- The tectonic discrimination diagrams of Maniar and Piccoli (17), the samples mostly fall in the post orogenic granitoids field (POG). Symbols as in Figure 3.

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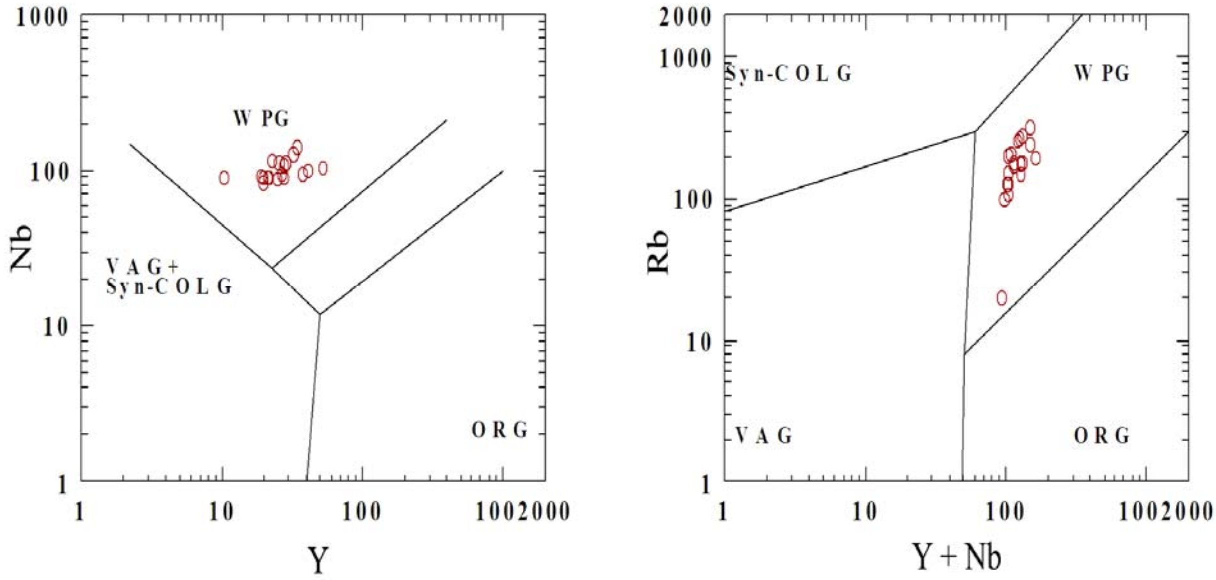

Figure 8 – Tectonic discrimination diagrams of Pearce et al., (14): WPG (field for With in Plate Granites), Syn-COLD (Syn Collistional), VAG(Volcanic Arc Granites) and ORG (Ocean Ridge Granites)

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Conclusion

There are three seperate granitic bodies in the area: (a) the Gosheh intrusion; (b) the Tavandasht intrusion and (c) Nelkhast intrusion. Based on the evidence presented in this study, the following conclusions can be drawn:

- A majority of the plutonic rocks are granites and granodiorites.
- Hydrothermal alterations have affected the intrusions.
- The Study of the variation of the major elements shows that the samples of the three studied intrusions all formed in a similar setting.
- The existence of perthite, granophyre and graphic textures together demonstrates 700 to 850˚C as the maximum temperature for the granitoides formation, and the pressure of H2O at the time of formation is estimated about 5 Kbar.
- The granitic magmas show typical calc-alkaline trends.
- Granitoieds present both I-type and S-type characteristics, however, some evidences, such as low normative corundum, indicate an I-type characteristic for the Gosheh granites.
- The intrusions are post orogenic granitoids and show the within plate granite features.

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