Iranian Int. J. Sci. ***3**(2), 2002, p. 171-185*

Petrogenesis of the Gold Bearing Zarrin Granite

M.V. Valizadeh[1], J. Omrani[2], and R.P. Moritz[3]
[1]Department. of Geology, Faculty. of Sciences, Tehran University, IRAN?Ð
e-mail: mvalizad@chamran.ut.ac.ir,
[2]Geological Survey of Iran, Tehran, Po. Box 13185-1494?
[3]Université de Génève, Department de Mineralogie,
13 rue des Maraichers, 1211 Génève 4, Switzerland
(received: 11/17/1998 ; accepted: 4/24/2002)

Abstract

Zarrin granite intrusion is located in the Central Iran, to west of Chapedoni and Posht-e-Badam faults. It consists of three separate outcrops situated at the northern end of a long mountain range, which is comprised of Mesozoic rocks. Lithologically the intrusion contains granites as well as, gneisses (?) and aplites. Petrographic and geochemical evidence strongly suggest that they are cogenetic. High aluminum contents and other characteristics of these rocks, as well as petrographic evidence, indicate that the granite is ″S-type″. Moreover, on the basis of geochemical evidence it is suggested that this granite intrusion may be classified as a Post-Orogenic Granite (POG) and Within Plate Granite (WPG). It is also suggested that the intrusion occurred in a relatively quiet period of the final stage of an orogeny.Lamprophyric dykes cutting Zarrin granite have similar orientations and are parallel to the major faults zone. It appears that their genesis is related to the deep faults, which extend down to the upper mantle. Due to the activities of these faults, the upper mantle melted and consequently caused, the crustal rocks melt at a higher level earlier than expected, and formed granite magma which moved upward along these faults. Gold mineralization occurred in the north eastern part of the intrusion. The mineralization is most frequent, where lamprophyric dykes are greater in number. It appears that hydrothermal fluids, which developed after lamprophyre intrusion, has leached the gold present in dykes and emplaced it in the surrounding rocks.

Keywords: *Petrogenesis, Zarrin Granite, S-type, Post Orogenic Granite, Within Plate Granite, Central Iran, Geochemistry, Lamprophyre, Fault zone, Upper Mantle, Gold Mineralization.*

Introduction

Previous studies on Zarrin intrusion in Central Iran were focused on the gold mineralization of placer type. In this paper by considering field studies and geochemical evidence of varieties of igneous rocks, it is attempted to clarify the relationships among them and finally the gold mineralization in the region.

Geological Setting

Zarrin granite is located 80 km to the northeast of Ardakan with an outcrop of over 100km². The intrusion consists of three separate outcrops (Fig.l), having an elongate north-south trend, and is affected by the tectonic activity during its emplacement, which caused abundant faults now present throughout the intrusion. Moreover, due to the deformation, a foliation system developed in the granite which produced the granite-gneiss in some places. Augen gneiss is found in the northern part of the intrusion. In these gneisses, there are some feldspar crystals which are more than four centimeters long. There is some textural variability in the Zarrin granite, producing microgranular to granular, and occasionally porphyritic textures. These mentioned varieties are observed within the northern and eastern parts, however the western part is homogenous and composed mainly of granite.

Another characteristic of Zarrin granite is the presence of frequent lamprophyric dykes. General trend of dykes is NW-SE, parallel to the length of the intrusion and major faults which appear to be related to their genesis. The dykes have variable thickness, ranging from 1 to 6 meters. Hydrothermal alteration is observed throughout the intrusion. It seems that this phenomenon has been the last thermal activity in the Zarrin area, because we can observe that this kind of alteration has even affected the lamprophyres. Some parts of the eastern intrusion is strongly altered resulting in kaoline occurrence.

The sedimentary formations in the area include different rock types. Lower Paleozoic dolomites occur at the west of the intrusion, and are intruded by lamprophyric dykes. These are the oldest units within the study area. Other sedimentary sequences are: Upper Paleozoic rocks, at the west and center of the intrusion; Triassic shaly-dolomitic sequence in the vicinity of the Zarrin village; Shemshak formation, which is composed of alternations of dark grey shale and sandstone in the west of the intrusion. Younger strata include red detrials of Miocene, and Quaternary conglomerate, which outcrop mainly to the north of the intrusion and near the Zarrin village.

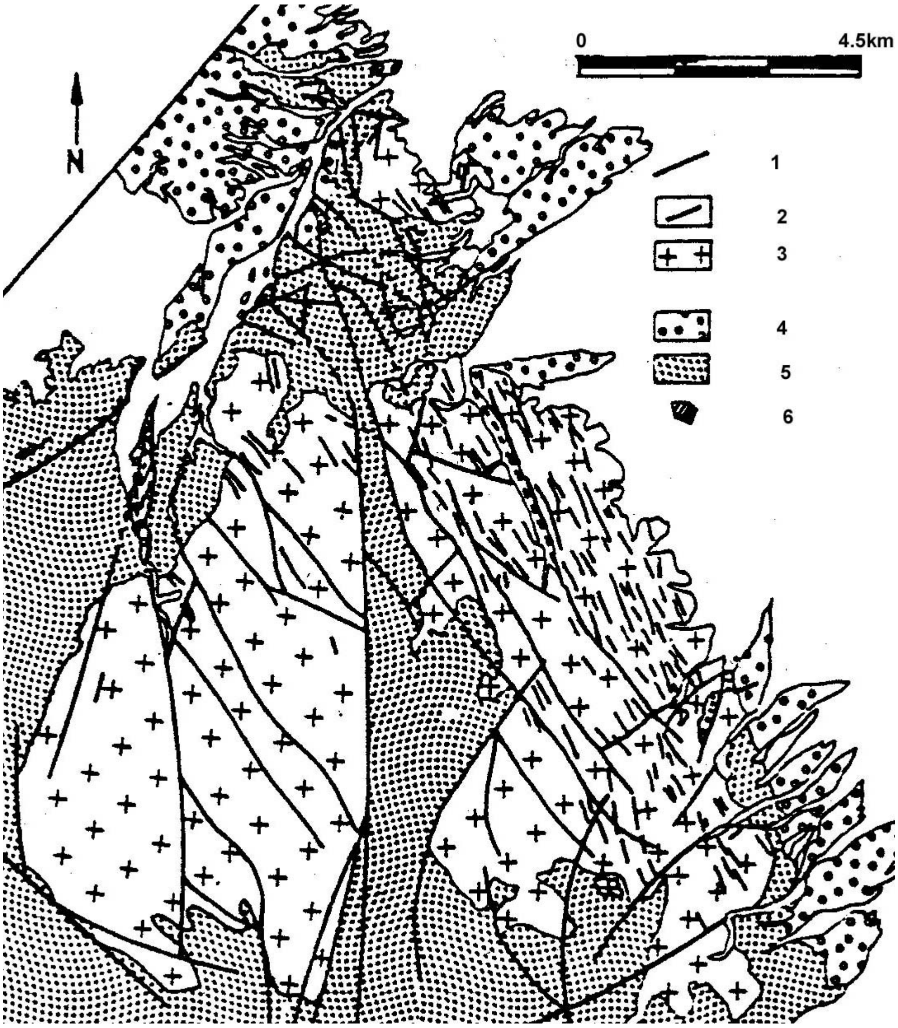

Figure 1 - Schematic map of Zarrin granite and country rocks.
1- Faults. 2- Lamprophyric dykes. 3- Granite. 4- Tertiary and Quaternary rocks. 5- Paleozoic and Mesozoic rocks. 6- Village. (Omrani, 1992)

Petrography

Igneous rocks in the Zarrin area, generally consist of granite, gniess, aplite and lamprophyre (as dyke). The granitic rocks which make up a great volume of the intrusion, are composed of 46% alkali feldspar, 27% quartz and 12% plagioclase. Accessory minerals are muscovite, zircon, alanite and apatite. Total alteration of minerals, as sericitization and kaolinization in feldspars and ondulatory extinction of quartz, are the most significant characteristics. Texturally, the grains vary from euhedral to anhedral. In porphyritic parts, coarse grains of feldspar are generally euhedral.

Another group of rocks are gneisses, which have lesser volumes, compared to granites. Petrographically there is no difference between granites and gneisses, except for their textures. Contact between gneiss and granitic units is mostly faulted. The augen gneiss unit conatins unmelted parts (restite) and is formed mainly of biotite, and yield parallel to the foliation in these rocks. Aplites, after than their texture, differ by having accessory minerals, such as tourmaline.

Lamprophyres are basic igneous rocks in the Zarrin area. They are mostly fine grained and occasionally prophyritic. Their mineralogical composition coincides with comptontie which belongs to the alkaline lamprophre series. Their mineralogical composition includes amphibole (hornblende) and plagioclase, the latter being mainly in matrix, but in the prophyry type has been observed to be more than 1.5 centimeter long. Despite the presence of secondary minerals, such as zoisite, clinozoisite, chlorite and epidote, plagioclases are mostly unaltered.

Geochemistry

Analyses of 17 samples for the major and trace elements were done at the Génève University, using X-Ray flourscence technique (results are reported in Table 1).The average contents of some elements for acidic rocks from the Zarrin area are: 73% SiO_2 , 12.5%, Al_2O_3, 3.6% K_2O, and 4.5% Na_2O . The same value for the lamprphyres are: 47.12% SiO_2, 16.3% Al_2O_3 10.9% Fe_2O_3, 6.84% MgO, and 10.38% CaO. Almost all samples of igneous rocks in the area fall in the alkaline field, according to Kuno diagram (1959) (Fig.2).

In Harker diagrams, some major and trace elements are plotted vs. SiO_2 (Fig.3). Only acidic rocks have been chosen for this comparison. As it is observed in these diagrams, TiO_2, Fe_2O_3, MgO and P_2O_5 have a negative trend with increasing SiO_2. The decrease of Fe_2O_3 and TiO_2 is expected to be due to crystalization of ferromagnesian minerals. Because of lower mobility Ti is a good indicator, so it usually has a sharp trend.

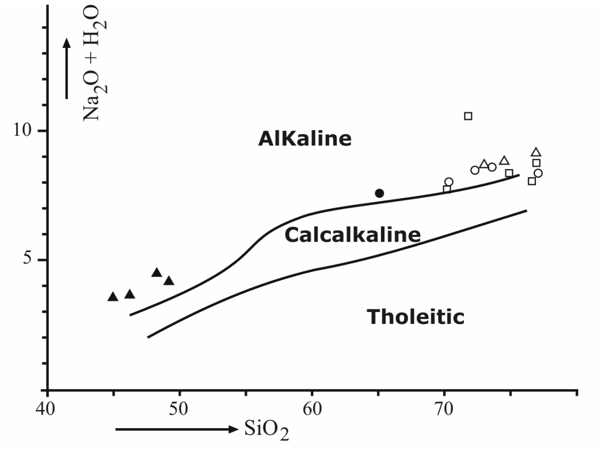

Figure 2 - Zarrin samples in Kuno diagram (1959). ?^: **aplite.** ?U: **granite,** ?U: **granodiorite,** ?U: **lamprophyre,** Δ **: gneiss**

Some trace elements which are concentrated in silicate phase rather than in accessory minerals, are most useful. Strontium, Rb, and Ba are from this kind of elements. In Fig. 4 Rb vs. SiO_2 has a positive trend, conversely Sr, Zr and Ba have a negative one. Rubidium is easily entered in the biotite, Also some minerals, such as K feldspar and hornblende can host Rb. Barium and Sr are replaced in plagioclase, anorthoclase and alkali feldspar. Specifically Sr easily replaces Ca, so that plagioclase contains more of this element.

The most important result from these diagrams is a close genetic relationship between gneiss, granite and aplite in the Zarrin area. There is a sharp interrelationship between the composition and mineralogy of gneisses and other acidic rocks in the area. Therefore, it is concluded that the gneisses are indeed, granite-gneiss which had developed under the influence of stress in the time of emplacement, and the texture represents that the pressure had been acting during or immediately after the emplacement. Their geochemical characteristics, as well as field observations show that they belong to the original magma. Previous results attributed the age of augen gneiss outcrops in the north of the Zarrin area to precambrian (Haghipour *et al.*, 1977). Bearing coarse grain alkali feldspars and texture features, made this gneiss to be considered as a high grade metamorphic rock with the age of precambrian in many parts of Central Iran. In this study, based on geochemical and petrological evidences, it has been proved that these outcrops are of magmatic rock types, not metamorphic ones, and are just the same as the magma, which formed Zarrin intrusive. Presence of light color granitic enclaves in these outcrops approves this idea. Unmelted parts in the form of black elongated enclaves consisting mainly of biotites, are seen in these parts, which indicate that this augen gneiss has not undergone the complete melting phase, and did not change to a homogenous granitic magma.

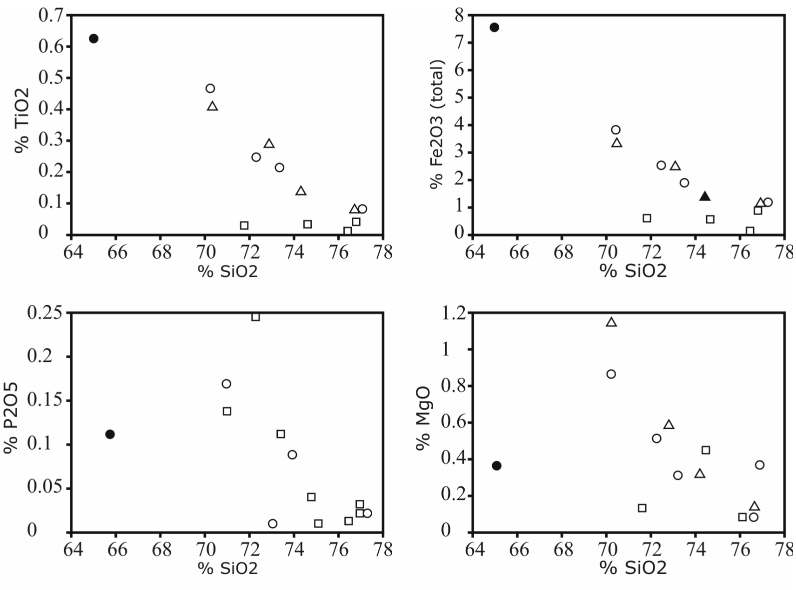

Figure 3 - Variation of some major elements vs. SiO_2. Symbols as in Figure 2.

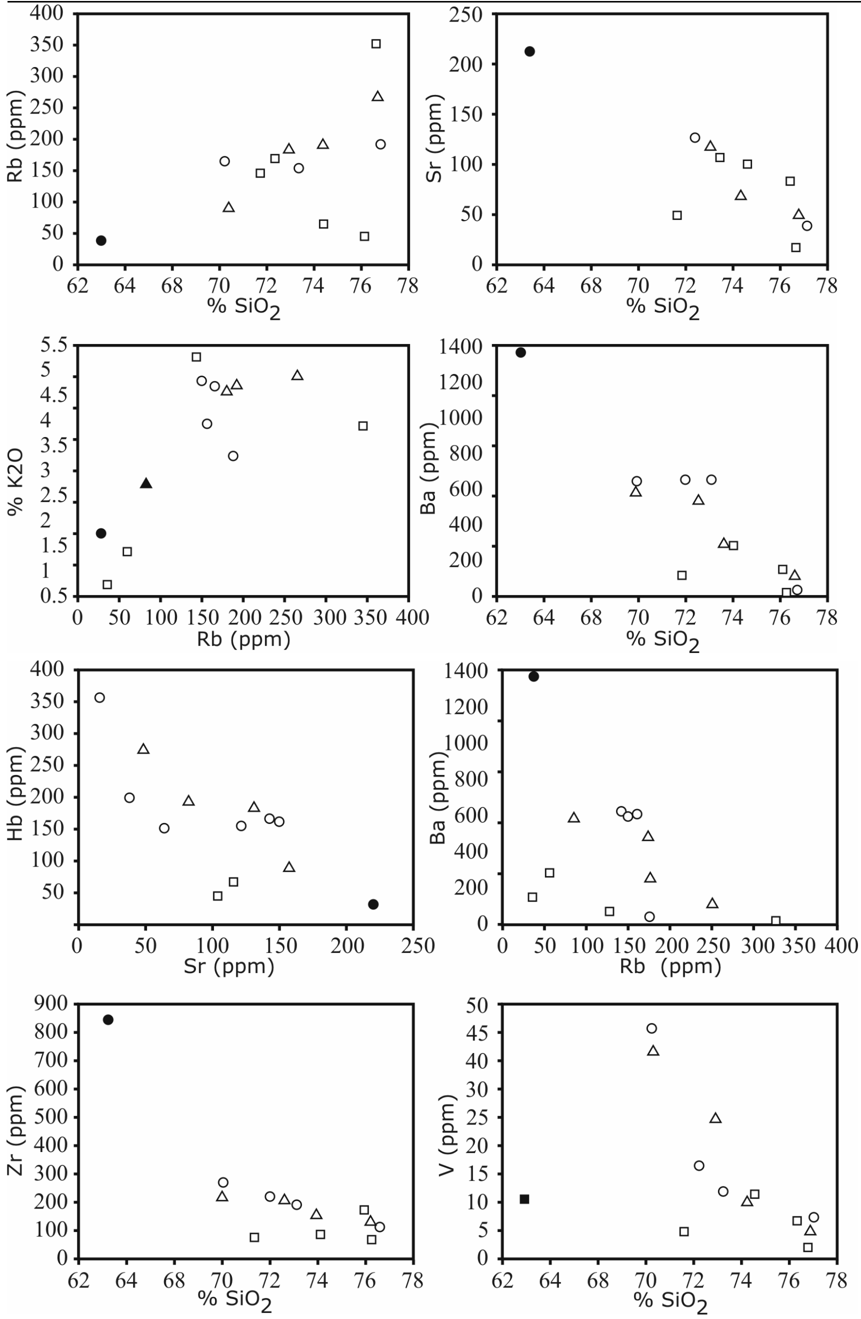

Figure 4 - Variation of some trace elements Vs. SiO_2. Symbols as in Figure 2.

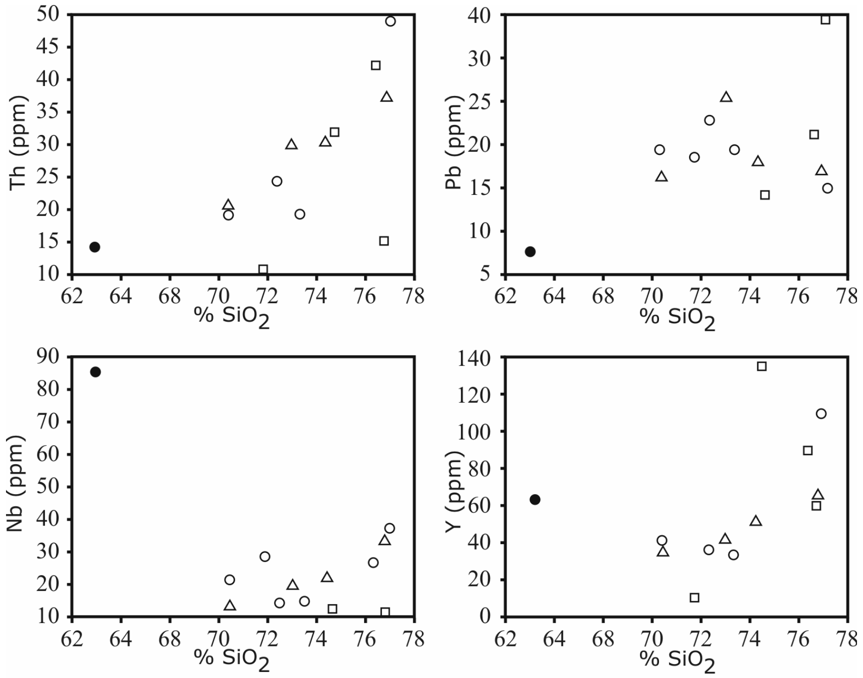

Figure 4 (continued)

Tectonic Setting

Granites occur in many different environments. There are some methods for the discrimination of environments, in which granites occur. These discriminations are mostly based on geochemical behavior of major and trace elements. Maniar and Piccoli (1989) using major elements represented diagrams by which some environments may be distinguished.

Zarrin granite is peraluminous and based on other petrological evidences is ″S- type″ (Omrani, 1992). Concerning the tectonic discrimination, the Zarrin area samples are plotted on Maniar & Piccoil (1989) diagrams (Fig.5). Zarrin granite falls in post orogenic (POG) field. According to their definition ″The post orogenic granitoids are rocks intruded during the last phase of an orogeny, generally after the deformationin the region has ceased.″

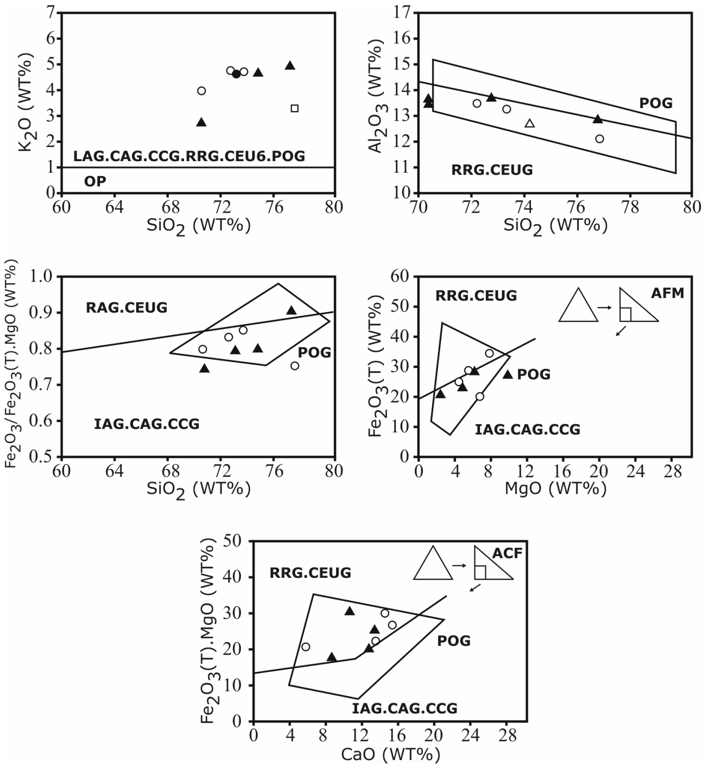

Figure 5 - Major elements of acidic rocks from the Zarrin area plotted on Maniar and piccoli (1989) diagrams.
Most samples fall in post orogenic field (POG). symbols as in Figure 2.

Agrawal (1995) suggests that field boundaries have been drawn purely subjectively by fitting lines by eye represented a numerical model for discrimination between late orogenic, post orogenic and anorogenic granites by their major element composition. This method is used preferably for biotite-granite with simple mineralogy. Zarrin granite is post orogenic according to the Maniar & Piccoli diagrams. With respect to trace elements, behavior, plotted in the Nb-Y and Rb-(Y+Nb) diagrams of Pearce *et al*. (1984), most samples fall in the field of Within Plate Granite (Fig.6).

Therefore, it is concluded that the Zarring granite is a post orogenic granite (POG) based on Maniar & piccodi (1989) and Agrawal (1995), and tectonically is related to continental crust, which according on pearce *et al*. (1984) is a Within Plate Granite (WPG).

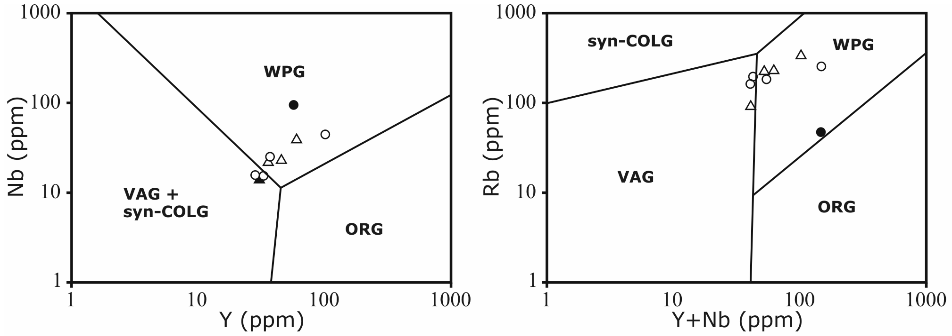

Figure 6 - Abundance of some trace elements of the acidic rocks from the Zarrin area plotted on the tectonic discrimination diagrams of Pearce *et al*., (1984): fields for Within Plate(WPG), Syn Collistional (Syn-Colg), Volcanic Arc (VAG) and Ocean Ridge (ORG) granites are indicated. Symbols as in Figure 2.

Zarrin intrusion is located in the west of Chapedoni and Posht-e-Badam faults, and has emplaced in the northern part of Mesozoic rocks, being as long as almost 200 km which begins with a NW-SE trend at Rafsanjan and finishes in the Zarrin area. The trend of major faults being mainly strik-slip is parallel to this structural orientation. In Fig.7 orientation of faults in Ardakan quadrangle(1:250,000), the faults of the Zarrin area and the dykes which intruded Zarrin granite are compared. It is seen that the main trend of faults in the Zarrin area is in the same direction as that of the main faults of this part of Central Iran, and also all dykes follow a similar trend.

It appears that crustal melting which formed the granitic magma is relate to the above mentioned major faults. In other words, the faults controlling emplacement of dykes are connected to the deep faults extending downwards to the source of magma, which formed the dykes in the upper mantle. At the point of most extension, due to the activities of faults, this part of the upper mantle has melted and intruded in the continental crust. When basic magma is emplaced into the continental crust, melting and generation of silicic magma can be expected. The fluid dynamics, and heat transfer processes at the roof of a basaltic sill, in which the wallrock melts are investigated both theoretically and experimentally by Huppert and Spark(1988).

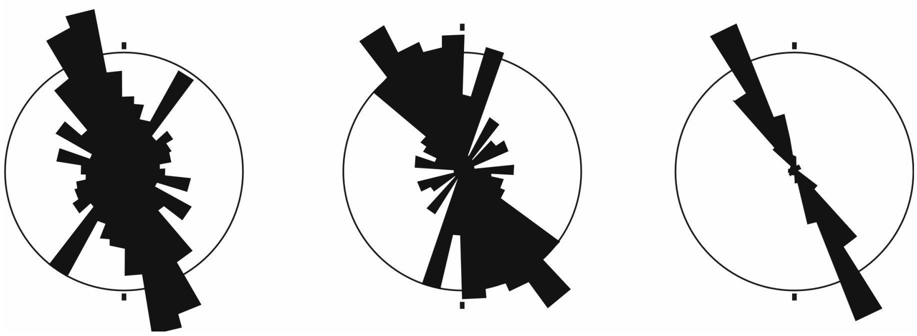

Figure 7- Orientation of major trend of structural features. A: faults of Ardakan quadrengle B: faults of the Zarrin area C: dykes intruded Zarrin granite.

The original cause of melting, presumably is decompression melting that occurred in the upper mantle. In addition, other factors in magma genesis which must be considered are: heat flow and chemical changes, which act in various degrees. Influx of volatile through degassing of mafic magma, would thus be the most important mechanism responsible for crustal anatexis. This factor, therefore may have caused both chemical changes and melting of the crust.

Alkaline lamprophyres are most like common igneous rocks being volatile rich version of alkaline basalts, basanites and nephelinites and of amphibole bearing gabbros (Rock *et al*., 1991). Both Zarrin granite and lamprophyric intrusions are alkaline. At the first stage of continental movement, due to the activities of faults, upper mantle melted and caused lamprophyric magma ascending upward. In a level, it shaped as a sill and provided conditions to transfer volatile and heat to overlying crustal rock. According to Huppert and Spart (1988) for a 500 m thick sill with a crustal melting temperature of $850°C$, the thickness of the silicic magma layer generated ranges from 300 to 1000 m for country rocks temperatures from 500 to $850°C$

It seems that a mechanism similar to the suggestions of Huppert and spark (1988) generated the silicic magma of Zarrin granite. The major fractures along the fault system permitted magma to ascend and crystallize at an appropriate level. Preferred orientation of minerals and common varieties of textures in intrusion, especially in the eastern part, indicate on active tectonic at the time of emplacement. Expansion of granite, which has been accompanied by intrusion of lamprophyric dykes shows the dominance of a tensional strain in formation of the granite. This condition has existed from beginning of the first fracturing and melting of upper mantle to the generation and ascending of acidic magma.

It is concluded that in post orogenic regimes and in somewhat stable continents, deep crustal anatexis is possible, especially in the presence of volatiles.

Gold Mineralization

The ″Zarrin″ name indicates indices of gold in the area. Very old excavations in the area reveal that the people of that period knew fully about gold. These excavations are good indicators of gold mineralization in the area and studies (e.g., Azarm,1985) show that gold concentration as placer has occurred in terraces and alluvial deposits in the north eastern part of Zarrin granite. The gold contents of same analyzed samples by atomic absorption are: granite 0.09 ppm, gneiss 0.05 ppm,lamprophyre 0.14 ppm and brecciated and silicified dolomites of country rocks 0.14 ppm.

Detailed field and/or geochemical evidence prove that the lamprophyres overlap the gold mineralization in the both time and space, and are often the only igneous rocks to have been emplaced at the same time as the gold. High gold contents are also recorded, not only in calc-alkaline, but also in the alkaline lamprophyres and other groups (Rock *et al*.,1991).

Gold mineralization has occurred in the area of most abundant lamprophyric dykes, where widespread hydrothermal alteration is evident within the study area. It appears that in this process, gold has leached from lamprophyric dykes and emplaced in the country rocks.

However, for a better understanding about the gold mineralization, a systematic work in the area is necessary.

Conclusions

Zarrin granite is located in Central Iran. Based on the geochemical characteristics and field observations, it has been proved that this intrusion is ″S-type″. Further more, using some methods in tectonic discrimination, it is suggested that Zarrin intrusion belongs to post orogenic and within plate granites.

Tectonic features and lamprophyric dykes cutting Zarrin granite indicate that the genesis of magma, which formed this intrusion is related to the deep faults extending down to the upper mantle. Some parts of Zarrin granite are composed of gneiss. Augen gneiss which is present in the northern part, is very similar to the high grade metamorphism gneisses, but based on the geochemical evidence and some other characteristics, it has been proved that the gneisses and granites are cogenetic and belong to an original magma. It appears that the gold mineralization is related to lamprophyric dykes which are widespread in the area.

Acknowledgement

The Research Deputy of University of Tehran is gratefully acknowledged for funding this study. Dr.M.R.Ghassemi is thanked for reading the manuscript and for critical comments.

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