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Petrology of the granitoid intrusions in the Shalair Valley area, northeastern Iraq

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Abstract

The granitoid bodies in the Shalair Valley are structurally located within so-called Iraqi Zagros Suture Zone, in the northeastern Iraq. One hundred and sixty-two representative samples were collected from five granitoid intrusive bodies in the valley: Aulan and Siristan in the northern part, Mishao and Laladar in the southern part and Demamna in the western part. Two major types of granitoids in the eastern and western part of the Shalair Valley area were indentified. The granitoids from the four locations in the eastern part, have similar mineral constitutes. These rocks are composed of plagioclase + quartz ± hornblende with two types of texture, equigranular texture represented by Aulan and Siristan in the northern part and porphyritic texture in the southern part represented by Mishao and Laladar. This reflects several stages of intrusive events, starting with stable fractional crystallization conditions represented by Aulan and Siristan granitic rocks with equigranular texture and a late stage of unstable crystallization conditions represented by Mishao and Laladar granitic rocks with porphyritic texture.

Damamna granites in the western part have different mineral composition. They are composed of K-feldspar, quartz and small amount of plagioclase with graphic texture represented by the intergrowth between K-feldspar and quartz, which reflects simultaneous crystallization of K-feldspar and quartz from a silicate melt close to the eutectic point.

Keywords: Zagros orogeny, Shalair Valley, granitoids, petrography,

بترولوجية مقحمات الصخور الكرانيتويدية في وادي الشلير، شمال شرق العراق

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الخلاصة

تركيبيا تقع الاجسام الكرانيتويدية في وادي شلير ضمن نطاق الالتحام لسلسلة زاكروس العراق في الجزء الشمالي الشرقي العراقي و يعتبر وادي شلير جزء من نطاق سننداج–سرجان في ايران. تم جمع مائة وأثنتان وستين عينة ممثلة للاجسام الكرانيتويدية الخمسة في منطقة الدراسة: اولان و سيرستان في الجزء الشمالي، مشاو و لالادار في الجزء الجنوبي ودمامنا في الجزء الغربي. بينت الدراسة البتروغرافية للصخور قيد التدريس انه هنالك نوعان من الصخور الكرانيتويدية. في الجزء الشرقي والجزء الغربي ضمن وادي شلير.الصخور الواقعة ضمن الجزء الشرقي والمثلثة : اولان، سيريستان، مشاو ولالادار لها تركيب معدني متشابة (بلاجيوكليز + كوارتز ± هونبلند) مع وجود نوعين من النسيج . النسيج المتساوي الحبيبات والممثل بصخور اولان

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وسيرستان في الجزء الشمالي والنسيج البورفيري والمتمثل بصخور مشاو ولالادار. هذه الصفات ممكن ان تعبر عن وجود عدة مراحل من الاقحام والتي تبدء بظروف تبلور مستقرة التي كونت النسيج المتساوي الحبيبات والمتمثلة بأجسام اولان، سيريستان، وظروف تبلور غير مستقرة والمتمثلة بتكون النسيج البورفيري ضمن اجسام مشاو ولالادار. ان صخور كرانيت دمامنا في الجزء الغربي لمنطقة الدراسة لها تركيب معدني مختلف عن الصخور الواقعة في الجزء الشرقي. تتكون هذه الصخور من الاورثوكليز وكوارتز وكميات قليلة من البلاجيوكليز ، مع تواجد النسيج الكرافي والذي يمثل النمو المتداخل بين الاورثوكليز والكوارتز، والذي يعكس توافق تبلور الاورثوكليز والكوارتز من الصهير السليكي قريبا من النقطة الحرجةالانصهارية.

Introduction

The igneous and metamorphic rocks are distributed in northern and northeastern Iraq forming a narrow zone along Iraq-Iranian and Turkish borders Figure-1(a) [1- 3]. They are related to igneous and metamorphic activities, which are resulted from subduction, obduction and collision processes, linked with the opening and closure of the Neo-Tethys Ocean [4- 8].

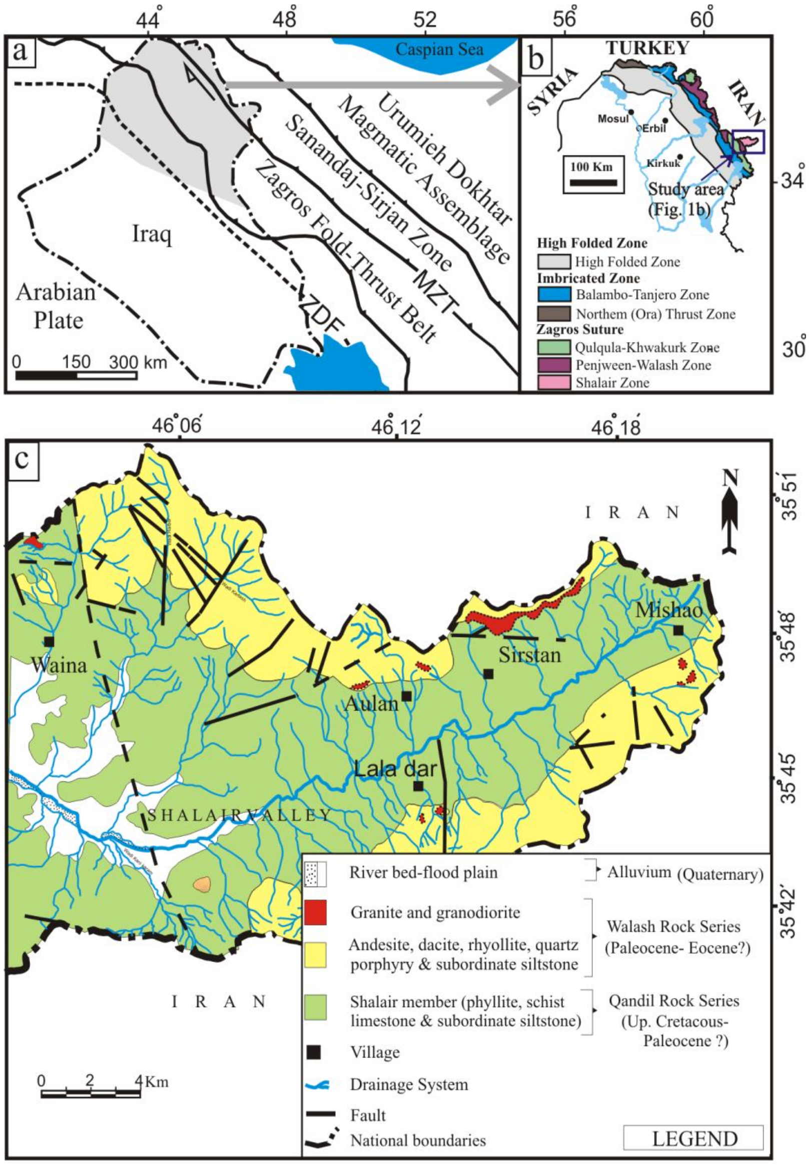

Figure 1- (a) The main tectonic units of the Zagros Orogenic Belt [5]. ZDF: Zagros Deformation Front; MZT- Main Zagros Thrust. (b) Tectonic zones of the Iraqi Zagros Suture Zone [3], showing the distribution of igneous and metamorphic rocks. (c) Geological map of the Shalair Valley area [9].

The Shaliar Valley runs parallel to the Zagros Fold-Thrust Belt and considered a part of Sanandaj-Sirjan Zone in Iran [10, 11]. The Zagros Orogenic Belt consists of three parallel tectonic subdivisions from SW to NE [5] Figure-1(a): (1) the Zagros Fold-Thrust Belt; (2) the Sanandaj-Sirjan Zone; and (3) the Urumieh-Dokhtar Magmatic Assemblage. Iraqi Zagros Suture Zone is divided into three subzones, which are parallel to Taurus- Zagros Zone and comprise from SW; the Qulqula-Khwakurk; the Penjween-Walash and the Shalair (Sanandaj-Sirjan) subzones Figure-1(b) [3]. The Sanandaj-Sirijan Zone (Zagros Imbricated Zone) is characterized by complicated structures and represented the central terrain of the Zagros Orogen [5]. It has a length of 1500 km and width from 150 to 250 km. This zone is mainly composed of deformed metamorphic complexes associated with deformed and unreformed granitoid intrusions, in addition to widespread Mesozoic volcanisms [12]. Mesozoic rocks are the major exposed rocks in this zone [13- 15], whereas Paleozoic rocks are less distributed in the northwestern part of the SSZ compared to the southeastern part [6]. The Shalair Valley area is located within the northwestern part of the SSZ. Plutonic intrusions of the Sanandaj-Sirijan Zone are mainly calc-alkaline granite and the volcanic arc and within plate are the main tectonic settings of granite.

This study focused on the granitoid rocks in Shalair valley within the SSZ in the northeastern Iraq. The present study throws light on the field and petrographic observations for five intrusive granitoid bodies (Aulan, Siristan, Mishao and Laladar) (Figure-1c) to clarify the mineral composition and textures and to find out the effects of deformation and alteration /and or low grade metamorphism on these rocks.

Geological setting

The Shalair Valley area has a complicated topography, consisting of rugged mountains with very steep valleys. Structurally, it is an eroded asymmetrical east – west large anticline, and gently plunging toward the east [2, 15]. It extends about 30 km. with width of more than 20 km [16]. The value of the dip ranges from 30° to 70° for the southern limb and from 20° to 40° for the northern limb. In the core of the Shalair anticline the Qandile Rock Series (also Known as the Shalair Phyllite Series [17] are exposed and composed of meta-sedimentary sequences [18], whereas the Katar Rash Volcanic Unit exposes along the limbs and consists of basic to acidic igneous rocks [3]. [19] suggested that the Shalair metamorphic rocks have calc-alkaline affinity in an island arc. The granitoid intrusions are mainly cropping out within the Katar-Rash Volcanic Unit. The Katar Rash rock series (also Known as the Walash Rock Series; [16]) overly the Shalair phyllite rocks by thrust planes; these are associated with shearing zones present along the contact between volcanic and metamorphic rock series. For more details on the geology of the Shalair Valley area see [17].

Methodology

For the purpose of the study of the petrography, the field observations and petrographic analysis are used. For petrographic study, thin sections of one hundred and sixty-two representative samples from the five bodies were prepared in Iraq Geological Survey and Nagoya University, Japan, and examined using polarized microscope (LEITZ LABORLUX 11 POL) to identify the mineral composition textures and textural relationships.

Results:

Aulan Granitoids (AG)

Aulan intrusion was observed as two bodies located to the northwest and northeast of Aulan village within the northern limb of the Shalair anticline. One of them is located 1.5 km to the northeast of Aulan village, and the other is located about 1.8 km to the northwest of Aulan village Figure-2. These bodies are surrounded by schist and volcanic rocks mainly andesite, respectively Figure-2.

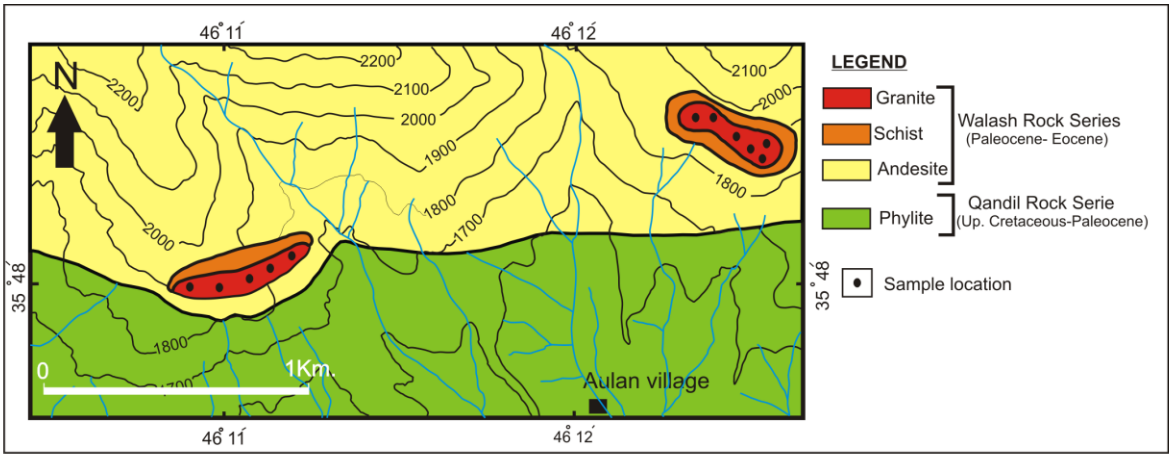

Figure 2- Geological map of the Aulan granitoids modified from [9].

The rocks are massive, coarse grained and highly fractured with high iron oxides. Quartz and epidosit veins are observed in these rocks (Plate 1a and b). The eastern part of the northeast body shows fine grained mafic enclaves as a spherical shape with lengths ranging from few to more than 5 cm. The northwestern body is massive, coarse grained granite without any trace of mafic enclaves.

Thin sections of thirty nine representative samples from the two bodies of Aulan granitic bodies (AG) (20 samples from the northeast body and 19 samples from the northwest body) were examined. In general, the studied samples show an equigranular texture and composed of plagioclase (45%), quartz (45%), within the range of mineral composition of granodirite to granite. The plagioclase is the most abundant constituent with quartz in both bodies. The accessory minerals are zircon, amphibole, iron oxide and in a rarely pyroxene. The average plagioclase composition is from albite to oligoclase. They are subhedral and show variable sizes (0.4–2.4mm) with an average of about 1.3 mm. The northwest body of Aulan shows graphic intergrowth relationships between feldspar and quartz (Plate. 1c). Some other samples are deformed and strained where plagioclase displays fractured and deformation twins (Plate 1d). Fresh plagioclase with weakly developed zoning are common, some of the plagioclase gains are partially or completely altered (cloudy) due to sericitization.

The quartz grains are anhedral with corroded boundaries, with some display undulose or wavy extinction due to deformation (Plate 1e). They have variable sizes (0.5–2.0mm) with an average of about 1.1 mm due to granulation (Plate 1e). They make about 10% of the volume of the rocks. Zircon present in all samples of the northwest body of Aulan, it is stubby and prismatic in shape, with an average grain size of about up to 0.1 mm whereas in the northeast body zircon is rare. Zircon grains are fractured and generally coated or surrounded by iron oxides. Sericitization, chloritization and saussuritization (epidotization) are typical alteration types in these rocks. Sericitization is obvious in plagioclase and some grains are completely replaced by sericite. In some thin sections, chlorite occurs as an alteration product after the pyroxenes and secondary amphiboles minerals, with pale green color and faint pleochroism. Its occurrence in the deformed plagioclase grains is rather restricted to the cracks, fractures, and grain boundaries (Plate 1f). The plagioclase crystals may also be replaced by minor epidote due

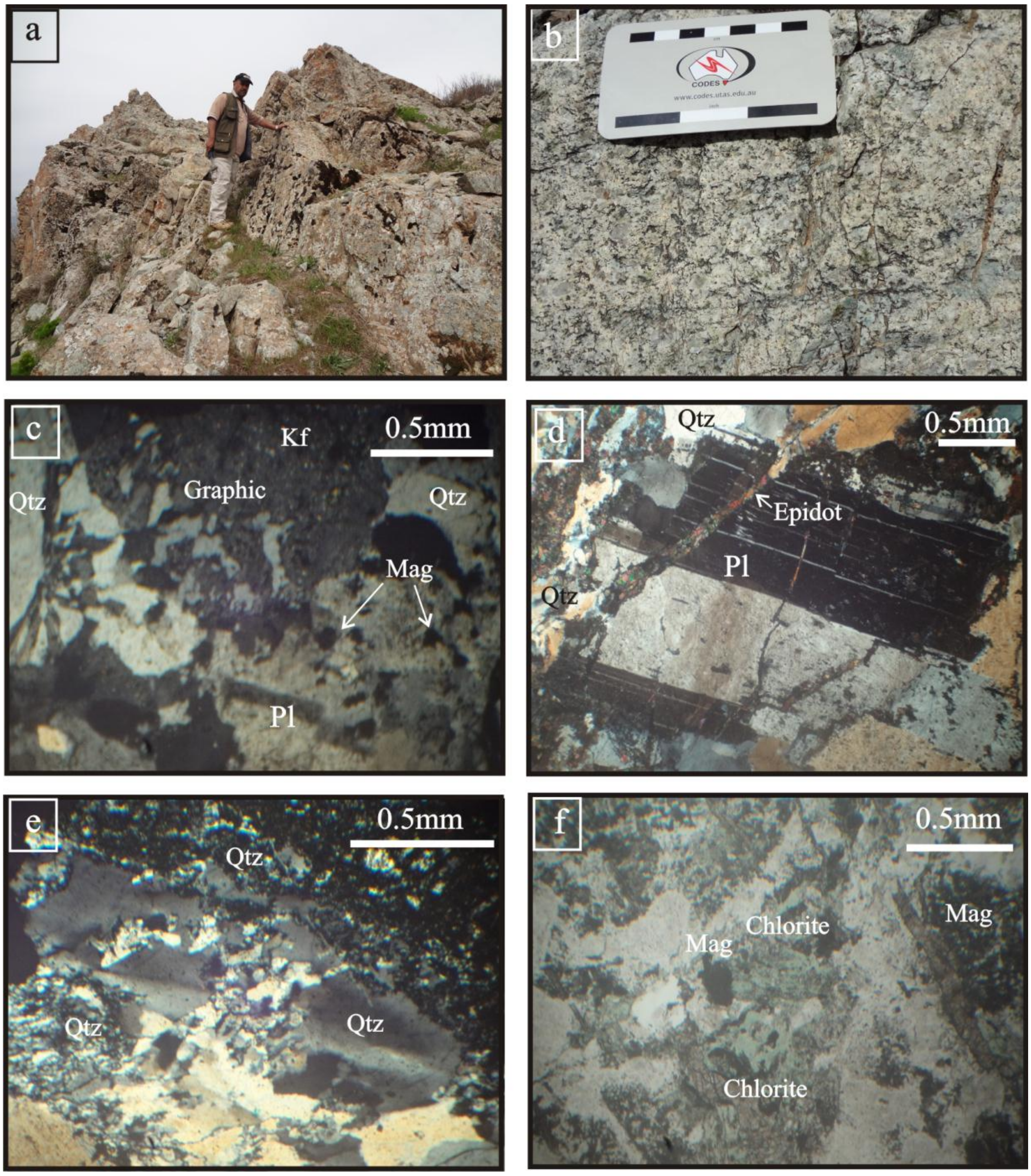

Plate 1- Field photographs and Photomicrographs of the AG rocks.
a and b) Field photographs, massive and coarse grained rocks.
c) Photomicrograph, (X.N.), graphic texture.
d) Photomicrograph, (X.N.), plagioclase displays deformation twins.
e) Photomicrograph, (X.N.), granulation of quartz along grain boundaries, due to deformation.
f) Photomicrograph, (X.N.), chlorite and magnetite minerals and also shows partially sericitized plagioclase. Symbols: Kf = alkali feldspar; Pl = plagioclase; Qtz = quartz and Mag = magnetite.

Opaque minerals are mostly magnetite, which occurs as disseminated aggregates of very fine grained, or as single grains and is commonly associated , coated or surrounded the zircon grains (Plate 1f).

Siristan granitoids (SG)

The Siristan granitoids body (SG) is the largest intrusion and is located to the north of Siristan village close to the Iranian border. It extends for about 5 km. and is characterized by a very steep slope with rugged topography and surrounded by volcanic rocks of Katar Rash from the north, and phyllite rocks from the south (Figure- 3 and Plate- 2a). These granitic rocks are coarse grained and cut by numerous quartz and epidote veins (Plate- 2b). Numerous fine grained mafic enclaves are observed within the coarse granitoid rocks. These enclaves are ellipse to spherical in shape with lengths ranging from few centimeters to more than 15 cm. (Plate- 2c).

The rock samples of the Sirstan pluton are composed mainly of plagioclase (45%), quartz (38%)

and hornblende with minor amount of pyroxene (9%), which can be estimated as diorite to granodirite. The zircon, sphene and magnetite are the accessory minerals and making of about 7%, sericite, epidote and chlorite are the alteration products of the major phase. The studied samples show an equigranular texture.

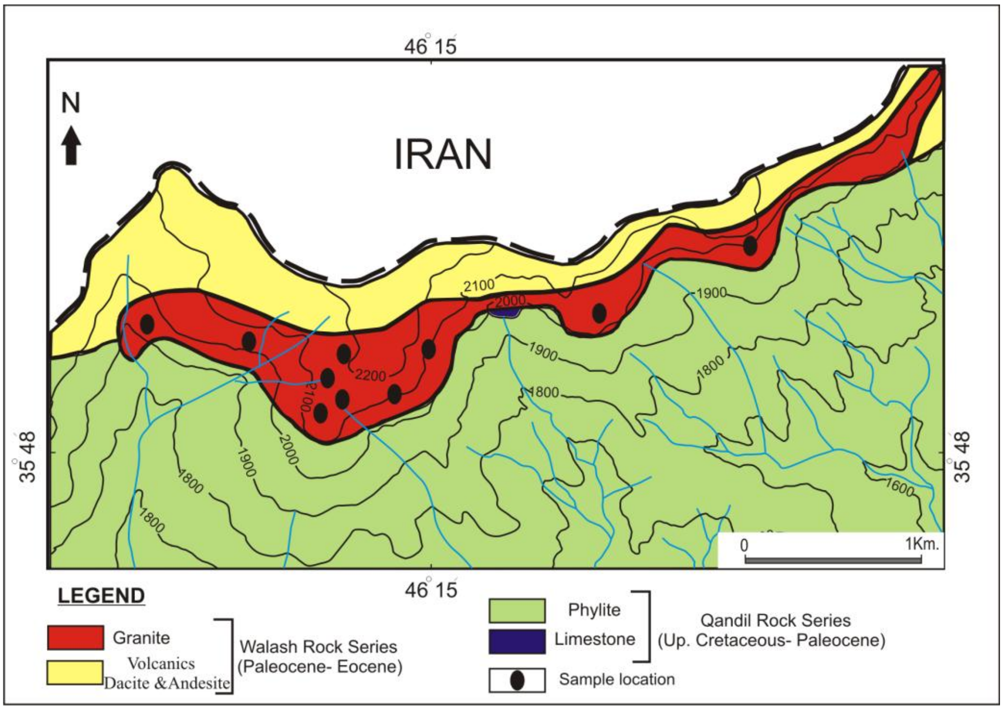

Figure 3- Geological map of the Siristan granitoids [9].

According to the extinction angle measurement, the average plagioclase composition ranges from albite to oligoclase. They are subhedral and show variable size (0.3–3.0mm) with an average of about 1.4 mm. Some plagioclase grains display deformation twins and fracturing and some partially or completely altered to sericite (Plate- 2d). The quartz grains are anhedral with an average size of about 1.2 mm, few show undulose extinction and few grains show granulation within a narrow zone along internal cracks. The mafic minerals are dominated by hornblende with minor pyroxene which presents in all the studied samples of the Sirstan granites forming about 5 to 25 % by volume. The hornblende grains are generally fresh and have well developed cleavage (Plate- 2e). They are subhedral to anhedral, greenish brown to brown in color and show strongly peleocroic from pale green to greenish brown. In some thin sections, hornblende contains inclusions of cloudy (altered) plagioclase, quartz and opaque minerals. Some grains are altered due to urilitization process along the grain boundaries and cracks. Sericite and epidote are found as alteration products of plagioclase crystals. Chlorite occurs as an alteration product after the hornblende; it is pale green in color and has faint pleochroism. Opaque minerals are mostly magnetite, which occurs as single euhedral grains or as disseminated aggregates of very fine grain associated with highly deformed and altered regions. The enclave samples exhibit more or less similar mineralogical and textural features to the enclosing host granitoids, but are finer-grained than the host and constitute more mafic minerals which are mainly hornblende along with biotite. These mafic minerals are surrounded by quartz and plagioclase forming microgranular texture (Plate- 2f).

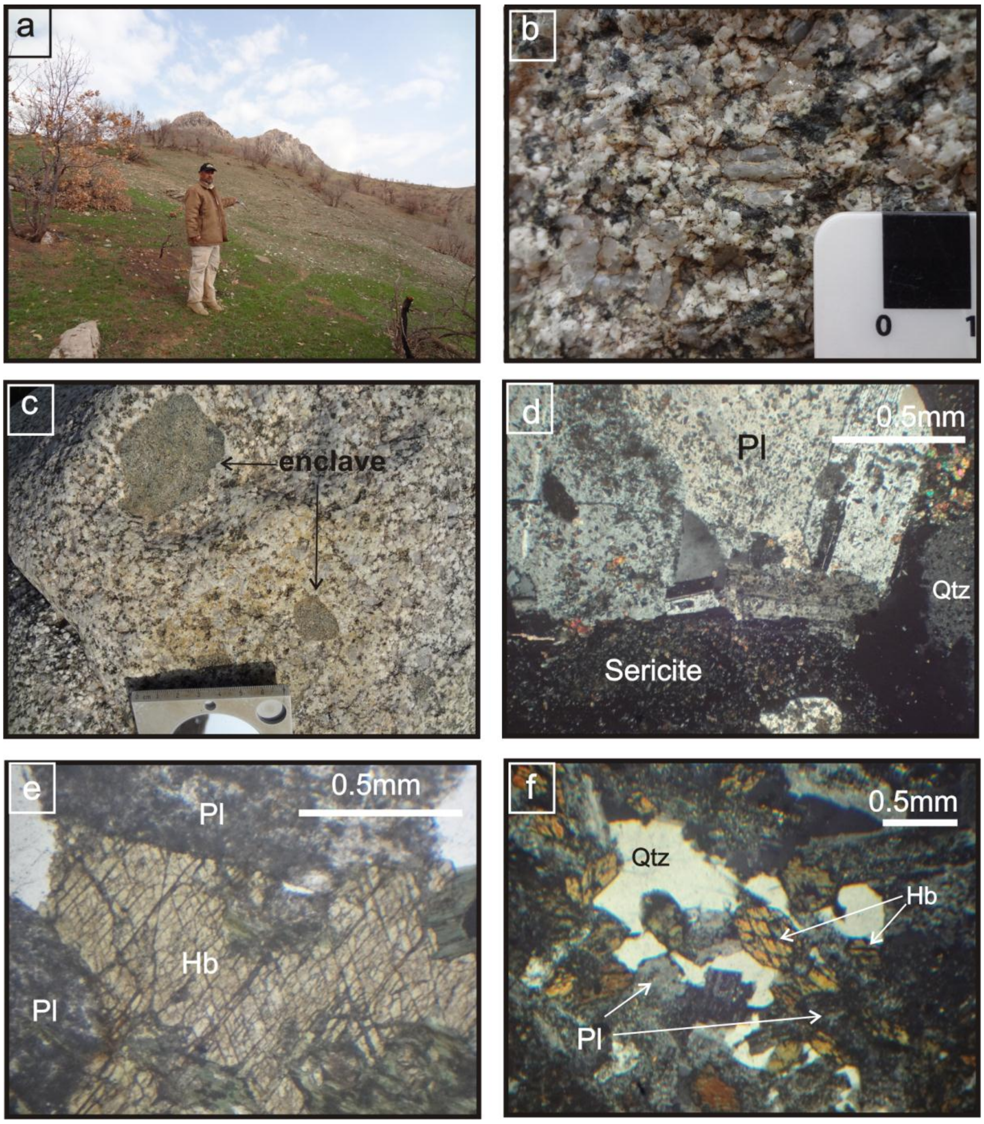

Plate 2- Field photographs and Photomicrographs of the SG rocks.
a and b) Field photographs, massive and coarse grained rocks of the SG.
c) Field photographs, (X.N.), enclaves hosted in the SG body.
d) Photomicrograph, (X.N.), plagioclase grain display deformation twins.
e) Photomicrograph, (P.P.L), fresh crystal with well developed cleavage.
f) Photomicrograph, (X.N.), enclave sample, hornblende with sericitized plagioclase. Symbols: Pl = plagioclase; Qtz = quartz; Hb = hornblende.

Mishao granitoids (MG)

Mishao granitoid rocks (MG) are observed as three bodies, which are located south of Mishao village (Figure- 4).These bodies are surrounded by schist and are coarse grained, porphyritic. The rocks in some parts show some banding sort especially those near the contact with schist and all show quartz and epidosite veins with iron oxides enrichments (Plate- 3a and 3b).

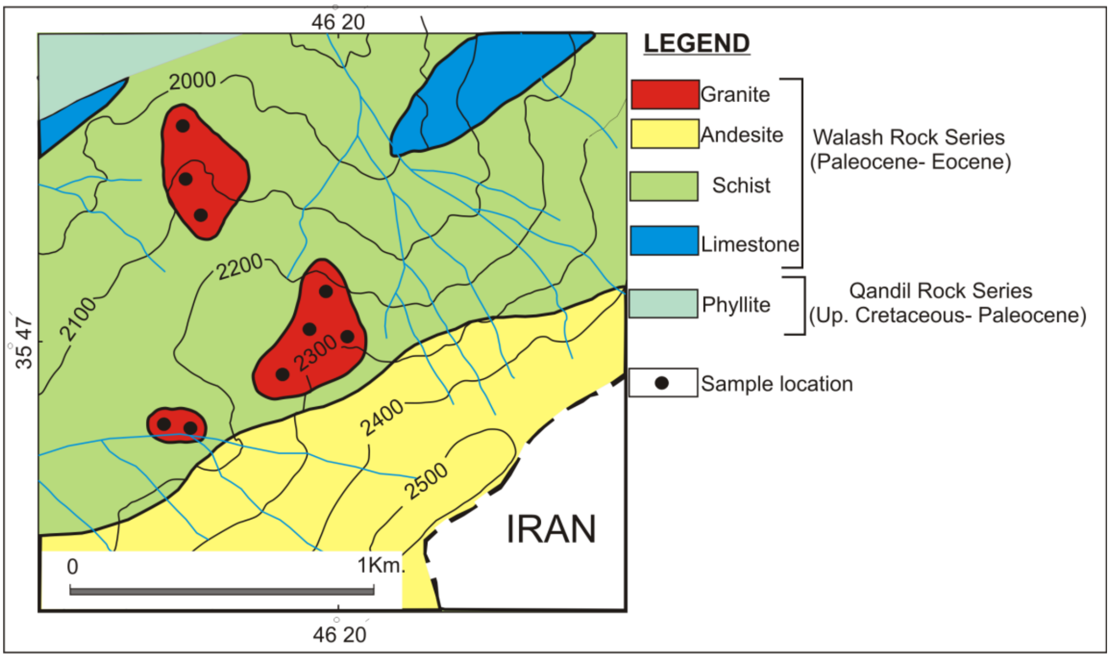

Figure 4- Geological map of the Mishao granitoids [9]

Thirty one thin sections of representative samples from the Mishao granitic intrusion were examined; 10 samples from the northern intrusion, 15 samples from the southeastern intrusion and 6 samples from the southwestern intrusion. The southwestern and southeastern bodies have the same mineral constituents and are composed of plagioclase (35%), Quartz (22%), whereas the northern body is composed of quartz (15%) plagioclase (10%). All show porphyritic texture and can be estimated within the range of mineral composition of granite. Generally, the groundmass composed of very fine grained of plagioclase and quartz in addition to the accessory minerals and alteration products (Plate 3c).

Petrographic examination shows that plagioclases are andesine in composition. They are anhedral to subhedral, with an average grain size of about 1.5 mm. In some of the studied samples, the plagioclase display deformation, fracturing and granulation (Plate- 3d), others show alteration. Quartz is observed in the most of samples. It is anhedral to subhedral, with an average grain size of about 1.8 mm (Plate- 3e). Quartz phenocrysts are the most abundant constituent in northern body. Some of the quartz grains show undulose or wavy extinction due to deformation. The groundmass is composed mainly of fine grains of plagioclase and quartz with small amount of accessory minerals including pyroxene and iron oxides. Chlorite and sericite are also observed as alteration products of the groundmass of both mafic and plagioclase minerals. The groundmass makes about 43 % by volume in the southeastern and southwestern bodies whereas in the northernern body it makes about 75 % by the volume of the total rock. The enclave samples exhibit more or less similar mineralogical composition to the enclosing host granitoids, but are finer-grained than the host and constitute more mafic minerals which are mainly amphibole and chlorite. These mafic minerals are surrounded by quartz and plagioclase
Forming microgranular texture(plate- 3f).

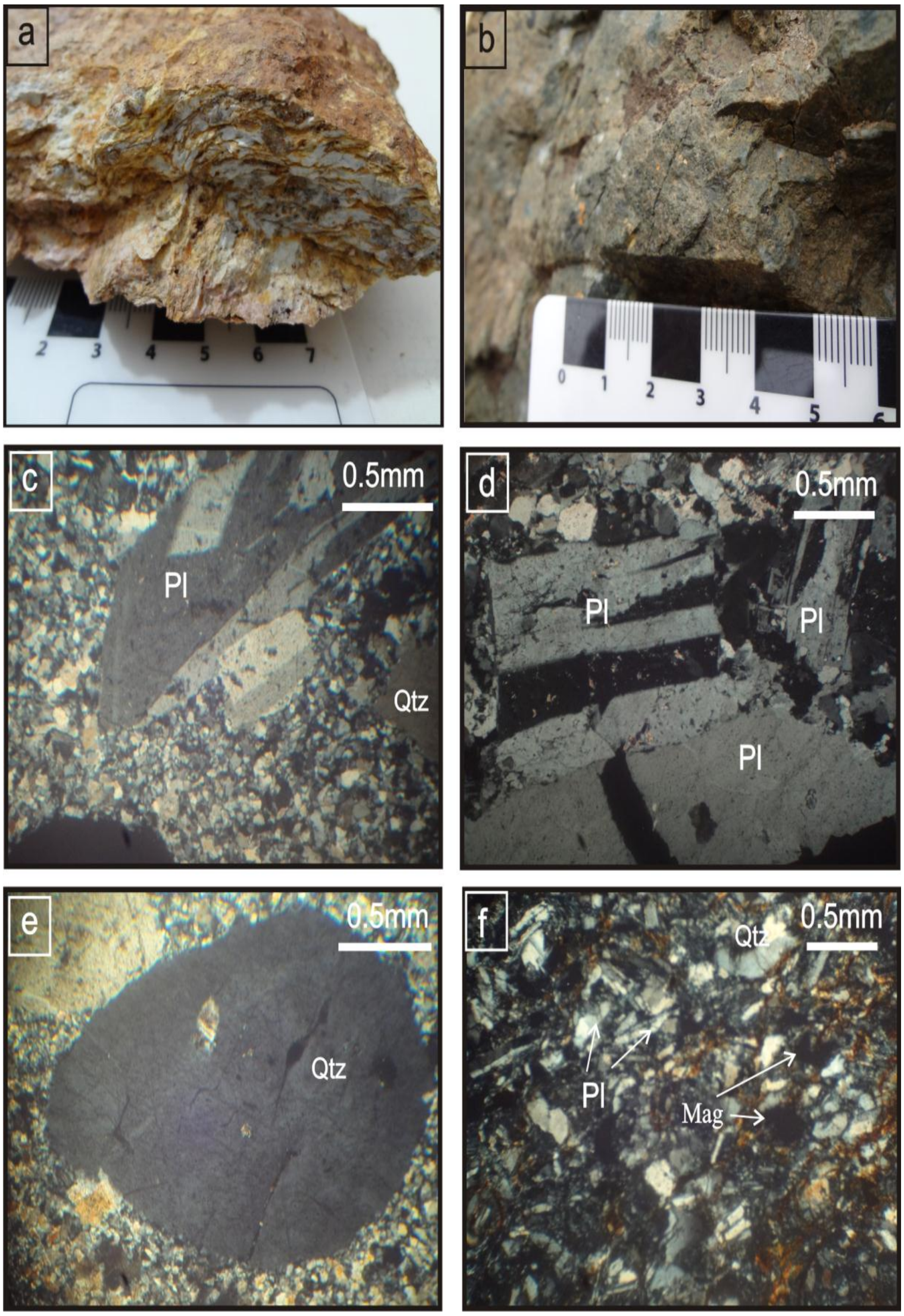

Plate 3- Field photographs and Photomicrographs of the MG rocks.
a and b)Field photographs, sort of banding minerals and iron oxides enrichment.
c) Photomicrograph, (X.N.), porphyritic texture.
d) Photomicrograph, (X.N.), plagioclase displays deformation twins.
e) Photomicrograph, (X.N.), relatively rounded quartz crystal imbedded in very fine grained groundmass.
f) Photomicrograph, (X.N.), mineral composition of enclaves in the MG rocks. Symbols: Pl = plagioclase; Qtz = quartz and Mag = magnetite.

Laladar granitoids (LG)

Laladar granitoid rocks (LG) are observed in two bodies, southeast of Laladar village within the Katar Rash volcanic rocks (Figure-5). They are medium to fine- grained, porphyritic with high iron oxides content. The rocks are generally highly altered and contain veins of quartz and epidosite, (Plates- 4a and 4b).

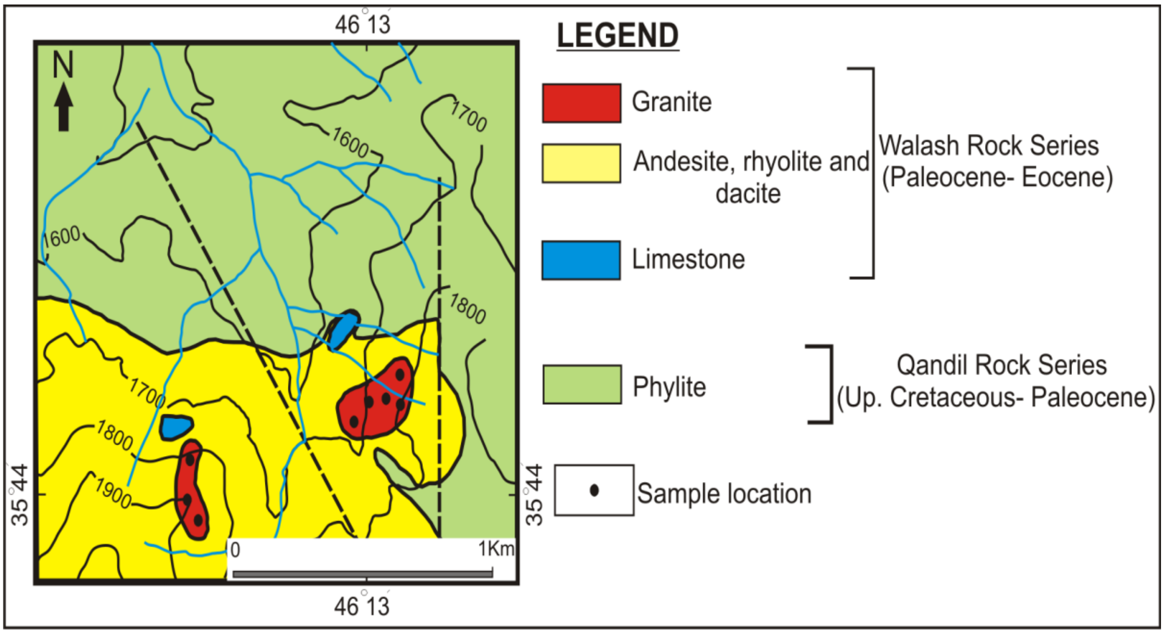

Figure 5- Geological map of the Laladar granitoids [9].

Thin sections of thirty nine representative samples from the two bodies of Laladar granitic intrusion were examined; 24 samples from the northeastern body and 15 samples from the northwestern body.
In general, the studied samples show porphyritic texture and composed of plagioclase (25%), quartz (21%) and (54 %) groundmass which is composed of very fine grained plagioclase and quartz in addition to the accessory minerals and the alteration products. These rocks can be classified as granodirite to granite based on mineral composition. Plagioclase is the most abundant constituent with composition ranging from albite to andesine (Plate- 4c). Some of the samples are deformed and strained where plagioclase displays deformation twins and show tapering away of the lamellae toward undeformed area. Others, plagioclase grains undergone alteration to sericite and epidote and some are completely altered (Plates- 4d and 4e). The quartz grains are anhedral to subhedral, with an average grain size of about 1.8 mm. Quartz grains mainly undergone deformation, which is clearly evidenced by the undulose extinction (Plate- 4f). The groundmass is composed mainly of fine grains of plagioclase and quartz with small amount of accessory minerals including pyroxene and iron oxides. Chlorite, amphibole and sericite are also observed as alteration products (Figure-9d).

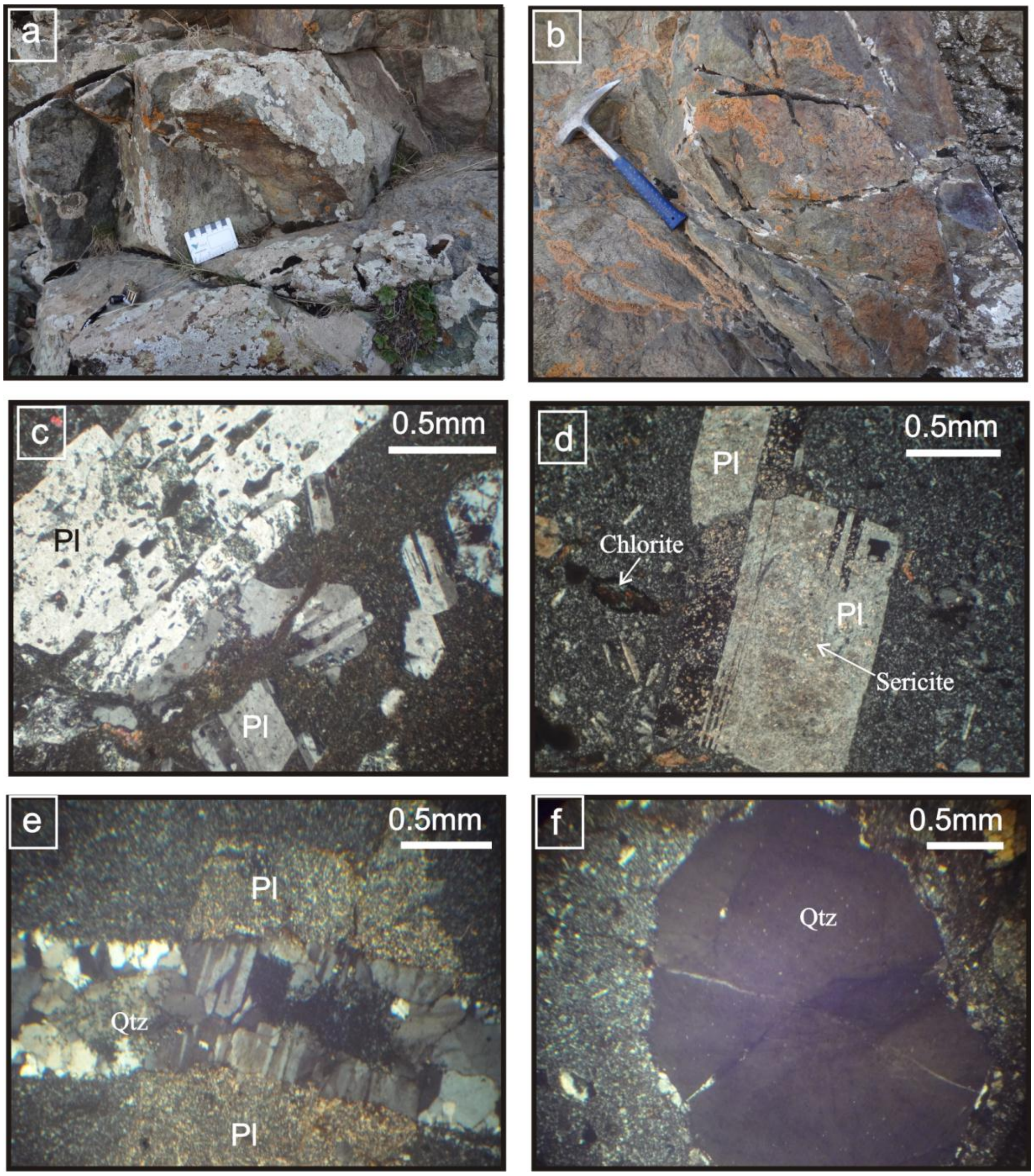

Plate 4- Field photographs and Photomicrographs of the LG rocks.
a and b) Field photographs, massive and iron oxides enrichment.
c) Photomicrograph, (X.N.), porphyritic texture with relatively fresh plagioclase.
d) Photomicrograph, (X.N.), the twin lamellae tapering away toward undeformed area.
e) Photomicrograph,(X.N.), quartz vein cut the sericitized plagioclase crystals.
f) Photomicrograph, (X.N.), relatively rounded quartz crystal imbedded in very fine grained groundmass. Symbols: Pl = plagioclase and Qtz = quartz.

Damamna granite (DG)
The Damamna granitic intrusion (DG) is located to the northwest of the Miran village. It is a dike-like granitic body which is located within Qandile Metamorphic Rock Series close to the Iranian border (Figure-6). This body is surrounded by schist and is whitish grey, pale green and pink in color, massive and fractured (Plates- 5a and 5b). Some samples are rich in iron oxides. The rocks near the contact with the schist show some sort of banding minerals.

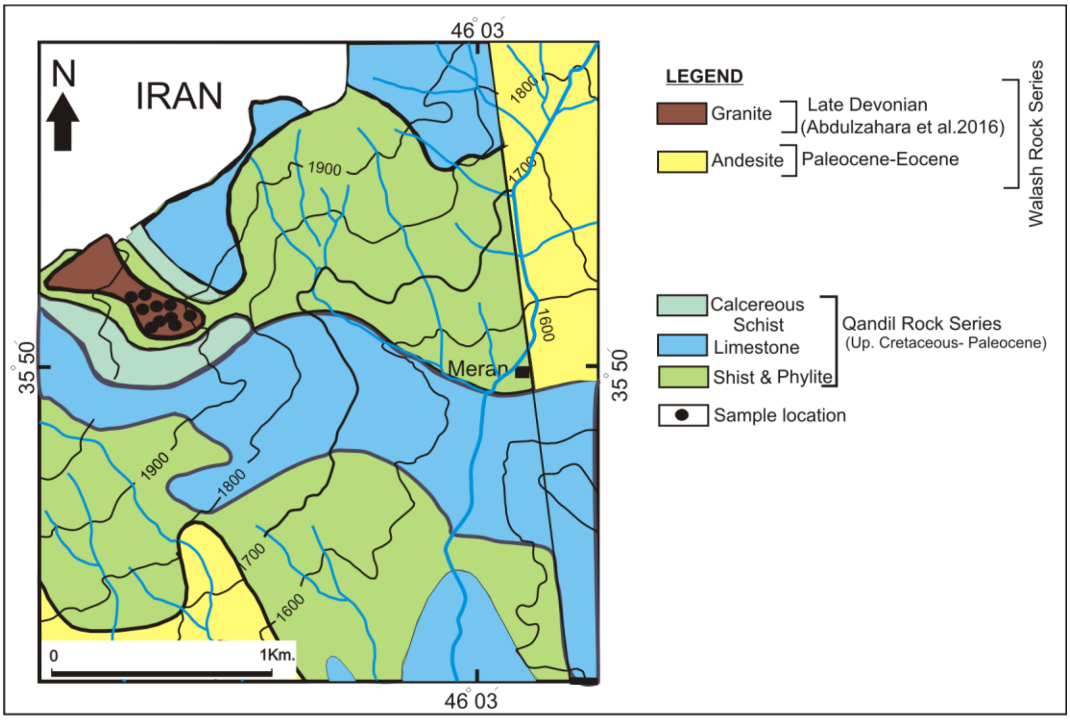

Figure 6- Geological map of the Damamna granites[9].

Twenty two representative samples from the DG rocks were collected from the central and southern parts. The northern part is neglected because it is very dangerous due to the spread of landmines. The r.ocks of DG are composed of K-feldspar (52%), quartz (38%) and small amount of plagioclase (<3%), and can be estimated as granite according to mineral composition. Zircon, apatite, and amphibole are the accessory minerals identified making about 7% with muscovite, sericite, chlorite and iron oxides as alteration products. The K-feldspar (orthoclase) grains are anhedral to subhedral, with an average grain size of about 1.7 mm. Graphic intergrowth relationships between feldspar and quartz is observed in most of the samples (Plate-5c). This reflects simultaneous crystallization of K-feldspar and quartz from a silicate melt close to the eutectic point. Perthitic textures are observed in few samples (Plate-5d) due to exsolution processes, which causes ionic exchange at low temperatures.

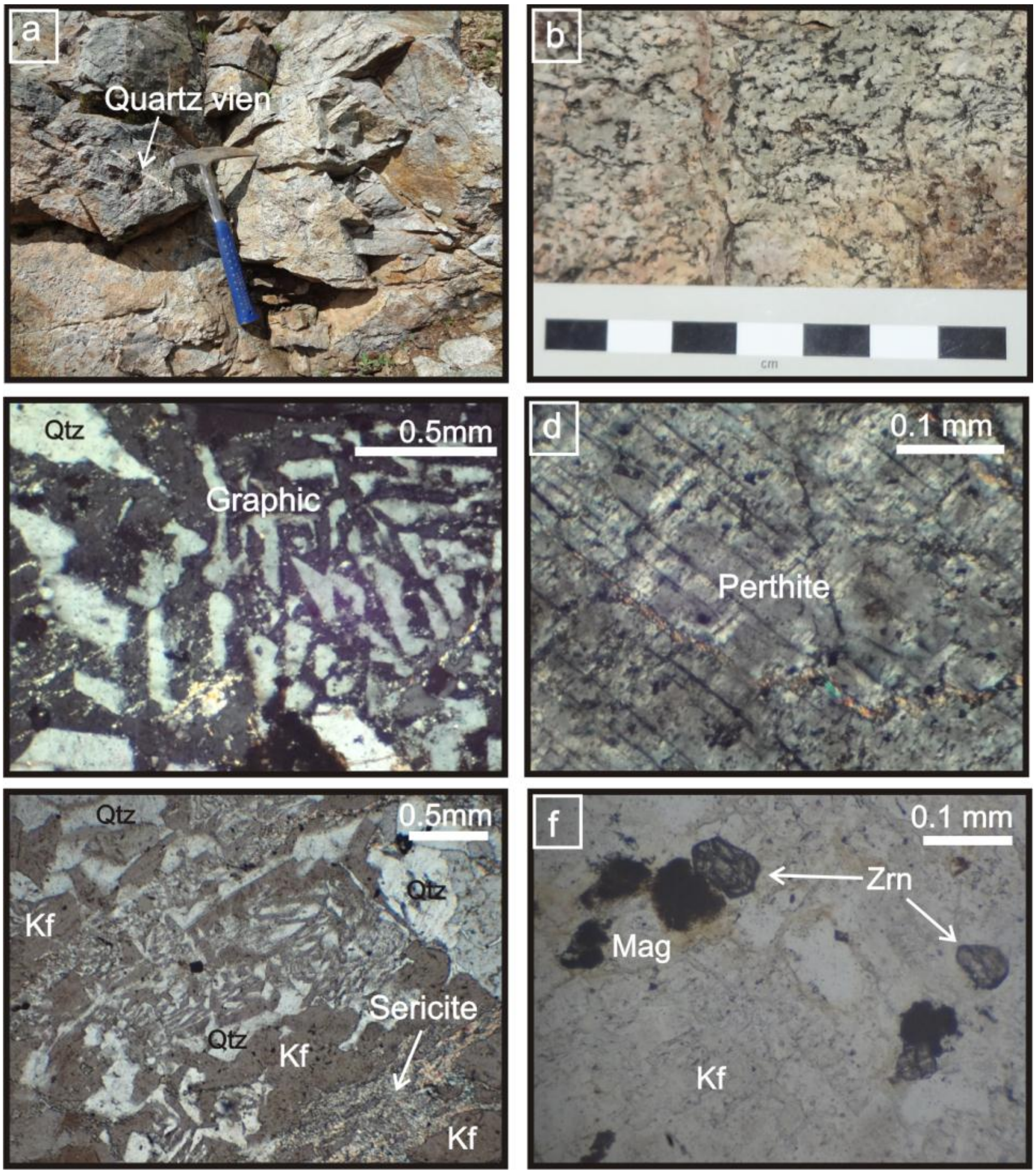

Plate 5- Field photographs and Photomicrographs of the DG rocks.
a and b) Field photographs, massive and coarse grained rocks.
c) Photomicrograph, (X.N.), graphic texture and Zircon grains.
d) Photomicrograph, (X.N.),
perthite texture consisting of intergrowth relationships between orthoclase and albite, where the orthoclase predominates.
e) Photomicrograph, (X.N.), euhehral zircon grains.
f) Photomicrograph, (X.N.), quartz grains occur in graphic, interstitial and as inclusions in feldspar.
Symbols: Kf = alkali feldspar; Qtz = quartz; Mag = magnetite and Zrn = zircon .

In some thin sections, orthoclase grains are cloudy due to alteration and some grains have been completely altered to sericite. The quartz grains are anhedral, with an average grain size of about 0.9 mm; occur in graphic, interstitial and as inclusions in feldspar with some display wavy extinction and some undergone granulation which affects grain size and shape (Plate-5e). In some samples, quartz occurs as micro-veins cross cutting these rocks. Zircon present in all rock samples of DG rocks, it is euhehral grains, with an average grain size of about up to 0.1 mm., and are generally coated or surrounded by iron oxides (Plate-5f). Opaque minerals are mostly magnetite, which occurs as disseminated aggregates of very fine grained, or as single grains (Plate-5e). Moscovite and apatite are rare and found in few samples as fine grained.

Discussion

As previously mentioned, two major types of granitoids are observed in the eastern and western part of the Shalair Valley area. The bodies in the eastern part (AG, SG, MG and LG), have similar mineral composition but show different events of fractional crystallization conditions. The Aulan and Siristan bodies in the northern part show equigranular texture, indicating stable fractional crystallization conditions. The Mishao and Laladar rocks show porphyritic texture, reflecting unstable fractional crystallization event. Variable degrees of deformation and alteration were observed in the Shalair granitoids. It is marked by abundances of secondary twins and granulation of plagioclase into smaller subgrains. Plagioclase crystals show deformation twin lamellae, where they show, tapering, bending and crossing of different sets due to post solidification processes [20]. By increasing of the deformation intensity, the subgrains boundaries in plagioclase and quartz crystals were developed, particularly where the large crystals impinge on each other. Sericitization, chloritization and saussuritization (epidotization) are typical alteration types in these rocks. Sericitization is obvious in plagioclase with some grains completely replaced by sericite and some are replaced by epidote. In some thin sections, chlorite occurs as an alteration product after the pyroxenes and secondary amphibole minerals. It is important to note that the southern limb of the Shalair anticline is more deform than the northern one, the value of the dip ranges from 30° to 70° for the southern limb and from 20° to 40° for the northern limb. [16]. It is likely that the granitic (MG and LG) magmas were reaching through fractures into shallow crystal levels and crystallized possessing porphyritic texture nature. Whereas the magma of the granitic bodies in the northern limb (Siristan an Aulan) shows relatively more stable crystallization condition and show equgranular texture. However, the granitic rocks are found in various tectonic settings, from anorogenic intraplate to orogenic subduction zone as well as continental-collision zone [21- 24]. The previous studies based on geological investigation estimated that the Shalair valley igneous activity was in Tertiary [16, 9] or in the late Cretaceous–Late Miocene [25] with calc-alkaline affinity in an active margin [3, 26]. Recently, [27] studied Zircon U-Pb ages and geochemistry of the DG rocks; they have been dated these rocks using zircon U-Pb ages and yield crystallization ages of 364 to 372 Ma, which corresponds to the Late Devonian period. Moreover, they suggested that the DG rocks were formed in the initial stage of rifting of the Sanandaj-Sirjan Zone away from Gondwana which is related to the Hercynian Orogeny and occurred in the Late Devonian.

Conclusion

Two major types of granitoids are observed in the eastern and western part of the study area. Aulan, Siristan, Mishao and Laladar rocks composed of plagioclase + quartz ± hornblende, suggesting cogenetic origin for them. These rocks reflect two stages of intrusive events, starting with stable fractional crystallization conditions represented by Aulan and Siristan granitic plutons with equigranular texture and a late stage of unstable crystallization conditions represented by Mishao and Laladar granitic plutons with porphyritic texture. Damamna granites in the western part have different mineral composition compared with the eastern part. These rocks are composed of K-feldspar, quartz and small amount of plagioclase with graphic texture represented by the intergrowth between K-feldspar and quartz, reflecting simultaneous crystallization of K-feldspar and quartz from a silicate melt close to the eutectic point.

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