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Petrological Conditions Igneous Intrusive Mass of Zahedan-Southeast Iran

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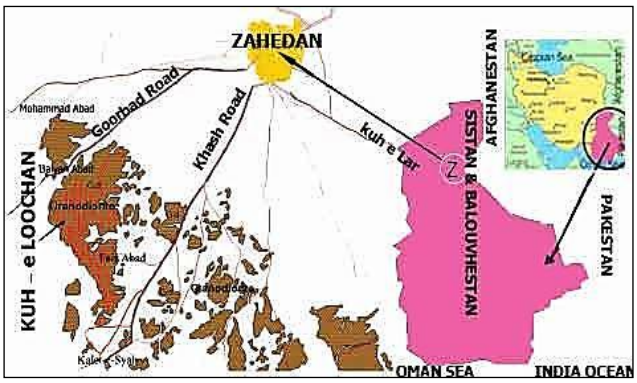
Abstract-Zahedan granitoid mass (upper Eocene - Oligocene), the largest intrusive igneous mass in granitoid belt Zahedan - Saravan the Southwest - West and south to southeast of Zahedan, the exposed populations such as narrow, low, high and larger populations scattered in neighboring Pakistan and Afghanistan that the flysch old in southeastern Iran and is the contact metamorphism of the host rocks. In this research field, petrographic ground conditions and specific mass of plutonic igneous tectonic zone in Zahedan, depending on the specificities of petrographic (microscopic sections) and petrology (chemical analysis) and large rock outcrops high in the batholith Loochan, three front is studied .
Petrological diagrams of binary and According to the Pertite and Large amounts of alkaline feldspars Orthoclase With Pertite the number of plaques obtained from Loochan batholith and Front of curved mica granite melting curve stability diagram also cited, Batholith intrusive igneous mass of water vapor pressure environment Loochan In Zahedan region About 2Kbar and temperatures of about 700°C, respectively.
According to a transformation of the old flysch rocks in the area and Diagrams of alkali - silica and The diagrams TAS, Mass of intrusive igneous Zahedan, Especially in the area of the batholith Loochan Land of birth and The collision of continental plates, The origin of Zahedan granitoid, Partial melting of continental crust in a shallow area.

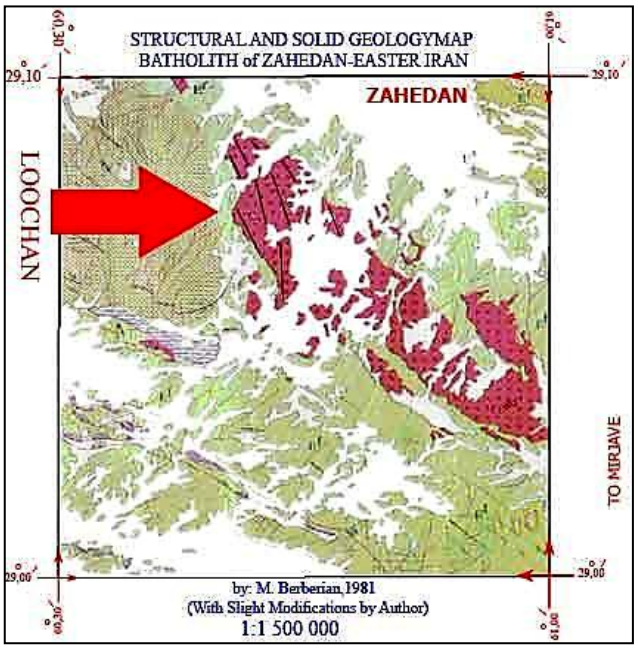
Keywords- *Southeast of Iran, Zahedan intrusive igneous mass, Petrological studies, the temperature and pressure, the melting of the continental crust*

I. INTRODUCTION

Mass of plutonic igneous Zahedan in the range of longitude 60˚ and 61˚40' eastern longitude and latitude 29˚ to 29˚30' North (Figure 1.b), with an area 750Km^2 [1] and the average height of 2200m above sea level in southeast and neighboring countries of Iran, Pakistan and Afghanistan are located (Figure 1.a).



(a)



(b)

Figure 1. (a) Mass of intrusive igneous Zahedan in southeast and neighboring countries of Iran. (b) Mass of intrusive igneous Zahedan (With slight modifications by author)

The mass of the batholiths in southern and southwestern city of Zahedan in the Southeast Iran, in the central region of Sistan-Suture zone [2], the two blocks broad and strong, but rotary motion Lout in West and the Afghan East as a part of outcrop of narrow [3], low dispersion and high Loochan with outcrops extensively on the surface appears (Figure 2).

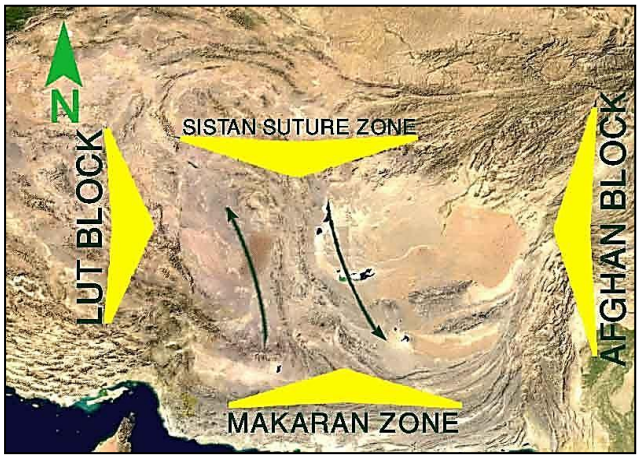


Figure 2. Location of Sistan- Suture Zone - South- East Iran

Intrusive igneous mass acme in Zahedan, the igneous peaks with an altitude of about 2565m above sea level is Loochan. Loochan lowest points mainly in southern regions, Have an altitude of about 1700m above sea level is. Loochan peaks and Morgan With an altitude of around 2565m and 2403m Zahedan located approximately parts of the central mass of the batholiths. So batholiths womb was generally high statistical average height above sea level which is about 2200m.

Therefore; the scope of tectonic batholiths Loochan is introduced. Loochan batholiths, The corners of the rectangular shape of the North and South sides of the rectangle, respectively Circuits29°10' to 29°25' north and eastern borders it to the west of the meridian of 61°40' to 61°45' East are given (Fig. 3).

Access roads to the north of the batholith Loochan, Goorband rural paved road length of about 20 km (distance to fault village Goorband 3 at the end of the valley of the same name) is Siyadak to the village. East side of road access to the village GharibAbad Loochan batholiths and eastern highlands Loochan and Morgan, about 20 km.

A. Access roads

Loochan batholiths of southern and south-western access route include about 10 miles of paved roads, the degree of a hermit - Kash and rural paved road about 20 km south of Faizabad -e- Loocho and Rahmatabad. Access to the western side of the batholiths Loochan about 30 km asphalt road in Zahedan - Kash and about 12miles of paved roads and 10kilometers of rural road sand Qatarkhanjak - Rural Ebrahimabad. In this area, adjacent to the batholiths contact and regional metamorphic schist's Loochan with igneous - metamorphic rocks older batholiths metamorphic visible. Specificities of climate on geographical limit mass of igneous intrusions Zahedan, hot and dry (Fig. 4) with drastic changes in daily temperature and y is the area of climatology in the border desert climate - semi-desert is located [4].

B. Regional climate

Specificities of the regional climate, plays a major role in the degradation and erosion of rocks and thus make certain geomorphological structure of the play. Low humidity, high temperatures and a wide range of temperature changes, especially during the day and seasons as the most important form of degradation phenomena Temperature cleavage and the water content in the cleavage of water and ice cleavage phenomenon has led to the degradation rocks occurred mainly in physical form, Performance of physical weathering chemical weathering in the region is evident.

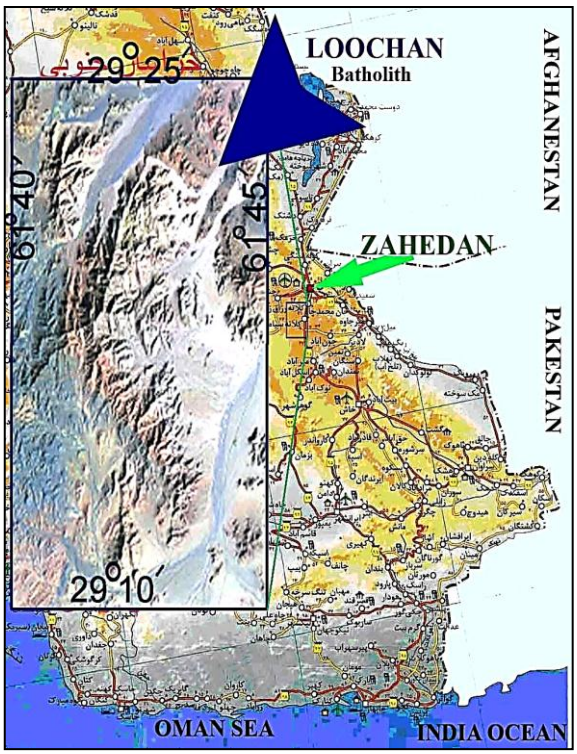


Figure 3. Geographic batholith outcrops and Loochan

Figure 4. Desert climate - semi-desert in the batholith Loochan

C. History of Geology

Studies on the geological history of the South East and intrusive igneous mass Zahedan published field studies Camps and Griffis(1982) [5], Berberian et al. (1982) [3], Tirrul et al. (1983) [2], McCall(1985) [6] and... Begins.

The dimensions of the batholith vary between stocks and dykes. The extent of intrusive igneous mass of Zahedan Garaghe mountain in the mountains Northwest of Zahedan Bug mountain- Mirjaveh near the border with Pakistan and Iran, about 200 kilometers [7]. Area about 250 kilometers long and extends longitudinally Saravan are.

Based on measurements of argon and potassium (Table 1) Zahedan examples granitoid Camps and Griffis (1982) [5] to determine the age of rocks formed about 32 million years for the time being.

TABLE I. RESULTS OF THE STUDIES ON GRANITE ZAHEDAN (CAMPS AND GRIFFIS 1982)

Igneous unit	Sample	Method	Age (M - Y)
Zahedan granite	G - 1081	Biotite	32.4 + 1.6
	G - 1079	Biotite	32.2 + 1.6
	G - 1077	Biotite	12.9 + 2.6
	G - 1038	Biotite	33.6 + 1.7

Zahedan Batholiths' age of the granite with K - Ar, about 31-33 million years is calculated Matches the upper Eocene - Oligocene beginning.

It forms the tectonic events in the Lout Block, the West Block Helmand (Afghanistan) in the East know[3]. Tectonic activity in the area that are affected by numerous faults, not the fault of Zahedan - Zahedan fault Nosratabad in the West and in the East (Fig. 5) are [5].

Lithology in Zahedan batholith consists of five original rock masses, dikes parallel or nearly parallel, Various xenoliths, of quartz veins and pegmatite's [7] has been divided. The final phase of magmatic activity in the southeastern Iranian city of Zahedan in Tectonic pegmatite's batholith can be seen.

II. PETROGENESIS

Lithology's outcropping in the broadest and highest in the region southeast of Zahedan intrusive igneous mass, the mass of the surrounding mountains and rocks Loochan includes the high mass granitoid Loochan, dikes, xenoliths and quartz veins and pegmatite consists in integrating the intrusion the Loochan are.

Specifications for accurate determination of the mass of plutonic igneous Petrogenesis Zahedan, Loochan batholith adjacent areas such as the highlands Rogan and Morgan, Poodchah, Gharib Abad, mass Manzelab single fault, Faizabad and outcrop area around the bed like Qtarkhnjk Loochan were also studied . Petrological study of the results of series of magmatic intrusive igneous mass in other areas of Zahedan and low-lying outcrops are small and scattered, and shall also be invoked.

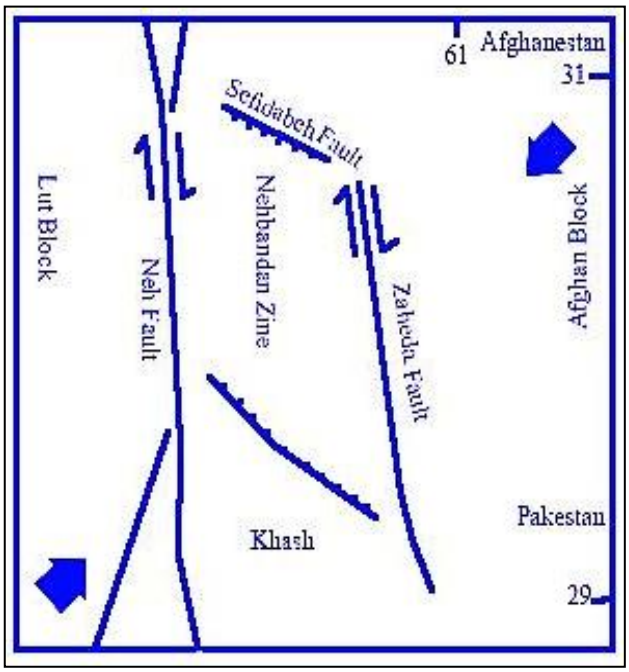


Figure 5. The main fault zone of eastern Iran

To determine the range of conditions of temperature and pressure, especially the pressure of water vapor during the formation studied granitoid, Petrological solutions of binary systems Ab - Or [8], and a trio of Ab - Or - Q[9] was used.

A. Petrological binary system albite – orthoclase

The following figure (Figure 6) Petrological binary system albite - orthoclase in terms of vapor pressure 2Kbar [8] shows.

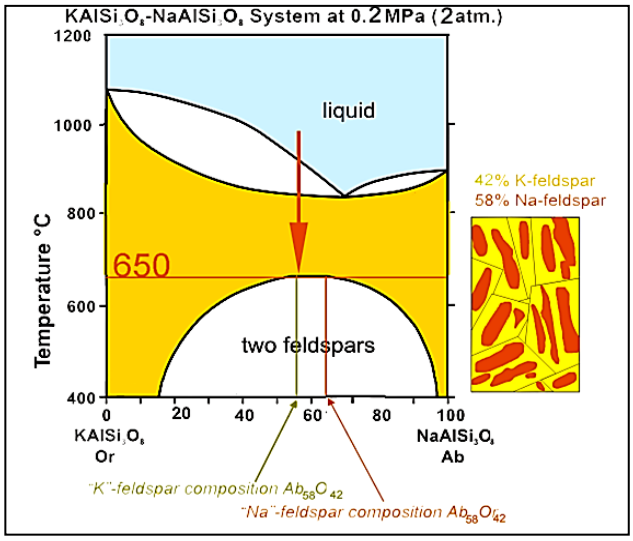


Figure 6. Binary system albite - orthosis in vapor pressure of 2 kilobars (Tuttle and Bowen, 1958)

In the binary system, the low vapor pressure (about 2Kbar pressure) melting curve (liquidus) and freezing curves (solidus) solution of feldspar Lkaln climbs to higher temperatures. Solidus thus deviating curve, Environmental conditions for the formation Prtyt provided. The following figure (Figure 2) binary system albite - orthoclase in terms of vapor pressure above the pressure of 5Kbar shows.

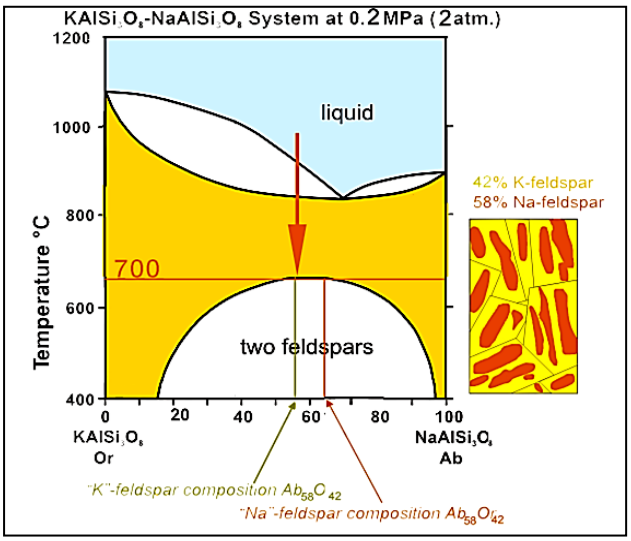


Figure 7. Binary system albite - 5Kbar orthosis pressure steam

In this binary system, the vapor pressure of about 5Kbar, liquidus curve and the curve solidus Transferred to lower levels of temperature and With the demise of the previous conditions, Other basic igneous rock texture, Prtyty or not MicroPerthite tissue formation, Orthoclase feldspar crystals of potassic and sodic Plagioclase hay apart are formed independently.

The microscopic study of thin sections of samples from the masses of igneous rocks, Combination of minerals, especially Orthoclase and quartz (Fig. 8) the formation of tissues. Like texture in igneous rocks is Prtyty [10] .

The figures refer to numbers 1 and 2, the vapor pressure of the environment in the area of Zahedan Loochan batholiths and the formation temperature of about 700^{oC} is about 2Kbar. So petro-genesis conditions (temperature - pressure) in the Southeast granitoid in Zahedan area of low pressure - low temperature is determined.

These findings have been reported on the degree of alteration of the intrusive igneous mass Zahedan On the rocks It shows that Regional metamorphic rocks from the intrusive igneous mass in Zahedan region Are low to medium grade metamorphism [1], Correspond.

Temperature to determine the mass of intrusive igneous Zahedan, Loochan batholiths in the southeast part of the mass, the ternary diagram orthosis - albite - quartz Normative was used.

Local Norm is calculated composition for the studied samples are shown in Figure 10.

Figure 8. Formation Ourthoclase with Pertite The granitoid rocks the area Loochan – Zahedan

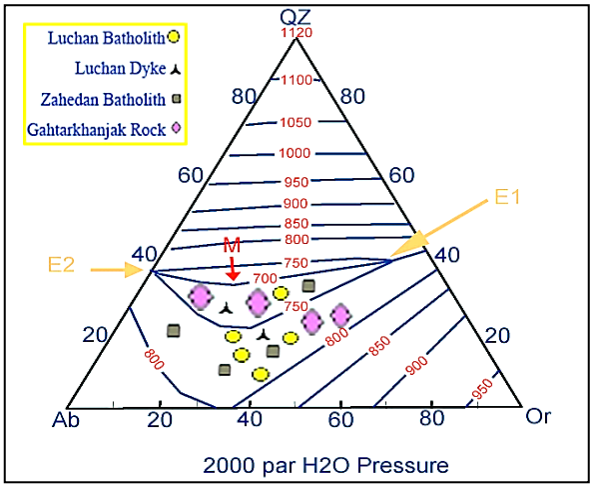


Figure 9. Ternary diagram (Winkler, 1976) isotherms line ... Ternary system Q-Ab - Or ... The pressure 2Kbar, Points E1 and E2 are eutectic point. Point of M, the temperature on the minimize ... Shows.

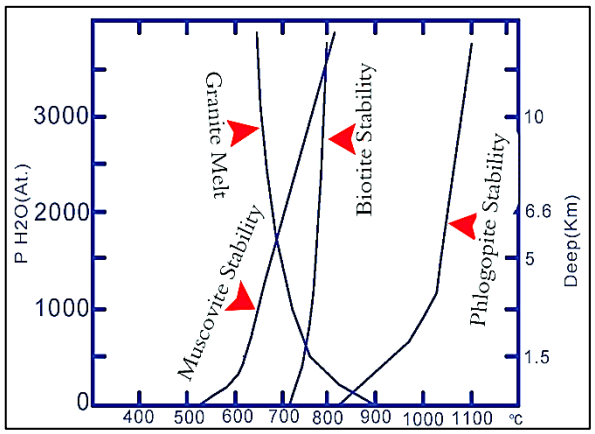


Figure 10. Stability curve of muscovite and Stability of phlogopite and Melting curve of granite [11] and [8]

According to this chart, petrographical, Temperature of the study area consists of igneous rocks Temperatures around 700°C to 800°C are determined.

B. Petrological stability diagram muscovite - Biotite granite along the melting curve.

Stability diagram of muscovite – Biotite Along the melting curve of granite It features a lot of pressure, temperature and water vapor during the formation studied granitoid masses and The validity of findings from field observations, the study of microscopic sections and diagrams Petrological study confirmed previous.

The diagram shows the curve at a temperature of 760°C temperature stability of Biotite and about 625bar the water vapor pressure Granite melting curve cuts And muscovite stability curve with decreasing temperature at 680°C and a vapor pressure of 1650bar, Granite melting curve cuts. As a result of providing any of the above conditions Mica is a specific form. All of the minerals Biotite and Muscovite minerals in Zahedan granitic rocks particularly integral part of the batholith shows Loochan Stability of the two minerals formed deep within the granite. 6 to 11 km near the surface (Fig. 10). The surface areas of the earth's crust.

All granites Zahedan quartz, orthoclase, plagioclase and Biotite are. In addition, secondary minerals muscovite and ... It can be seen in [10]. Zahedan in Zargoly batholith granites in the northwest, a Biotite - and Biotite granite - granodiorite are [12]. PhonoCrystall see many sections of Biotite in plutonic igneous rock mass Zahedan [7], [1], especially in the area Loochan, Conditions of low temperature, low pressure, about 760°C and shows. The mass of granitoid systems Simulation The heating mantle near the crust cooling system, there is [1].

Based on the data obtained from the analysis Makroprop amphibole minerals contained in the granitoid rocks of Zahedan, Using the formula proposed by Schmitt (1992) [13] Zahedan intrusive igneous mass substitution depth of about 9 km deep in the Earth's surface is Then come the higher elevation [1].

At the end of the final magma Shrinkage cracks and fractures in the dike intrusion - tectonic made in bulk in large parts of the mass of intrusive igneous Zahedan has emerged. Generally fine-grained matrix Myrmekitic the granitoid rocks Intrusive igneous mass in Zahedan Granite shows very quickly (less depth) is cool and solidifies [1].

Experimental work Winkler(1974) [9] shows that the water-saturated conditions and at low pressures in the crust between 2 to 4 kilo bars pressure, partial melting of sedimentary rocks Such as shale and greywacke, Granitic melt is obtained.

The experimental work Clinic (1972) [14] showed that a molten granite or granodiorite melt plate of scale can be achieved. The following evidence suggests that the origins of granites are shallow continental [15]:

- Adoption of the acid and the formation of large igneous body mass batholith solid and rigid shell is problematic unless they are the result of partial melting of continental crust to know.

- Many different enclaves, especially enclaves of sedimentary and metamorphic, that some are even little changes cannot be seen (Fig. 11).

Figure 11. Example of Sedimentary xenoliths in the Loochan

The transformation of low- grade metamorphic rocks indicate formation under low temperature and low pressure, the lower the melting of deep continental crust, is (Fig. 12).

Figure 12. The Batholith near Zahedan (brighter part) metamorphic rocks from the melt (darker parts) - (Photo from the southern part Loochan – Takhtak (Small beds) – e- Ghatarkhanjak is harvested.)

The granitoid masses and chemical analysis of major elements and trace elements, diagrams and charts to fit experimental the role of tectonic origin, Two groups. Orogeny and non-orogeny granitoid of granitoid are classified. Terms of orogeny granitoid Al2O3 amounts of non-orogeny granitoid are richer There are Diaper batholith the calk-alkaline batholith and domes are seen to be of materials that are rich in alkali. In contrast, non-orogeny granitoid are associated with alkaline complexes[1].

To determine the origin of rocks and tectonic granitoid masses based on the main elements of the chemical analysis of samples taken from outcrops of plutonic igneous masses Manior and Piccoli (1989) [16] have presented a model. They are related to the basic elements, the type of orogeny granitoid are divided as follows:

1 -Type of IAG, the type (Island Arc Granitoid) which includes a granite island arc subduction of an oceanic plate under another oceanic plate are formed in island arcs.

2 -Type CAG, continental arc granitoid (Continental Arc Granitoid) the subduction of one plate of a typical subduction

of the oceanic plate under a continental heavy to lighter continental parts are inside.

3 -Type CCCa, continental collision granitoid (Continental) during the collision and the collision of two continental plates - continental form.

4 -Type POG, granitoid are in the final stages of an orogeny at the end of deformations in the continental crust are formed.

The diagram K_2O/SiO_2 Manior and Piccoli (1989) [16] to separate the ocean plagiogranite (Op) Series granitoid used.

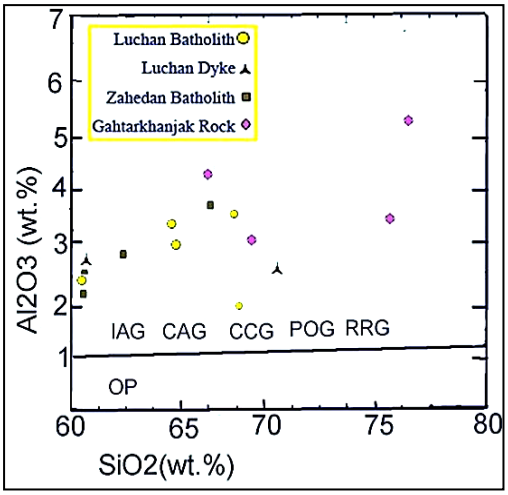


Figure 13. Position of the rocks in the study area variation wt% K_2O Changes compared to wt% SiO_2

According to the diagram (Fig. 14), outside the range of granitoid are plagiogranite oceans.

The diagram Al2O3/SiO2 Manior and Piccoli (1989) [16]granitoid of Group I (type of IAG, Ggg) granitoid of Group II (types CEUG, IRRG) and Group III (type POG) have been separated.

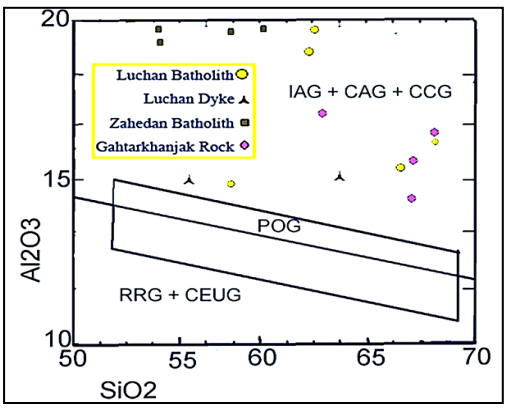


Figure 14. Position of the rocks in the study area variation wt% Al_2O_3 Changes compared to wt% SiO_2

The above diagram (Fig. 14) shows that the granitoid Zahedan Group I (Types TAG, GAH and CCG) are placed.

Diagram A / N + K vs. A / C + N + K [16], [17], which represents the change in mole percent Cat ion and h is the index of Shand (Shand's index) [15] is known for the separation of continental collision granitoid (CCG) from two other types of granite Group I (TAG, CAG)is used.

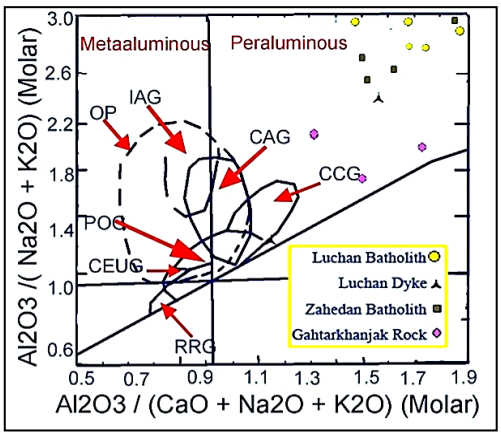


Figure 15. Position of the rocks in the study area Shand index chart

This diagram shows examples of intrusive igneous mass, geographic range, and especially in Zahedan batholith, Located within the Peraluminous, Granites formed in this region, Granite type of aluminum-rich TAG, CCG that the continental plates are colliding with, is. Peraluminous granites of the batholith is the nature of evidence suggests [18], [12].

For a breakdown of granite type's I, II and III together, shows the changes of the weights of SiO2 to FeO/FeO+MgO percent by weight changes are used.

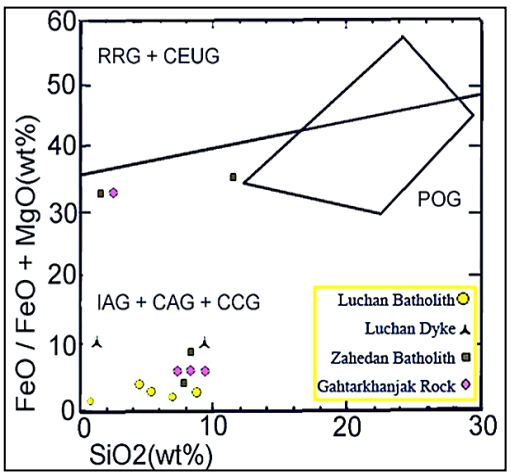


Figure 16. Graph changes oxide into the silica rocks Position

The diagram (Fig. 16) shows that within the studied granitoid of Group I and type granites TAG, CAG, CCG are placed. Based on petrography studies, I type granites can be introduced Zahedan [10], [12].

Diagram of the wt. % FeO and wt. % MgO [16] for further separation of the three groups of rocks are used.

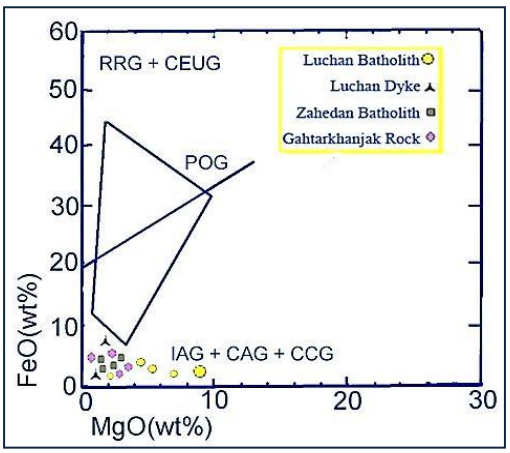


Figure 17. Graph FeO change of position versus MgO variations of granitoids south of Iran

The diagram (Fig. 17) also shows that the studied granitoid are placed in group I.

Wt. % CaO variation diagram of the variation of wt. % FeO + MgO (Manior and Piccoli, 1989) for the separation of granitoid from Group I, II and III are used.

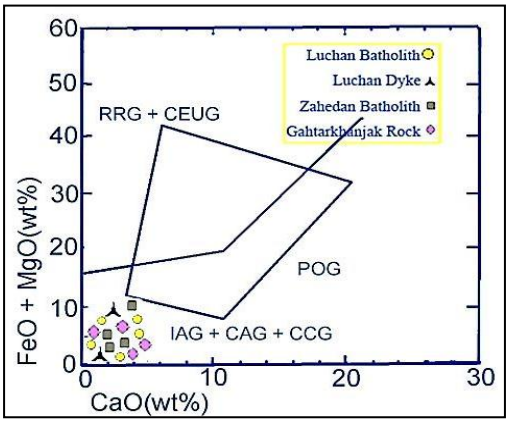


Figure 18. The chart changes in wt% FeO + MgO vis-a-vis wt% CaO and position changes the rock

The diagram (Fig. 18) also confirms that the Group I granitoid are located within the study area. I -type granitoid intrusive igneous mass belongs to Zahedan [10], [1]. Lakhshak mass of granodiorite, 10 kilometers northeast of the city of Zahedan in great abundance The P2O5 and SiO2, similar to I -type granites [19].

The last step for the separation and determination of granitoid Non-orogeny RRG and CEUG types of chart weight wt.% TiO2 versus SiO2 (Fig. 20), was used. This chart shows the range CEUG are Zahedan granites and granite -type continental onshore are creating.

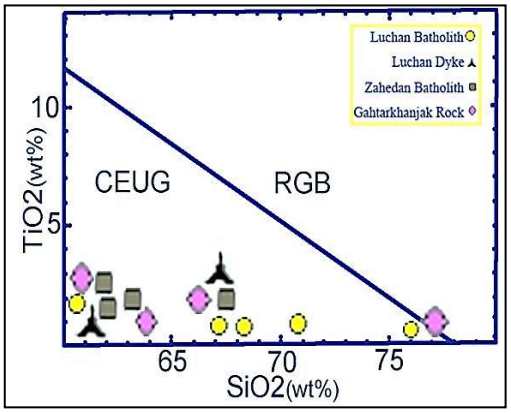


Figure 19. Graph of changes in the status of granitoids wt% TiO_2 wt% vis-a-vis Changes SiO_2

Tectonic setting of granitoid based on the major, minor and rare earth similar position tectonic granites formed in continental margin located [7], a continental arc granitoid and pre-treatment are treated as Orogeny granites are considered part of the [1]. Lakhshak mass of granodiorite in the region, the northern part of the mass of intrusive igneous Zahedan, the amount of TiO2 in the rocks of the continental margin in the range of values are granite TiO2 [19].Tectonic setting discrimination diagrams, the position of the volcanic arc granites (VGA) for the continental margins of intrusive igneous mass appears Zahedan idea [18]. The granitoid rocks of orogeny granitoid types are VGA and CAG [1].Apparently, during the Cretaceous, Two Lout and Afghan blocks Separated by an ocean and a continent have. Looking at the various movements of continental Eurasia, closing the ocean, causing the two blocks together is great. The result of this approach, the flysch sediments a0.15end oceanic crust thrust rocks of calk-alkaline magmatic in the Zahedan granitic rocks were formed [10].

III. CONCLUSION

Petrological diagrams of binary Albite - Orthoclase in 2Kbar vapor pressure and The vapor pressure of 5Kbar Based on the observation of the presence of alkaline feldspar Orthoclase With Pertite and the numerous plaques made from intrusive igneous rocks of the batholith Loochan Zahedan, According to the stability diagram and the mica granite melting curve, The vapor pressure of the magma The mass of plutonic igneous batholith Loochan In the South East region of Iran. About 2Kbar and Formation temperature of about 700°C

to 800$^{\circ C}$, respectively. Studied granitoid of low pressure - low temperature is determined. Based on field evidence - microscopic and Petrological numerous diagrams, Granitoid magma genesis land of creation and study area The collision of continental plates, The origin of granitoid, Zahedan, Partial melting of continental crust in a shallow area.

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TABLE II. RESULTS OF CHEMICAL ANALYSIS OF SAMPLES OF INTRUSIVE IGNEOUS MASS ZAHEDAN - ANALYSIS OF THE LOOCHAN – ZAHEDAN GRANITOID. (ANALYZER: TIRANSETOON CO.)

Sample No.	SiO2	FeO+ Fe2O3	Al2O3	MgO	CaO	Na2O	K2O
L-1	60.73	2.82	21.36	5.42	4.97	3.45	2.25
L-2	68.23	2.33	16.51	6.65	3.02	2.98	2.25
L-3	59.78	2.61	17.87	9.40	5.90	3.29	2.17
L-4	65.10	2.42	17.28	6.79	4.05	3.02	2.34

TABLE III. CHEMICAL ANALYSIS OF SAMPLES TAKEN FROM THE MASS OF INTRUSIVE IGNEOUS ZAHEDAN - ANALYSIS OF THE ZAHEDAN GRANITOID. (ANALYZER: AB AND KHAK CO.)

Sample No.	SiO2	FeO+Fe2O3	Al2O3	TiO2	MnO	CaO	Na2O	K2O
Z-1	62.88	4.68	17.42	0.66	0.11	3.68	3.33	3.41
Z-2	68.3	3.12	14.50	0.52	0.03	2.11	2.96	4.17
Z-3	68.26	2.96	15.49	0.48	0.01	2.56	3.23	4.07
Z-4	66.6	3.37	15.20	0.56	0.04	3.32	2.75	3.32
Z-5	63.0	5.11	16.20	0.64	0.07	2.94	1.93	3.92
Z-6	78.8	0.92	10.00	0.13	0.01	1.26	2.84	5.58
Z-7	77.5	1.47	13.30	0.25	0.03	1.21	2.55	5.48

TABLE IV. CHEMICAL ANALYSIS OF SAMPLES TAKEN FROM THE MASS OF INTRUSIVE IGNEOUS ZAHEDAN - ANALYSIS OF THE KATKHANJAK – ZAHEDAN GRANITOID. (ANALYZER: KEMIASANG CO.)

Sample No.	SiO2	FeO+Fe2O3	Al2O3	TiO2	CaO	Na2O	K2O	MgO	LoI
K-1	67.1	3.59	15.79	0.15	3.46	3.79	2.85	1.27	0.12
K-2	68.2	3.16	16.10	0.15	3.44	4.20	1.95	1.75	0.07
K-3	56.9	6.16	24.30	0.10	3.12	3.48	2.45	1.96	0.22
K-4	61.4	4.78	18.90	0.12	3.36	3.68	2.23	1.76	0.13
K-5	67.5	3.58	15.50	0.15	3.46	3.80	3.36	1.37	0.12
K-6	54.8	6.52	26.20	0.12	3.01	3.12	2.86	2.02	0.49
K-7	59.9	5.31	21.70	0.11	3.18	3.29	2.34	1.68	0.47

TABLE V. CHEMICAL ANALYSIS OF SAMPLES TAKEN FROM THE MASS OF INTRUSIVE IGNEOUS ZAHEDAN - INTERMEDIATE DYKE ANALYSIS OF THE ZAHEDAN GRANITOID. (ANALYZER: AB AND KHAK CO.)

Sample No.	SiO2	FeO+Fe2O3	Al2O3	TiO2	MnO	CaO	Na2O	K2O	P2O5	MgO	LoI
D-1	70.0	2.70	15.8	0.05	0.05	3.03	4.41	2.66	0.13	1.02	1.9
D-2	58.1	5.20	15.6	0.85	0.08	5.60	3.70	2.91	0.29	3.64	2.9