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Geochemical Characteristics of Mourzidie Intrusive Rocks (South of Libya)

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Abstract:

This study is based on the chemical composition of the Merzidie rocks in southern Libya. It utilizes previously documented data to complement and expand upon earlier studies. This data includes an analysis of the igneous rocks in the study area, focusing on the chemical composition of the main elements. The available data is used to better understand these rocks. The results show that the rocks are primarily composed of granite, granodiorite, and quartz diorite, and that most are rich in silica. Specialized diagrams such as TAS and (SiO_2–K_2O) diagrams were used in this study to classify the rocks and determine their affiliation with different groups. The Merzidie rocks are characterized by a high silica content, exceeding 65%, which classifies them as felsic igneous rocks. From a geochemical perspective, considering the potassium content of the rocks, most samples exhibit potassium-rich alkaline calcifications with a slight tendency towards shoshonitic characteristics. Regarding aluminum saturation, most rocks are meta-aluminous with some peraluminous and peralkaline formations. Tectonically, the study indicates that the igneous rocks in the study area likely formed in a tectonic environment encompassing post-collision and post-collision environments, with some indications of pre-collision and post-collision conditions. The limitation of this study is the lack of the interpretation based on data of trace elements and rare earth elements. Such data would improve the interpretation of magma sources and their evolution and is recommended for future studies.

Keywords: Mourzidie, Geochemical data, Igneous rocks, Tectonics, South of Libya,

I. INTRODUCTION:

Most of the geological studies that included volcanic activities in the Tibesti Mountains were in the twentieth century, though the publications were not significant [1,2,3,4]. There is a petrology study in 2004 [5] based on Emi Koussi volcanic series. Another remote sensing interpretation study was done in 2007 [6]. A geological review based on available data was conducted in 2015 [7]

The Tibesti massif is made up of massif intrusive and metamorphic rocks, encircled by Paleozoic and younger sedimentary rocks, and partially capped by Tertiary volcanic rocks. On the other hand, the ages of the crystalline rocks are not clearly defined. The earliest radiometric dates [8] show that different granitic rocks in the Tibesti massif were formed 500 – 600 million years ago. There are several studies [9,10,11] concerning geology of Tibesti massif. Also, there are two studies [12,3] described 30,000 km^2 of volcanic rocks that make up the central and southern Tibesti massif. The basement and Phanerozoic cover are two distinct large gaps in the lithostratigraphic column of the study area. In the Mourizidie and Dur al Qussah regions, the basement is exposed to the surface [13]. The Late Tibestien basement, which represent the youngest segment of The Proterozoic Pan-African orogenic belt is composed of meta-sediments. These rocks consist of meta-greywackes, calcsilicate rocks, marble, meta-arkoses, and meta-conglomerates. This basement rock is made of syntectonic granite and seldom granodiorite and gabbro [13].

The Mourzidie region, which is part of the Tibesti massif, is an important area in linking the type of magma and tectonic processes, as it is located within the Pan African orogenic belt, which expresses complex geological events.

II. OBJECTIVES OF THE STUDY:

This study primarily aims to classify the intrusive igneous rocks in the Mourzidie region based on their mineral composition, in addition to using the main rock-forming elements to understand the formation of these rocks, as well as attempting to understand the tectonic environments that formed them, while reusing previously published geochemical data in order to add a clearer geological interpretation to the study area

III. LOCATION OF STUDY AREA:

In the southern region of Libya, the 100,000 km^2 Tibesti volcanic province stretches from approximately °15 00 to °16 30 N latitude and °23 00 to °24 00 E longitude (Fig 1). Tibesti province is located above the late Neoproterozoic metamorphic basement and covered by Paleozoic (Cambrian to Devonian) sandstones, a small amount of Carboniferous limestone and marls, and Cretaceous sediments represented in Nubian sandstones. Granitoids have also been found to intrude on Neoproterozoic metamorphic basement.

IV. METHODOLOGY:

The methodology of this study relies on the reinterpretation of previously published data, including an analysis of intrusive rocks in the Mourzidie area [14] performed using X-ray spectroscopy. A set of classification diagrams was done based on this analysis. These diagrams were used to attempt to infer the tectonic environments of the region, as well as the geochemical properties of the rocks. It is important to note that this study is based on previously published analyses and not on recent laboratory results, which is properly cited in this study.

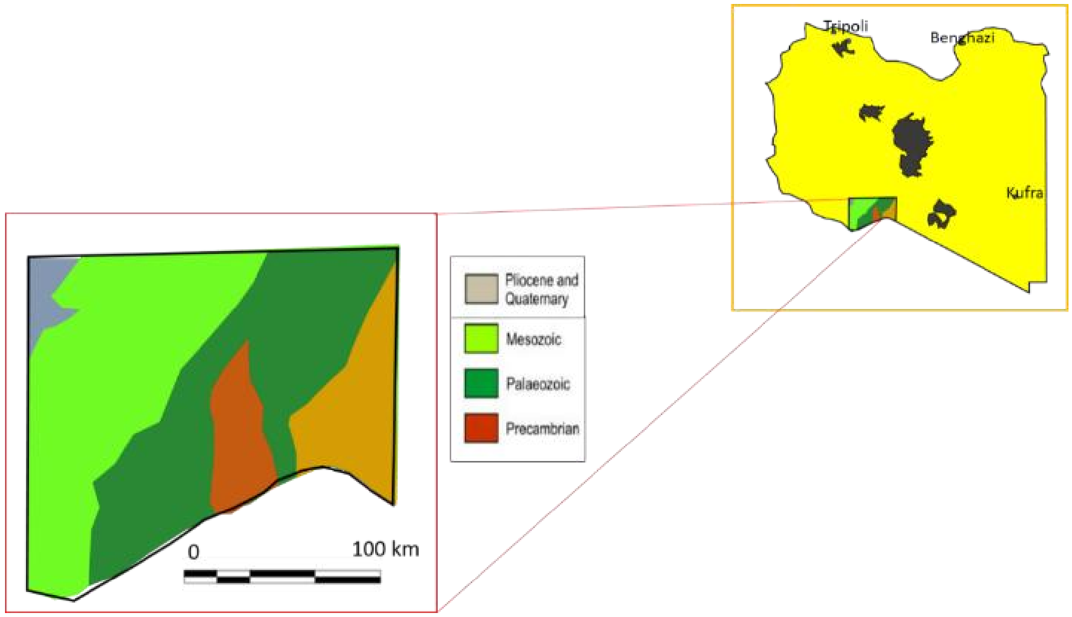

Fig. 1: Overview map of Libya showing the location of area study in the Mourizidie area (Modified after [14])

V. STRATIGRAPHY

It is explained in [15] that Precambrian crystalline rocks were formed before Paleozoic strata were deposited. Paleozoic sediments of the Tibesti region were transported from a southern source and then deposited close to the North African shoreline [15]. According to a study in 1963 [16], the basement is exposed in the Murzuq basin edges as a high-grade metamorphic suite made up of mica-schist, gneiss, and amphibolites associated with granite and granodiorite. The sedimentary cover of the platform is made up of rocks from the Palaeozoic, Mesozoic, and Cenozoic eras.

A. Palaeozoic Rocks

The Palaeozoic begins with the Upper Cambrian Hasawnah Formation whereas Ordovician is represented by Ash Shabyiat, Melez Shuqran and Mamunyiat. Silurian begins with transgressive marine shaly graptolitic sediments of the Tanezzuft Formation. Shales become more arenaceous in places, particularly in the area of the Mourizidie horst. Devonian is represented by the Tadrart, Ouan Kasa and Awaynat Wanin formations. On the top of Awaynat Wanin, Marar formation is present and then Assedjefar and Dembaba deposited on the top. Assedjefar Formation (Lower Carboniferous) is made up of cycles which are thinner compared to the cycles of sediments that are characteristic of the Marar Formation. The Dembaba Formation (Middle Carboniferous) lies concordantly over the sediments of the Assedjefar Formation. The Tiguentourine formation (Upper Carboniferous) is of limited extent in the investigation area. [17,18]

B. Mesozoic Rocks

A new cycle of sedimentation started in the Mesozoic. Mesozoic formations are represented by the Triassic Zarzaitine Formation, Jurassic Taouratine Formation and Upper Jurassic -

Lower Cretaceous Bin Ganimah (Messak) Formation. [19]

C. Tertiary Rocks

Tertiary (mostly Palaeogene) formations are exposed in the farthest north and east of the investigation area. Basalt occupies a special place in the geological composition of the NE periphery of the investigation area. These are just small parts of the prominent Neogene - Quaternary basalt Al Harūj massif. Quaternary sediments, particularly eolian sediments, are extensive in the investigation area. They a form relatively thin cover over a large part of the terrain, particularly in the Murzuq Basin. [20]

VI. GEOCHEMISTRY

Analysis of thirty-five (35) samples of Mourzidie intrusive rocks have been chosen for this study [14] in order to characterize the geochemical features. The bulk geochemical data is given in Tables1. Geochemical characteristics of each rock type are discussed below separately.

A. Tas diagram (Cox *et al*, 1979) [21]

The twelve (12) rock samples under investigation were plotted in TAS diagram. This diagram is based on the relationship between the percentage of silica (SiO_2) and the total percentage of sodium and potassium (Na_2O $+K_2O$). Most of the samples (9) were placed in the field of granite and the rest three samples (3) were located in the field of quartz diorite (granodiorite). It also appeared from the TAS diagram that all samples are acidic, because they were placed in the acidic range of the chart. As for the samples that fell in the field of granite, five (5) of them fell in the alkaline class, and the rest of the samples were plotted in the subalkaline part of the diagram (Fig. 3).

Table 1: Whole-rock analyses of selected samples of granitic rock from the Mourzidie intrusive [14].

Sample	1	2	3	4	5	6	7	8	9	10	11	12
Rock type	Gnt	Gnd/QD	Gnd/QD	Gnd/QD	Gnt	Gnt	Gnt	Gnt	Gnd/QD	Gnt	Gnt	Gnt
SiO2	70.82	67.6	64.55	70.4	67.01	70	70.55	68.3	67.98	66.28	71.4	73.2
Al2O3	15.08	15.18	16.72	14.5	13.8	13.05	13.66	14.69	14.347	14.44	14.16	14.26
Fe2O3	0.69	3.78	4.33	2.35	3.72	3.48	3.71	3.76	5.34	5.58	0.77	1
MgO	0.43	1.05	1.25	0.66	1.61	0.63	0.58	0.64	1.582	1.84	0.12	0.09
CaO	1.38	2.48	3.93	1.28	2.06	2.10	1.99	1.83	2.011	2.86	0.91	0.79
Na2O	4.76	5.32	4.80	4.41	4.44	4.80	4.84	5.01	3.14	3.531	5.26	5.28
K2O	5.59	3.42	3.01	5.31	2.94	4.60	3.65	4.56	3.92	3.62	5.17	4.34
TiO2	0.02	0.20	0.48	0.25	0.27	0.31	0.24	0.26	0.03	0.42	0.03	0.05
P2O5	0.004	0.061	0.036	0.023	0.059	0.034	0.025	0.025	0.008	0.043	0.006	0.014
MnO	0.01	0.09	0.11	0.05	0.10	0.06	0.07	0.08	0.53	0.11	0.01	0.01
LOI	0.24	0.80	1.17	0.76	3.39	0.92	0.66	0.83	0.32	0.8	1.13	0.93
Total	99.02	99.98	100.38	99.99	99.39	99.98	99.97	99.98	99.21	99.52	98.96	99.96

Gnt= Granite, Gnd= Granodiorite, QD= Quartz diorite

A. R1-R2 plot (De la Roche *et al*. 1980) [22]

This diagram is based on the relationship between silica, sodium, potassium, iron, and titanium in the x-axis, while the y-axis includes calcium, magnesium, and aluminum. This diagram shows the distribution of samples into five types of rocks. These are granite (5 samples), granodiorite (2samples), alkali granite (2 samples), quartz monzonite (2 samples) and tonalite (1 sample) (Fig. 4).

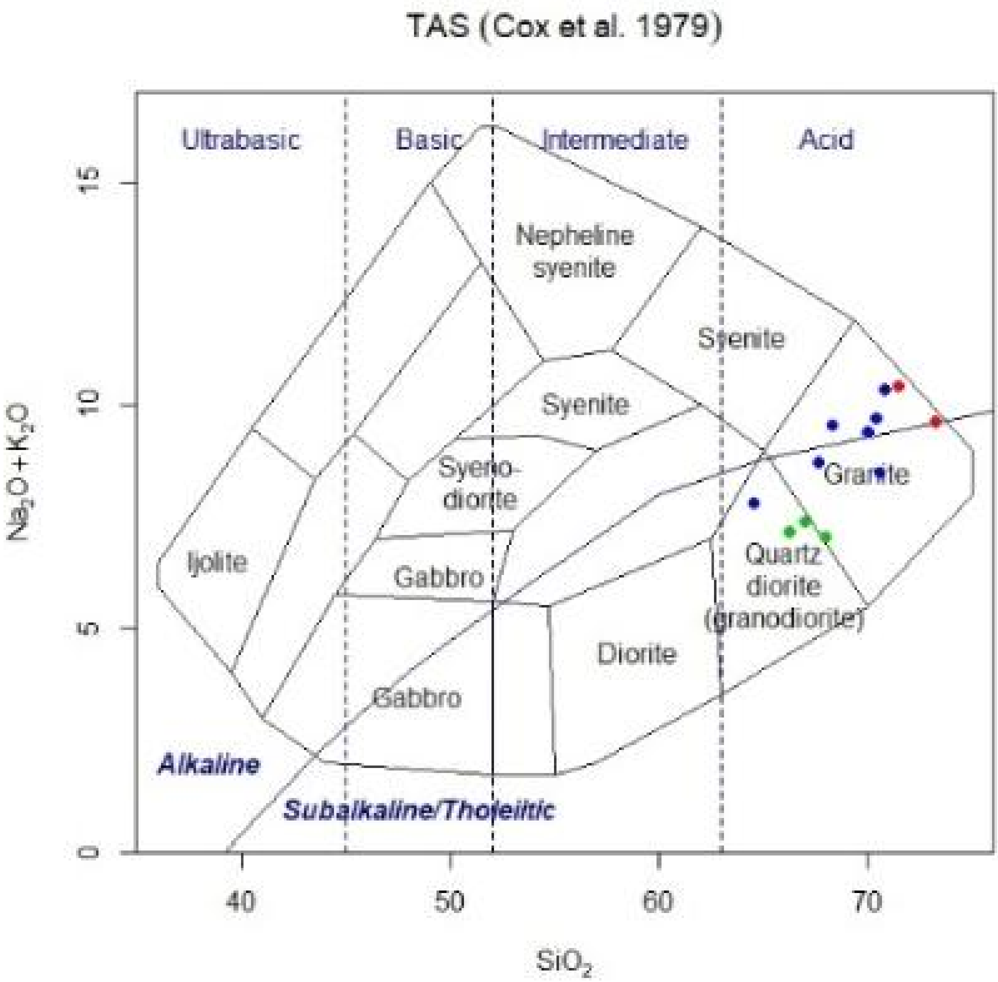

Figure 3: Locations of the different type of intrusive rocks from Mourzidie basement on SiO_2 vs $Na_2O + K_2O$ (TAS Diagram) of Cox *et al* (1979) [21].

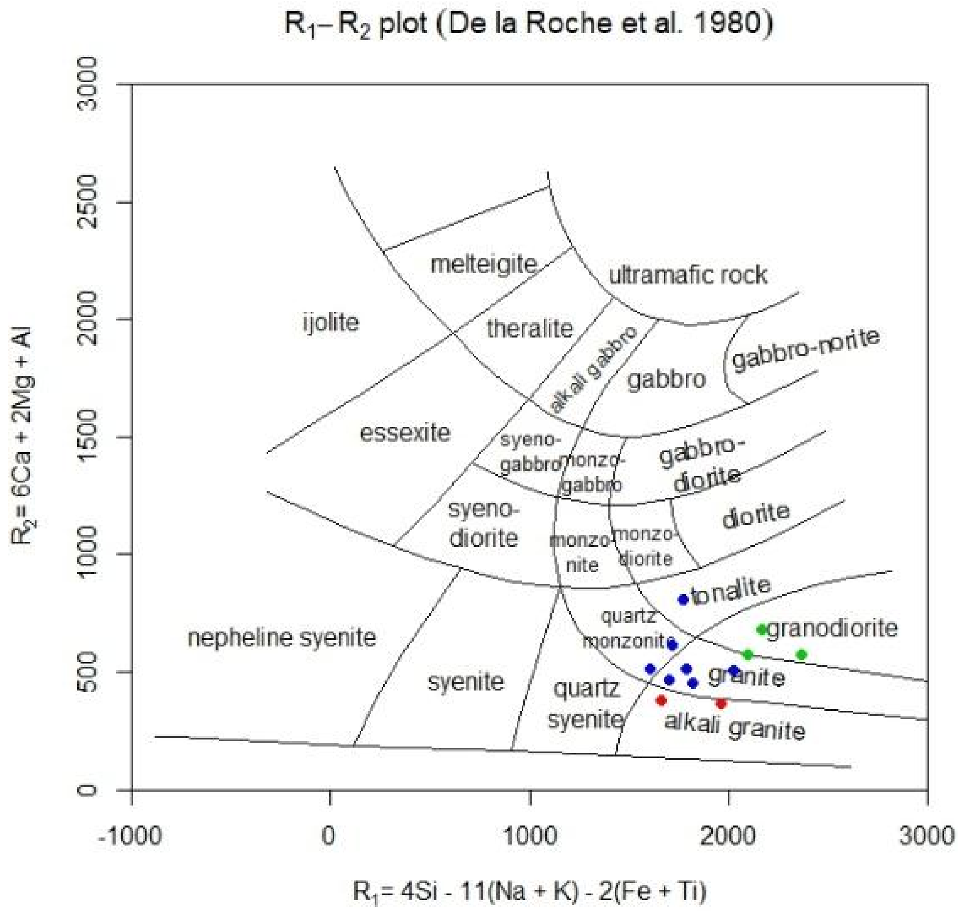

Fig. 4: Locations of the different type of intrusive rocks from Mourzidie basement on R_1-R_2 plot of De la Roche *et al*. (1980) [22].

B. SiO_2 – K_2O Plot (Peccerillo & Taylor 1976) [23]

This diagram shows the degree of potassium saturation of the rock samples. The diagram is divided into four regions, starting with the Tholeiite series, which is the lowest zone in terms of potassium content, and ending with the Shoshonite series the most potassium saturated. It appears through this diagram that the samples under study are divided into two groups. Nine (9) of the samples occurred in the range of the High-K calc-alkaline series and three (3) samples were located in the field of high potassium shoshonitic rocks (Fig. 5).

D. A/CNK – A/NK plot (Shand 1943) [24]

This diagram is based on the amount of aluminum saturation in the rock sample. In this study, it was shown through this diagram that most of the rock samples were located in the Metaluminous range, while one sample appeared in the peraluminous area, with one sample in the peralkaline range.

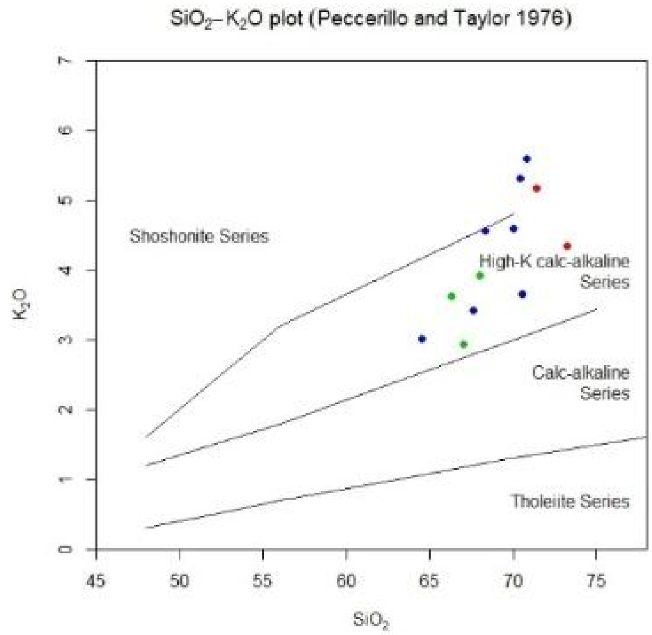

Fig. 5: Locations of the different type of intrusive rocks from Mourzidie basement on R_1-R_2 plot on SiO_2 vs K_2O diagram of Peccerillo & Taylor (1976) [23].

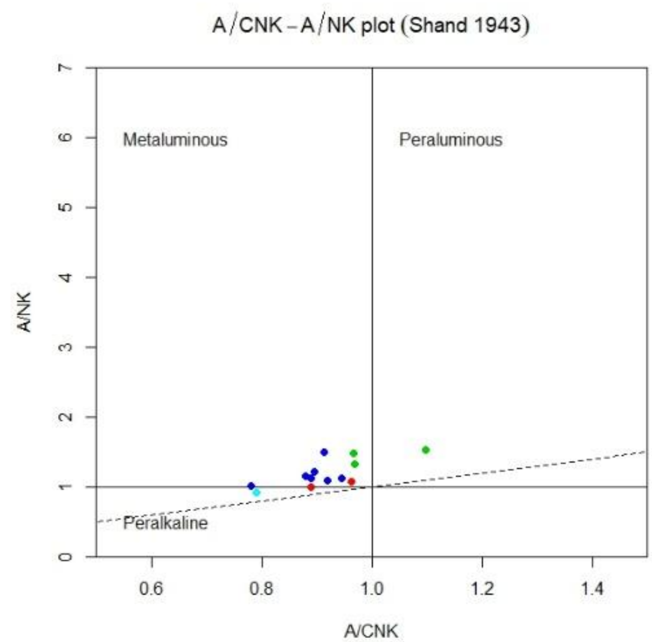

Fig. 6: Locations of the different type of intrusive rocks from Mourzidie basement on A/CNK – A/NK plot of Shand (1943) [24]

VI. TECTONIC DISCRIMINATION

It is possible to recognize the tectonic conditions that form distinctive igneous rocks based on the proportions of certain elements in their chemical composition. This is done by using diagrams that link the chemical composition of igneous rocks to their tectonic conditions. Therefore, it can be inferred the tectonic conditions during the period of rock formation. As it is noted in this study, the rocks studied are divided into three groups: Granite which is formed in late orogenic to post collision uplift, and Alkali granite with anorogenic setting. However, the granodiorite is mostly formed in syncollision setting.

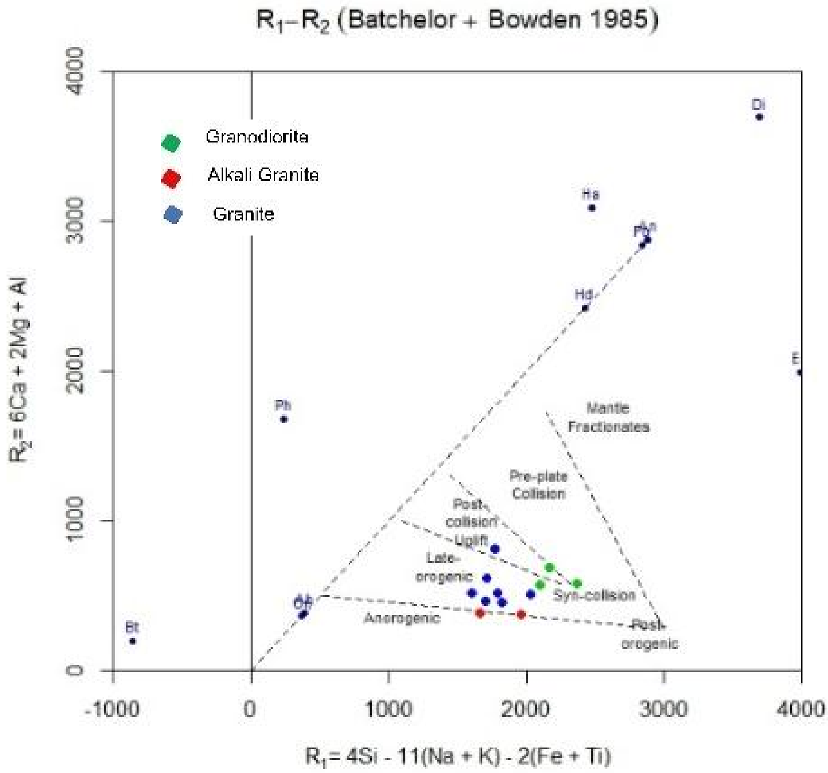

Fig. 7: Locations of the different type of intrusive rocks from Mourzidie basement on R1 – R2 discrimination diagram of Batchelor and Bowden (1985) [25]. Syn-COLG:

VII. CONCLUSIONS

The present study indicates that there are different types of intrusive igneous rocks in the study area. These are ranging from granite, quartz diorite, quartz monzonite, and tonalite. However, some granite samples contained a high percentage of alkali feldspar, with the potassium content in some samples exceeding 5%, which considered high percentage, and classified under the shoshonitic series. In general, all the samples are felsic igneous rocks with a high silica content (over 65%).

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