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Petrography of Sandston Units in Gercus Formation, Shaqlawa and Dokan areas Northern Iraq

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Abstract

The petrographic study of sandstone units of Gercus formation in Shaqlawa and Dokan areas revealed that sandstone is composed primarily of rock fragments (sedimentary, igneous and metamorphic), quartz grains (monocrystalline and polycrystalline), and feldspars (orthoclase, microcline and plagioclase). These components are cemented by carbonate and iron oxides. The studied sandstones are classified as litharenites. Sandstones of the Gercus Formation are chemically and mechanically unstable due to the high percentage of rock fragments; such a grain assemblage infers that the source of the rock fragments is nearby. The petrographic analyses indicate that the studied sandstones are immature mineralogically because of the high content of unstable components, such as lithic fragments and feldspars. The tectonic provenance for Gercus formation can be described as lithic recycled.

Keywords: Gercus Formation, Petrology, Sandstone, Tectonic provenance.

بتروغرافية وحدات الحجر الرملي لتكوين الجركس في منطقة شقلاوة ودوكان في شمال العراق

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الخلاصة:

أظهرت الدراسة البتروغرافية للوحات الرملية لتكوين الجركس انها بصورة أساسية من القطع الصخرية (رسوبية، نارية ومتحولة)، الكوارتز (الأحادي والمتعدد التبلور)، الفلدسبارات (اورثوكليز، مايكروكلين وبلاجيوكليز). ان المادة الرابطة هو السمنت الكاربونايتي واكاسيد الحديد ,صنف الحجر الرملي على انه ليثارينيت ,صخور الحجر الرملي لتكوين الجركس غير مستقرة كيميائيا وميكانيكيا بسبب النسبة العالية من القطع الصخرية وهذا التجمع الحبيبي يشير الى ان مصدر القطع الصخرية قريب .تشير التحليلات الصخرية الى ان صخور الجركس الرملية المدروسة غير ناضجة من الناحية المعدنية بسب محتواها من المكونات غير المستقرة مثل القطع الصخرية و الفلدسبارات، كما يمكن وصف الاصل التكتوني ان تكوين الجركس بانه معاد الترسيب لأكثر من دورة ترسيبية.

1. Introduction

Maxon first described the Gercus Formation in the Gercus region of SE Turkey [1]. Wetzel described a supplementary type section for Iraq from the Duhok area of northern Iraq

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(originally referred to as Duhok Red Beds). It has a length of 850 m, It is composed of red and purple shale, mudstone, sandy and gritty marls, pebbly sandstones, and conglomerates. The Demir Dagh area has brown clastics and limestone[2]. The formation is cropping out in the High Folded zones of the Unstable Shelf. In N Iraq, the formation is overthrust along the N Thrust Zone; the original depositional limit lay further to the north [3].

The thickness of the formation decreases towards the SE; near the Iranian border along the Sirwan (Diyala) River, it is usually less than 100 m thick. The Gercus Formation is present in Taq Taq (66 m thick) and Demir Dagh wells (117 m thick) [3], in which fossils are scarce and probably mostly reworked [3,4]. [5] was dated the Gercus Formation as Late Lower Eocene using palynological data. [6] It has a length of 850 meters and is composed of red and purple shale, mudstone, sandy and gritty marls, pebbly sandstones, and conglomerates. The geochemical significance of the distribution of Ni and Co in clayey-siltstone associated with northern Iraq's Gercus Formation was investigated [8].

This research includes a study of petrography and mineralogy, classification of sandstone, stability of sandstone, determination of the maturity of sandstone and tectonic setting provenance.[9] Sandstone Gercus formation in the Zakho, Dukok, Shaglawa and Haibat sultan is of lithic Arenite.

2. Geology of the study area

Iraq can be divided into three tectonically different areas: the Stable Shelf, the Unstable Shelf and the Zagros Suture. The Stable Shelf is divided into three major tectonic zones from the west. These are the Rutba- Jazeera, Salman and Mesopotamian Zones. The Unstable Shelf is divided into four zones, the Foothill Zone, the High Folded Zone (in which the studied area is included) and the imbricated Northern (Ora) and Balambo-Tanjero Zones.

The Mid-Late Eocene sequence was deposited to the southwest of an emergent uplift during the final phase of subduction and closure of the remnant Neo-Tethys ocean. Red beds were deposited in the basin to the northeast of the uplifted area and were also deposited in a narrow intermountain basin, between the uplifted area in the northeast and a ridge located along the northeast side of the Balambo-Tanjero Zone, running from Amadiya in the northwest through Ranya, Sulaimaniya and Halabja in the southeast [3]. A strongly subsiding trough formed southwest of the Balambo-Tanjero Zone ridge, in which Gercus Red Beds molasses was deposited. The clastic sediment supply from the uplifted area to the northeast ceased at the end of the Mid Eocene, and the basin was filled with Pila-Spi Formation lagoonal carbonates[3]. as shown in (Figure 1).

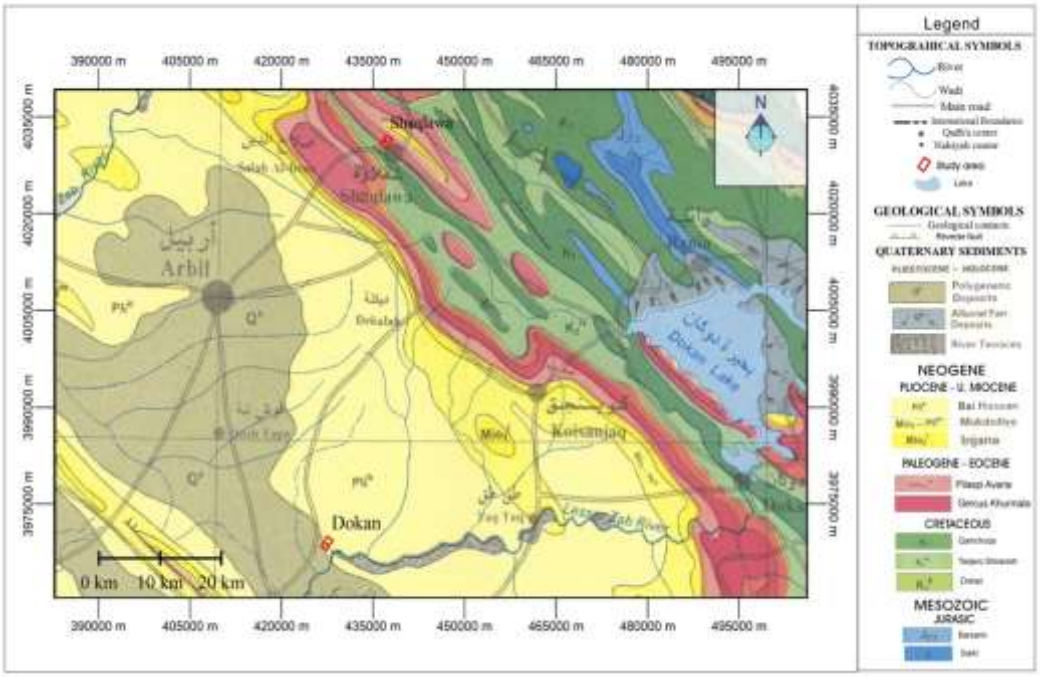

Figure 1: geological map of studied sections after [3]

3. Location of the study area

The area of study is located northeast of Iraq (Kurdistan region) from two sections (Shaqlawa and Dokan) between latitude (36^0,26^0,01^0, and 35^0,52^0,43^0 N), while longitude (44^0,19^0,51^0, and 44^0,09^0,49^0 E) as shown in Figure 2.

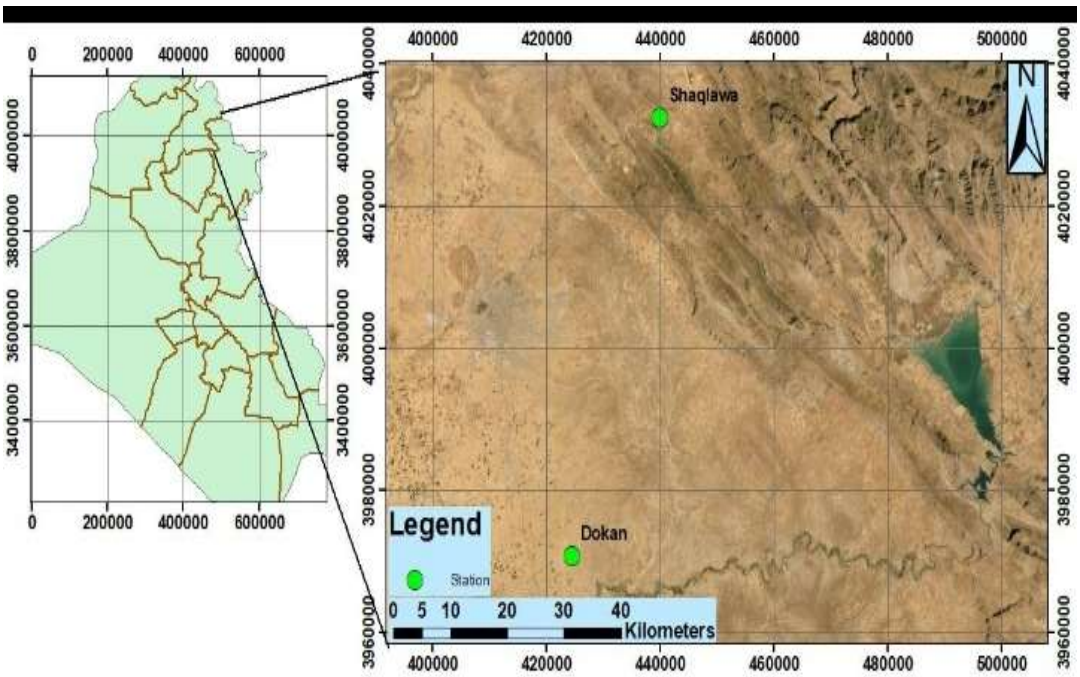

Figure 2: Location map of studied sections.

4. Methods and Materials

Eight sandstone samples were chosen for petrographic examination using a polarized

microscope for sample analyses to determine the mineralogical composition, classify the sandston maturity and determine the tectonic provenances.

5. Petrography of Sandstone

The percentage, range and average of all Shaqlawa and Dokan sandstone constituents are shown in Table 3-1 and 3-2. The main components of sandstone unit in the studied sections in Shaqlawa and Dokan composed are: Quartz (monocrystalline and polycrystalline), feldspar [(Potash-Feldspar-Orthoclase and microline)], Plagioclase Feldspar), rock fragment (sedimentary, igneous and metamorphic) Because it is a close transportation distance and there is a source close to it from northeastern Iraq, the sedimentary rock fragment includes; chert, carbonate, mudstone, ancient sandstone), cement (carbonate and iron oxides), and matrix

6-Results and Discussion

Identified and described the main components of Sandstone unit in the studied sections in Shaqlawa and Dokan composed are quartz, feldspar, rock Fragment, cement and matrix the description of these components as follows:

A. Quartz is the most common mineral in sandstone and is the most stable of all minerals under sedimentary conditions [9]. The percentage of quartz in the shaqlawa sandstone ranged between 6.8-11.4%, with an average of 16.9%, while the percentage of quartz in Dokan sandstone ranged between 8.3-12.4%, with an average of 9.4%, Quartz percentage in the study area is not the most common but the rock fragments.

The monocrystalline quartz ranges between 6.2 and 8.5%, with an average of 7.2%**.** In Dokan, it is ranged between 7.1 and 9.5%, with an average of 7.25%. In contrast, the polycrystalline quartz in the Shaqlawa ranges between 0.6 and 2.9%, with an average of 1.4%. In Dokan, the polycrystalline ranges between 1.2 and 2.9%, with an average of 2.15%. The quartz grain has an angular to very angular shape (Figure 3- A and B). The origin of monocrystalline quartz is an igneous rock, while the origin of polycrystalline quartz is metamorphic rock [11].

Table 3-1: Percentage, range and average of sandstone constituents in the Shaqlawa section of Gercus Formation.

Components		Sh1	Sh10	Sh12	Sh13	Min	Max	Avg
Quartz	Monocrystalline	6.2	8.5	7.2	6.9	6.2	8.5	7.2
	Polycrystalline	2.9	1.6	0.6	0.6	0.6	2.9	1.4
Feldspar	Potash-Feldspar (Orthoclase)	1.9	1.2	0.9	0.9	0.9	1.9	1.23
	Potash-Feldspar (Microcline)	0.9	0.6	-	-	0.6	0.9	0.38
	Plagioclase Feldspar	1.2	1.8	2.1	2.0	1.2	2.1	1.78
Rock Fragments	Carbonate Rock Fragments	32.5	32.8	35.1	34.7	32.5	35.1	33.78
	Chert Rock Fragments	7.8	8.4	7.3	6.9	6.9	8.4	7.6
	Mudstone Rock Fragments	3.9	2.7	3.8	3.0	2.7	3.9	3.35
	Sandstone Rock Fragments	2.1	1.8	1.5	2.4	1.5	2.4	1.95
	Metamorphic Rock Fragments	3.0	4.9	3.8	3.1	3.0	4.9	3.7
	Igneous Rock Fragments	4.1	3.7	3.7	4.5	3.7	4.5	4
Cement	Carbonate	13.6	13.7	14.2	16.8	13.6	16.8	14.58
	Iron Oxides	4.1	5.6	6.1	5.9	4.1	6.1	5.43
	Opaque Grains	5.8	4.6	5.0	4.5	4.5	5.8	4.98
	Matrix	8.4	6.9	5.8	6.9	5.8	8.4	7
	Others	1.6	1.2	2.9	0.9	0.9	2.9	**1.65**

Table 3-2: Percentage, range and average of sand stone constituents in Dokan section of Gercus Formation .

Components		D5	D6	D12	D15	Min	Max	Avg
Quartz	Monocrystalline	7.1	9.5	7.5	8.9	7.1	9.5	**7.25**
	Polycrystalline	2.9	1.2	1.6	2.9	1.2	2.9	**2.15**
Feldspar	Potash-Feldspar (Orthoclase)	1.2	1.6	0.9	0.6	0.6	1.6	**1.08**
	Potash-Feldspar (Microcline)	0.6	-	-	0.3	-	0.6	**0,23**
	Plagioclase Feldspar	1.9	1.5	1.0	1.4	1.0	1.9	**1,45**
Rock Fragments	Carbonate Rock Fragments	34.9	33.2	36.6	38.7	33.2	38.7	**35.85**
	Chert Rock Fragments	7.9	8.2	8.2	6.8	6.8	8.2	**7,78**
	Mudstone Rock Fragments	4.0	1.9	3.7	2.9	1.9	4.0	**3.13**
	Sandstone Rock Fragments	2.8	2.6	1.5	2.5	1.5	2.8	**2.35**
	Metamorphic Rock Fragments	2.7	3.5	3.8	3.0	2.7	3.8	**3.25**
	Igneous Rock Fragments	3.5	3.8	3.0	2.8	2.8	3.8	**3.28**
Cement	Carbonate	13.5	14.0	16.4	14.4	13.5	16.4	**14,58**
	Iron Oxides	4.7	4.8	4.2	3.8	3.8	4.8	**4.38**
	Opaque Grains	5.2	3.8	5.3	4.9	3.8	5.3	**4.8**
	Matrix	5.9	7.8	4.7	5.2	4.7	7.8	**5.7**
	Others	2.2	2.6	1.6	0.9	0.9	2.6	**1.83**

B- Feldspars

The term feldspar refers to a short transportation distance [12]. The feldspar mineral is found in granite and pegmatite rocks and, to a lesser extent, metamorphic rocks [13]. Feldspars in the Shaqlawa sandstone range between 2.7 and 4.9%, with an average of 3.39%**.** Feldspars in the Dokan Sandstone range between 1.6 and 4.1%, with an average of 2.76% .potash feldspar in the sandstone of Shaqlawa and Dokan are dominated by orthoclase, whereas the microcline is found in less than orthoclase. Some feldspars are of fresh grains, but others are altered. The fresh feldspars may indicate a process of fragmentation from igneous rocks, followed by a short transport distance [11] (Figure 3- C, D and E).

C- Rock fragments

The rock fragments represent the most abundant of the detrital component of Shaqlawa and Dokan sandstone. The rock fragments in Shaqlawa sandstone ranged between 50.3 and 59.2%, with an average of 54.38%**.** In Dokan sandstone ranged between 48.9 and 61.3%, with an average of 55.64%. These fragments reveal the source of the sediments [14], and the source rock location influences the rock fragment percentage. This percentage rises when the source rocks are close to the sedimentary basin or have a high topography [15]. They are of the following types:

C-1 Carbonate rock fragment

The carbonate rock fragments constitute the most significant percentage of rock fragments in both sections, Shaqlawa and Dokan. The carbonate rock fragments in Shaqlawa sandstone range between 32.5 and 35.1%, with an average of 33.78%. In Dokan sandstone range between 33.2 and 38.7%, with an average of 35.85%. The carbonate rock fragments are chracterized by coarse to fine grains and rounded to sub-rounded (Figure 3F and G). Carbonate rock fragments reflect unique conditions for rapid mechanical erosion rather than chemical dissolution [16].

C-2 Sedimentary rock fragment

The sedimentary rock fragments represent a large proportion of the other rock fragments forming the sandstone of Shaqlawa and Dokan sandstone. The sedimentary rock fragments in Shaqlawa sandstone ranged between 43.6 and 49.8%, with an average of 46.68%, while in Dokan sandstone, they ranged between 43.4 and 53.7%, with an average of 49.11%. They include various types of chert (Figure 3H and I), mudstone (Figure 3- J) and sandstone rock fragments (Figure 3K).

C-3 Metamorphic rock-fragments

The percentage of metamorphic rock fragments in Shaqlawa sandstone ranged between 3.0-4.9%, with an average of 3.7%, while the percentage of metamorphic rock fragments in Dokan sandstone ranged between 2.7-3.8%, with an average of 3.25%**.** Fine to coarse sand size, generally subrounded to subangular shape, represents less resistant fragments and indicates a short transportation distance. The metamorphic rock fragments include schist rock fragments with foliated texture (Figure 3L) and serpentine fragments (Figure 3-M).

C-4 Igneous rock fragments

The igneous rock fragments in the Shaqlawa sandstone ranged between 3.7 and 4.5%, with an average of 4%, whereas in the Dokan sandstone, between 2.8 and 3.8%, with an average of 3.28% **.** Igneous rock fragments are generally of medium to fine with few coarse sand size grains and subrounded to subangular. These fragments include volcanic igneous rock-fragment (Figure 3N).

D- Cement

Cement is the material that binds components together, deposited chemically from the solution found between the grains (10). The percentage of cement in Shaqlawa sandstone ranged between 17.7-22.9%, with an average of 20.01%, while the percentage of cement in Dokan sandstone ranged between 17.3-21.2%, with an average of 18.96%, the present study shows many types of cement include various types of carbonate (Figure 3-O) and iron oxides cement (Figure 3-P).

E- Opaque grains

This group includes all the opaque grains consisting predominantly of iron oxides. The opaque grains in Shaqlaw sandstone ranged between 4.5-5.8%, averaging 4.98%, while the percentage of opaque grains in Dokan sandstone ranged between 3.8-5.3%, with an average of 4.8%. The shape of these grains is mostly angular to sub-angular (Figure 3-Q).

F- Matrix

The matrix in Shaqlaw sandstone ranged from 5.8 to 8.4 % averaging 7%, and in Dokan ranged from 4.7 to 7.8%, averaging 5.7%. The matrix is made up of very fine silt to clay and micritic materials (Figure 3R).[17] The sandstone rich in rock fragments contained a good quantity of matrix, most of which were of secondary origin. Unstable grains such as (feldspar and rock fragments) are an important source of matrix production [18]. The presence of these materials in sandstone (silt and clay) reflects a short transportation distance.

Figure 3: Photomicrographs of detrital grains of the formation in the Gercus area (XPL) A: Angular monocrystalline quartz,-B: Very angular polycrystalline quartz,C: Potash feldspar (microcline) with cross-hatching twining, D: Angular altered potash feldspar (orthoclase),E: Plagioclase feldspar with polysynthetic twining,-F: Sub-rounded carbonate rock fragment (crystalline limestone), G: Rounded carbonate rock fragment (fossiliferous limestone),.H: Angular microcrystalline chert rock fragment, I: Angular macrocrystalline chert rock fragment, J: Sub-angular mudstone rock fragment, K: Sub-rounded old sandstone rock fragment. L: Metamorphic rock fragment with foliated texture (schist fragment), M: Metamorphic rock fragment (serpentine fragment), N: rounded igneous rock fragment (volcanic igneous fragment). O: Carbonate cement. P: Iron oxides cement. Q: Angular opaques grains, R: Matrix fragments (silt and clay grains).

7. Classification of sandstone

The sandstones are classified based on their texture and mineralogical composition**.** For determined the type of sandstone of the Gercus Formation (Shaqlawa and Dokan), the [11] classification used the major detrital framework components (quartz, feldspar and rock fragments) have been recalculated to 100%. This classification showed that all Shaqlawa and Dokan sandstone samples are classified as Litharenite (Figure 4A, and 4-B). Litharenites are immature, implying rapid sediment production from supracrustal sources and a short transport distance [10].

According to [19,20], "Litharenites are compositionally immature sandstones that form under conditions that favor the production and deposition of large volumes of relatively unstable materials." Immature lithic sands may be abundant in high relief sources [16].

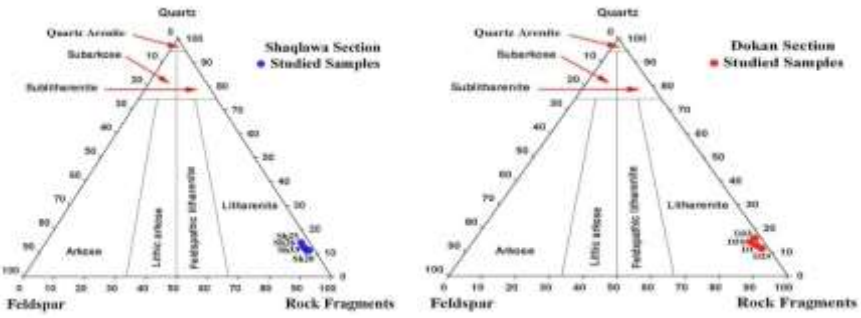

Figure 4: Classification of sandstone after [11]

(Figure. 5-A, and 5-B) shows that the sandstone classification of the Shaqlawa and Dokan sandstone according to the rock fragments type (sedimentary, igneous and metamorphic) are sedarenite.

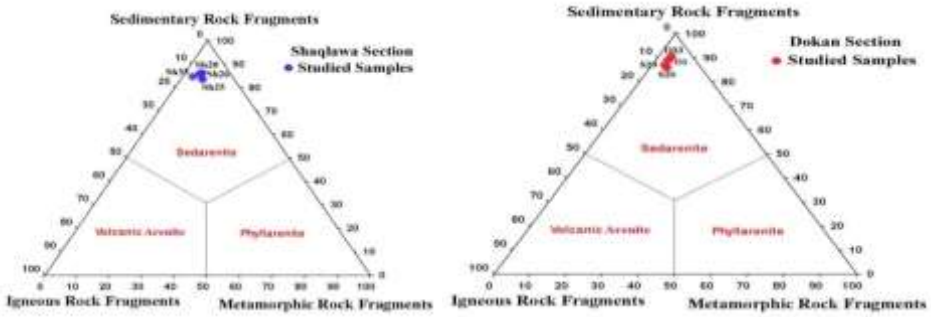

Figure 5: Classification of sandstone ,after[11].

8. Stability of sandstone

[21] classified stability of sediments into chemical and mechanical, using a ternary diagram (quartz-feldspar- rock fragments). He stated that the sandstone that contains a high percentage of quartz that means sandstone is chemically and mechanically stable, but when the sandstone contains a high percentage of feldspar means the sandstone is mechanically stable but chemically unstable, and when the sandstone contains a high percentage of rock fragment means the sandstone is chemically and mechanically unstable. According to this classification, the sandstone of Shaqlawa and Dokan formations are chemically and mechanically unstable due to the high percentage of rock fragments (Figure 6A and B).

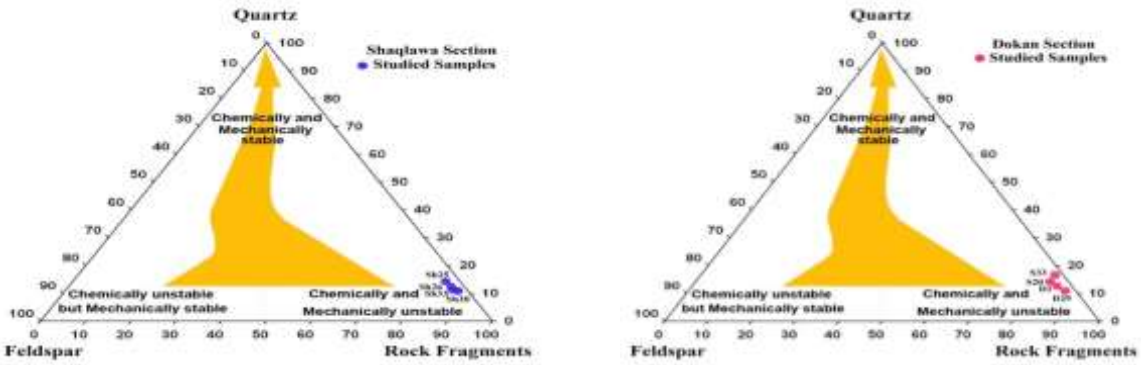

Figure 6: Ternary diagram of stability of sandstone, after [21]

9. Maturity

Mineralogical (compositional) maturity refers to the relative abundance of the stable and unstable framework. Mature sandstone contains abundant quartz, whereas immature sandstone contains unstable minerals or rock fragments such as feldspar and carbonate rock-fragment [22]. Mineralogical (compositional) maturity is defined by [12] as the extent to which clastic sediment approaches the ultimate end product that is derived by the formative processes that operate upon it. [23] gave an index of compositional maturity, calculated from the ratio (quartz + chert / (feldspar + rock fragments). This index was determined for each sample of the Shaqlawa and Dokan sandstone. The calculated index values for the studied samples show that the index of mineral maturity of the Shaqlaw sandstone ranged between 0.28-0.37%, with an average of 0.32; in Dokan sandstone, the values of mineral maturity ranged between 0.34 and 0.39, with an average of 0.355. As a result, the sandstones of Shaqlaw and Dokan are mineralogically immature (Because it is the same formation and the distance between the two sections is not far, and they have the same sedimentation basin). As a result of the source area high relief, rapid erosion and transport conditions, and short transport distance, the presence of stable and unstable types of rock fragments and minerals coexists in areas with high relief, fast flowing rivers, and dry climatic conditions, which is a characteristic of unstable tectonic crusts [24].

10. Tectonic provenances

Sandstone composition reflects the nature of sedimentary processes within the deposition basin and the character of sedimentary provenance. The tectonic regime governs the provenance and depositional basin, which governs the distribution of sandstone types [25]. [26,27,28,29,30] and others demonstrated a close correlation between sandstone composition and tectonic settings.

Accordingly,[26] proposed three principle types of tectonic settings or provenance they are (1) continental block provenance, (2) magmatic arc provenance, and (3) recycled orogen provenance. To differentiate sediment derived from these three major tectonic provenances,[26, and 29] suggest the use of triangular composition diagrams showing framework proportions of (monocrystalline quartz, feldspar, and (rock fragments + polycrystalline quartz) (Figure 7A, and B). From the modal analysis of the sandstone of the Gercus Formation, the monocrystalline quartz, feldspar, and rock fragments plus polycrystalline quartz were plotted (Figure 7A and B). This Figure shows that the average composition of monocrystalline quartz, feldspar, rock fragments and polycrystalline quartz of the sandstone of the Gercus Formation lies within the Lithic Recycled provenance**.** Lithic recycled zones are zones of plate convergence where major plate collisions create uplifted source areas along the collision suture belt [22], with two examples:

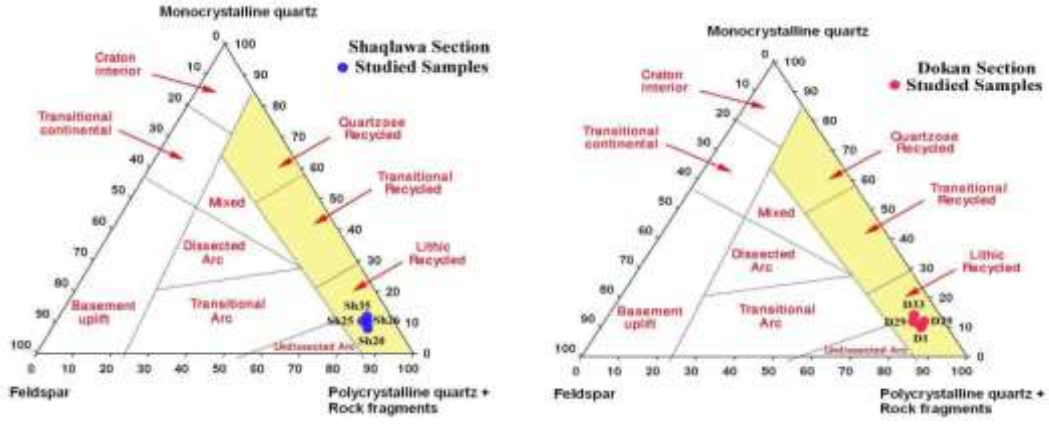

Figure 7: QFL ternary diagram of sandstone, after [29]

10. Conclusions

1- The sandstone of the Gercus Formation was classified as litharenite type that led to high relief rapid erosion near the source area. According to the type of rock fragments, they were classified as sedarenite.

2- Because of the high percentage of rock fragments, the sandstone of the Gercus Formation is chemically and mechanically unstable. The calculated mineralogical maturity (MMI) indicates that the Shaqlawa and Dokan sandstone is mineralogically immature.

3- The ratio of rock fragments to quartz and feldspar is high, and the dominance of fresh feldspars indicates a low weathering effect and transportation distance. Such mineral association indicates dry weather in the source area.

4- The high proportion of sedimentary rock fragments compared to igneous and metamorphic rock fragments indicates recycled sediments.

5- Monocrystalline quartz is more abundant than polycrystalline quartz. This indicates that it is of reworked origin, probably from metamorphic and plutonic igneous.

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