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Petrology of the Lower Succession of Injana Formation, Shorr Shareen area, Wasit Governorate, - Eastern Iraq

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Abstract

This study deals with the petrology of the lower succession of the Injana Formation in the Shorr Shareen area, Wasit Governorate, Eastern Iraq. The study revealed that the sandstone is litharenite consists of 45.56% rock fragments, 22.13% quartz and 8.5% feldspars. The matrix is about 8.39%, consisting of silt and clay particles. The cement is variable (carbonates 8.42%, evaporites 1.78% and iron oxides 0.96%). The grain assemblage infers that the source of the rock fragments is nearby. The petrographic analyses indicate that the studied Injana sandstones are immature mineralogically because of their content of unstable constituents, such as lithic fragments and feldspars. In addition, the presence of such fresh feldspars indicates that the climate in the source area and the deposition site were arid to semi-arid.

Key words: Injana Formation, Petrology, Sandstone, Provenance.

بترولوجية التتابع الأسفل لتكوين انجانة في منطقة شور شيرين, محافظة واسط, شرق العراق

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الخلاصة:

تم دراسة بتروغرافية مكاشف للجزء الأسفل من تكوين انجانة (المايوسين الأعلى – البلايوسين) ضمن منطقة شورشرين في محافظة واسط شرق العراق. اظهرت النتائج ان الصخور الرملية للتكوين تتالف اساساً من القطع الصخرية بنسبة 45.56% وهي الأكثر شيوعا ويليها الكوارتز بنسبة22.13 % والفلدسبارات بنسبة 8.5%, واما الحشوة تتالف من حبيبات باحجام الطين والغرين و بنسبة 8.39% والسمنت يكون متنوع (الكربوناتي بنسبة 8.42% و المتبخرات بنسبة 1.78% واكاسيد الحديد بنسبة 0.96%). كما تم تصنيف الحجر الرملي للعينات المدروسة على انه ليثارينايت بسبب احتواء العينات المدروسة على نسبة عالية من القطع الصخرية الرسوبية الكربوناتية. تدل هذه المكونات على ان القطع الصخرية قريبه المصدر ولا تنتقل الى مسافات بعيدة ومن ناحية النضوج المعدني فان الحجر الرملي لتكوين انجانة غير ناضج معدنيا بسبب احتواءه على مكونات غير مستقرة كالفلدسبارات والقطع الصخرية بصورة عالية. فضلاً عن ذلك أن كثرة الفلسبارات غير المتأثرة تدل على أن الترسيب في منطقتي المصدر والترسيب كانتا جافة الى شبه جافة.

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1. Introduction

The Neogene succession is widely exposed in Iraq. Previously, the stratigraphy of the upper part of the Neogene was introduced to Iraq by [1]. The terminology was first used in the Fars Province (Table 1). The names and details of these formations were changed later in Iran and Iraq. The upper Miocene, Injana Formation, was introduced to the Iraqi geological column consisting of two lithostratigraphic units named the Upper and Middle Fars formations [2]. The Neogene succession begins with lagoonal deposits (Fatha Formation, previously named Lower Fars Formation) and progressively changes into lacustrine (Middle Fars Formation) and then to fluvio-lacustrine conditions, which is represented by the Injana Formation [3]. A transition succession represents the lower part of the Injana Formation (Middle Fars Formation). This transition succession is not well developed in most places in Iraq, which led to appending it to the Injana Formation. The lower part of the Injana Formation is currently represented by it [2]. The Middle Fars towards the east is well developed and can be considered separate entities. Studies on this unit are scarce and scanty. Further consideration of its entity is thought to be very useful as it represents transitional conditions between the shallow marine and lagoonal Fatha Formation and the fluvial Injana Formation. The present work deals with the Injana Formation, consisting of a rhythmic pattern of sandstone and mudstone. Its sediments were sourced from Paleozoic and Mesozoic rocks found in the northern and northeast territories [4]-[7]. The formation forms hilly areas and badlands, with continuous strike ridges and valleys due to alternating troughs and brittle rocks. 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.

2. Geology of the study area

Major thrusting occurred during the late Miocene – Pliocene when the Neo – Tethyan terrains and the Sanandaj- Sirjan microplate collided with the Arabian Plate. The High-Folded Northern Thrust Zone, and the NE parts of the Balambo-Tanjero and Mesopotamian Zones, were uplifted due to this event. The Jezira, Rutba and Salman Zones have a major foredeep that has been uplifted. The High Folded Zone was uplifted with increasing intensity during the late Miocene and especially the Pliocene. The studied area is divided into two zones: The Mesopotamian Zone (Tigris Subzone) of the Stable Shelf and the Foothill Zone (Hemrin-Makhul Subzone) of the Unstable Shelf (Fig.1). The Mesopotamian Zone is the Stable Shelf's easternmost unit. The folded ranges of Pesh-i-Kuh in the east, and Hemrin and Makhul in the north, form the northeastern boundary. The Injana Formation is composed of fine-grained pre-molasses sediments deposited first in the coastal zone and then in the river system. Sandstones and mudstones are nested in a pattern of fining upwards successions that indicate fluvial deposits [9].

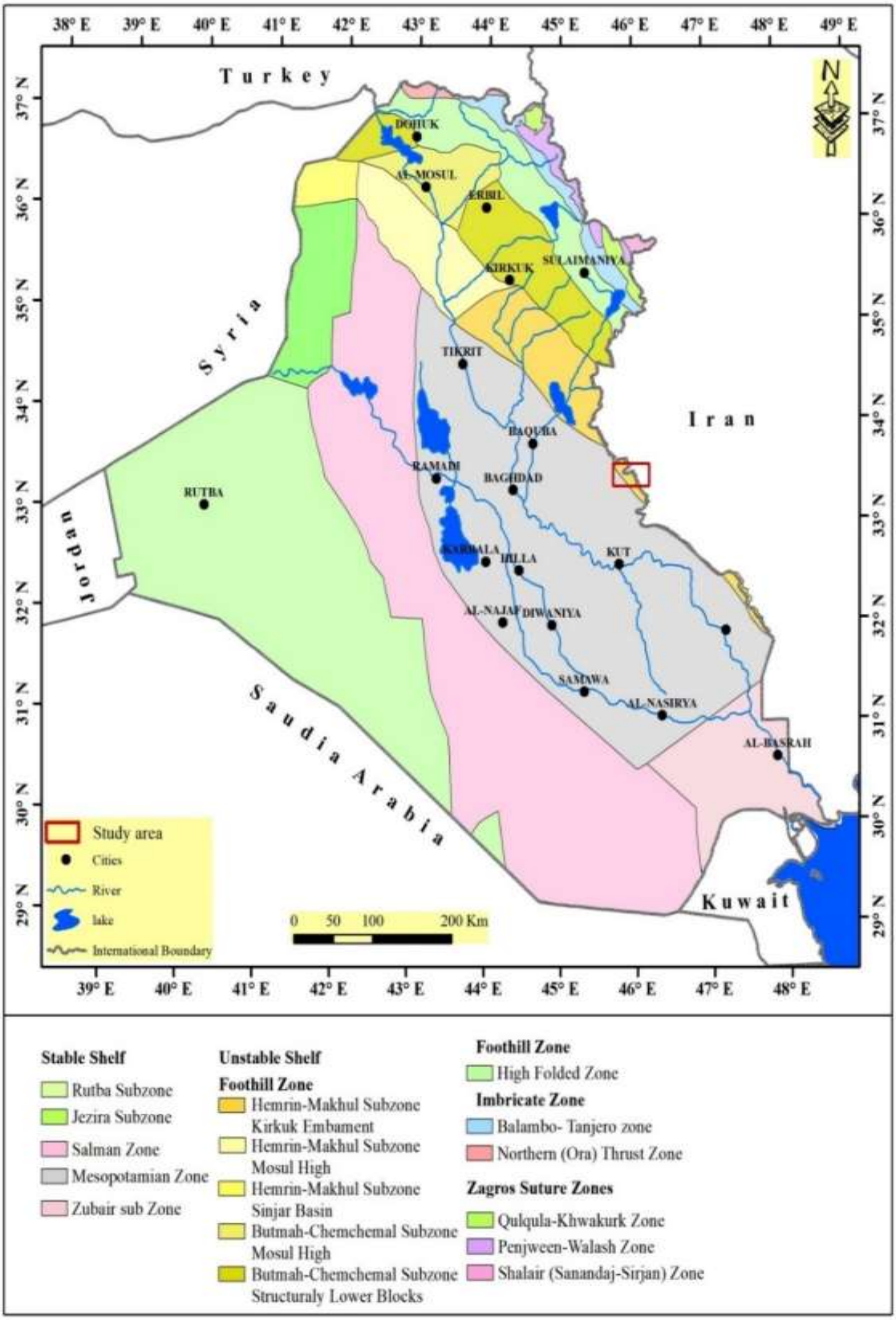

Figure 1-Tectonic map of Iraq Modified after [8].

3. Location of the study area

The study area is located in eastern Iraq and adjacent to the Iranian borders at Zorbatiya town between Wasit and Diyala Governorates (Fig.2). It is bordered by the following coordinates: N 33° 26' 09", E 45° 58' 31".

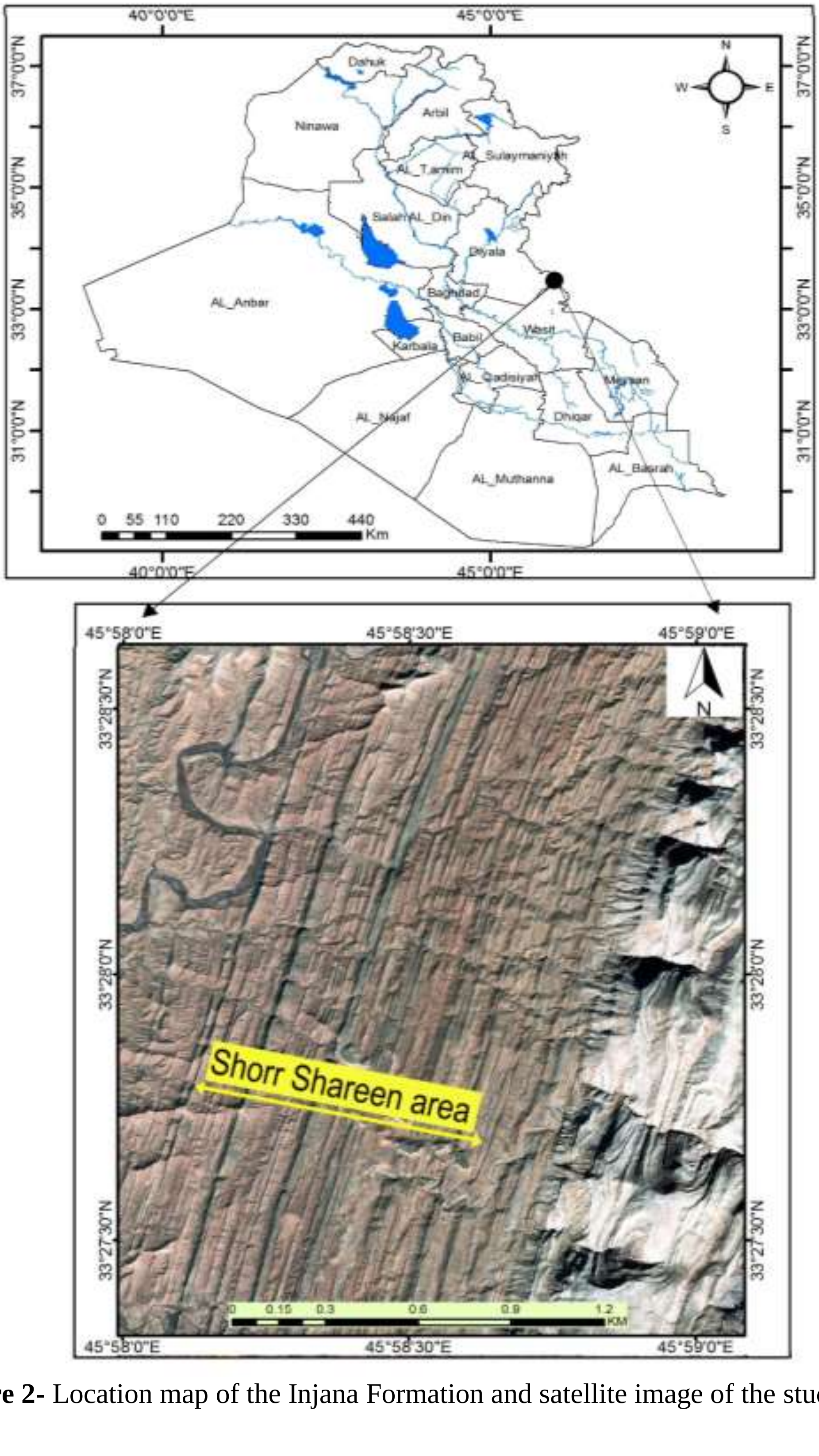

Figure 2- Location map of the Injana Formation and satellite image of the studied area.

4. Methods of study

Thirteen sandstone samples were chosen for model petrographic study using a polarised microscope to determine the mineralogical composition using the point-counting method and determining the main diagenesis processes.

5. Petrography and mineralogy

Sedimentary petrography is the analysis of depositional and diagenetic fabric from the thin section. It includes mineralogical composition, sediment provenance, fabric studies and determination of the sequence of diagenetic events of the sedimentary rock [10]. The rounded, subrounded, and subangular quartz grains, feldspar, and rock fragments comprise most of the Injana sandstone fragments [7]. The proportion, range, and average of all Injana Formation constituents are presented in the table below (Table. 1).

Table 1-The proportion average and range of minerals of Injana Formation samples in the Shorr Shareen section.

Section	Formation	Slide No.	Quartz		Feldspar			Rock Fragment						Cement			Others		
			Monocrystalline	Polycrystalline	Potash-Feldspar (Orthoclase)	Potash-Feldspar (Microcline)	Plagioclase Feldspar	Carbonate .R.F.%	Chert .R.F.%	Mudstone .R.F.%	Sandstone .R.F.%	Metamorphic .R.F.%	Igneous .R.F.%	Carbonate	Evaporates	Iron Oxides	Opaque Grains	Matrix	Others
Shorrshareen	Injana	**3**	17.5	2.8	2.3	1.9	4.2	32.6	5.8	4.4	0.9	3.5	2.7	8.2	2.3	0	2.8	7.2	0.9
		7	20.8	2.1	3.5	2.6	2.2	28.6	4.5	3.7	1.2	2.7	3.8	7.5	2.7	2.1	2.4	8.4	1.2
		9	17.7	3.7	2.7	2.8	3.0	27.4	7.3	3.9	1.2	3.7	2.6	9.6	0	0	3.4	9.5	1.5
		14	22.6	2.3	3.7	2.6	2.8	27.4	5.6	3.7	1.5	1.8	2.8	7.4	2.6	2.5	2.7	6.8	1.2
		21	19.4	1.6	4.2	1.8	3.7	26.4	6.8	3.2	1.8	2.7	3.1	9.9	2.6	0	3.2	8.7	0.9
		29	16.6	1.8	2.6	2.4	3.2	26.7	7.2	4.4	1.5	3.1	3.8	7.4	2.1	4.3	3.7	8.6	0.6
		32	17.5	2.4	2.1	2.3	3.2	29.9	4.8	3.9	1.2	2.4	3.1	10.7	2.7	0	4.3	8.3	1.2
		34	19.9	2.2	2.9	1.8	2.8	28.7	5.5	4.7	1.5	2.7	2.8	9.2	2.7	0	3.2	8.5	0.9
		36	20.8	2.7	3.7	2.8	3.1	28.6	5.9	3.7	0.9	2.0	3.2	8.7	0	0	2.9	9.5	1.5
		38	21.9	2.2	2.8	2.4	3.6	33.5	6.2	2.1	1.5	2.5	2.8	7.7	0	0	2.6	7.3	0.9
		42	21.6	1.8	2.4	1.5	3.8	28.2	4.8	4.7	1.8	2.8	3.1	7.5	2.7	2.0	2.9	7.5	0.9
		47	24.2	2.7	3.1	2.4	3.5	27.5	5.7	2.6	1.2	2.5	2.6	7.4	0	1.7	2.4	8.4	1.2
		49	15.8	3.2	2.7	2.4	3.2	30.8	6.3	3.7	1.5	2.7	2.0	8.3	2.8	0	3.6	10.4	0.6
		Min	15.8	1.6	2.1	1.5	2.2	26.4	4.5	2.1	0.9	1.8	2.0	7.4	0	0	2.4	6.8	0.6
		Max	24.2	3.7	4.2	2.8	4.2	33.5	7.3	4.7	1.8	3.7	3.8	10.7	2.8	4.3	4.3	10.4	1.5
		Avg.	19.71	2.42	2.97	2.28	3.25	28.94	5.87	3.74	1.36	2.7	2.95	8.42	1.78	0.96	3.08	8.39	1.03
		Total	22.13		8.5			45.56						11.16			12.5		

Quartz - Quartz is the most common mineral in sandstone and the most stable of all minerals under sedimentary conditions [11]. The percentage of quartz grains in the Injana Formation for the Shorr Shareen area ranges between 17.4 and 27.9%, with an average of 22.13%. Quartz percentage in the study area is not the most common but the rock fragments. There are two types of quartz: monocrystalline and polycrystalline quartz. The rate of monocrystalline quartz for the Shorr Shareen area ranges between 15.8 and 24.2%, and the average is 19.71%. The percentage of polycrystalline quartz for the Shorr Shareen area ranges between 1.6 and 3.7%, with an average of 2.42%. The quartz grains are anhedral and angular to subangular in shape (Fig. 3 A and B).

Feldspars - The feldspars are present in most of the studied samples of the Injana Formation. The percentage of the feldspars in the Injana Formation at the Shorr shareen area ranged between 5.8 and 11.2%, with an average of 8.5%. The feldspars are rounded to a subrounded shape, orthoclase is altered (Fig. 3 C), and microcline is fresh (Fig. 3 D). Alkali feldspar in the sandstone of Injana is dominated by orthoclase. In contrast, the microcline is found in less per cent than orthoclase, and the percentage of plagioclase in Injana sandstone is less than that of alkali feldspar (Fig. 3 E).

Rock fragments - The most abundant detrital component of the Injana Formation is rock fragments. The percentage of rock fragments in the Injana Formation in the Shorr Shareen area ranges between 37.7 and 54.8%, with an average of 45.56%. They include various types are

Sedimentary rock fragment- The sedimentary rock fragments in Injana sandstone be a high representative rate of the other rock fragments. For the Shorr Shareen area, the percentage of sedimentary rock fragments ranges from 0.9 to 33.5%, with an average is 39.91%. They include various types of carbonates (Fig.3F), chert (Fig. 3 G), mudstone (Fig. 3 H) and sandstone rock fragments (Fig. 3 I).

Metamorphic rock fragments - The percentage of metamorphic rock fragments in the Injana Formation for the Shorr Shareen area ranges between 1.8 and 3.7%, with an average of 2.7%. The metamorphic rock fragments include angular regional schist's rock fragments (Fig. 3J).

Igneous rock fragments - For the Shorr Shareen area, the percentage of Igneous rock fragments in the Injana Formation ranges from 2.0 to 3.8%, with an average of 2.95%. Igneous rock fragments are medium to coarse sized, subangular to rounded in shape; these include volcanic igneous rock fragments (Fig.3 K).

Cement - The present study shows many types of cement, mostly carbonate (Fig.3 L), with subordinate evaporate (Fig. 3 M) and iron oxides (Fig. 3N). The percentage of cement in the Injana Formation in the Shorr Shareen area ranges between 7.4 and 17.8%, with an average of 11.16%. The carbonate particles in these sandstones are detrital and thus considered amongst the framework fragments, whereas others are cement. The detrital fragments are rock fragments like limestone, whereas the cement is diagenetic. In rare cases, it wasn't easy to distinguish either of them.

Matrix -The matrix is composed of very fine clay and silt. The percentage of matrix grains in the Injana Formation at the Shorr Shareen area ranges between 6.8 and 10.4%, with an average of 8.39% (Fig. 3 O).

Figure 3- Photomicrographs of detrital grains of the formation in the Shorr Shareen area **(XPL**) A: Anhedral, subangular monocrystalline quartz; B: Angular polycrystalline quartz; C: Subrounded, altered potash feldspar (orthoclase); D: Subrounded Fresh potash feldspar (microcline); E: Plagioclase feldspar with subrounded shape; F: a fragment of carbonate rock (fossiliferous limestone); G: Subrounded chert rock fragment; H: Rounded mudstone rock fragment; I: Fine sandstone rock fragment; J: Angular regionally metamorphosed rock fragment; K: Igneous rock fragment (volcanic rocks) L: Carbonate cement; M: Evaporite cement; N:Iron oxide cement; O: Matrix: silt + clay size.

6. Classification of sandstone

The classification of sandstone is based on texture and mineralogical composition. The composition has proved to be the most important in identifying the mineralogical composition of source rocks. To determine the type of sandstone of the Injana Formation, [12]. classification is used. The major detrital framework components (quartz, feldspar and rock fragments) are recalculated to 100%. According to this classification, the sandstones fall into three main groups (quartz arenite, arkose, and litharenite). This classification showed that all the samples of Injana sandstone are classified as litharenites (Fig. 4). Litharenites have an immature composition, implying high sediment deposition rates from supra-crustal sources and short transport distances [11], [13]. has stated that the "Litharenites are immature sandstones that form under conditions that favour the deposition and production of large amounts of relatively unstable elements.

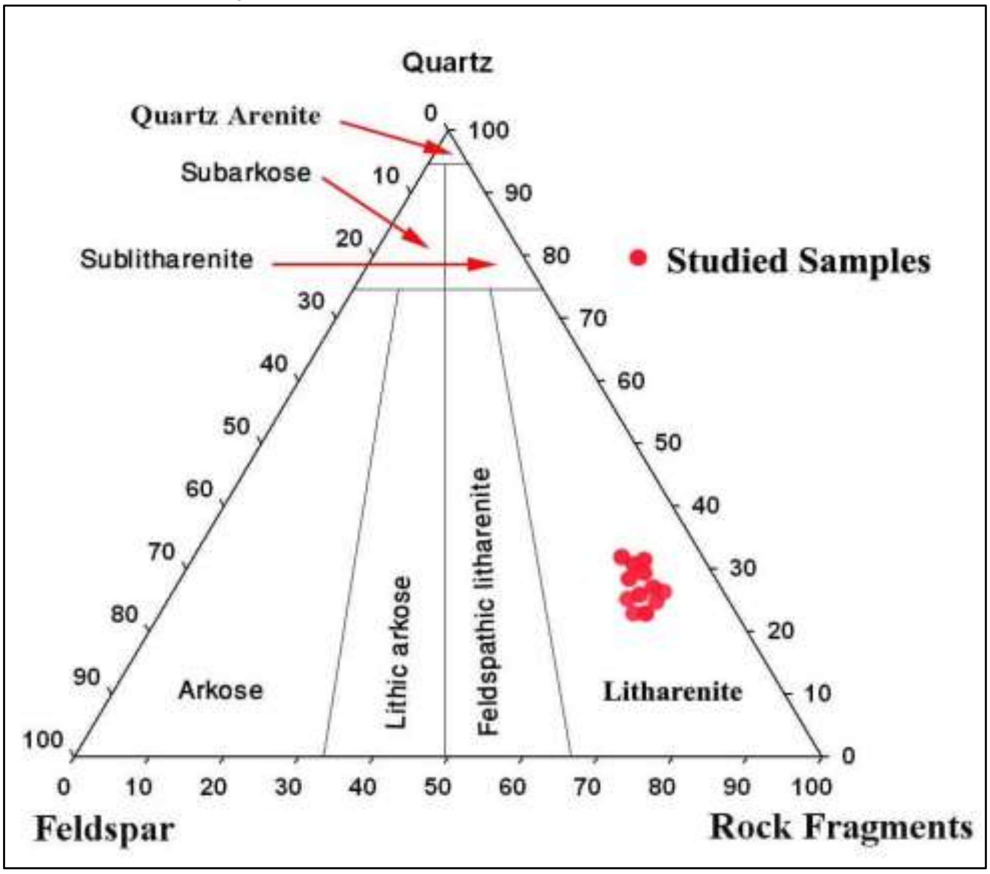

Figure 4-Classification of Injana Formation at the Shorr Shareen area [12].

7. Stability of sandstone

Bjorlykke [14]. classified the stability of sediments into chemical and mechanical, using a ternary diagram QFR: (Q: quartz- F: feldspar- R: rock fragments). Sandstone with a high percentage of quartz is chemically and mechanically stable. When the sandstone contains a high rate of feldspar, the sandstone is mechanically stable but chemically unstable. When the sandstone has a high percentage of rock fragments, the sandstone is chemically and mechanically unstable. According to this classification, Injana Formation's sandstones are chemically and mechanically unstable due to the high percentage of rock fragments (Fig. 5).

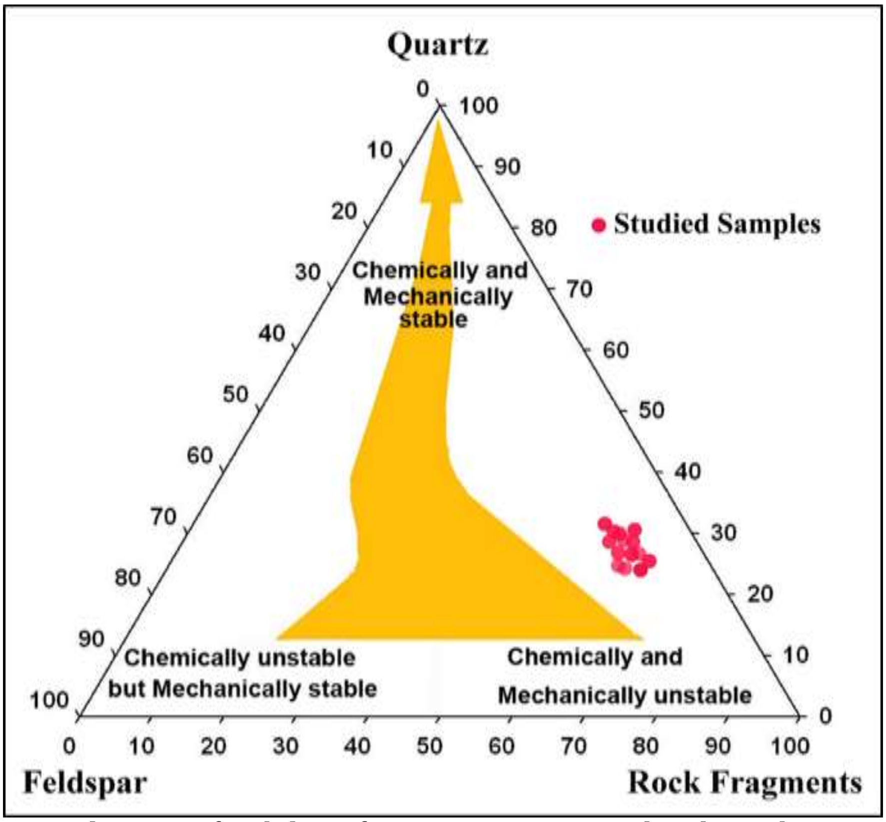

Figure 5- Ternary diagram of stability of Injana Formation at the Shorr Shareen area based on [14].

8. Maturity

Mineralogical (compositional) maturity is defined by [15]. as the extent to which clastic sediment approaches the ultimate end product derived from the formative processes that operate upon it [16]. gave an index of compositional maturity, calculated from the ratio [(quartz + chert) / (feldspar + rock fragments)]. This index was determined for each sample of the Injana Formation sandstone. The calculated index values for the studied samples show that the index of mineral maturity ranged between 0.44 and 0.63%, with an average of 0.51% in the Shorr Shareen area. The mineralogy of the Injana sandstone is immature, indicating that the source area was high-relieving and had rapid erosion and a short transport distance [17]. In areas with high relief, fast-moving rivers, and dry climatic conditions, a characteristic of unstable tectonic crusts, the existence of both stable and unstable types of rock fragments and minerals occurs together [18].

9. Tectonic setting and provenance

Clastic sedimentary rocks were divided into three broad provenances by [19] and [20]: continental block, magmatic arc, and recycled orogen. These classifications are primarily based on the petrographic properties of rocks of a specific provenance. They suggested ternary composition diagrams QFL (Q: total quartz, F: feldspar, and L: total unstable lithic fragment) to distinguish sediment from the three major tectonic provenances. The QFL is recalculated to 100%. According to [21]. deeply eroded or dissected magmatic arcs along continental margins may also expose deep-seated plutonic rocks. Volcanic rocks tend to cover undissected arcs in a nearly continuous layer. As a result, undissected arcs shed mostly volcaniclastic debris [19]. The samples from the formation at area fall into the Recycled orogeny and Transitional arc fields on the QFL diagram (Fig. 6). This difference is mainly due to the difference in the percentage of rock fragments in the formations. These sedimentary rocks are derived from sources on active continental margin under orogenic activity. These sediments are the uplifted terrains (Mesozoic and Tertiary); recycled detritus of sedimentary and meta-sedimentary origin was introduced into the basin through folded and faulted strata.

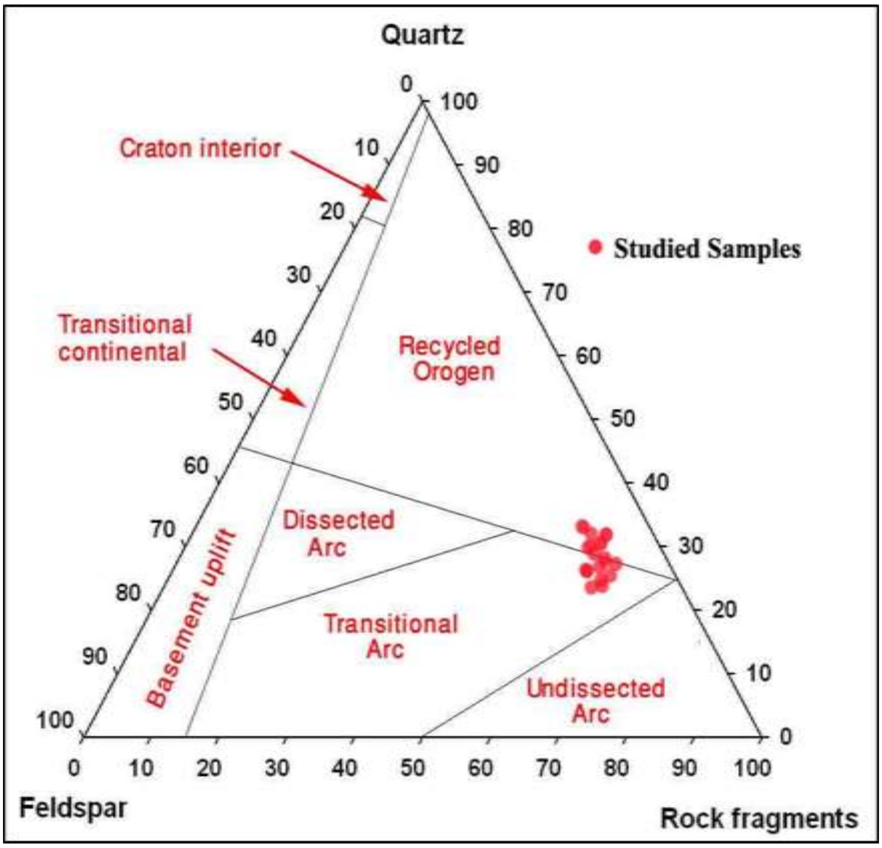

Figure 6-QFL ternary diagram of Injana Formation tectonic region provenance [20] at the Shorr Shareen area.

Petrographic studied sections of the Injana sandstone revealed that they have close content of framework grains (i.e. quartz, feldspar and rock fragments). Rock fragments, quartz, and feldspars are the minerals found in descending order. The content of rock fragments is about twice that of quartz. The dominant rock fragments are of sedimentary origin (especially carbonates). Compared to igneous and metamorphic rock fragments with a high percentage of sedimentary rock fragments, they are recycled sediments. Monocrystalline quartz is much more common than polycrystalline quartz, indicating its reworked origin, probably from plutonic igneous and metamorphic predecessors. Rock fragment to quartz and feldspar ratio is high, suggesting a common effect of weathering and low transportation distance. Another evidence of dry weather in the source area is the dominance of fresh feldspars. The sandstone of Injana Formations at the Shorr Shareen area is classified as litharenite according to classification [12]. due to the high relief, rapid erosion, and proximity of the source area, a provenance was deduced. The major framework mineral composition of the Injana sandstone indicates that the sediments derived their detritus from the Tectonic regions, Recycled orogen and Transitional arc. The Injana sandstone is mineralogically immature, according to the calculated maturity of minerals (MMI).

10. Conclusions

The sandstone of both studied sections of the Injana Formation is composed of quartz, feldspar and rock fragments in comparative percentages. Rock fragments, quartz, and feldspars are all present in descending order. Most of the rock fragments are of sedimentary origin (especially carbonates). Compared to igneous and metamorphic rock fragments with a high percentage of sedimentary rock fragments, they are recycled sediments. Monocrystalline quartz is more abundant than polycrystalline quartz, and its characteristics indicate that it is of reworked origin, probably from a metamorphic predecessor and plutonic igneous. The ratio of rock fragments to quartz and feldspar is high, and the dominance of fresh feldspars indicates a low weathering effect and low transportation distance. Such mineral association means dry weather in the source area. The litharenite classification of the Injana Formations sandstone in the Shorr Shareen area led to the deduction of provenance with high relief, fast erosion, and proximity to the source area. Because of the high percentage of rock fragments, the sandstone of the Injana Formation is chemically and mechanically unstable. According to the mineral composition of the Injana sandstone's framework, the sediments derived their detritus from the Tectonic regions Recycled orogen and Transitional arc. The calculated mineralogical maturity (MMI) indicates that the Injana sandstone is mineralogically immature.

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