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Petrography of Sandstone Units of Injana Formation in Al-Teeb Area South Eastern Iraq

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Abstract

The present study deals with study the sandstone units of Injana Formation in Al-Teeb area, east of Missan Governorate southeastern Iraq. Ten samples of this sandstone were collected in order to make thin sectioned for petrographic description. These sandstones are made of quartz (monocrystalline and polycrystalline), feldspar (potash feldspar and plagioclase feldspar), and rock fragments (sedimentary, igneous, and metamorphic rock fragment), the sedimentary rock fragments composed from; carbonate, chert, old sandstone, mudstone, and evaporate rock fragments. Three types of cement were observed these are: carbonate, evaporate, and iron oxide cement. These sandstones classify as litharenite, sedarenite, and calclithite, dure to the predominant of carbonate rock fragment. These sandstone chimachaly and michanicaly unstable due to low percentage of stable componants (quarts and chert).

Tectonically the Injana Formation was deposited under convergent plate boundaries: lithic recycled and transitional recycled conditions

Keywords: Sandstone, Polarizing Microscope, Maturity, Stability, Monocrystalline Quartz.

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Introduction

Injana Formation (Upper and Middle Fars Formations) (Late Miocene-Pliocene) symbolizes the finer grained lower molasse sediments initially formed in coastal environments and gradually in fluvio-lacustrine environment [1].

The formation was first described by [2]. The name used widely in Iraq too [3], the formation was later abandoned in Iran [4]. In Iraq [5] suggested the name Injana Formation. The type section was measured near Injana area at Jabal Himreen, the thickness in the type section is (620 m), and the age of the formation is usually accepted as Late Miocene.

The lithology of the formation consists predominantly of alternating red, brown and gray marls, siltstone and sandstone with rarely fresh water limestone, seams of gypsum are also present. The sandstone is carbonate rich with a considerable amount of detrital carbonate fragments [6].

The current study aims to know the mineral and lithological components that make up the sandstone units of the Injana Formation, in order to identify the tectonic environment in which the formation was deposited, as well as to determine the degree of stability of the formation's sediments.

Location of Studied Area

The area of study include the outcrops of Late Miocene – Pliocene formation that are located in the Al-Teeb area east of Missan Governorate (Figure 1).

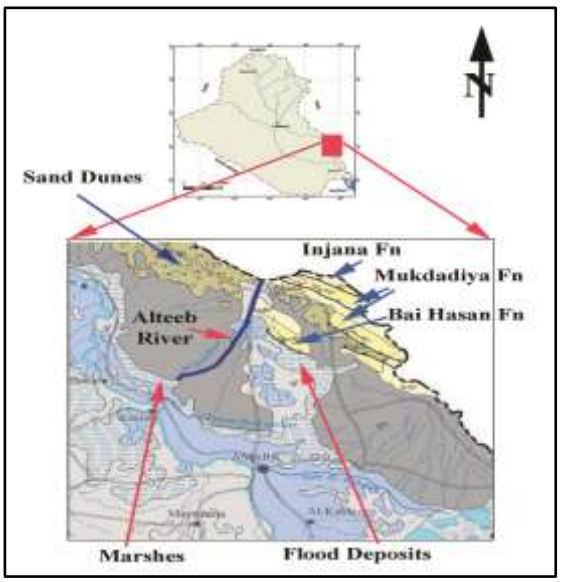

Figure 1: Location of the area under study [7].

Geology of Studied Area

The Injana Formation was discovered to be an erosional surface that extends across a large area in the examined area. and along the core of the anticline, such distribution may be due to differential weathering, a case limited the measurement of the exact thickness of the formation. The formation is composed of several progressive cycles of sandstone, siltstone, and claystone with a predominant red coloring. Many veins of secondary gypsum were noticed within these units (Figure 2)

The gradual transition from marine to lacustrine and fluviatile sedimentation is what defines the cycle. Gradational coarsening of the clastics deposited over the cycle coincided with this transition. [1].

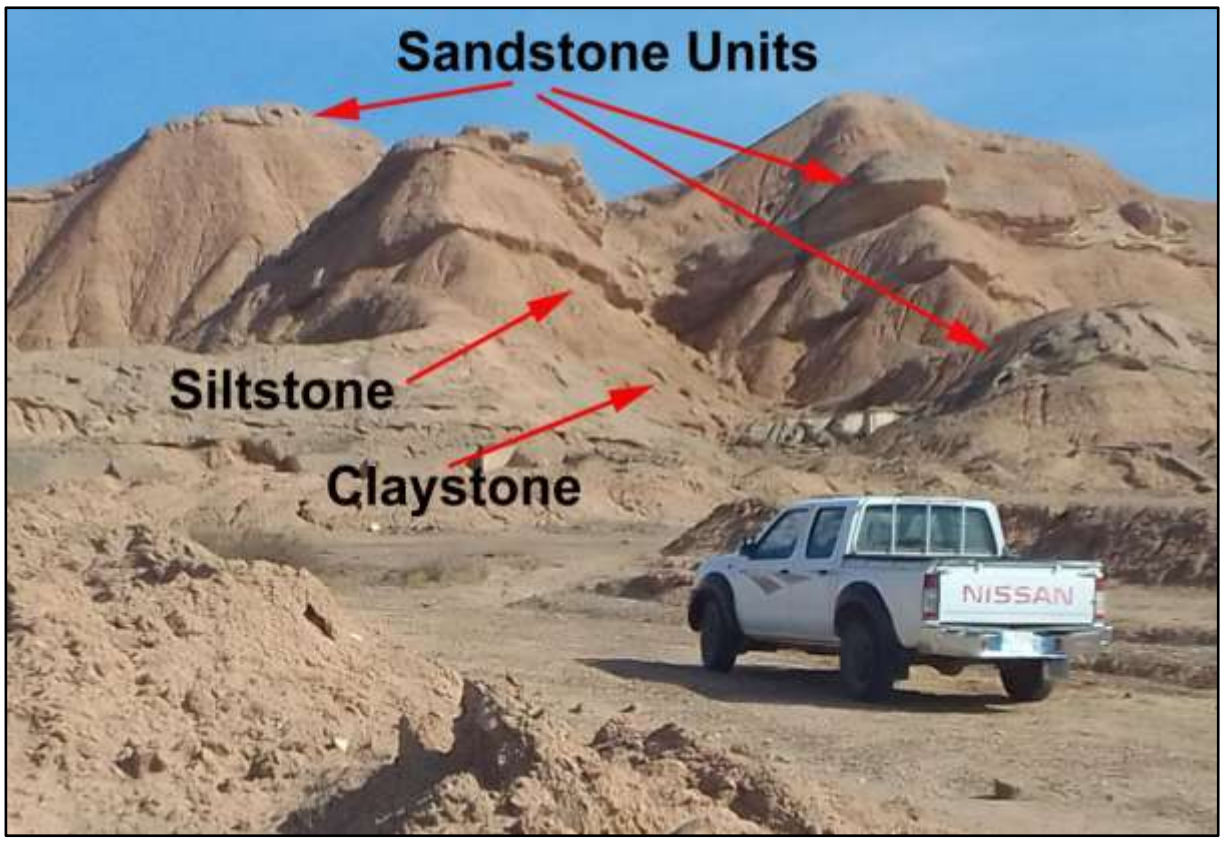

Figure 2: Outcrops of Injana Formation in the area under study.

Tectonically the area under study lies in two zones, Mesopotamian Zone (Tigers Subzone), and Foothill Zone (Himreen-Makhul Subzone), (Figure 3). The Himreen-Makhul Subzone is the

structurally deepest part of the Foothill Zone. The subzone was the depocenter of the Neogene's molasse but has been a subsiding unit throughout the Mesozoic and Tertiary [8].

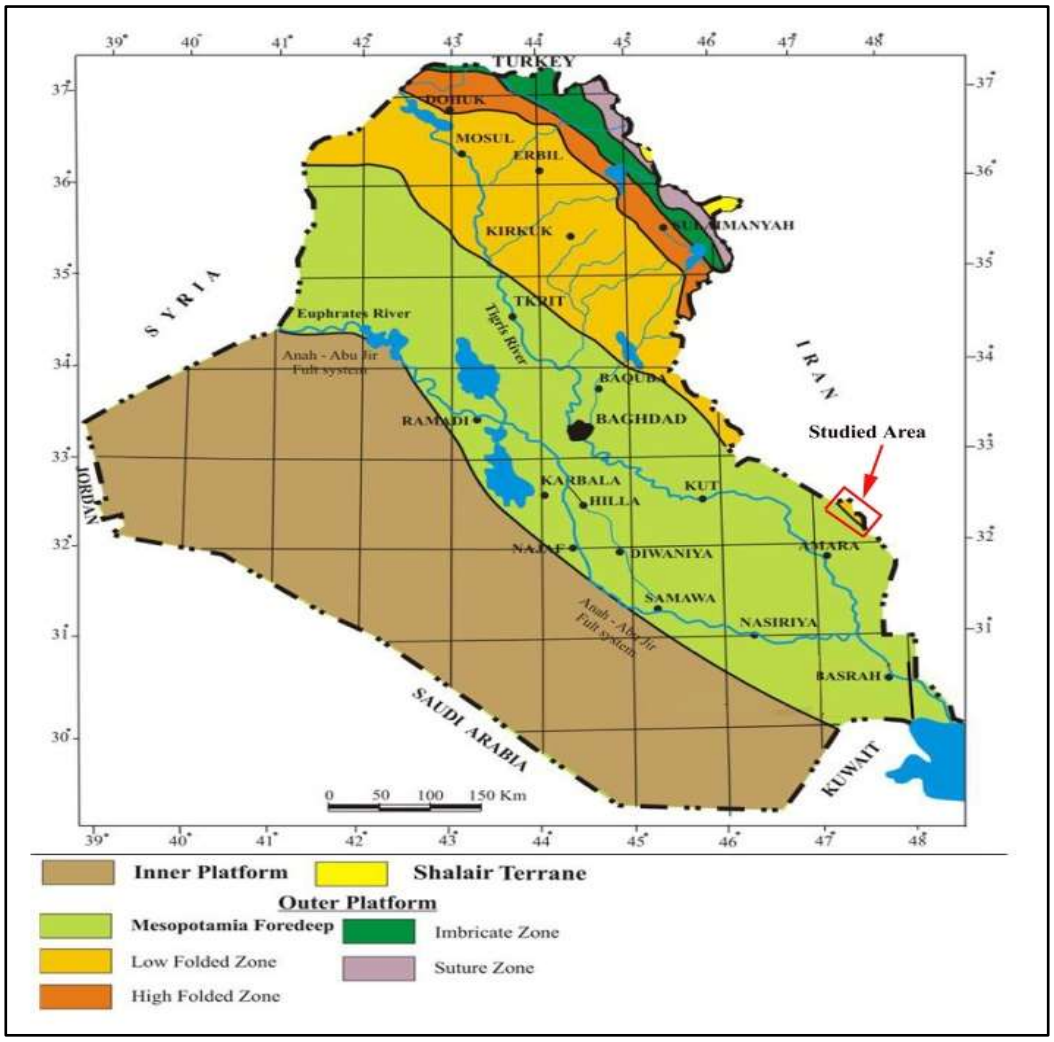

Figure 3: Tectonic map of Iraq [9].

Methods of Study

Ten samples from outcrops of Injana Formation sandstone units are collected during field surveys in November 2020 This study is to cover sandstone units in order to determine the model analysis of these sandstones after preparation the thin sections , the components of these sandstones determined by using boint counting methods that suggested by [10] by using Leitz research polarizing microscope.

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Result and Discussion

Studied samples of sandstone units of Injana Formation were examined under the polarizing microscope in order to determine the modal analysis of this sandstone. Table 1 represents the percentages and average of the components of these sandstones. Figure 4 represent the photomicrograph of the components of studied sandstones.

Table 1: Components of sandstones with their percentages.

Sandstone Components		Samples Number										
		TI1	TI2	TI3	TI4	TI5	TI6	TI7	TI8	TI9	TI10	Average
Quartz	Monocrystalline	23.4	21.6	21.1	24.7	22.3	19.5	20.5	18.6	17.4	18.7	20.77
	Polycrystalline	2.2	2.5	3.2	2.1	4.6	3.4	2.6	2.5	1.5	2.5	2.75
Total Quartz		25.6	24.1	24.3	26.8	26.9	22.9	23.1	21.1	18.9	21.2	23.49
Feldspar	Potash-Feldspar	2.9	3.4	2.7	2.6	2.9	2.3	2.7	2.8	2.1	3.1	2.74
	Plagioclase	2.3	1.8	2.4	2.8	2.5	1.9	1.5	2.5	1.7	2.2	2.15
Total Feldspar		5.2	5.2	5.1	5.4	5.4	4.2	4.2	5.3	3.8	5.3	4.91
Rock Fragments	Carbonate R.F.	26.5	27.3	22.5	21.4	27.6	26.7	22.7	23.4	21.5	22.5	24.20
	Chert R. F.	7.4	8.9	7.7	6.2	7.8	6.4	6.3	7.3	6.3	7.2	7.14
	Mudstone R. F.	4.8	4.6	3.8	4.5	4.6	5.6	4.6	3.8	4.5	4.6	4.53
	Sandstone R.F.	2.6	1.8	2.5	1.7	1.9	1.7	2.8	2.9	2.3	1.5	2.16
	Evaporites R.F.	-	-	3.3	4.8	-	1.2	3.2	2.2	4.5	3.2	2.23
	Metamorphic R. F.	2.8	1.6	2.5	2.7	3.5	2.3	2.8	2.9	2.6	2.7	2.63
	Igneous R. F.	3.4	3.6	3.1	2.8	3.4	3.4	3.3	3.2	3.1	3.4	3.26
Total Rock Fragments		47.5	47.8	45.4	44.1	48.8	47.3	45.7	45.7	44.8	45.1	46.19
Cement	Carbonate	8.1	8.6	8.3	9.4	7.3	8.3	9.8	6.8	6.8	6.5	7.98
	Evaporites	-	-	4.5	3.5	-	3.0	3.5	8.1	5.4	4.9	3.28
	Iron Oxides	2.4	-	2.0	-	-	1.6	1.6	-	3.5	3.2	1.43
Total cement		10.5	8.6	14.8	12.9	7.3	12.9	14.9	14.9	15.7	14.6	12.70
Opaque Grains		2.3	3.2	1.8	2.9	2.9	3.5	2.9	3.2	2.3	1.8	2.67
Matrix		7.7	9.6	7.5	6.4	7.1	8.0	7.5	10.7	11.4	10.4	8.63
Others		1.2	1.5	1.1	1.5	1.6	1.2	1.7	1.2	2.0	1.6	1.45

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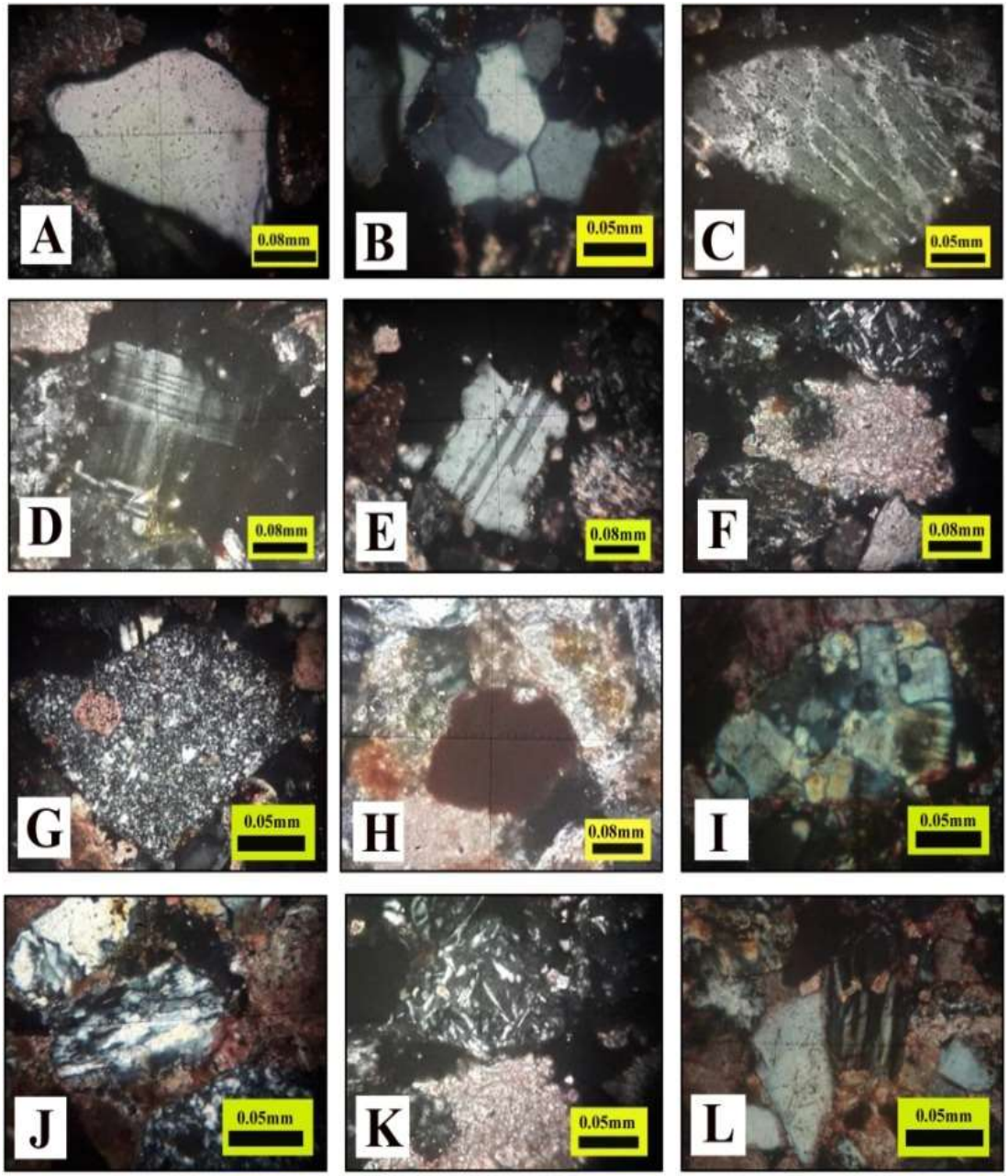

Figure 4: Components of studied sandstones were by A: Monocrystalline Quartz, B: polycrystalline quartz, C: potash feldspar (orthoclase), D: Potash feldspar (microcline), E: plagioclase feldspar, F: carebonate rock fragment, G: chert rock fragment, H: mudstone rock fragment, I: old sandstone rock fragment, J: metamorphic rock fragment (schist), K: igneous rock fragment (basalt), L: carbonate cement.

The following represent the petrographic description of each component:

A- Quartz

The proportion of quartz that ranges from 18.9 –26.9 %, averaging 23.49%. There are two varieties of quartz that are known: monocrystalline and polycrystalline. The monocrystalline quartz grain (unitary quartz) are characterized as grains that only contain one crystal. [11], their percentage with an average of 20.77% and a range of 17.4-24.7%. Generally speaking, monocrystalline quartz has an angular form and fine grains. (Figure 4), these characteristics can suggest that the distance to be traveled from the source place is not too far. [12].

The Injana Formation sandstone has an average of 2.75% of polycrystalline quartz, with a range of 1.5% to 4.6%.The term "composite quartz" refers to quartz grains that are composed of two or more quartz crystal units with distinct optical orientations [11]. Sandstones include a certain amount of polycrystalline quartz, which increases in proportion to grain size [13].

Generally angular, fine-grained, and about equidimentional in shape, the polycrystalline quartz discovered in the Injana Formation exhibits straight to slightly undulose extinction. Within these grains, inclusions have also been detected (Figure 4).

B- Feldspars

The percentage of feldspars in the sandstone of Injana Formation ranging between 3.8-5.4%. with an average 4.91%. This is a minor constituent of Injana Formation. Feldspars identified include, alkali feldspar (orthoclase and microcline), with an average of 2.74%, and plagioclase with an average of 2.15 %. Additionally, noted were perthtic grain. Some of the subhedral, corroded feldspar grains are fresh, while others have been altered (Figure 4). The newly formed feldspar grains may indicate a fragmentation process from igneous rocks along with a short transit distance. [12].

C- Rock Fragments

These Components represent the main component of sandstone units of Injana Formation, these components ranging from 44.1-48.8%, with an average 46.19%, they consist of carbonates, cherts, mudstone, sandstones, evaporates, igneous, and metamorphic rock fragments. Below is a discussion of each of these categories' attributes and abundance:

- Carbonate Rock Fragments: It's found in the Injana Formation sandstone, carbonates have the highest percentage, with a mean of 24.20% and a range of 21.4–27.6 %. The fragments of carbonate rock are rounded to sub-rounded in shape and range in size from extremely coarse to fine grained (Figure 4). They comprise fragments of fossiliferous limestone, reworked skeleton, shell, and carbonate fragments from micritic deposits.

- Chert Rock Fragments: These fragments exhibit the second category in terms of abundance among rock fragments; they ranged in size from very coarse to fine grained, the percentage of chert rock fragments ranging between 6.2-8.9%, with an average of 7.14 percent. They have an angular shape. The following chert types were found in the Injana Formation sandstones: microcrystalline chert, macrocrystalline chert, chalcedonic chert, jasperoid chert, radiolarian chert was also observed in some samples, in addition, few grains of nodular type (Figure 4).

- Mudstone Rock Fragment: The percentage of mudstone rock fragments ranging between 3.8-5.6 % with an average of 4.53 %. Different types of mudstones rock fragments were observed, earthy dark red color, dense fragments, range from yellowish to brownish, and mudstone rock fragments are usually rounded to sub rounded in shape, fine grained in size, indicating an intra-basinal origin (Figure 4).
- Sandstones Rock Fragments: These fragments composed of cemented fragments of older sandstones (Figure 4), their percentages ranging between 1.5-2.9 %, with an average of 2.16%, the fragments are irregular in shape, but some fragments are subrounded.
- Evaporites Rock Fragments: These fragments composed of gypsum and anhydrite grains (Figure 4), their percentages ranging between 0-4.8 %, with an average of 2.23%, the fragments are irregular in shape, with chemical texture.
- Metamorphic Rock Fragments: 2.63% is the average proportion of metamorphic rock fragments, which range from 1.6 to 3.5 %. Among the fragments of metamorphic rock are the following: schist rock (Figure 4). Some grains are altered, others are fresh.

- Igneous Rock Fragments: The average proportion of igneous rock fragments is 3.26 percent, with a range of 2.8- 3.6%. The majority of the grains are fine-sized, subangular fragments of volcanic rock, such as basalt (Figure 4).

D- Cementing Materials

The percentage of cement ranging between 7.3-15.7%, with an average 12.7%.Three types of cementing material were observed in the studied sandstone samples of Injana Formation. Carbonate cement is abundant in Injana sandstone (Figure 4), The carbonate cement occur in several forms, the first is the coarse clear sparite or microsparite carbonate and the second is the thick micritic crystal that fills the gaps left by the detrital component. Iron oxide cement and evaporates cement was also observed with lesser existence as coating materials around the detrital grains.

E- Opaques Grains

This group consists of all opaque minerals grains, with an average proportion of 2.67% percent and a range of 1.8 to 3.5% in the Injana Formation sandstone, the shape of these grains are mostly angular, the opaque minerals may include many opaques minerals such as limonite, magnetite, hematite, chromite, pyrite etc, these minerals need more technique for identification such as reflected light microscope. as suggested by the distinct and noticeable red and yellow coloration and stain.

F- Matrix

The percentage of matrix in the sandstone of Injana Formation ranging between 6.4-11.4 %, with an average of 8.63 %. The silt to clay-sized particles that make up the matrix is extremely fine. Matrix consists of very fine material of silt to clay sized.

Classification of Sandstone

Sandstones are categorized according to their mineralogical composition and texture. Composition has proved most meaningful and forms the base for nearly all classification systems. Thus, in order to reach a more complementary view about the types and consequently a better ability to make a reliable conclusion concerning the mineralogical composition source rocks, the sandstones of Injana Formation are classified with much depending on the different modal components and named. The types and nature of these sandstones are as follows:

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Depending on the nature and percentage of their rock fragments content 14], classified the sandstone into three main groups; (quartz arenite, arkose, and litharenite) (Figure 5). According to the above classification all the Injana sandstones are Litharenite, characterized by extremely low quartz and feldspar content and significantly higher proportions of rock fragments.

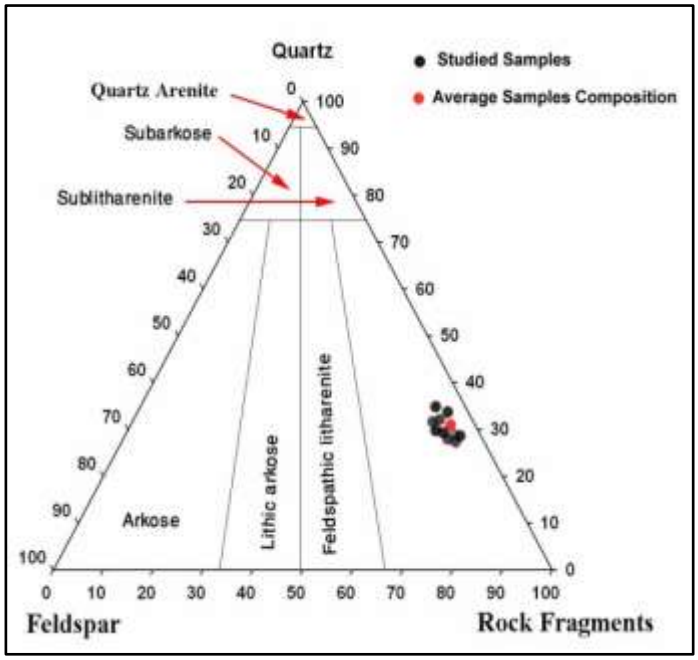

Figure 5: Classification of the sandstone of Injana Formation [14].

Because litharenites have an immature composition, they are thought to have been produced at high rates from supracrustal sources over short travel distances. A large portion of riverine sandstone is litharnite [11].

The composition of litharenites is immature sandstones that form in an environment that is conducive to the formation and deposition of a significant amount of relatively unstable elements [15].

Numerous lithic fragments in the sandstone exhibit mechanical weakness, indicating that their origin was likely a rough, high terrain location [16]. A lot of immature lithic sands can be found in high relief sources [12].

The sandstone of Injana Formation is reclassified according to the types of rock fragments, the sandstone of Injana Formation are **Sedarenite** [14], (Figure 5, 6, and 7).

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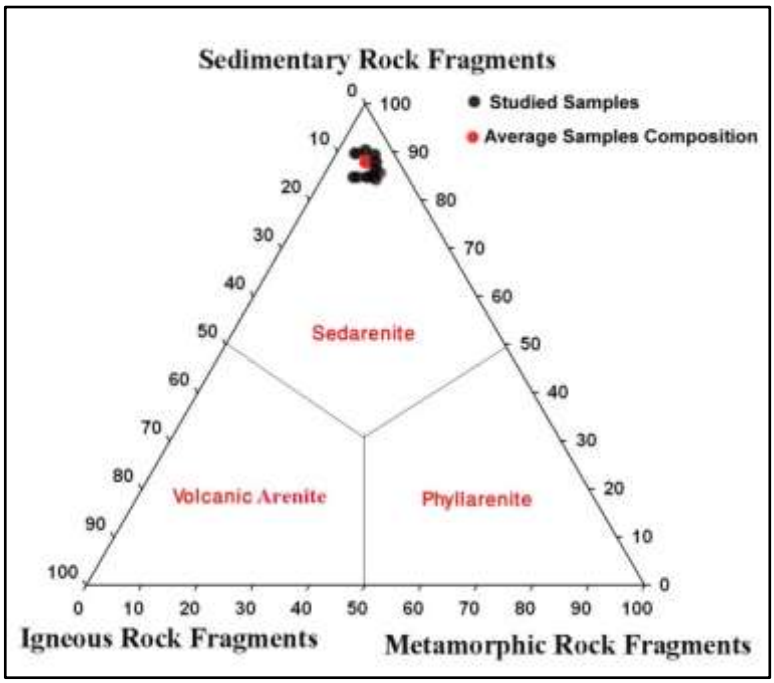

Figure 6: The classification of studied sandstones according to the types of rock fragments [14].

The Injana Formation sandstone was classed based on the kind of sedimentary rock pieces found in it. [14]. According to this classification, the sandstones of Injana Formation are equally distributed into the **Calclithite** (Figure 7). [14] regarded these sandstones with high carbonate content as a distinct and significant category of the Litharenite type.

The deposits of calclithite are deposited in river channels and alluvial fans, with varying levels of maturity and numerous carbonates. The source areas of the rock show a rough relief. Most, if not all, calclithites are cemented using calcite. [14].

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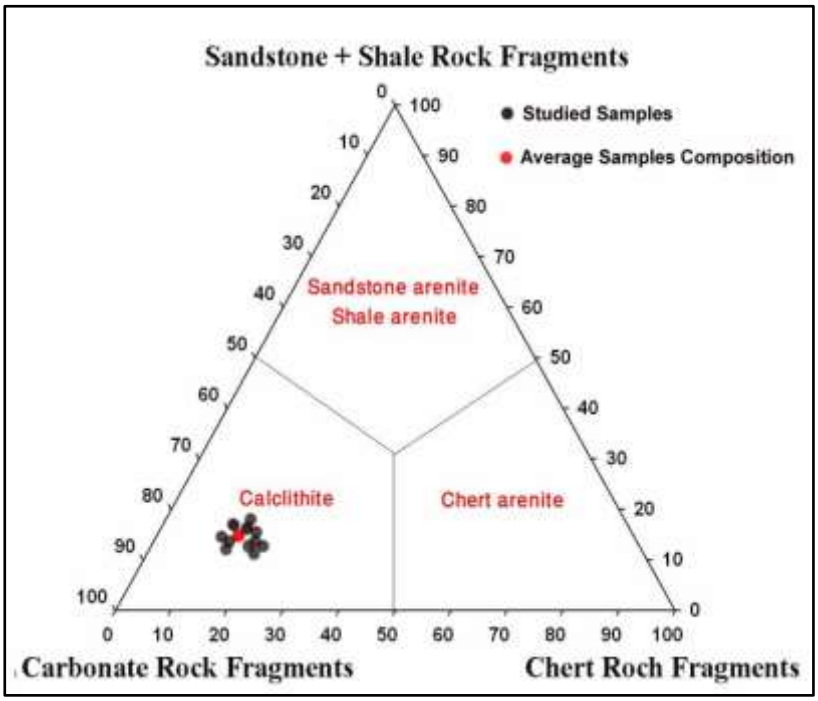

Figure 7: The classification of studied sandstone according to the types of sedimentary rock fragments [14].

Stability

The maturation of sand takes place in two ways, chemically, which represents the compositional maturity, and physically, which point to textural maturity [17].

Both physical and chemical maturation occur during the history of a sand population, but they are not closely related [18]. Thus a chemically mature may be physically immature and vice versa. From the above, Injana sandstones are found both chemically and physically immature. This is indicated by the presence of a high percentage of unstable grains such as feldspars and carbonate rock fragments, on the other hand, physically immature sandstones refer to poorly sorted with a size range from gravel to clay size.

The chemical and mechanical stability classification proposed by [19] in [11], he used the ternary diagram (quartz-feldspar-rock fragments) (Figure 8), [19] state that When the percentage of quartz in the sandstone is high, When the percentage of feldspar in the sandstone is high, it suggests that the sandstone is both mechanically and chemically stable; when the

percentage of rock fragments in the sandstone is high, it suggests that the sandstone is both mechanically and chemically unstable. According to this classification, the sandstone of the Injana Formation is unstable chemically and mechanically. (Figure 8).

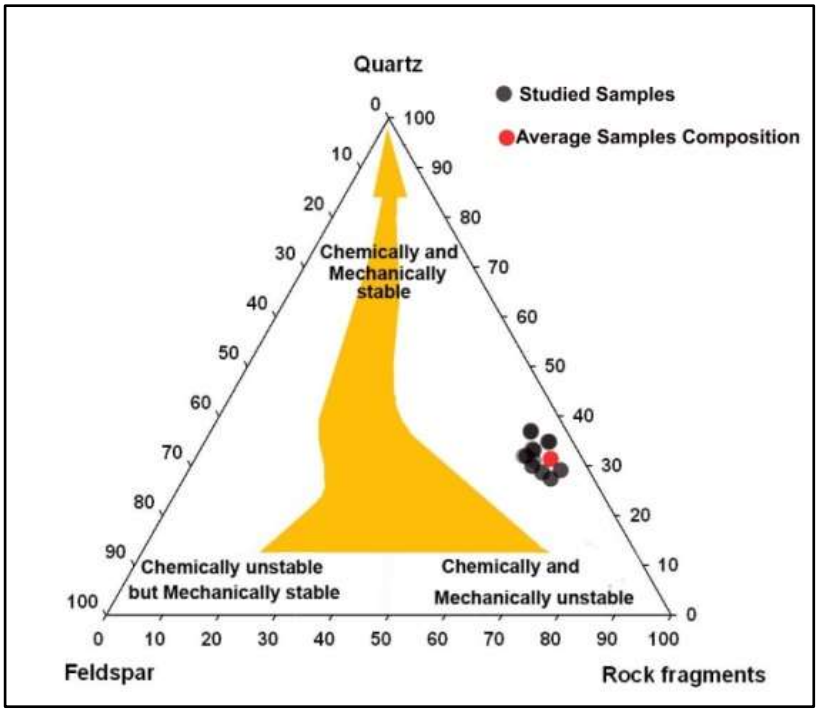

Figure 8: Ternary diagram of the stability of the Injana Formation sandstone [19].

Tectonic Setting

The nature of sedimentary processes and the provenance of sediments within the deposition basin are reflected in the composition of sandstone. Provenance and depositional basin are governed by the tectonic regime, which in turn control the distribution of types of sandstones [20].

There are strong relationship between plate-tectonic activity and sandstone composition. In light of this [21]; [22]; [23]; [24]; and [25], [21] suggested three Tectonic settings, or provenance, can be divided into three primary categories:

(1) Provenance from recycled origins; (2) provenance from magmatic arcs; and (3) provenance from continental blocks.

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The three-component diagrams (ternary diagram) recommended by [21] and [24], which depict the framework ratios of [monocrystalline quartz, feldspar, and (rock fragments + polycrystalline quartz)], were used to distinguish between deposits that come from these three primary tectonic sources (Figure. 9).

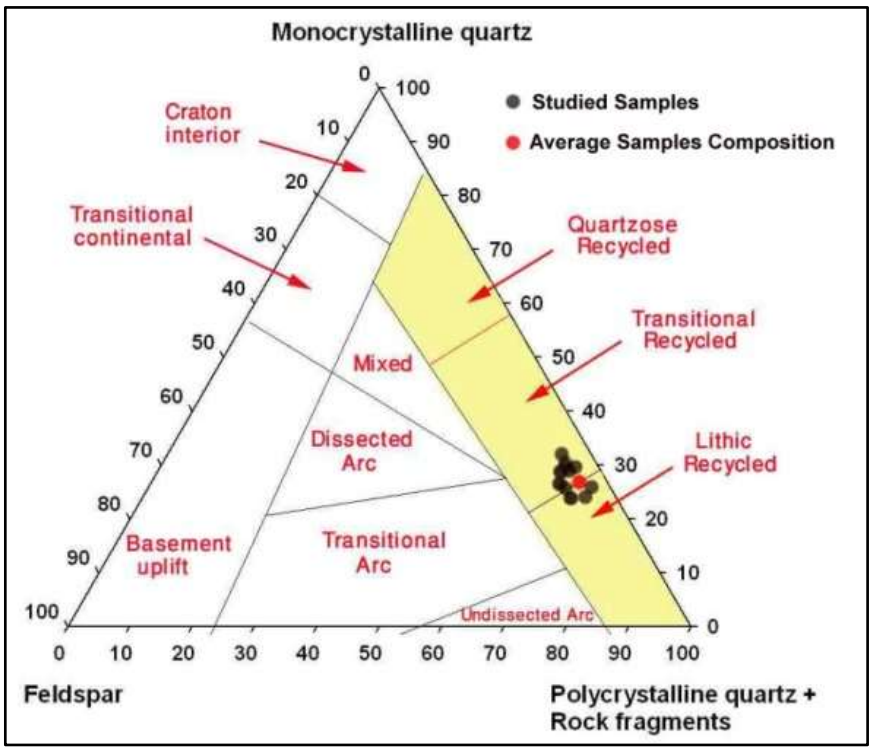

Figure 9: Provenance diagram showing the relationship between framework composition of the sandstone of Injana Formation and tectonic setting [24].

The percentage of rock pieces + polycrystalline quartz, monocrystalline quartz, and feldspar were plotted from the modal analysis of the Injana Formation sandstone (Figure 2-8). This figure illustrates the average composition of monocrystalline quartz, feldspar, and rock fragments, rock fragments +polycrystalline quartz of the sandstone of Injana Formation lies within the **Lithic Recycled** provenance**.**

Lithic recycled are zones of plate convergence, where collision of major plates creates uplifted source areas along the collision suture belt [16].

Conclusions

A- The sandstones of Injana Formation are classified as Calclithite, consist predominantly of rock fragments 46.19%, mainly carbonate rock fragments, quartz 23.49%, feldspars 4.91%, opaques grains 2.67%, cement 12.70%, and matrix 8.63%. The mechanically weak character of many of the lithic fragments in the sandstone suggests that they were probably derived from rugged; high relief source area. High relief sources may yield abundant immature lithic sands.

B- The studied sandstones are mostly chemically and physically immature as indicated by the high ratio of the unstable grains (carbonate rock fragments and feldspars).

C- The tectonic provenance of the sandstone of Injana Formation is Lithic Recycled, and Transitional Recycled. The abundance of different types of rock fragment, fresh feldspar and angular to subangular nature of the grains are the most important indications of such characteristics of the source area.

Lithic recycled are zones of plate convergence, where collision of major plates creates uplifted source areas along the collision suture belt.

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