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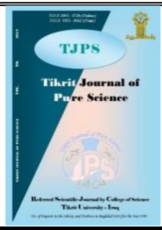

Provenance of sandstone layered in Injana Formation from Zawita and Dekala areas Northern of Iraq

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ABSTRACT

To interpret the provenance 0f Injana Formation, 20 sandstone samples of Injana Formation were collected from Zawita and Dekala areas north Iraq (10 for each sections), then thin section have been done sildes. The petrographic study showed that the sedimentary, metamorphic and igneous rock fragments, quartz (mono&polycrystalline) and feldspars (microcline, orthoclase and plagioclase) make up the main grain components of the sandstone. Carbonate cement is more common cementing minerals, and the matrix is subordinate. The percentage of mono-quartz and sedimentary, igneous rock fragments are greater than the amounts of feldspar and poly-quartzand metamorphic fragments. A diagenetic processes were represented by the carbonate, iron oxides and evaporite cements, as well as compaction, cementation, and dissolution. The majority of the rocks of Injana Formation's provenances are sedimentary and igneous, with minor amounts of subordinate metamorphic rocks. These sandstones are considered to be immature and classified as immature Litharenites type. The tectonic provenances that are extrapolated from petrographical results are transitional and lithic with effect of uplifting of Alpaine oroging recycled origin which are derived from the order rocks during the Miocene age.

مصادر طبقات الحجر الرملي في تكوين انجانه في مناطق زاويته وديكله شمالي العراق

ساره علي العامري ، لفتة سلمان كاظم

قسم علوم الارض التطبيقية ، كلية العلوم ، جامعة تكريت ، تكريت ، العراق

الملخص

تم جمع (20) عينة من الحجر الرملي لتكوين إنجانة متمثلة (10) عينات من مكشف زاويته و(10) عينات من مكشف ديكلة.(20) عينة عملت منها شرائح رقيقة لغرض الدراسة البتروغرافية ((10) شرائح من مكشف زاويته و(10) شرائح من مكشف ديكلة).

الملاحظات البتروغرافية أظهرت ان الصخور الرملية لتكوين إنجانة مؤلفة بصورة اساسية من القطع الصخرية (الرسوبية، النارية والمتحولة)،الكوارتز (الاحادي التبلور والمتعدد التبلور) الفلدسبار (اورثوكليز ،مايكروكلين والبلاجوكليز).الحشوة تكون ثانوية والسمنت غالبا كاربوناتي. اصل تكوين إنجانة يتألف بصورة اساسية من صخور رسوبية ونارية وبصورة ثانوية صخور متحولة. ومن خلال دراسة العمليات التحويرية وتمثلت بوجود عملية الانضغاط والاذابة والسمنتة بأنواعها .هذه الصخور تصنف على انها ارينايت صخري وغير ناضجة معدنيا .الاصل التكتوني للتكوين أظهر بأنها تقع ضمن نطاق الاورجيني المعاد الترسيب.

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1-Introduction

Injana Formation (previously nominated Upper Fars Formation), of Upper Miocene age and widely exposed throughout Iraq, initially described by Busk and Mayo in 1918 [1]. And studied by the grained molasses sediments known as Injana Formation were initially deposited in fluvial environments [2]. Injana Formation is used in place of the names of the Upper Fars Formation [3]. Due to their exposure and extension, there are many studies on Injana Formation. As [4] showed provenance and petrology, [5] appear sedimentology of Injana Formation in Zawita, [6] showed petrography and sedimentology, [7] appear of geochemistry and petrography in Zawita area . This study is aimed to interpret the origin and tectonic setting of the provenance area many authors, The study area's coordinates are Longitude 33 °52ˈ 20ʺ, Latitude 40° 88ˈ 988ʺ for Zawita and Longitude 45° 01ˈ 81ʺ, Latitude 39° 97ˈ 686ʺ for Dekala included Injana Formation.(Figure-1)

2-Geological Setting

Zawita areas is situated at High Folded Zone north iraq (Outer Platform) [8] .The Arabian Plate Tectonostratigraphic Megasequnce AP11 includes Injana (Upper Miocene) Formation[9]. The NE Arabian Plate margin's closing of the Neo-Tethyan Terranes Mio-Pliocene molasses in the foredeep basin to the southwest of the Zagros Suture, in the N and NE drift of Arabia, is up to 3000m thick. Is dominates the megasequence in the Foothill and northern and northeastern high Folded Zones of iraq [10]. The gradual transition from marine sedimentation to lacustrine and fluviatile sedimentation is a feature of the Upper Miocene cycle [10].Then coarsening of the clastics gradually deposited over the cycle accompanied this transition. The rising mountain in the northeast Iraq served as the primary source area for clastics [2]. The final limestone bed indicates the gradational lower contact of Injana Formation with the underlying Fatha Formation whereas gravely sandstone appears near the overlying Mukdadiya Formation's Upper contact with also gradational [4]. Major thrusting occurred in Late Miocene-Pliocene, when the Sanandaj-Sirjan Zone and Neo-Tethyan terrane sclashed with the Arabian Plate. The NE portion of the Balambo-Tanjero Zones, the Northern Thrust Zones, and the high foleded and Mesopotamian zones were all uplifted as a result of this event. The High Folded Zone was elevated as the up lift the Late Miocene and particularly in the Pliocene; intensity; where the by products deposits of erosion were deposited in the molasses basin[10].

3-Methods of Research

Twenty sandstone samples of Injana Formation. were collectedand thin from Zawita and Dekala areas (10 for each section),then sections have been done to thin slides, stained with Alizarin red's to differential the type of carbonate rock fragment, and examined under a transmitted polarizing microscope. According to recommendations made by point-counter mechanical stage, 300 grains per thin section are counted to determine the percentage of various components [12].

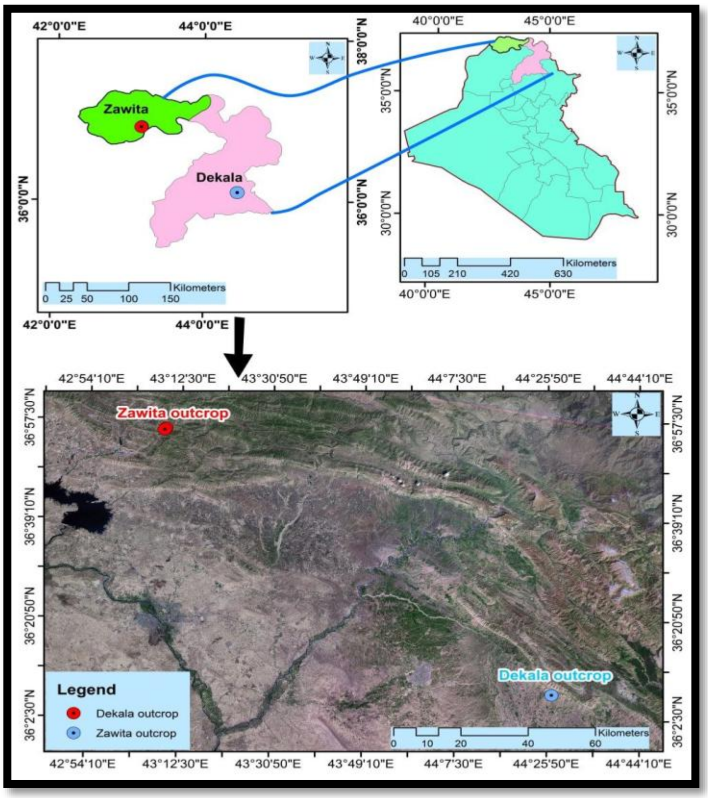

Fig. 1: Geological map of the studied area shows the location of the studied sections.

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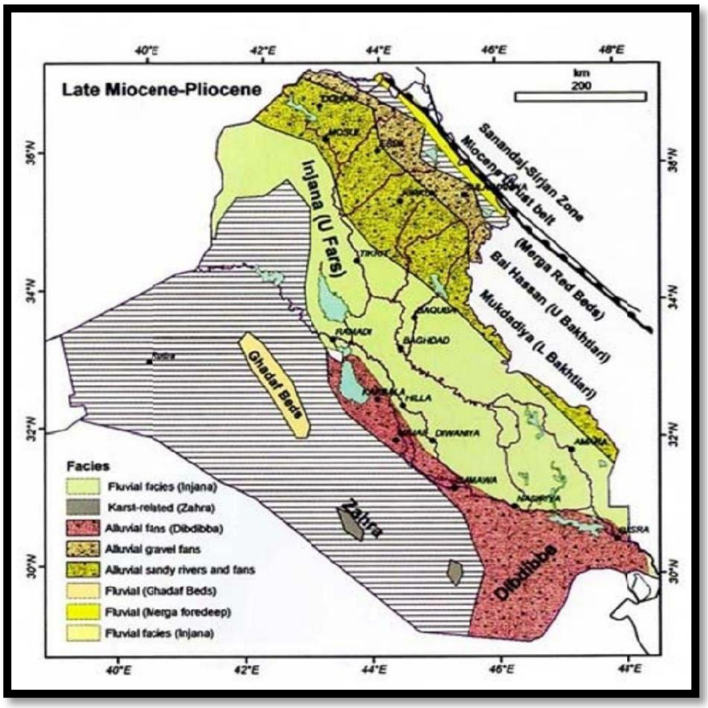

Fig. 2: Late Miocene-Pliocene Palaeogeography [10].

4- Field description

The field trip includes the determination of the lower contact between the last layer of the carbonate rocks of the oldest Fatha Formation and the beginning of the sandstone to the Injana Formation. The determination of the upper contact with the Makhdadia Formation depends on the appearance of the first thin beds of the fine conglomerates and this is represents the gradual contact and beginning of sedimentation of the Mahkdadia Formation. Mahkdadia Formation consist of the succession of sandstone and clay stone rocks in both two outcrops as a cyclic succession of the detrital rocks (Figure -3).

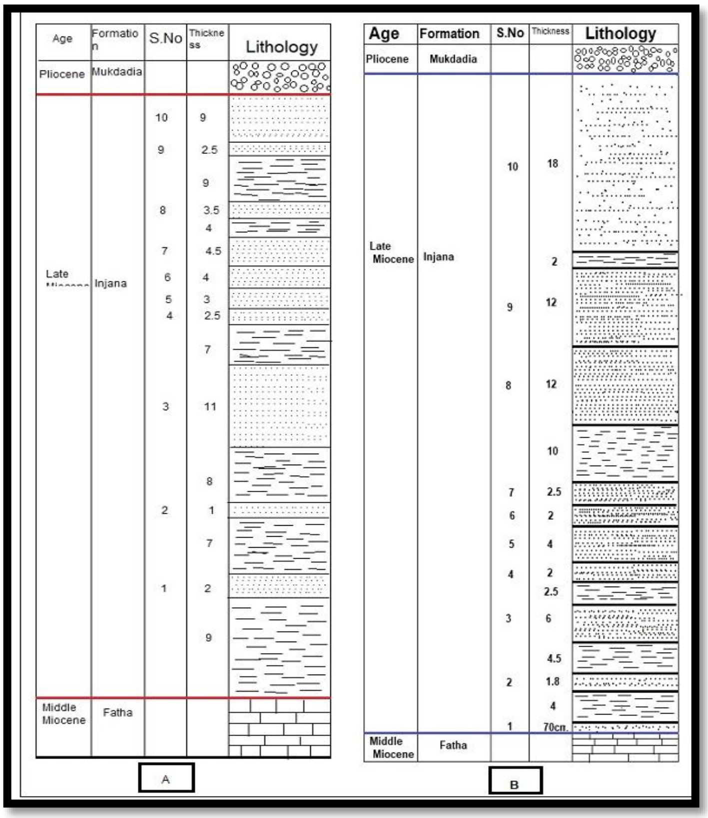

Fig. 3: Sedimenological section of Injana Formation at Dekala area (A) and Zawita area (B).

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5- Results and analysis

5.1. Textural Components

Injana Formation sandstones mostly immature grains derived from many source. The majority of grains are sub angular or sub rounded which transported for short distance with high speed currents of affected by the continuous of uplifting in source area. Injana Formation sandstone has finer, less angular grains. Injana sandstone's primary detrital components are subordinate matrix and poorly sorted because content many of mono-quartz and poly-quartz .Shape of grain rock fragment rounded.

5.2. Mineralogy and Lithic components

The main components of Injana Formation sandstones are, quartz (Q), feldspar (F), and rock fragments (L). Combined together mainly by carbonate cement. Quartz and rock fragment percents are larger than feldspar percent note. This results demonstrating that source area features are characterized by the high relief, quick weathering, short transport distance and unstable tectonic crust swiftly moving streams, and arid climates [21]. (Table-1).

Table 1-Petrographical components of injana Formation sandstone at the Zawtia and dekala area, with its Percentage and average

Sample No.	Quartz%	Feldspar%	Rock Fragment%	Others		
				Cement%	Matrix%	Others %
Z1	13.4	8.9	58	12	7.4	0.3
Z2	13.9	11.3	55.3	9.9	8.5	0.2
Z3	12	9.6	55.3	12.1	10.7	0.3
Z4	12.6	9.3	58.7	9.5	9.3	0.6
Z5	10.6	7.4	57.2	12.4	10.4	0.9
Z6	11	9.1	58	12.6	9.7	0.6
Z7	12.3	7.7	57.2	8.5	10.7	0.9
Z8	13.1	10.9	59	8.2	8.4	0.6
Z9	10.7	9.9	55.9	12.4	9.7	1.4
Z10	10.1	7.9	59.4	10.7	10.6	1.5
Average	11.97	9.2	57.4	10.83	9.54	0.73
D1	13.3	9.7	58.2	10.5	7.7	0.6
D2	15.9	10.2	53.5	9.9	9.6	0.9
D3	15.4	8.5	54.9	9.2	10.8	1.2
D4	14.9	8.8	51.9	13.4	9.7	1.3
D5	15	10.9	55	9.7	8.8	0.6
D6	12.4	8.5	55.2	14.7	9.3	0.9
D7	12.9	8	59	10.6	8.1	1.4
D8	14.1	8.5	55.9	12.1	8.8	0.6
D9	11.5	9.9	59.1	8.5	9.7	1.3
D10	14.1	10.6	56.4	7.8	10.8	0.3
Average	13.95	9.36	55.91	10.64	9.06	0.91

Rock fragments (L) –The majority of the detrital components in Injana Formation sandstones are rock fragments, which range from 55.3%-59.4% (average57.35) in the Zawita area,(average 55.5) in the Dekala area 51.9%-59.1%. The main type of rock fragments are sedimentary origin, including chert, carbonate, argillaceous, and sandstone. carbonate rock fragments are the most prevalent. Secondary types of rock fragments are igneous (volcanic and plutonic) and metamorphic rock. Sandstone rock fragments are often sub angular to sub rounded and are typically coarser than the other component in both locations. Figures-4 (F, G, H, I, J and K)

Quartz (Q) - The second frequently detrital mineral is Quartz. Mostly mono crystalline linear extinction. The fraction of quartz grains with rim and crisp outline varies from 7.3%-11.4% (average 9.35%) in the Zawtia sandstone and from 8.9%-12.5% (average10.7%) in the Dekala area. Polycrystalline quartz from 2.2%-3.9% (average3.05%) in theZawita and in the Dekala area the percentage ranges from2.2% to 3.5% (average 2.85%). Figures-4 (A and B) show that the quartz grains are often subangular in form.

Feldspar { F}–The less frequent mineral is feldspar. Its proportion varies between 7.4%-11.3% (average 9.35%) in Zawita area and ranges from 21.7%-38.3% (average 30%) in the Dekala. In both areas, plagioclase feldspar predominates over the less common alkali feldspar. The majority of the fresh feldspar grain simply climate that is dry to semi-dry in source area Figures-4 (C,D and E).

Matrix -The proportion of matrix in the Dekala region ranges from 7.7% to 10.8% (average 9.25%) ,and the proportion of matrix in the Zawita sandstone ranges from 7.4% to 10.7% (average 9.05%) and The percentage of matrix in the Dekala region ranges from 7.7% to 10.8% (average 9.25%). Very fine silt to clay and micritic elements make up the matrix Figure-4 (O).

Cement –Cement content in the Injana Formation varies from ranges from 8.2% to 12.6% (average 10.4%) inthe Zawita area and from 7.8% to14.7% (average 11.25%) in the Dekala area.The present study demonstrates that the detrital components are filled in by the highly concentrated carbonate cement that consist of calcite and low amount from evaporate cement and iron oxide cement in both section. Figure-4(L, Mand N).

Other component-(0.2%-1.5%) in the Zawita (average 0.85) and in the Dekala (0.3%-1.4%) (average 0.85) is represent of chlorite, Muscovite and heavy minerals Figure-4(P).

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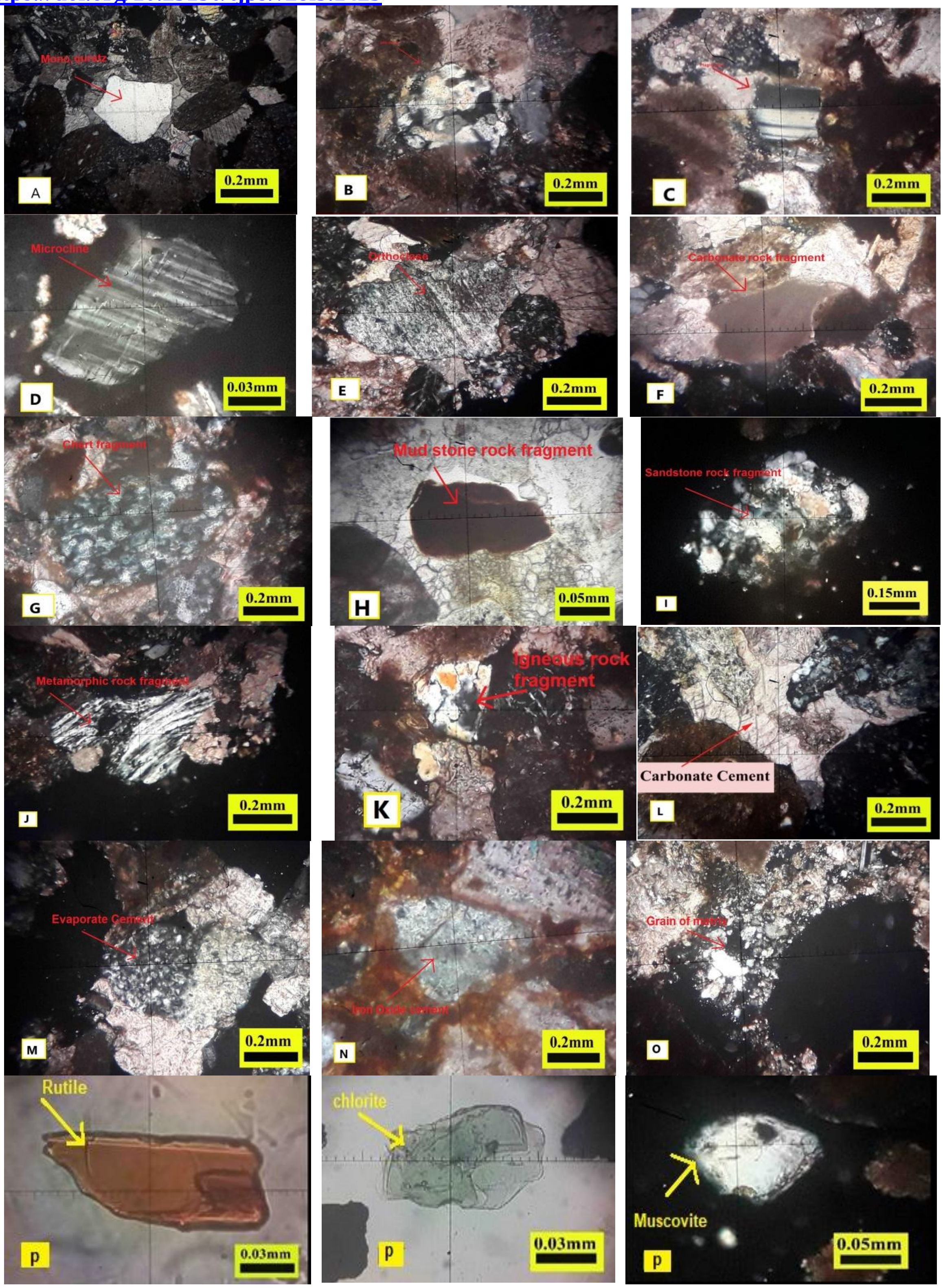

Fig. 4: Crossed Nicol (XPL) photomicrograph ofInjanasandstone detrital grains atTheZawita and Dekala region, demonstrating: A: mono. quartz, B: poly.quartz, C:plagioclase, D: microcline, E:orthoclase, F:carbonate rock fragments, G:Chert fragments and H: Mud Stone rock fragments, I:Sandstone rock fragments, J: Metamorphic rock fragments, K: Igneous rock fragments, L: Carbonate cement, M: Evaporate cement, N:Iron Oxide cement, O: Grain of Matrix and P: Other Component

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6. Digenesis Process

A wide variety of diagenetic processes have been noticed in the sandstones of Injana Formation. These processes includes compaction, cementation, and dissolution of mineral grains.

Compaction: The point and linear contact of the grain and the degree of curvature and distortion of mica grains are clear evidence of the limited effect of compaction on sandstone samples (plate 1- A, B,)[13].

Cementation: Different types of cement are recorded in the sandstone of Injana Formation; carbonate cement is the main dominant; it is blocky spary calcite forming poikilotopic texture with surrounding finer clastic grains (plate 1-C). Sometimes pervasive cement found as floated grains in the matrix. The above mentioned types of cement occurred before the completion of compaction (Adams, 1964). Thin film of iron oxide cement is found around the grains with brown to red color (plate 1-D). iron oxide cement was resulted from the weathering process of the source rocks bearing iron[14]. A low amount of silicate cement is found as a thin film coating quartz grains as quartz overgrowth (plate 1-E).

Dissolution is limited to unstable lithic carbonate fragment and feldspars and partly on quartz grains. These frameworks grains sometimes are dissolved partly or completely resulting of feldspars and formation of secondary porosity (plate1-F).

Mostly the diagenic process are of Eogenesis or Mesogenesis which characterize the diagenic environment.

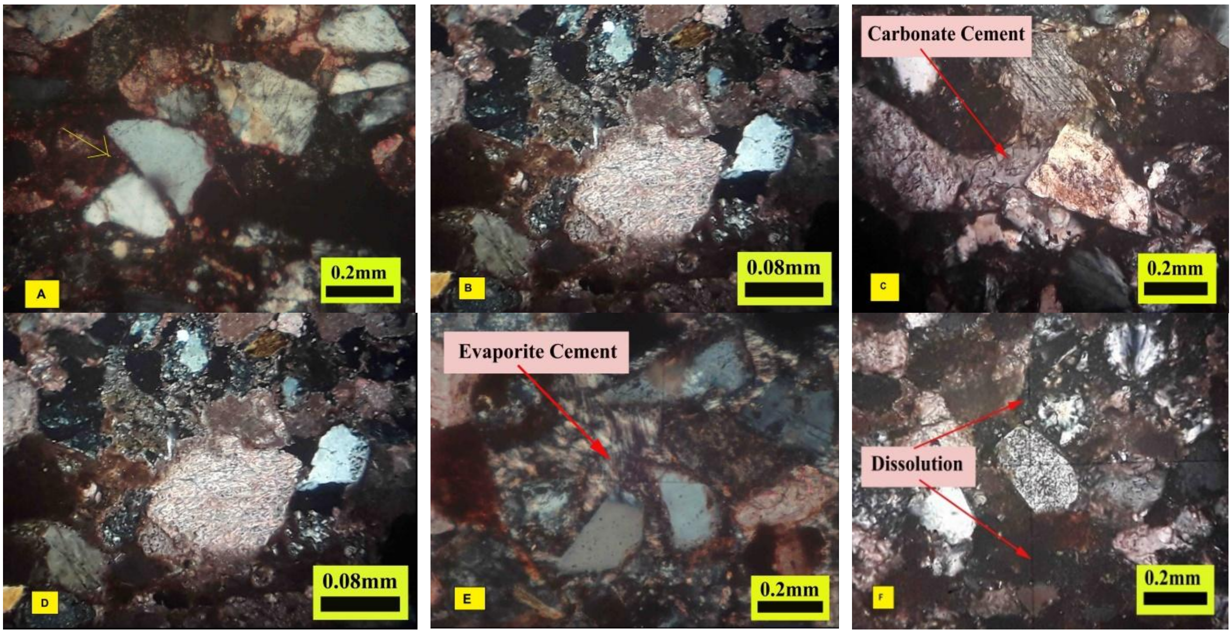

Plate 1: (A)Point&liner contact,(B)Low degree of curvature (C)Carbonate cement and blocky spary calcite,(D)Iron oxide cement,(E) Evaporate cement,(F) Dissolution process

7. Classification of sandstone

The classification of Injana sandstones Formation is based on classification of Folk, 1974 [15]. The percentage of sandstone's main components used as the basis for classification (feldspar, quartz and rock fragments). As a result, Lithareniteis the classification given to all samples of Injana sandstone from both section (Figure-4). Such litharenites are composed of an immature mineral manner suggests rapid derivation, nearby transportation and deposition of the sediment from supra-crustal sources [16].

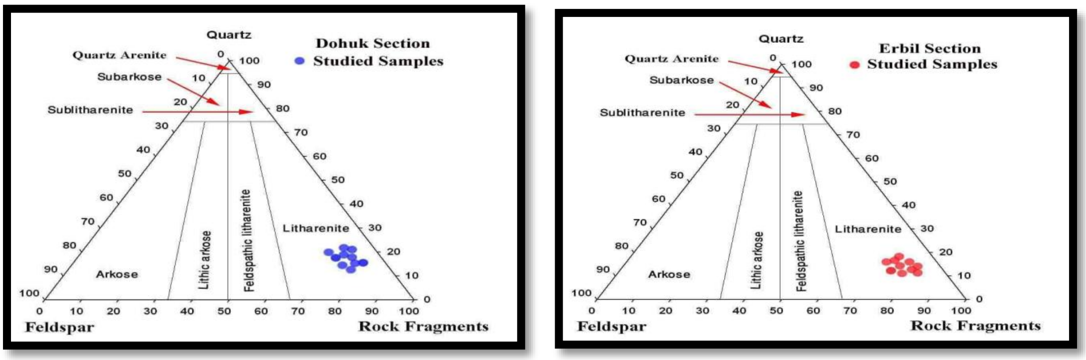

Fig. 5: Injana Formation sandstones in the Zawita and Dekala sections after classified according to Folk 1974, [15].

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8. Maturity

The relative abundance of framework grains that are stable and unstable is referred to as compositional maturity [18]. The following two formulas are employed in this work to determine the mineralogical maturity of Injana sandstone:

Maturity index (MI) = Quartz /Rock Fragments +Feldspar ………….. (1) [19]

Mineral maturity index (MMI) = (Chert+ Quartz) / (Rock Fragments +Feldspar)………….. (2) [20]

Using the first formula, it was determined that the Injana Formation sandstone's mineral maturity levels ranged from 0.16 and 0.24 in the Zawita section and between 0.15 and 0.20 in the Dekala section. The second formula is applied due to the large percentage of carbonate fragments, and it reveals that the Injana sandstone's mineral maturity levels range from 0.27 to 0.36 in Zawita section and between 0.24 to 0.30in the Dekala section. Thus the samples are mineralogically immature. [17] "Litharenites are compositionally immature sandstones that arise under conditions encouraging the synthesis and deposition of high volume of somewhat unstable materials" it was stated.

9. Provenance

The kind of sedimentary provenance, and the types of relation between provenance and depositional basin of dispersal pathways all have an impact on the composition of composition of sandstone [22]. Sandston's modes of detrital component reveal details regarding the provenance's tectonic setting and composition [23].

The majority of provenance studies are depended on Petrographic analysis [24]. Quartz is one of the main mineral components sandstone because of its high chemical stability, relatively high hardness, and lack of cleavage. The occurrence of extinction in monocrystalline quartz that is straight to somewhat undulose was investigated in this work.

Most of the igneous rocks in (Figure -4) (A) are plutonic in origin [25]. The most highly undulose monocrystalline quartz is indicative of metamorphic rocks [26], [16],[27]. The intercrystalline borders of the polycrystalline quartz are mainly straight or slightly curved that indicate its derivation from igneous, metamorphic and sedimentary rock. The plutonic beginnings are depicted inFigure-4 (B) [17], [16]. Intercrystalline suture borders are present in some grains, indicating their metamorphic origin [16].

Due to feldspar is chemically unstable, they are less than quartz and are not as likely to be recycled, which makes them helpful as provenance indicators [26]. Plagioclase and Orthoclase Figures-4 (C and E) maybe derived from plutonic igneous, granite rock is the source of the microcline, perthite, and graphic texture, according to [30].

The Figures -4 (C, D, E and K) show less typical in volcanic rocks and more prevalent in plutonic igneous rocks. Fresh feldspar may be found in Figures-4 (C, D and E) ,which may imply that igneous rocks were fragmented while being transported over a short distance and in arid conditions[20].

When studing source rocks, rock fragment are crcuial and more dependable than studying individual minerals like quartz and feldspar since they might come from of various types of rocks [31]. Chert rock fragments it's possible that the radiolarian chert in Figure-4 (G) came from the Cretaceous Qulqula Series of the Thrust zone sequence [5], as well as from carbonate formations that include chert nodules [5].

It is thought that Figures-4 (F) Carbonate rock fragment came from a nearby location, most likely from the Arabian Shelf's subsurface Mesozoic and Cenozoic carbonate rocks. Instead of chemical rock fragment indicate a unique situation of fast mechanical erosion.

High concentrations of carbonate rock fragments found in the Injana sandstone the source rocks were abundant in carbonate rocks, travelled quickly , and predominated in a climate that is dry .Figure-4 (K) igneous rock fragments indicate imperfect rapid erosion [15]. in places where there is considerable and a dry climate do Such weathering and erosion take place[29]. These shards might have come from the Thrust Zone, claims [30]. Figures-4 (J) metamorphic's rock fragments are most likely sourced from the Zone and Sanandaj-Sirjan Zone, According [31].

10-Tectonic setting of provenance

[24], [25] created three major provenance classifications for clastic sedimentary rocks, magmatic arc, recycled orogen and continental block. The primary basis for this classification is the petrographic characteristics of rock from a certain provenance. They recommended using the ternary composition diagrams QFL and QmFLt, Where Q stands for total quartzose, F for feldspar, and L for all unstable lithic fragments and to distinguish sediment from the three main tectonic provenances (Lt: complete unstable lithic fragment plus polycrystalline quartz, Qm: monocrystalline quartz, F: feldspar). The tectonic origin of Sandstone are determined in the current study using a petrographic modal analysis that takes into account the tectonic discrimination diagrams QFL and QmFLt as proposed by [22].The field of recycled orogeny contained group of sample of Injana sandstone QFL diagram.

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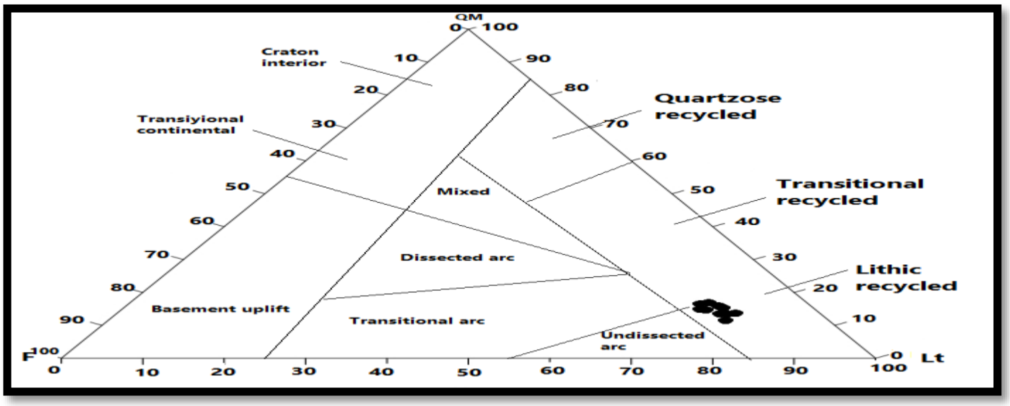

Fig. 6: QmFLt Injana samples in both sections from the field placed with recycled lithic zone according to the QmFLt diagram.

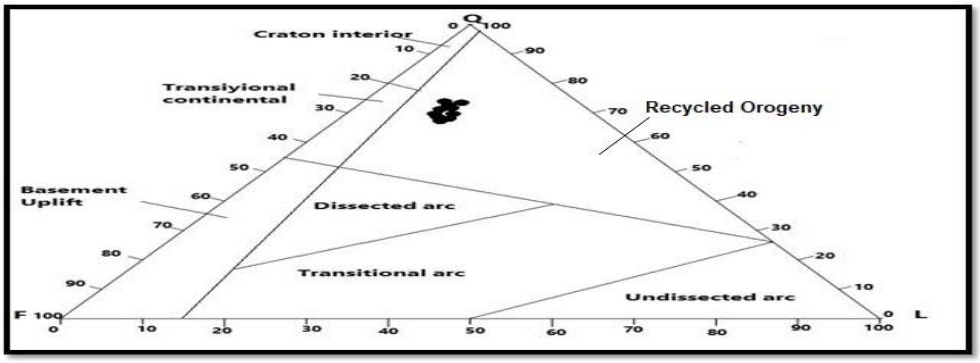

Fig. 7: QFL injana samples in both sections in recycled orogens are the orginal tectonic source of studied samples that produced via the up folding or up faulting of sedimentary or metasedimentary terrains, enabling the recycling of the rock debris into associated basins.

This is conclusion consistent with what is observed in the region where the mountain ranges zone of Taurus and Zagros collide, where terrains that were originally different continental blocks collided to form several recycled orogeny.

11. Conclusions

The rock fragments content in both Zawita and Dekala section of Injana sandstone are the common content. amount in both location, monocrystalline quartz is more prevalent than polycrystalline quartz; This quartz's characteristics show that it primarily comes from plutonic igneous and metamorphic rocks sources. Plagioclase is present in both section, although K-feldspar (orthoclase and microcline) predominates. Feldspar typically has plutonic igneous. In comparison to igneous and metamorphic rock fragments sedimentary rock fragments make up a higher fraction, which suggests recycled sediments. As litharenite class, The Injana Formation's sandstone is characterized by high relief, quick erosion, and proximity to the source location. The diagenitic process include compaction, cementation, and dissolution .The computed mineral maturity (MMI and MI) show that the Injana sandstones are mineralogical immature and the study include only sedimentology and Mineralogy.

The Injana sandstone's major framework mineral composition suggests that the sediments are from a lithic recycled area with recycled orogeny.

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