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Lithofacies and depositional regimes of the Kolosh Formation Successions in the Tigran region, North-eastern Iraq

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ABSTRACT

The current study depends on lithofacies analysis of Kolosh Formation at Tigran region in north-eastern Iraq. Depending on the physical criteria as grain size, color, texture, and etc., the formation is divided to five lithofacies: pebbly sandstone, coarse sandstone, graded sandstone, mudstone and shale lithofacies. Several sedimentary cycles and depositional regimes were fixed in the studied section represent by high energy regime as pebbly sandstone and medium to low regime as mudstone and shale lithofacies. Based on the data of lithofacies which compared with hypothetical model of the common turbidity deposits, the formation was deposited in submarine fans environments. The secondary depositional environments of the study section are divided into channel and inner fan environments. The Kolosh Formation in northern Iraq was deposited in an active margin basin when the northeast Arabian Plate collided with the Eurasian plate at the final stages of Neo-Tethys closing, which has resulted in large uplifts and subsidence episodes due to eustatic rises and falls.

1. Introduction

The Kolosh Formation (Middle Palaeocene) is one of the most widely distributed formations in north-eastern Iraq. It was first described by [1] in the Kolosh village north of Koysingak, Zagros basin, Northern Iraq, at the type section. The section of current study was found for the first time near the Tagaran village, in Chwarta area by [2] which described it very shortly, to describe the connection of basinal and paleogeographic relations between the Walash and Kolosh Formations in the Thrust and High Folded Zones respectively. The formation consists of dark-green mudstone, shale and sandstone layers. Sandstone beds make up the majority of the stratigraphic sequences of clastic deposits with various thicknesses, and also with additional lenses of siltstone and limestone, as well as a few conglomerates. Where the section under study is located in the Sulaymaniyah Governorate (fig.1), by coordinates latitude (35°40'24.4"N) and longitude (45°31'27.2"E) Which is represent a rock outcrop exposed Kolosh Formation as suggested by [2].

According to [3, 4], the Paleocene Kolosh Formation is deposited as flysch facies of sandstones, marls, shales, intraformational conglomerates and thin beds of arenaceous limestone, which are deposited in subduction trench, parallel to the suture zone that is formed by closing of the Southern Neotethys Ocean and final collision between the Arabian and Iranian plates, that has resulted in large uplifts and subsidence episodes, as well as base level volatility due to eustatic rises and falls. This section of the Kolosh Formation is composed of four asymmetrical sedimentary cycles resulting in relative S.L. fluctuation as well as an imbalance between accommodation space and sediment influx [5]. According to [6], Kolosh Formation is coeval with several other formations in other parts of Iraq, they added that these formations are diachronous and defined according to lithology in north Iraq as inter tongue with algal reef limestone (Sinjar Formation) and reef to back reef deposit (Khurmala Formation).

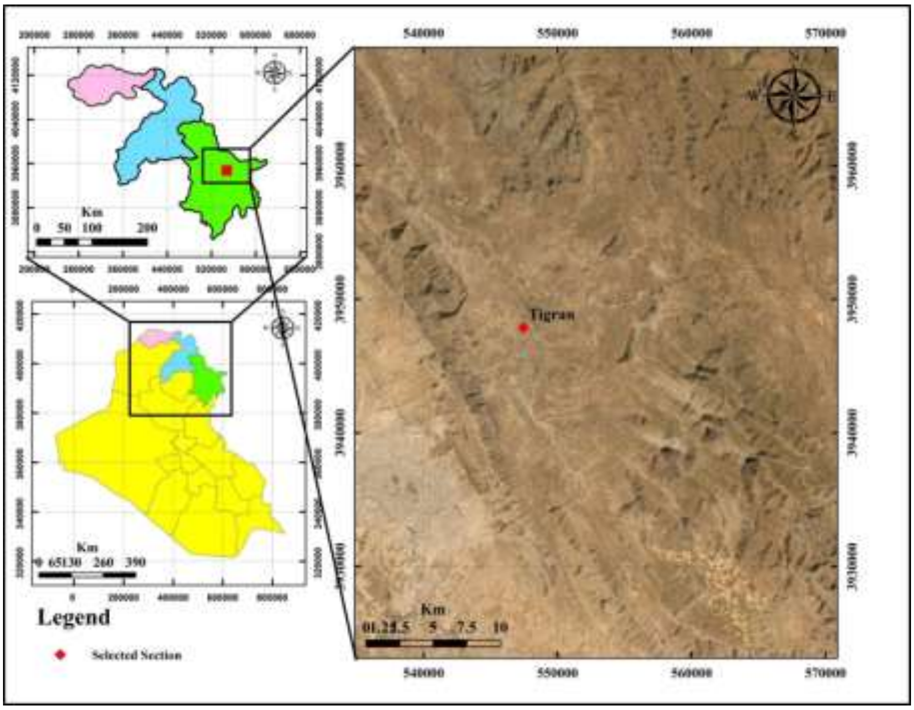

Fig. 1: Geographic location of the studied area.

The lithofacies in the section under study were analyzed and divided Kolosh Formation into several lithofacies, in order to defining, the sedimentary cycles at the time were deposited. Depending on the sedimentary cycles, their sedimentary characteristics, and the sedimentary structures, the sedimentary regimes of the formation were determined in the section under study. The main aim of current study is determining lithofacies analysis of Kolosh Formation, sedimentary cycles and depositional regimes of study section.

About (100) m thick of Kolosh Formation consists of pebbly sandstone, coarse sandstone, graded sandstone, mudstone and shale beds. The green mudstone beds about (0.15-0.4)m thick, characterized by their laminating, as well as aggregate of mud balls or it is chaotic. The shale beds are composed of fissile shale about (0.25 – 0.8)m thick. Pale to green pebbly sandstone with about (5-20)m thick. The pebble grains about (2-5 cm.) diameter of limestone, chert, igneous, and metamorphic in origin. The beds of coarse Sandstone are dark green and (0.4 – 10)m thick, and also contain sedimentary structure of scoured and fill with few solid, very thin layers of secondary gypsum are founded in the pebbly sandstone beds. It may be gypsum in the surfaces of fractures and joints. Several thin layer of secondary gypsum were founded in pebbly sandstone beds. Limestone was composed of several thin layers. It is containing some macrofossils, (0.5 – 0.15) m thick, (fig.2). Khurmala Formation was observed and identified within the Kolosh Formation sequence, Its thickness ranges from 1 to 1.50 m.

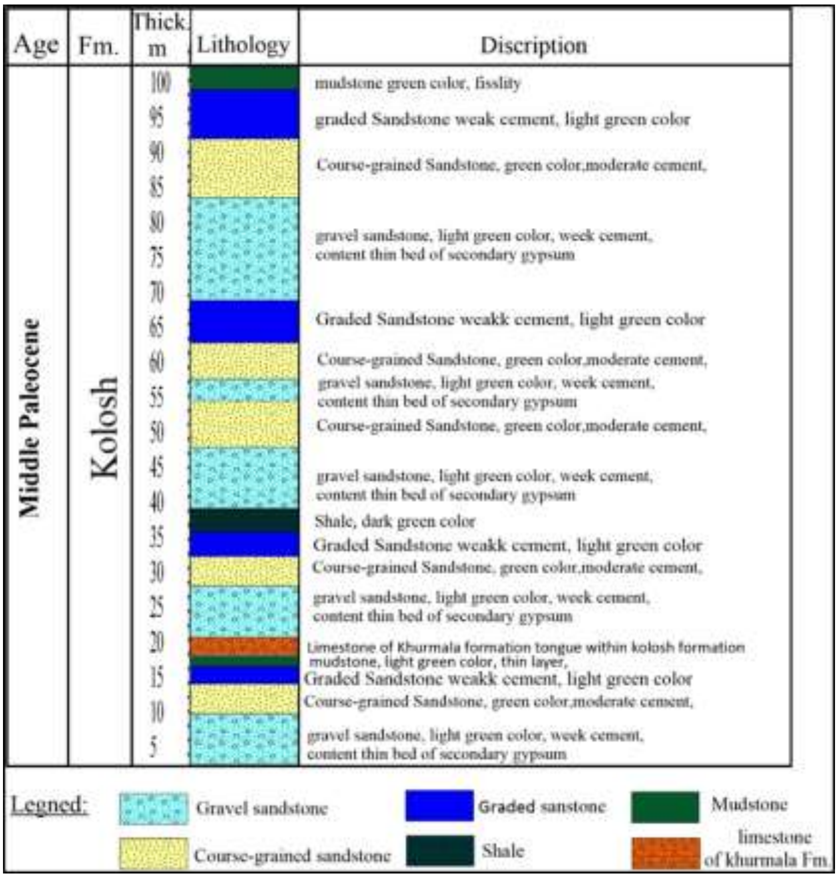

Fig. 2: The lithological column of the Kolosh Formation in Tigran section

2. Geological setting

The location of the research shows in Figure-3, which is located within the High Folded Zone in the outer part of the Arabian Plate [31], within mostly tight asymmetrical fold and parallel to Zagroz belt trend (NW - SE). In general, faults arise in most folds, which content tow direction fault (NW – SE) extending several kilometers and (NE - SW) minor portion reverse type [31]. The study area is located within the area that suffered from the orogeny, which led to the formation of folds. Recent tectonic evidence indicates that these forces are still active [32].

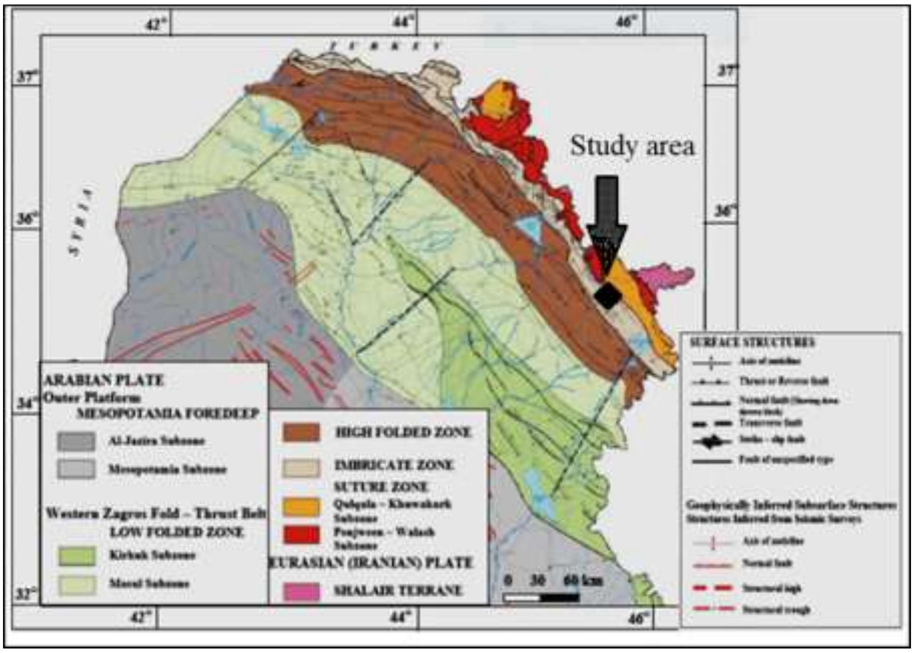

Fig. 3: A map showing the location of the study area [7].

3. Methodology

The study of lithofacies which are includes several field trips used to the identified the studied section, and to recording of the field observations, photography, in order to modeling layers and measuring the thickness of each layer. Grain size analysis of some layers was also carried out to find out the predominant granular size within the layer. Surfer v. 21 program was used to draw the stratigraphic section and facies analysis.

In addition to the petrographic study of sandstone beds.

4. Results

4.1 Petrography

Petrographic study sandstone beds showed the percentage of matrix more than 10% which represent greywacke according to [15] classification, as in the (table-1), which represents the average of each component, and its classification (fig. 4).

Table 1: Ranges and average of Mineral components for Tigran section

	The sandstone components	Range %	Average %
Quartz	Monocrystalline quartz	1.57 - 9.61	5.343
	Polycrystalline quartz	0 – 3.93	1.56
Feldspar	Orthoclase	0 – 4.85	3
	Plagioclase	2.91 – 6.3	5.35
Rock Fragments	Sedimentary rock fragments	42.3 - 53.54	48.12
	Igneous rock fragments	33.07 - 36.54	32.53
	Metamorphic rock fragments	1.57 – 5.77	4.06

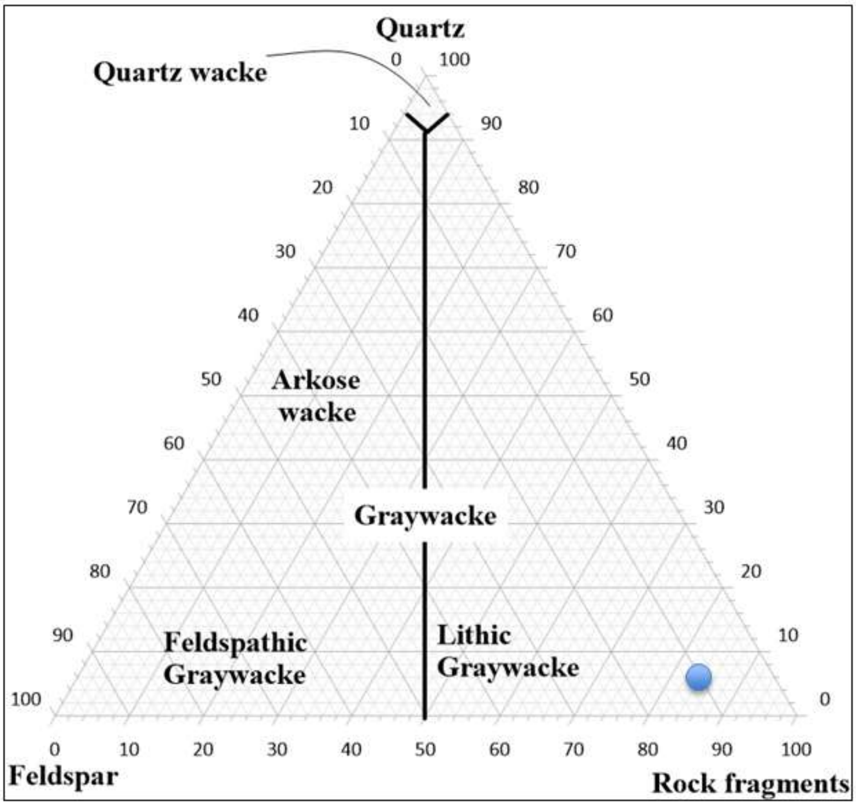

Fig. 4: Classification of sandstone rocks, after [15].

4.2 Lithofacies

According to their field characteristics, the lithofacies are divided into:

4.2.1 Pebbly Sandstone lithofacies PSL

PSL consists of several beds each about (3-10 m. thick) which is friable and dark to green sandstones, which contain pebbly grains about (1-10)cm at the base, poorly sorted, heterogeneous in origin and showing declining in size upward. It was composed mostly of calcareous, flint, igneous and metamorphic origins. It is mostly randomly oriented. It is resulted from active hydrodynamic and tectonic conditions in general, although these conditions were decreasing through successive tectonic episodes that were gradually fading away [27]. Sandstone rock, dens deposited by debris flows and sands are rapidly deposited by high-density turbidity currents [6] (fig. 4). This facies represents the beginning of each sedimentary cycle in the section under study, where the turbidity currents loaded with sediments of different sizes and the high depositional regime. This high energy is evident by the presence of a high amount from coarse gravels.

4.2.2 Coarse sandstone Lithofacies CSL

CSL is green to dark green sandstone rock (plate 1 B) about (0.3 - 2.5)m thick. This facies represent the second facies in the sedimentary cycle, which is deposited as a result of low turbidity currents at medium to high energy regime.

4.2.3 Graded sandstone lithofacies GSL

GSL is composed of graded sandstone (plate 1 C). This facies showed that the grain size was graded, in addition to the massive and lamination sedimentary structure are common. This facies attains thicknesses range from 0.5 to 5 m. It is dark green to light green color, with sharp surface of lower boundary and mostly scoured surface with load cast sedimentary structure surfaces. All sandstone beds in Kolosh sequences are fining upward [10], which is recognized in study section. This facies is deposited in low to medium energy regime.

4.2.4 Mudstone lithofacies MF

MF is composed from thin bed to lamina of dark green to light green of mudstone about (0.5-3)m thick with gradational lower contact, which contain pyrite and limonite (fig. 4) that contain mud balls (plate 2 A), this phenomenon occurs in turbid environments as mentioned by [33] and [34] within the Kolosh Formation. It is give an indication of the deformation amount within the layers due to the pressure caused through deposition of thick beds over the beds of pre-deposited lamellar mud, it is causing this distortion [9]. It is may be chaotic (plate 1 D). They are common in the Kolosh Formation. Several studies indicate that the sequences of the darker laminates mudstone in harmony with the sandstone layers, are one of the strongest evidences for the environment turbidity [10-16]. This facies deposited in low energy regime and represent the end of all cycle sedimentary within the study section.

4.2.5 Shale lithofacies SL

SL is composed of thick to thin dark gray (sometimes near black) fissile shale. Fissility property is coming from high compression. The thickness of this lithofacies is ranging from 0.25 to 1 m. The lower base of the SL is gradational while the upper surface is scoured and load casted. It is presented as low energy regime (plate-1 E).

5. Facies association

Facies types in the Kolosh Formation are followed the definition and classifications of [17-19]. The facies study reveals thick interbedded succession of pebbly sandstones(dominant), graded sandstones, coarse-grained sandstone and mudstone. The facies and features observed are compatible with deep marine environment depositional setting from the field evidences. The facies types of the Kolosh Formation can be grouped in facies associations, each one refers to certain depositional regime. These are;

5.1 Channels

Channel deposits commonly reveal the following facies representing a spectrum of submarine mass-movement processes [24-30]. These facies association consist of pebbly sandstone deposited by collapse of high-density turbidity currents, sandstone/mudstone deposited from low-density turbidity currents, thin bedded of mudstone/shale which are deposited from dilute, low-density turbidity currents and Non-graded sandstone mud-rich facies deposited from debris flows.

The channel deposits are coarse sands and gravel and graded beds of high energy regime. This sequence indicates that the presence high supply of sediments, which showed a massive bedding with the beds (plate-2 B). The coarser load is deposited at the bottoms of the submarine fan channels, followed by the finer particles to the suspended mud volumes. According to the assumed model [13], the environment of the fan channels located within the inner fan and middle fan ranges in coarse mass deposits. Thick-bedded of pebbly sandstone and course sandstone were deposited by collapse of high energy depositional regime as suspended load and through traction reworked of bed load sediment (fig. 4). Gravity flows transport sediment to slope submarine channels, which led to create channels via erosion and deposition as a result of the active channel floor's motion and the preservation of sediments [19]. Turbidities and debrites are the result of the sediment-gravity-flows' latter stages. Debrites are formed by mass transport deposits when debris flows deposit coarse grains sands and gravels in a cohesive matrix of interstitial fluid and mud [20]. Sand and mud turbidites are deposited from suspended loads and graded upwards in the channel by fluid turbulence. The facies, which represent a range of submarine mass-movement processes, are widely spread in channel deposits [19]. This association are interpreted here as inner fan deposits such as (PSL, CSL) when the current has high flow density, while if the current low flow density, it will deposit fine facies (such GSL, ML) (fig.5).

5.2 Inner fan

The sandstone and mudstone beds are arranged in finning upwards sedimentary cycles. These succession reveals characteristic sedimentary structures of turbidity origin like balls, scour and fill surfaces. Sediments of the inner fan are mostly debrites and coarse turbidite, commonly channelized. Interbedded thin, fine-grained turbidite represent channel and levee facies [22]. The channel is maintained by relatively high- velocity high-density turbidity currents flowing within the confines of the levees [18]. The sedimentary is widely deposited by high-density turbidity currents and the fan is characterized by sandy channels and lobes. The inner fan area is dominated by channels with some lobes. This facies association characterized by fine upward cycle of sandstone beds, which deposited in proximal fan with association thin bedded fine grained turbidities, and which indicate the operation of variety of sedimentation mechanisms. The inner fan area includes deposits of coarse sandstone, high-density turbidite beds and channel abandonment facies that are muddy turbidities, which are interpreted here as inner fan deposits such as (CSL, ML and GSL) (fig. 5).

6. Sedimentary structures

Sedimentary structures are an important indicator of the sedimentary environment and the palaeocurrent. Several important structures were diagnosed in the section under study, which gave evidence of the ancient environment and the energy of the current to deduce the depositional regime related to the current, which shows its effect on the sediments.

The spread of normal graded bedding and is very clear in most of the sedimentary cycles that make up the sequences of the Kolosh Formation. The presence of coarse sandstone lithofacies coupled with the phenomenon of fine grain size upwards within some Kolosh Formation cycles is an important feature of the observed features within the flysh turbidities facies. The existence of graded bedding structures of various scales (Plate 2 E), and in their complete and incomplete forms within the sequences of the Kolosh Formation. The Kolosh deposits are poorly sorted due to the high speed of the transport and sedimentation of the sediments, a characteristic of the internationally known turbid sedimentation mechanism [23]. Massive bedded structure was diagnosed within the Kolosh Formation successions (Plate 2 B), which the lower surfaces of beds are mostly scoured (Plate 2 F).

Lamination structure was observed within Kolosh Formation (plate-2 C), which indicated to medium to low regime.

Slump structure was observed within Kolosh Formation (plate-2 D). It is caused by the displacement of unstable sediment accumulations, which resulted from earthquakes, excess load and turbidity currents. The slump beds are transport through a basal slip zone and display varying degrees of inter deformation. It is one important of evidence into turbidity environments.

Balls structure were recognized in Kolosh Formation section. Balls are observed in mudstone beds (Plate-2 A) and sandstone (plate-1 F). They have various sizes in diameter and the origin mud balls, there are two opinions, the first that they are formed during burial after deposition by differential load pressure and tectonic stresses [33]. The model includes jointing and possibly fracturing (as starting point during burial stage) and converting to spheroidal or pillow-like bodies at the final stages of developments by tectonic deformation and load pressure [33], and the second that they represent internal deformation due to slump rolling of semi coherent sediments via slope surface. It is present and formed like rolling glacial balls [34]. The mud balls also occur in turbidity environments after the deposition of the mud layers as a result of being affected by turbulent currents, which gives it the identity of the ball.

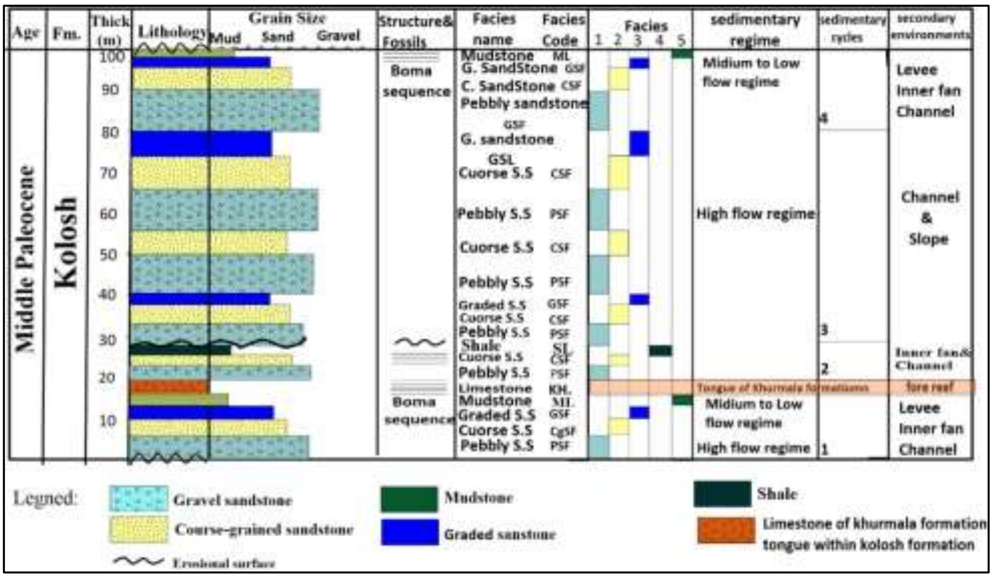

Fig. 5: The division of sedimentary cycles, depositional regimes and sub-environments.

7. Conclusion

The Kolosh Formation described in detail in Tigran area and divided into five lithofacies depending on the field characteristics and their sedimentary properties, these are pebbly sandstone, coarse sandstone, graded sandstone, mudstone and shale lithofacies. The petrographic study is resulted in determining type of the sandstone. It was classified a lithic greywacke, according composites of sandstone rocks and clay content.

The subenvironments of the lithofacies were identified as a channel and inner fan from high regime gravel to low regime mudstone deposits. The section under study consists of 4 sedimentary cycles finning upwards and several sedimentary structures, which are massive bedded structure, lamination structure, slump structure, balls structure and scoured surface structure, which give indicative to different energy regimes. The sedimentary structures and petrographic study of sandstone beds also indicative to turbidity deposits of Kolosh Formation successions. Also these deep turbid clastic facies in northern Iraq indicate the deposition of the formation in an environment influenced by the tectonic conditions of the last stages of the closing of Neo-Tethys ocean.

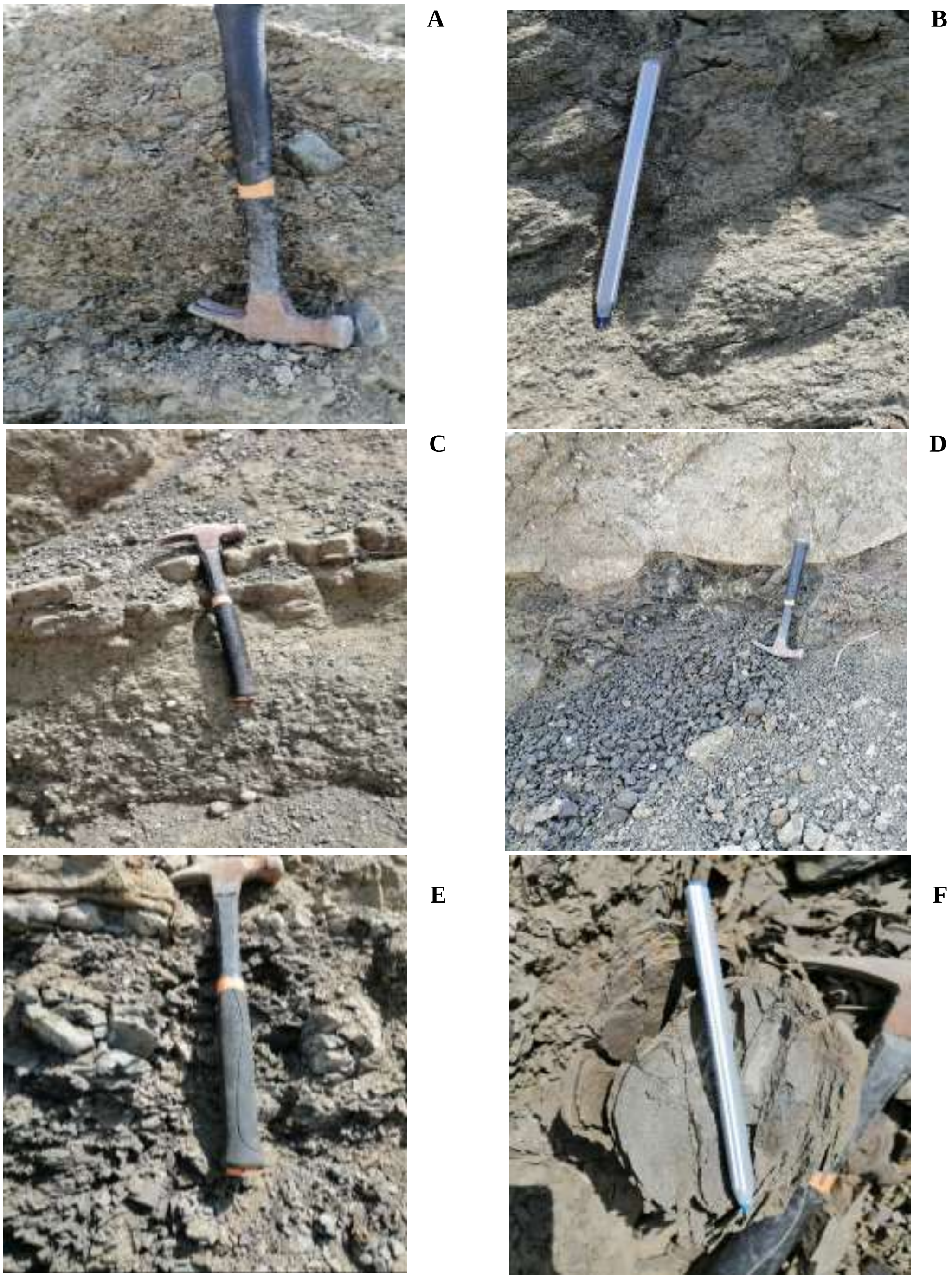

Plate 1: (A) gravely sandstone lithofacies. (B) course-grained sandstone lithofacies. (C) Graded sandstone lithofacies inside pebbly sandstone. (D) Limestone of Khurmala Formation. (E) Shale lithofacies. (F) Sandy ball.

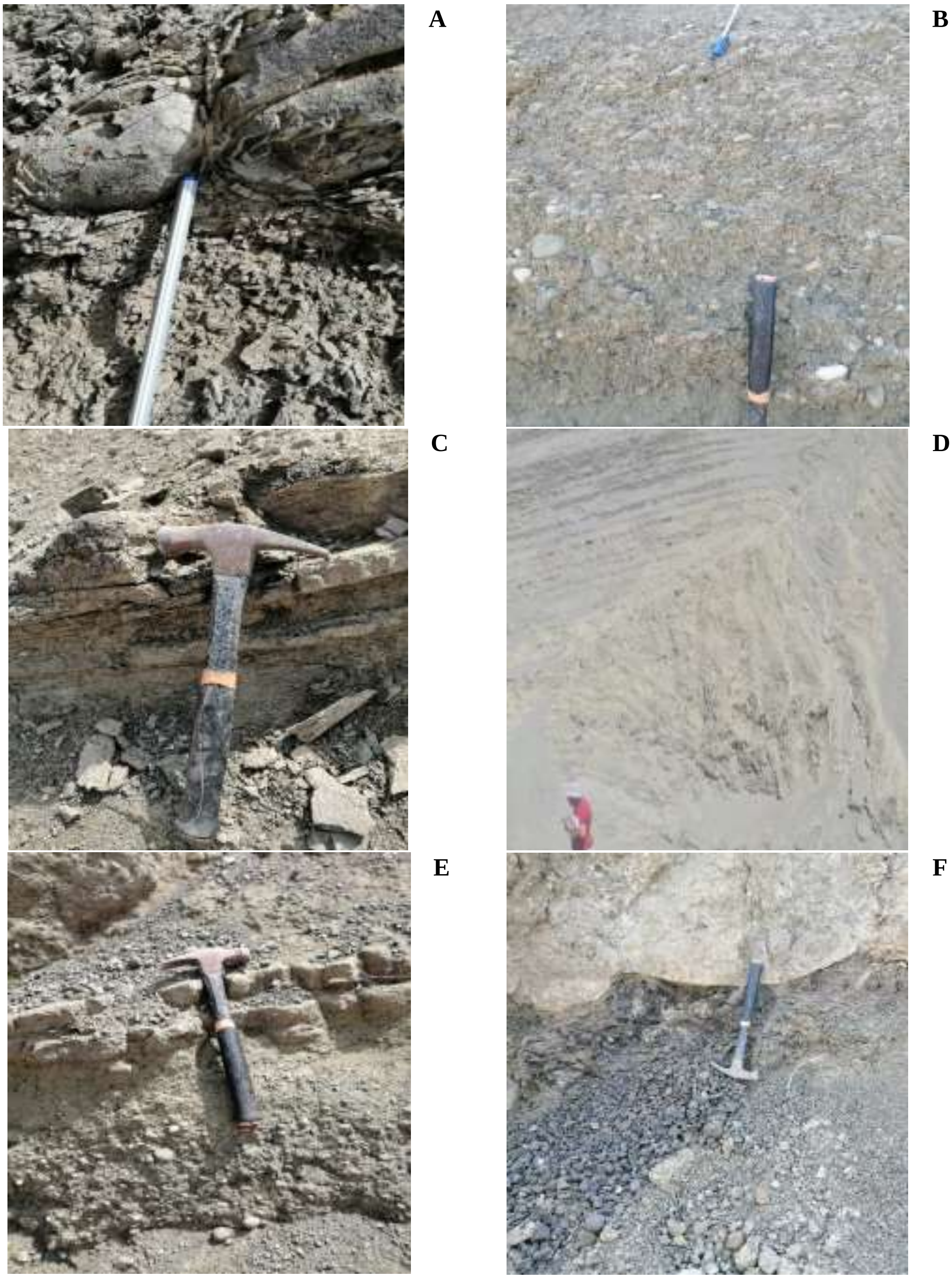

Plate 2: (A) Mud balls. (B) Massive bedded structure (C) Lamination structure. (D) Slump structure (E) finning upwards beds. (F) Scoured surface

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السحنات الصخرية والانماط الترسيبية لتتابعات تكوين كولوش في منطقة تكَران، شمال–شرق العراق

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الملخص

اعتمدت الدراسة الحالية على تحليل السحنات الصخرية لتكوين كولوش في منطقة تكران شمال شرقي العراق. اعتمادا على الصفات الفيزيائية لصخور التكوين الفتاتية مثل الحجم الحبيبي واللون والنسيج والصفات الأخرى، فقد قسم التكوين الى أربعة سحنات صخرية هي سحنة الحجر الرملي الحصوي وسحنة الحجر الرملي الخشن الحبيبات وسحنة الحجر الرملي المتدرج وسحنة الحجر الطيني وسحنة الطفّل. تم تحديد الدورات الرسوبية والانماط الترسيبية في مقطع الدراسة وتمثلت بنمط عالي كترسيب سحنة الحجر الرملي الحصوي وبنمط متوسط الى واطئ كترسيب سحنات الحجر الطيني والطفل. اعتماداً على صفات السحنات الصخرية ومقارنتها مع النموذج الافتراضي لرواسب العكارة فان التكوين ترسب في بيئة المراوح التحت بحرية وبخمسة دورات رسوبية، حيث تم تحديد البيئات الترسيبية الثانوية وهي بيئة القناة الثانوية وبيئة المروحة الداخلية الثانوية. ترسب تكوين كولوش خلال الباليوسين الأوسط – الإيوسين المبكر في حوض الحافة النشطة عندما استطمت الصفيحة العربية مع الصفيحة الإيرانية في المراحل الأخيرة لانغلاق بحر التيثس الجديد والتي نتج عنها ارتفاعات كبيرة وحلقات هابطة، أدى الى ارتفاع وانخفاض مستوى سطح البحر العالمي.