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# Indication of calcareous tempestite inside the Qulqula Group in the Zagros Suture Zone, KRI

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**Abstract**

This sedimentological study focuses on carbonate storm deposits (calcareous tempestites) have been recognized for Qulqula platform in the Zagros Suture Zone outcropping at Sharbazher area in the northeastern Sulaimani City. This deposits are recorded between the oolitic limestone and calcareous turbidities in the Qulqula Group for the first time. These offer the first indication of event sedimentation in the Qulqula domain. Calcareous tempestites deposited on subsided eastern Arabian continental margin at initial stage of continental rifting, most possibly during Early Late Triassic to Early Jurassic. It is mostly encompasscalcarenite beds and indicating by some storm generated criteria such as: hummocky cross-stratification, parallel lamination, symmetrical wave-ripples, normally graded flat pebble conglomerate, and sole mark (flute caste, load cast, groove mark). Moreover, found Cruziana and Skolithos trace fossils with these calcarenite beds. Finally, for paleogeographic configuration of Qulqula carbonate platform, facies-depth connections on carbonate ramp model build up as shallowing-upward cycles from calcareous turbidities which deposited in distal part of outer ramp and carbonate distally steepened ramp to calcareous tempestites in mid ramp to oolitic limestone were formed in high-energy inner carbonate ramp.

## Introduction

The Qulqula Radiolarian Formation composed of different marine deposits which started to deposition both on the Arabian divergent-passive margin basin and deepZagros Neo-Tethys ocean basin. Most of thesesediments deposited directlyeither onthe center of the basin over the oceanic crust and represent the pelagic domainor partlyon the margins of the basin over the continental crust and represent the neritic domain. This deposition had occurred during the Late Triassic to the Early Late Cretaceous (Late Cenomanian) age (Baziany, 2014). He divided the Qulqula Radiolarian Formation into sixlithostratigraphicunit(Figure.1). These units (from old to young) are: Neritic Succession Limestone Unit *(NSLU)*, Grayish-Green Sheared Shale Unit *(GSSU),* Radiolarian Chert and Siliceous Limestone Unit *(RChSLU),* Red Radiolarian Claystone Unit *(RRCU),* Red Siliceous Mudstone Unit *(RSMU)* and Reddish-Green Mudstone and Limestone Unit *(RGMLU).* From facies analysis the *NSLU* was deposited in carbonate ramp (Baba Shekh, 2009; Kamal *et al*., 2009; Baziany, 2014) and the *GSSU* deposited in carbonate distally steepened ramp (shallow subsided basin), while the other units were deposited in the basin (Baziany, 2014). The carbonate strata between the Neritic Succession Limestone Unit *(NSLU)*, Grayish-Green Sheared Shale Unit *(GSSU)* of the Qulqula Radiolarian Formation analyzed in this paper and are amalgamated limestone which composed from calcirudite to calclutitefacies of most possibly during the Late Triassic to Early-

Jurassic age. Now it tectonically a part of Zagros Suture Zone outcropping in the north-eastern Sulaimani City (Figure.2).

The characteristics of these beds analogous to other storm layers identified in the sedimentological literature. Comprehensive descriptions of storm deposits in the sedimentological literature change enormously. Numerous authors have described the diverse features of carbonate tempestites (Kreisa, 1981; Aigner, 1985; Wright, 1986; Burchette and Wright, 1992; Myrow and Southard, 1996; Sageman, 1996; Molina et al., 1997; Einsele, 2000; Drummond & Sheets, 2001; Perez-Lopez and Perez-Valera, 2012), while others have attempted to condense the fundamental structures characterizing these deposits (Harms et al. 1975; Dott and Bourgeois; 1982; Myrow, 1991; Molina et al., 1997; Mohseni& Al-Aasm, 2004). Additionally, a few papers have managed questionable viewpoints identified with tempestites (Einsele and Seilacher, 1991; Knaust, 2000; Bourrouilh-Le Jan et al., 2007). For instance, a few features of many fine-grained tempestites, such as an erosional base with different types of sole marks, graded bedding, small-scale ripple bedding and amalgamation, are like those of turbidities particularly when comparing their more distal expressions. However, they also differ in several key features. Tempestite is a storm deposit, showing evidence of violent disturbance of pre-exiting sediments followed by their rapid redeposition, all in a shallow water environment (Ager, 1974). Tempestites frequently demonstration hummocky or swaley cross-stratification and wave ripple lamination (Einssele&Seilacher, 1991). In Iraqi Zagros Fold-Thrust Belt, some authors have described the tempestite (Karim, 2007; Bakhtiar and Kamal, 2007; Tamar-Agha, 2015).

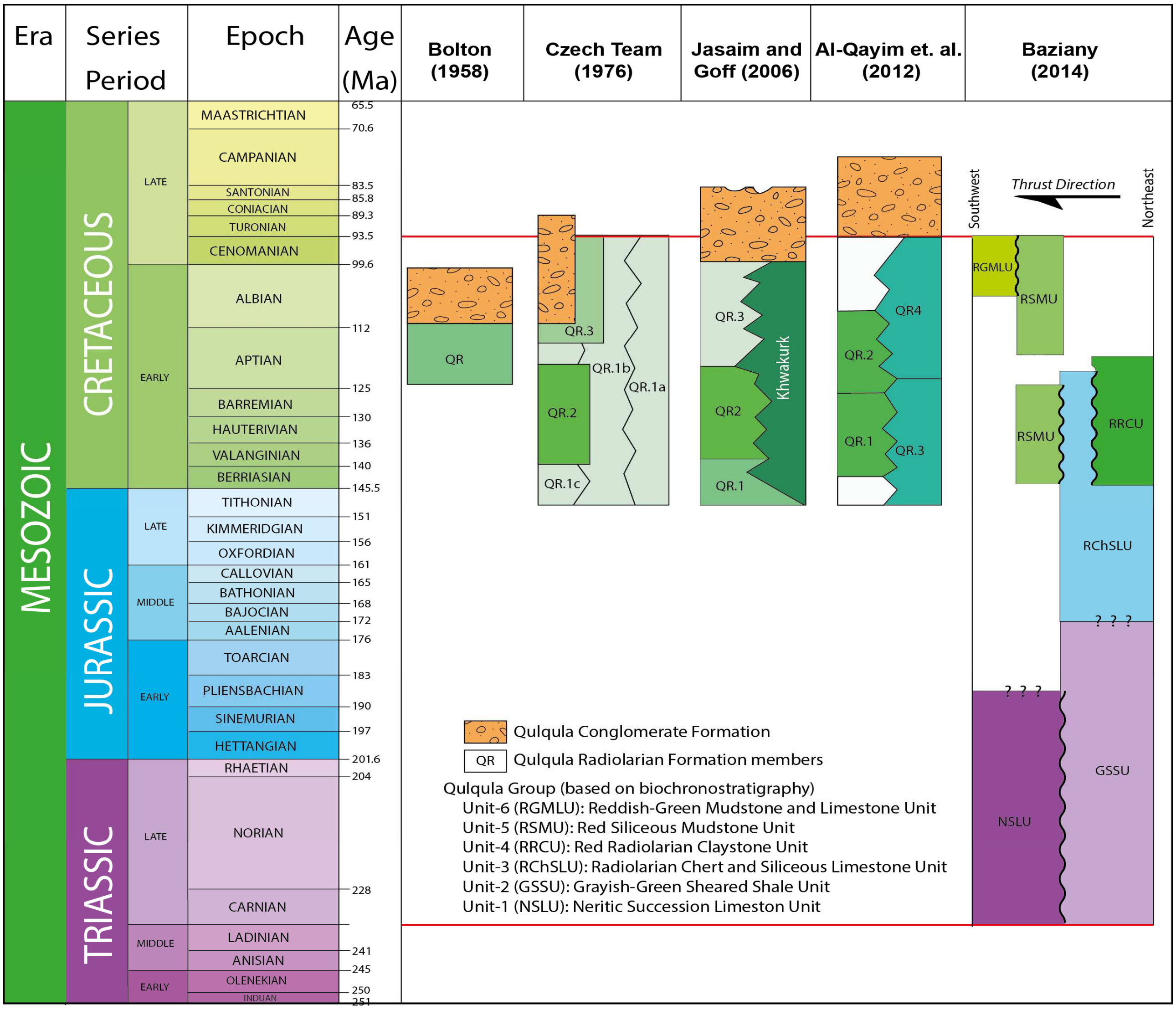

Figure.1: Diagrammatic presentation of the different tectono- stratigraphic classification schemes of the Qulqula Group (modify from Baziany, 2014).

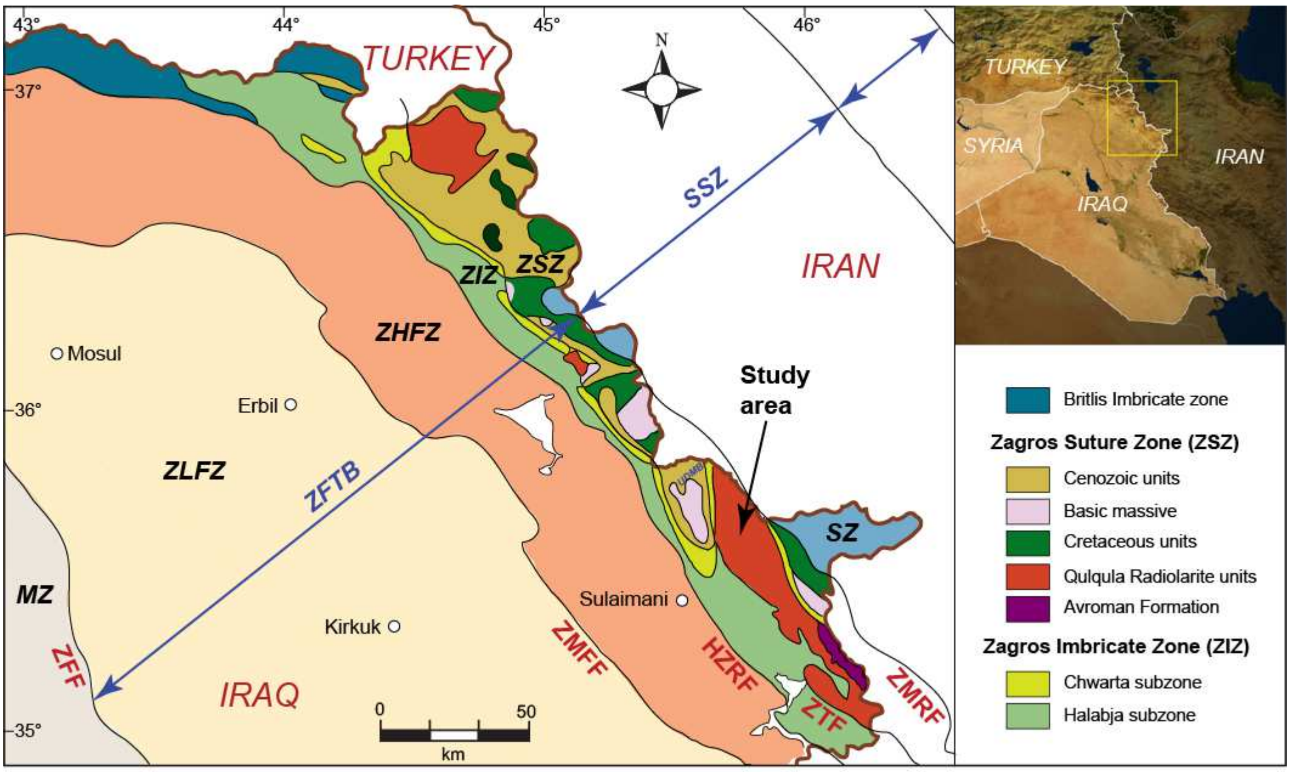


Figure.2: Geologic Setting of the northeast Iraq outcrops within the regional tectonic context and showing the location of the study area within the Zagros Orogenic Belt. (ZFTB: Zagros Fold–Thrust Belt; SSZ: Sanandaj-Sirjan Zone; UDMB: UrumiehDokhtar Magmatic Belt; MZ: Mesopotamian Zone; ZLFZ: Zagros Low Folded Zone; ZHFZ: Zagros High Folded Zone; SZ: Shalair Zone; ZFF: Zagros Foredeep Fault; ZMFF: Zagros Mountain Front Fault; HZRF: High Zagros Reverse Fault; ZTF: Zagros Thrust Front; ZMRF: Zagros Main Reverse Fault (modify from Baziany, 2014).

## Geological Setting

In spite of the fact that the principle subject of this paper is calcareous tempestite, but because of it is record for the first time in the QulqulaFormation,Qulqula Group likewise should be considered. Despite the Qulqula Group is not a new stratigraphic name in the geology of Iraq, but here utilize as a new constituent that more comparably differ from the previous name and studies. Henceforth it must be use as a newly term base on last decade studies on it. Since Heron and Lees's work in 1943, in most of published and unpublished forethoughts this group divided into two main formations; the Qulqula Conglomerate Formation and Qulqula Radiolarian Formation (e.g. Bolton, 1958; Czech Team, 1976; Buday, 1980; Nunnaet al., 1981; Jassimet al., 1984; Sissakian, 1997, 2000 & 2005; Jassim and Goff, 2006; Ibrahim, 2009; and Al-Qayimet al., 2012; Lawa et al., 2013). The abandoning of Qulqula Conglomerate Formation is recommended by Baziany, 2006 and Karim and Baziany, 2007 dueto belonging of the conglomerate either tothe Red Bed Series or Tanjero Formation or to Quaternary deposits. Previous authors wereaged this conglomerates as a sediment of Albian-Cenomanian, but recently this age changed to Upper Paleocene to Middle Eocene on the basis of larger foraminifera biozonationof the Alveolinidae, Nummulitidae and Soritidae familiesin the type section (Ghafor and Baziany, 2009), and to Quaternary age in the Halabja–Avroman area (Baziany and Karim, 2007; Baziany, 2013 & 2014). The conglomerate being Quaternary in the later area is proved by geomorphologic, stratigraphic, structural and sedimentologic evidences. Moreover, along the Zagros fold–thrust belt (ZFTB; Koyi, 1988), Baziany, 2006 and Kamal et al., 2011 were founded a major angular unconformity between this Conglomerate unit and the underlie Qulqula Radiolarian Formation.

On other hand, in a detail tectonostatigraphical study, in the Zagros Suture Zone outcropping in Sulaimani and Halabja governorates in northeastern Iraq, Baziany, 2014 recognized six lithostratigraphic units (Figure.1) to the Qulqula Radiolarian Formation as a new division. This division is based on detailed sedimentologicaloutcrop examination upheld by petrographic studies and radiolarian biochronology. He represented the Qulqula Radiolarian Formation by a numerous thrusted sheets of long-ranging marine deposits (from ramp to distal abyssal plain), and evidenced that it consists of intensively deformed neritic limestone, debrites and turbidities, hemiturbidite, hemipelagite, pelagic limestone and radiolarite, red claystone and basaltic volcanic extrusions. From the Late Permian to the Triassic, Cimmerian terrines (Iran, Afghanistan, Karakoram and Qianbtang) rifted from Afro-Arabian plate by the opening of Neo-Tethys and NE passive margin of Afro-Arabian plate begins to subside (Beydoun, 1991; Stampfli and Borel, 2002; Golonka, 2004; Golonka, 2007; Haq and Al-Qahtani, 2005; Muttoni, et al., 2009; Ibrahim, 2009; Kearey, et al., 2009). Baziany, 2014 concluded that, in this rifting system and on this subsided margin to the deep ocean, the units of the Qulqula Radiolarian Formation deposited within the Zagros Neo-Tethys Ocean close to the NE of the Arabian continental margin (Figure.3). Further he added that this deposition had happened during the Late Triassic to the Early Late Cretaceous (Late Cenomanian age), through rifting phase and continuous basinal floor spreading. Later they were tectonically emplaced over the northeastern Arabian continental margin and forming Zagros Suture Zone after the collision of Arabian Plate and the Sanandaj-Sirjan Block. From these points, the Qulqula Group must be use as a newly term just for the Qulqula Radiolarian Formation in the geology of Kurdistan and Iraq. However, this study achieves the most illustrative deposits of carbonate parts of Qulqula Group in terms of their storm deposits were deposited in an area proximal to the ooliticturbiditie in the Qulqula Group. The study area is outcropping in the north-eastern Sulaimani City in Zagros Suture Zone (Figure.2).

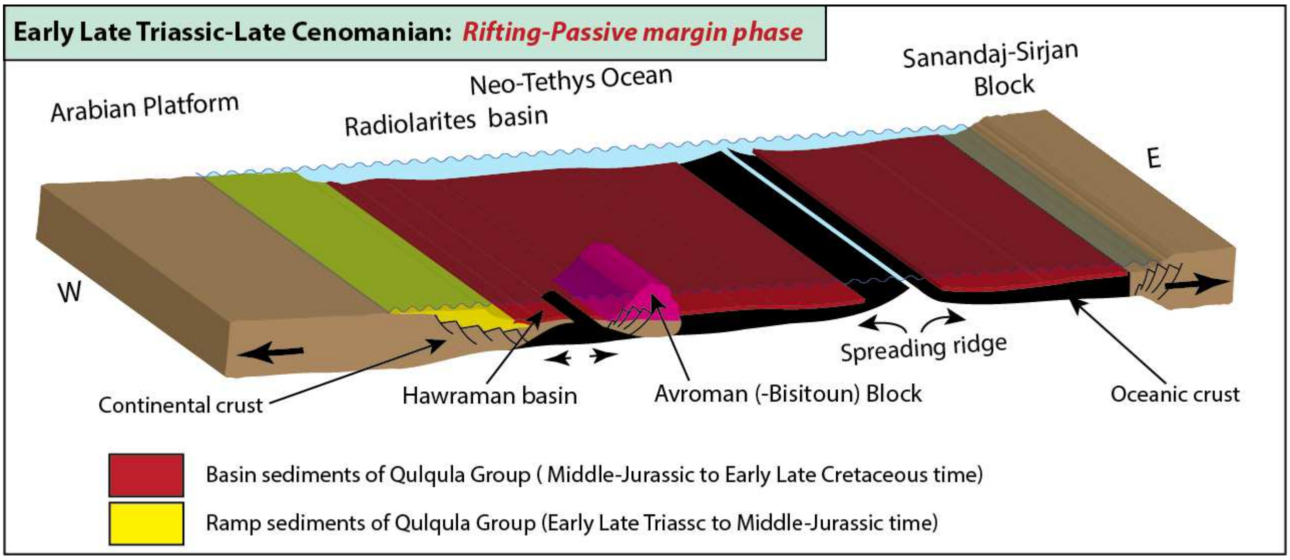


Figure.3: Tectonic evolutional models for the deposition of Qulqula Group during Early Late Triassic to Late Cenomanian time in the Zagros Neo-Tethys Ocean between Arabian plate and Sanandaj-Sirjan block (modify from Baziany, 2014).

## Methodology

The Qulqula Group are composed of different types of marine sediments which were represent the western Neo-Tethyan margin in Iraq, ranging from inner ramp to deep basin. Along the western limbs of Surkew and Suren mountains, the limestone beds between the Neritic Succession Limestone Unit (NSLU), Grayish-Green Sheared Shale Unit (GSSU) of the Qulqula Group were studied. For analysis of their lithology, sedimentary texture and structures. Ten thin sections of tempestites were examined under the petrographic microscope to complement field observations. The Dunham (1962) and Embry &Klovan (1971) carbonate classification schemes were used to describe the sediments.

# Result

## Indicator of Storm Deposit

Although the studied area is intensively deformedand very complex stratigraphically and structurallydue its location inside the Zagros Fold-Thrust Belt, but for the first time many diagnose signals of the storm related features are recorded in the amalgamated limestone beds between the autochthonous oolitic limestone and theallochthonousooliticturbiditie of the QulqulaFormation. Thesetwo facies were formed in high-energy inner carbonate ramp and carbonate distally steepened ramp, respectively (Baziany 2014). However, in study area, in some locality, these features can be seen, spatially along the road of Bayanan-Nurabab village, at nearly 1 km of the southwest of Nurabab village in Sharbazher area. This amalgamated limestone represent a thick package of carbonate rock (Figure.4), nearly about 8m and frequently consists of shallow water constituents of thin to moderate calcarenite beds, with some calcirudite (Figure.6) and calcisiltite beds (Figure.10). According to many authors the calcarenite beds are mainly tempestites on carbonate ramp (Brenchley, 1989; Burchette and Wright, 1992 Arnott, 1993; Myrow and Southard, 1996; Molina et al., 1997; Vera & Molina, 1998). The thickness of these calcarenite beds ranging from three centimeters to nearly 30 centimeters. It is interbedded with thin shale and marls. More or less, these calcarenite beds showing an internal structure with graded bedding and hummocky cross-stratification.

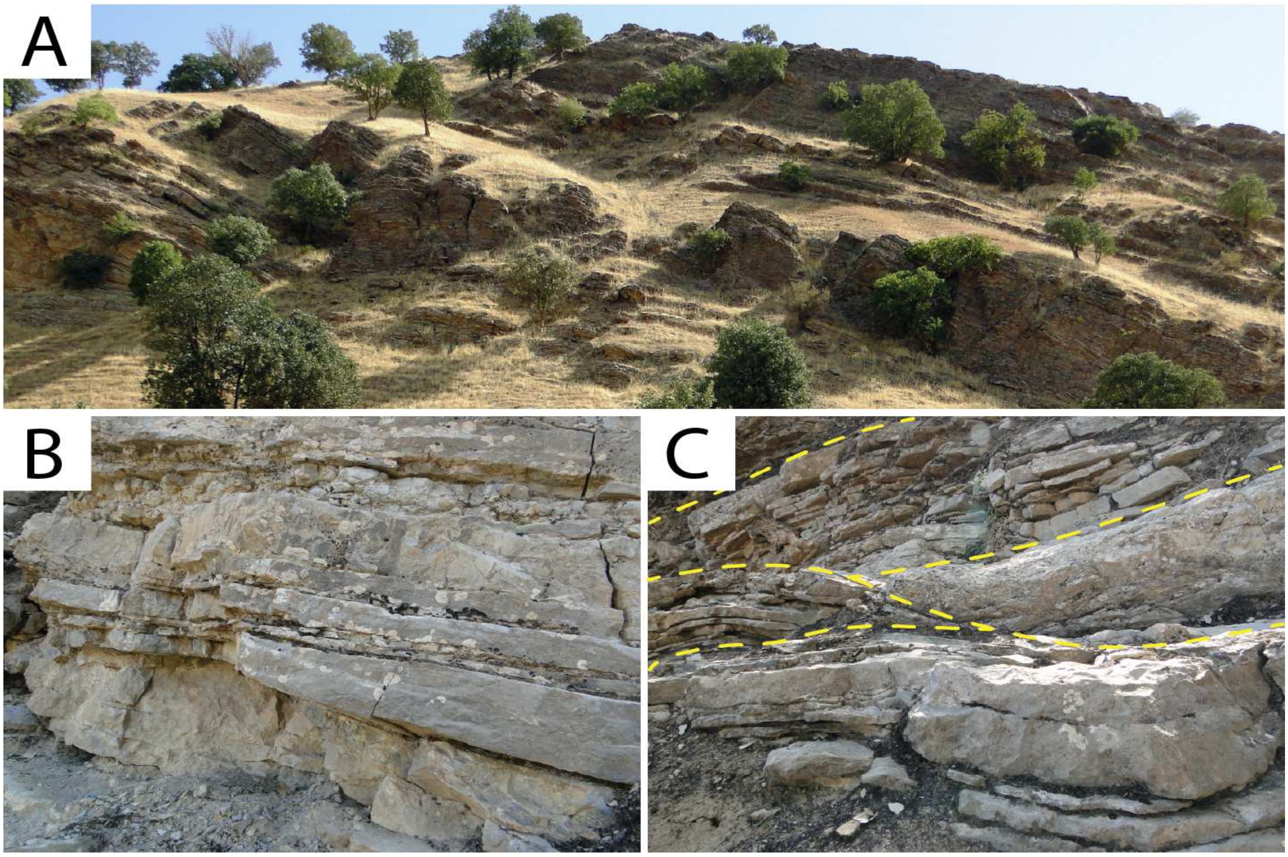


Figure. 4: A) Amalgamated limestone beds display the repeated storm deposits, along the road of Bayanan-Nurabab village, at nearly 1 km of the southwest of Nurabab village in Sharbazher area. B & C) Thin to moderate calcarenite beds showing cross-stratification.

In some locality, wave ripples are also present. Some of these beds are developed with erosional base and escaping structures. Generally, they comprise sheet-like beds of calcarenites and bioclasticpackstones-grainstones with non-skeletal grains including peloids, ooids, intraclasts and skeletal grains with some crinoid fragments. *Rhizocorallium, Planolites*and*Chondrites* of *Cruziana* and *Skolithos* trace fossils are identified in this facies.

The main features of the ideal tempestites (Figure.5) which originate as an illustrative diagram by Perez-Lopez and Perez-Valera, 2012, can be seen in this amalgamated limestone package. In this diagram, graded tempestites exhibition wave ripple lamination and hummocky cross-stratification parallel to lamination, with vertical and lateral variations. He mentioned that the record of wave action on the sea floor is a good indicative marker of tempestites, while other characteristics need to be considered subsequent to the structures present in a tempestite bed vary broadly.

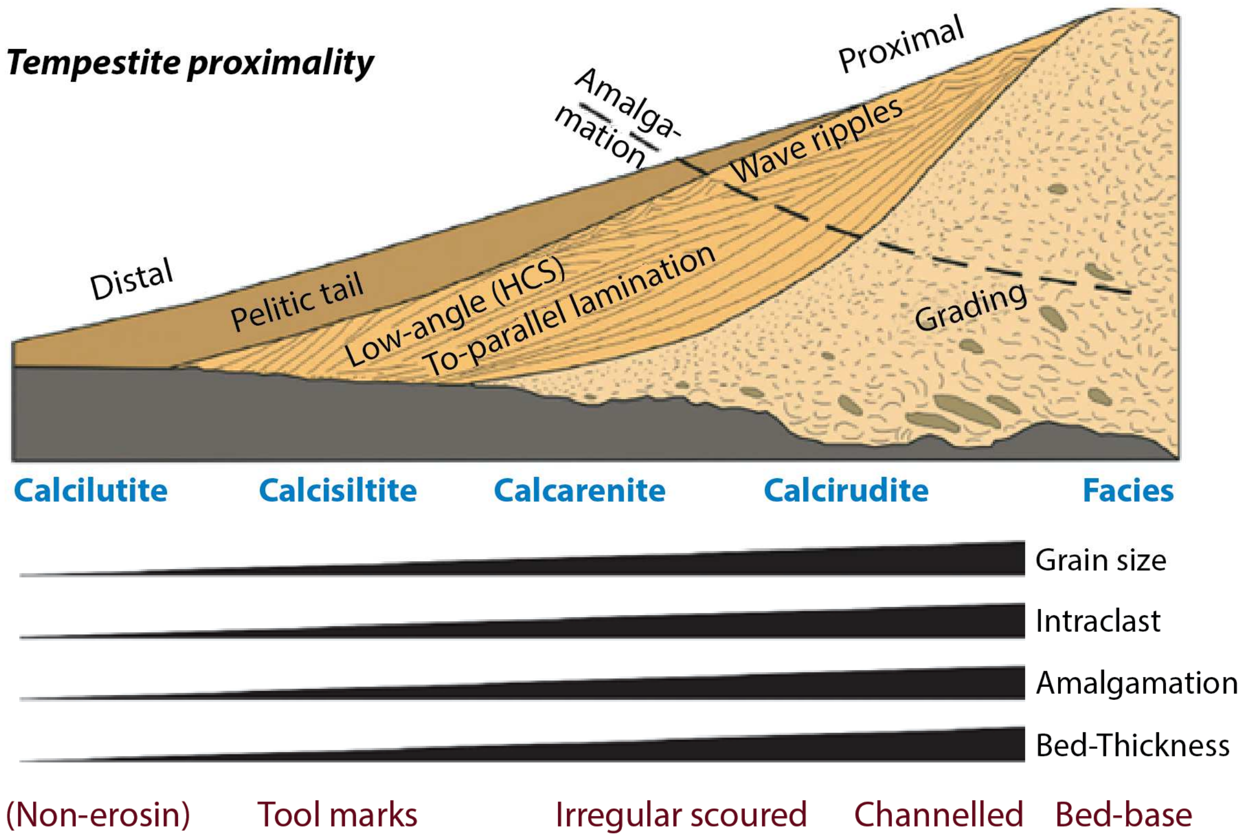


Figure.5: Main features of the 'ideal' tempestite (from Perez-Lopez and Perez-Valera, 2012).

## Sedimentary Facies

Despite the fact that it is hard to locate a complete ideal facies model for tempestites in an area which is tectonically and structurally complex, however along the western of Surkew and Suren mountains from different locality in association with the oolitictu rbiditie of the Qulqula Group, the ideal facies can be built up.

### 1. *Normal graded calciruditefacies*

Thenormal graded calciruditefacies are mainly represented by graded massive monomicticcalcirudite (Figure.6), with basal erosional relief such as load cast, groove mark (Figure.6A&C). Their thickness about 70 – 90 cm thick. The gravelsof this calcirudite are subrounded to well rounded, but moderately sorted. The chief clastsize differs from 1 to 8 cm, and have some orientation. They chiefly spherical, discoidal and elongate fragments of limestone and marlstone.Matrix is fine grained calcareous sand. The calcirudite bed shows clear normal grading (Figure.6A&B). It overlies erosionally a calcisiltite bed (Figure.6B). Pebbles are composed of packstone to grainstonebioclastic, ooids, peloids and composite oolite. This facies represents the proximal part of storm deposits.

*2. HCS calcarenitefacies*

This facies are generally composed of whitish to light grey, with a brownish grey weathering color. Their beds have thin to moderate thickness with sharp evenbase andmostly amalgamated beds with the mean grain size varies from coarse to fine sand. The internal sedimentary structures include hummocky cross-stratification and parallel lamination (Figure.7). The cross-beds formed at low angle, and their upper surfaces arehummocky. Petrographic examination shows that it composed of packstone – wackestonebioclastic, ooids, and peloids.

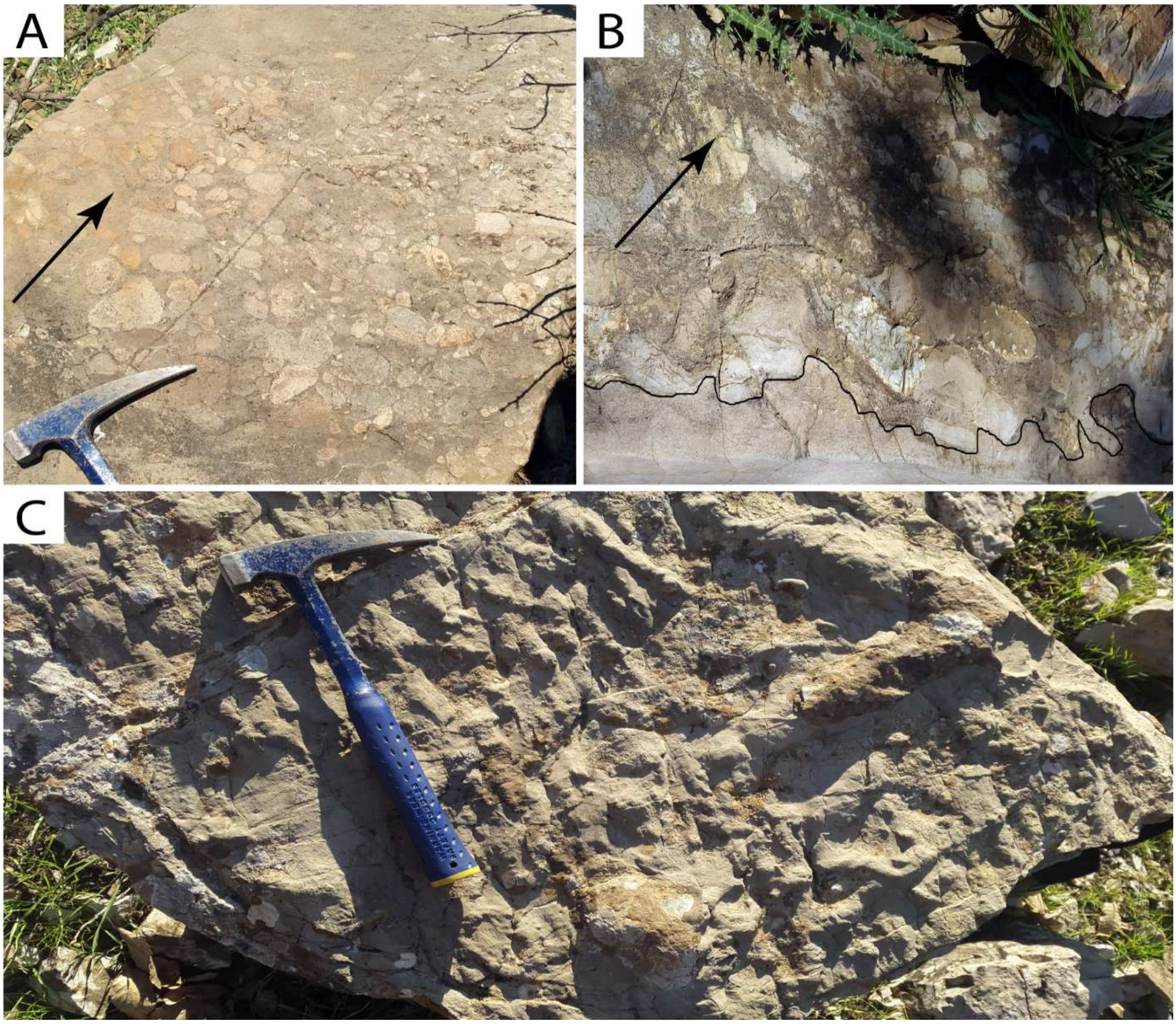


Figure.6: Close-up photo of massive monomicticcalciruditefacies at about 1 km of the east of Kokhi Baba Shekh village along the road of Nurabab village. (A) Clear normal grading of monomictic carbonate pebbles, from coarse-grain to fine. (B&C) top view of basal erosional relief which indicating by tool marks (load cast, groove mark).

*3. Parallel lamination calcarenitefacies*

This facies are generally composed of whitish to light grey calcarenite. Their beds frequently amalgamated or laminatedwith no erosional reliefbases andtheir grain size varies from medium to fine sand. In most locality, located above the HCS, but in some case shows under the HCS. The internal sedimentary structures include plane parallel lamination (Figure.8).

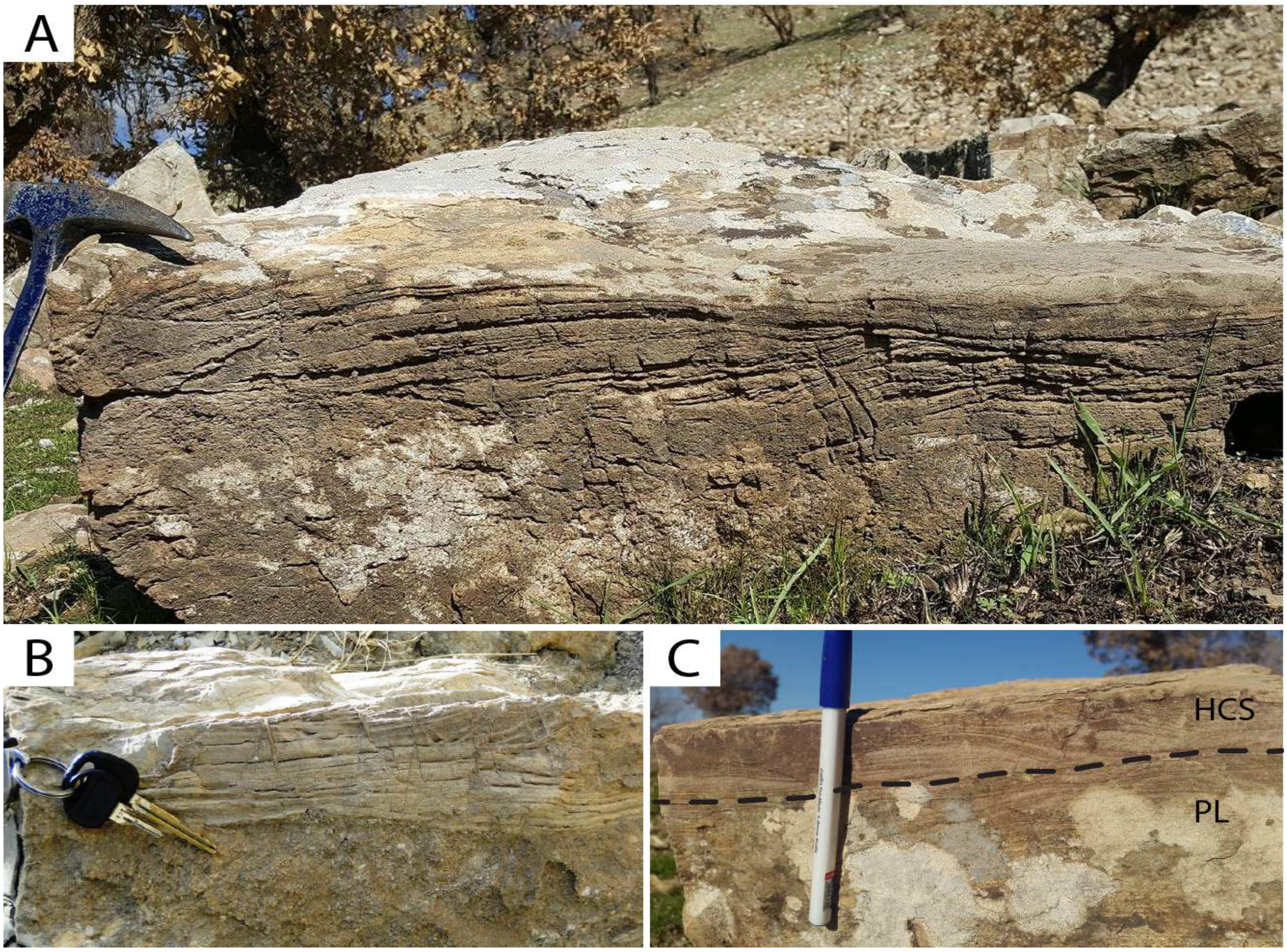


Figure.7: Close-up photos of Hummocky cross-stratification in calcarenite beds at about 1 km of the east of Kokhi Baba Shekh village along the road of Nurabab village. (A) Oblique view of calcarenite beds showing hummocky and swaley surface. (B) Low angle HCS directly superimpose the fine calcirudite facie. (C) Fine calcarenitefacies display HCS with parallel lamination.

Figure.8: Amalgamated fine calcarenite lamination in Siawash village at about 500m of the northeast of Kokhi Baba Shekh, which clearly showing plane parallel lamination.

## 4. *Wave ripple calcarenitefacies*

This calcarenitefacies composed of whitish to light grey. Their beds have thin to thick thicknesswith sharp even base and varies grain size from fine to moderate sand. It shows clearly the presence of wave-formed sedimentary structure. Locally the upper surfaces of such beds are wave rippled (Figure.9A & B) and mostly symmetrical, but also some asymmetrical ripples are present. In some cases formed in a large scale like mega-ripple. *Cruziana* is identified as typical element of trace fossils in this facies include*Rhizocorallium* (Figure.9C) and *Planolites*(Figure.9D).

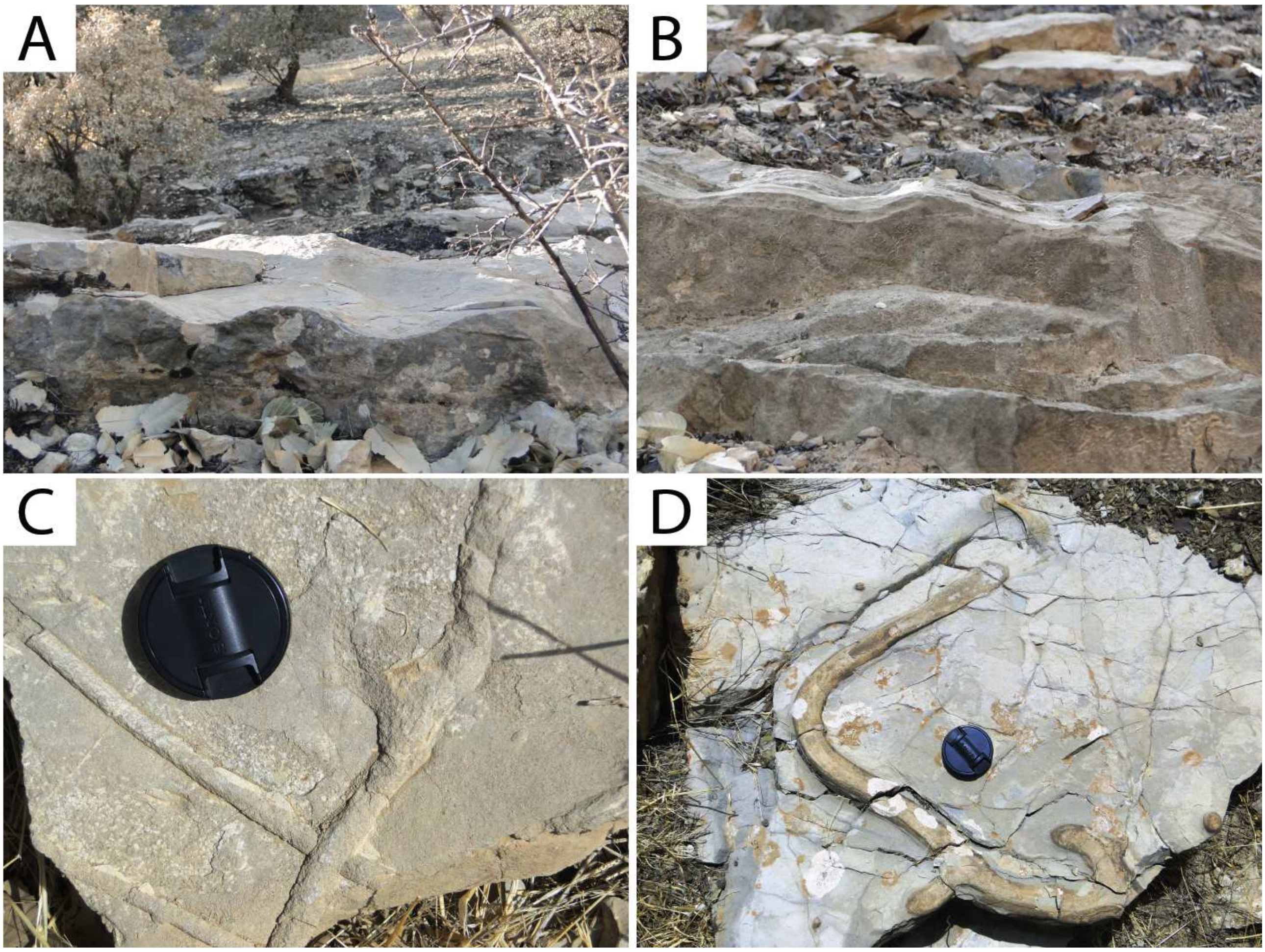


Figure.9: (A & B) Calcarenitefacies showing symmetrical ripples at 1km of the east of Kokhi Baba Shekh village. (C & D) Two type of *Cruziana* (*Rhizocorallium andPlanolites)* trace fossil found on the top of calcarenite beds in the same position with ripple marks.

## 5. *Calcisiltitefacies*

In general, this facies is whitish yellow to light grey. Mostly composed of marly silt. It display very slight lamination with tool marks (flute cast) on the bases of beds (Figure.10). In some locality, *Skolithos* (Figure.10A) and *Chondrites*(Figure.10B) trace fossil can be seen.

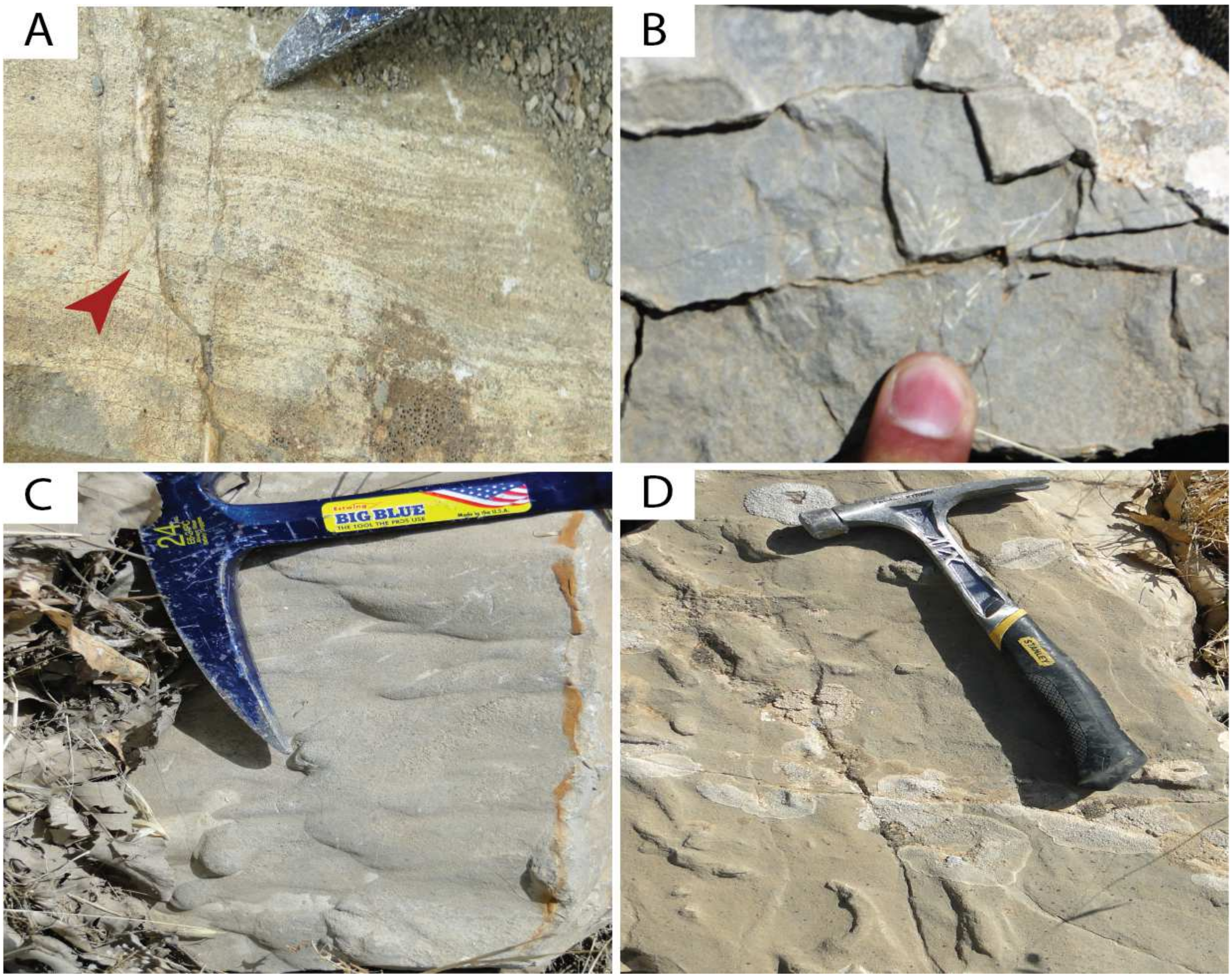

Figure.10: Different sedimentary structures in calcisiltitefacies. (A) Burrow Skolithos (red mark) trace fossil excavate the coarse calcisiltite bed. (B) Cruziana (Chondrites) trace fossil found on the top of calcisiltite bed. (C & D) Sole markings (flute cast) are common features on the base of the calcisiltitefacies.

## Discussion

Some calcarenite beds in QulqulaFormation display storm-generating features and deposited as storm deposits. Calcarenite beds associated with some calcirudite and calcisiltite beds and frequently consists of shallow water constituents. It is interbedded with thin shale and marls. Fairly, these calcarenite beds display an internal structure with graded bedding, hummocky cross-stratification, wave ripples with erosional base and escaping structures. Generally, they encompass sheet-like beds of calcarenites and bioclasticpackstones-grainstones with non-skeletal grains including peloids, ooids, intraclasts and skeletal grains with some crinoid fragments. *Rhizocorallium, Planolites*and*Chondrites* of Cruziana and Skolithos trace fossils are identified in this facies. On other hand, field observation shows that this storm deposits positioned between the Neritic Succession Limestone Unit (NSLU) and Grayish-Green Sheared Shale Unit (GSSU) of the QulqulaFormation. Baziany, 2014 concluded that the NSLU is characterized by the oolitic-peloidswackestone-grainstonemicrofacies with bioclasts distribution and little rudstone and floatstonefacies. He proved that this unit mainly deposited in carbonate ramp with the possibility of the existence of barrier shoal and named as oolitic limestone. As well as, represented the GSSU by microbreccia, packstones to grainstones to rudstonesdebrites, slumps and pebbly sand to mud turbidities facies. He evidenced that the GSSU was deposited in distal outer ramp and carbonate distally steepened ramp along the carbonate slope and inner basin and named as calcareous turbidities.

Calcareous tempestites are skeletal carbonate from carbonate ramps and platforms are redeposited as graded beds at the site of erosion and in deep water (Tucker, 2003; Einsele, 1998). Molina et al., (1997) and Vera and Molina, 1998, specified that the water depth in which the calcareous tempestite in framed can't have been much deeper than the storm-wave base and the tempestite most likely shaped throughout relative sea-level lowstand. They further included that proximal storm beds are relatively thick-bedded, bioclast-dominated and coarse-grained, with numerous composite and amalgamated beds. Distal counterparts are mud-dominated and thinner one-event beds. This configuration is a function of reducing strength of storm waves and currents away from the coastline. Distal tempestites are thin, fine-grained and show the same inorganic sedimentary structures as distal turbidities, however they contrast from turbidities in their faunal characteristics and vertical facies trends (Einsele, 1998 and 2000). As indicated by Einsele (2000), at greater water depth, hummocky cross-stratification turns out to be less distinct and is more or less replaced by parallel lamination, wave-ripple cross-bedded and lenticular-wavy bedding with ripple marks. The Cruziana and Skolithos trace fossils signifies mid and distal ramp situations, below normal wave base, but may be influenced by storm activity (Cheel and Leckie 1993; Buatois&Mangano, 2011).

Consequently, these facies association in this study represent the deposits in the mid ramp between fair-weather wave base and storm-weather wave base. The adequate supply of bioclasts and intraclasts from nearby shoal and the strong disturbance of storm wave will result in the development of thick-bedded coarse-grained tempestites (calcirudite) with common amalgamation of storm beds. Besides in examination of these criteria, which for the first time recorded in the Qulqula Group, with the turbiditie and tempestite criteria in Fulgel (2004), the tempestitefacies more suitable for the storm-related deposits between the oolitic limestone calcareous turbidities in mid ramp. Due to the constituents of this tempestite comprise carbonate components, so the calcareous tempestite can be used. Field inspection along the northwestern segment of Zagros Fold-Thrust Belt shows that the turbiditie are common and tempestite are rare in Qulqula Group. Therefore, the distally steepened for outer carbonate ramp is most suitable instead the gentle carbonate ramp in configuration of Qulqula platform. This platform can be made along a continental margin that in the rifting phase demonstrations an ocean floor topography with troughs (grabens or half-grabens) and swells (tectonic horsts), when the accumulation rate was greater than the subsidence rate and the sedimentary fill was enough to level the sea floor. Finally, toward build up facies-depth connections in the sedimentary interpretation toward paleogeographic configuration of the Qulqula platform deposits, the carbonate ramp depositional model of Vera and Molina, 1998, is well-matched the shallowing-upward cycles from calcareous turbidities which deposited in distal part of outer ramp and carbonate distally steepened ramp to calcareous tempestites in mid ramp to oolitic limestone were formed in high-energy inner carbonate ramp (Figure.11).

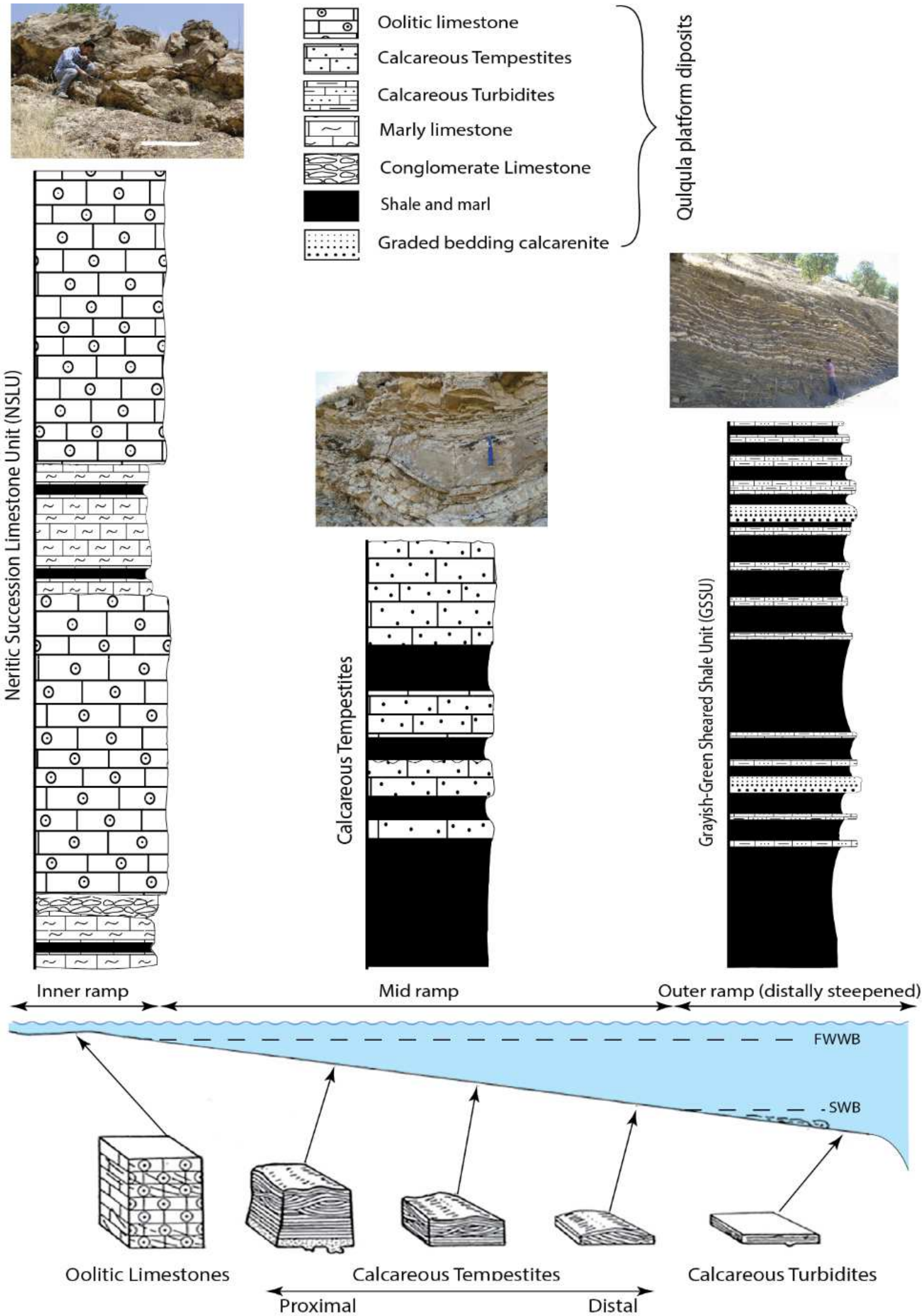


Figure.11: Conceptual model for the carbonate ramp (Qulqula platform) and the shallowing-upward cycles (modify from Vera and Molina, 1998). FWWB: fair-weather wave base; SWB: storm wave base.

## Conclusions

This paper reports the presence of calcareous tempestite for the first time in the QulqulaGroup in the Iraqi Zagros Suture Zone. This tempestite is representative as storm deposit by hummocky cross-stratification, parallel lamination, symmetrical wave-ripples, normally graded flat pebble conglomerate, and sole mark (flute caste, load cast, groove mark). It is attributed to paleogeographic configuration of Qulqula carbonate platform during Early Late Triassic to Early Jurassic. Shallowing-upward cycles from calcareous turbidities to calcareous tempestites to oolitic limestone build up the carbonate ramp with distally steepened depositional model that have resulted in the Arabian continental margin at rifting phase.

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