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# Campanian Calciturbidites from Northeast Iraq, Kurdistan Region: Insight into Paleogeography and Source Areas of the Shiranish Formation

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**Abstract**

Calciturbidites are similar to siliciclastic turbidites in structure, texture, basin physiography and processes of deposition; nevertheless, their clasts (grains) are carbonate minerals. Turbidity currents transport carbonate grains from carbonate source areas and coastal areas to the deep basins after passing the shelf (peri-platform). These currents are triggered by short-lived catastrophic events, such as tsunamis, earthquakes, marine slides, and typhoons. The Late Cretaceous Zagros Foreland and Hinterland in NE-Iraq (Kurdistan Region) was an active source for the shedding of voluminous sediments to the deep basin of Zagros Foreland Basin. During late Campanian, Shiranish Formation was deposited in the foreland basin; it occurs in the most famous oil fields in the Middle East and represents hemplagite facies (much diluted turbidite facies). Previous studies have not broached the origins of Shiranish Formation, neither in detail or briefly. Conversely, the present study focused on linking the calciturbidite system to the origin of the deposition of the Shiranish Formation via derivation from main carbonate source areas. Along long distance, the sediments crossed the marginal slope, scoring submarine channels and depositing coarse detrital carbonates before reaching the basin plain. On the plain, mostly the fine fractions have settled down and mixed with pelagic sediment. The calciturbidite evidence could be tracked for more than 40 km in the studied area from the slope and outer shelf (present Thrust Zone) to the basin plain (High Folded zone). In several places, channelized detrital laminated limestones are found inside Shiranish Formation and in the most proximal area near Qaladiza town. Bouma sequences are clearly observable with erosional base and A, B, and C divisions. These calciturbidites are keys for picturing Campanian paleogeography and nature of the source area which was consisted of limestone.

**Keywords:** calciturbidite facies, Shiranish Formation, Zagros paleogeography, Zogros belt,

# الرواسب الكلسية –العكرة للعصر الكامباني في شمال العراق (كردستان) ,فهم الجغرافية القديمة ومناطق المصدر لتكوين الشرانش

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**الخلاصة:**

تعتبر ترسبات التيارات العكرة الكلسية مشابهه لترسبات التيارات العكرة الفتاتية من حيث التركيب والنسيج

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وطبيعة الحوض الجغرافية وعمليات الترسيب، مع ذلك فان حبيباتها هي معادن كاربونايتية. التيارات العكرة تنقل هذه الحبيبات من منطقة مصدر الصخور الجيرية والمناطق الساحلية الى الأحواض العميقة بعد مرورها منطقة الرف. تنشأ هذه التيارات بفعل أحداث كارثية قصيرة المدى مثل التسونامي والهزات الأرضية والانزلاقات البحرية والاعاصير.

الجبهة الامامية والبعيدة لسلسلة زاكروس خلال العصر الطباشيري المتأخر في شمال شرق العراق (منطقة كردستان) كانت منطقة نشطة من حيث تجهيز عالي للرواسب الى الجزء العميق من حوض زاكروس. في هذا الحوض ترسب تكوين الشيرانش خلال العصر الكامباني المتأخر، وهو يظهر في معظم حقول النفط المعروفة في الشرق الاوسط ويمثل سحنات شبه بحرية.

الدراسات السابقة لم تتطرق الى أصل تكوين الشيرانش بشكل مفصل أو مختصر، خلاف ذلك، سلطت الدراسة الحالية الضوء على ربط نظام ترسبات التيارات العكرة الكلسية بأصل ترسيب تكوين شيرانش بواسطة المنشأ من مناطق المصدر الرئيسية للصخور الجيرية. على امتداد مسافات طويلة عبرت هذه الرواسب حافة المنحدر مكونة قنوات تحت بحرية ومرسبة الصخور الكاربونايتية الفتاتية الخشنةقبل وصولها لقاع الحوض، وعلى القاع ترسبت الأجزاء الناعمة لهذه الرواسب واختلطت مع الرواسب الحوضية العميقة.

ان شواهد رواسب التيارات العكرة الجيرية يمكن تتبعها لاكثر من 40 كم في منطقة الدراسة، من منطقة المنحدر الى الرف الخارجي (نطاق الفوالق الزاحفة حاليا) الى قاع الحوض (نطاق الالتواءات العالية). في مناطق عديدة وجدت الصخور الجيرية الفتاتية ذات الترقرق في تكوين شيرانش وفي المناطق الأكثر قربا من الحوض قرب مدينة قلعة دزه. تم ملاحظة تتابع بوما بوضوح مع قاعدة التعرية وتقسيمات ال A و B و C.

الرواسب الجيرية للتيارات العكرة هي مفاتيح لتصوير الجغرافيا القديمة للعصر الكامباني وكذلك لطبيعة منطقة مصدر الصخور الجيرية لهذه الترسبات.

## Introduction

Shiranish Formation was described by Bellen *et al*. [1] as 225 m of blue marls and thin beds of marly limestone. They added that it contains abundant planktonic foraminifera and ammonite which indicate Upper Campanian to Maastrichtian ages. The above authors further added that it conformably rests on Bekhme Formation in its type section, near Shiranish Islam at the north east of Zakho town, while in other place it is unconformable with older Cretaceous formations. Many authors concluded unconformable contact in Sulaimani Governorate [1, 2, 3, 4]. In contrast, other authors [5] discussed in detail the nature of the lower boundary with the Kometan Formation and concluded its conformity in sections studied in Sulaimani Governorate. They proved that the claimed conglomerate by previous authors is of diagenetic chert nodules.

A review about the formation [6] stated that the age of the formation is the Late Campanian in northeastern Iraq while it enters the Maastrichtian in the northwestern part of the country. Buday [2] referred to pelagic marl and marly limestone as a lithology of the formation, in addition to local presence of limestone conglomerate. He attributed its deposition to deep open marine environment, while others [7] assigned it to deposits of the outer shelf. Similarly, an earlier work [8] defined the environment as a middle shelf to middle bathyal depositional one. Abdula *et al*. [9] concluded a deep basinal, pelagic (open marine), frequently reducing euxinic environment of Shiranish Formation.

The present study focuses on depositional processes, provenance, paleogeography and nature of the source area of Shiranish Formation in Zagros Early Foreland Basin during Campanian. Specifically, it tries to prove that the source area of the formation was limestone terrain and that its derivative sediments were calciturbidites facies. These facies are calcium rich deposits resulting from turbidity currents, which are deposited when the current loses its energy. They are similar to siliciclastic turbidites in structure, texture, basin physiography and processes of deposition; nevertheless, their clasts (grains) are carbonate minerals. Short-lived catastrophic events such as tsunamis, earthquakes, large submarine slides, hurricanes and typhoons trigger the generation of turbidity currents that transport carbonate clasts to deep basin. Bouma [10] first described turbidities while studying deep-water sedimentation.

## Location and Geology of the area

Geographically, the studied area is situated between the northern latitudes of 35° 07' 90" and 36° 30' 60" and eastern longitudes of 46° 44' 22" and 44° 18' 53" in Sulaimaniya area, northwestern Iraq in

Kurdistan Region (Figures-1 and 2). The area has a dendritic drainage pattern and drain runoff toward southwest into the upstream of Little Zab and Diyala rivers, which flow into Dokan and Darbandikhan lakes, respectively. The area has semi-arid climate of Eastern Mediterranean region with annual rainfall of more than 650 mm of monsoon type. The study area, from northwest to southwest, includes towns such as Sulaimaniya city, Ranyia, Dokan, Surdash, Qaladiza, Chwarta, Barzinja, Said Sadiq and Halabja (Figure- 2).

Structurally, the area consists of chains of high mountains and deep valleys, most of which are built from partially exhumed anticlines and synclines. The cores of most of the anticlines are eroded along their axes, forming deep subsequent valleys and gorges, while the consequent or obsequent valleys dissect the anticline limbs. These folds trend northwest and southeast and have the general trend of Zagros orogenic belt.

Tectonically, the area is part of the western Zagros Fold-Thrust belt, and the main Zagros thrust fault is passing directly to the northeast of the studied area [11]. In the tectonic division of Iraq, it is located in the High Folded and Imbricate Zone of [2] and [7]. The area was a part of the northeastern Arabian platform Margin which was transformed to a foreland basin during the Campanian by uplifting to the terrestrial land (foreland) due to colliding of the Iranian and Arabo-Nobian plate. According to other reports [12, 13], Shiranish Formation was deposited in the foreland basin directly after the uplift due to weathering and erosion of the terrestrial land.

During late Cretaceous, the platform was transformed to a foreland basin and the previous northeast sediment transport was reversed to the southwest [12, 14]. The Upper Cretaceous Formations are Shiranish (marl), Tanjero (sandstone, marl and conglomerate) and Aqra (fossiliferous and detrital limestone) Formations which have extensive outcrops in the synclines [12, 15, 16].

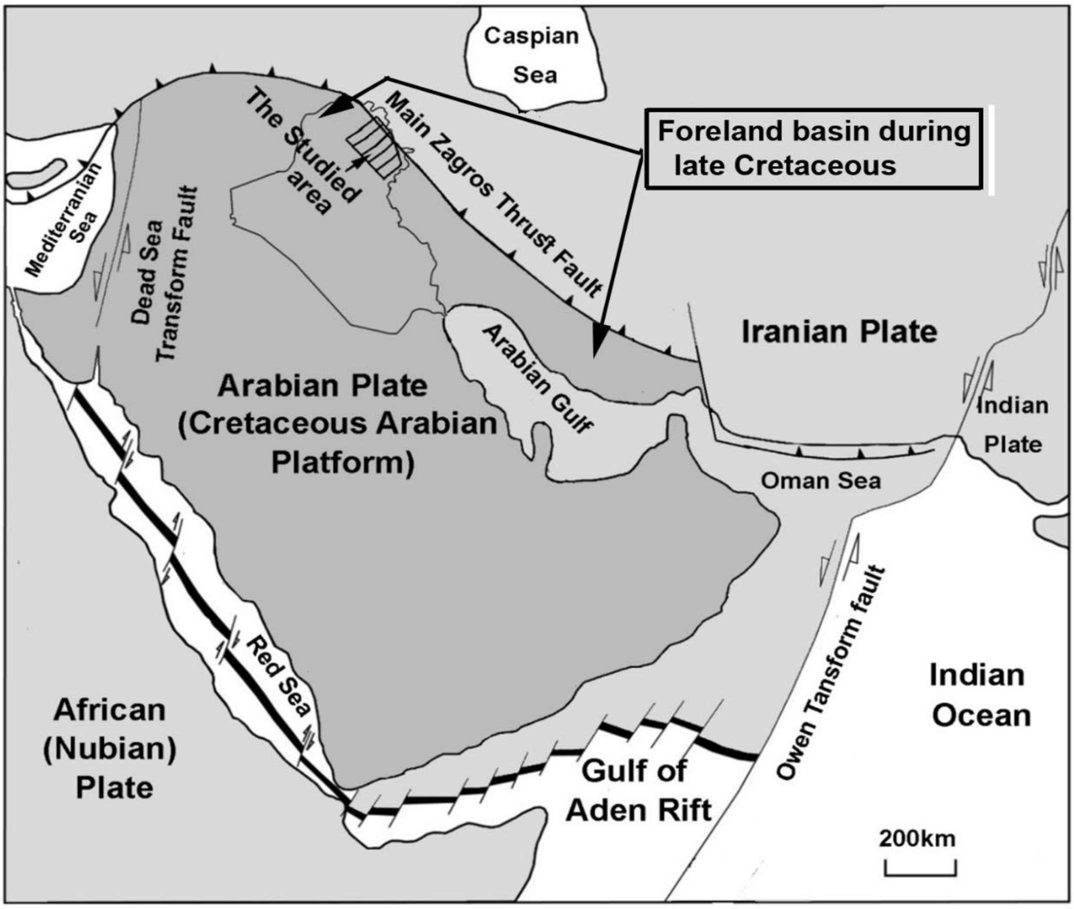


**Figure 1-**The location of the studied area on a tectonic map of the Arabian Plate (platform) at the present time (modified from [17], [18] and [19])

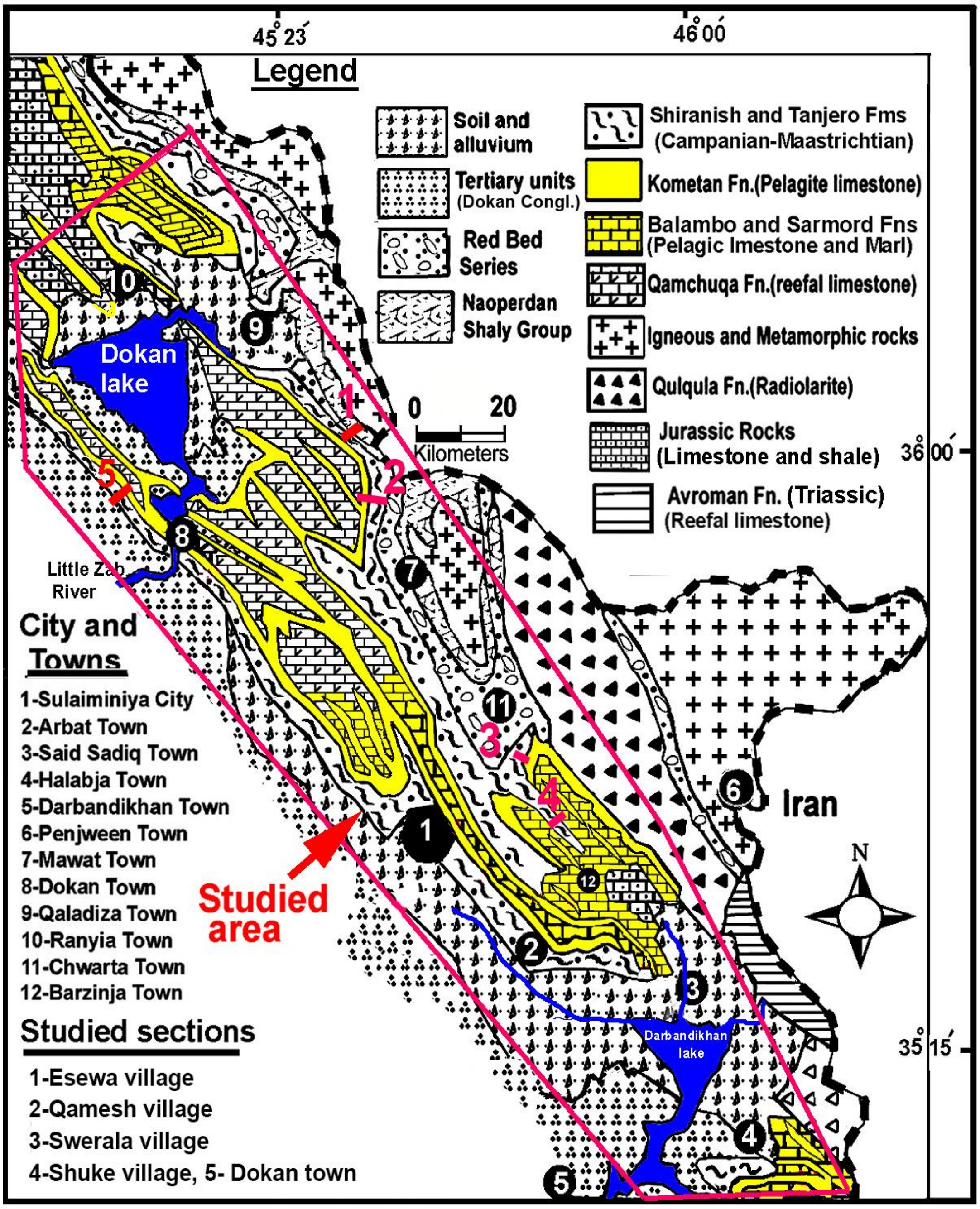


**Figure 2-**A Geological map of the studied area (modified from [20] and [13]) on which the location of the studied stratigraphic sections are indicated.

**Methodology**

The study is the result of fieldworks in the Zagros belt wherein the authors inspected tens of sections by eyes, hand lens and stereomicroscopes during a reconnaissance survey for collecting initial ideas about the scale, boundary, and distribution of the calciturbidite in Shiranish Formation. During these works, four sections were selected and sampled from bottom to top and suitable samples were taken. For detailed analyses, 50 significant samples were taken systematically in intervals of 1-2 meters from two of the four sections and thin section were prepared for the indication of the lithology, structures and fossils content. Smear slides were prepared for nannofossil aging and the GPS was used for locating the geographic position of the boundaries and samples. In the field, the studied sections and stratigraphic units, after differentiation were plotted on the map and related stratigraphic columns were drawn for marginal and basinal facies. The present study modified the previous geological map to show the location and distribution of the stratigraphic units that are under consideration (Figure-1 and 2). Finally, the present study applied the Bouma sequence to characterize a calciturbiditic succession and identify its units.

## 2. Results

### 2.1. Upper and lower boundaries of the Shiranish Formation

#### 2.1.1. Tanjero Formation

The Maastrichtian Tanjero Formation overlies the Shiranish Formation in all the studied sections and consists of about 400 m of sandstones and calcareous shale in the distal areas to the south of the Sulaimani city and Dokan areas [11, 2, 7]. It consists of turbidite sediments deposited by turbidity currents [12, 21]. In more proximal areas around the Chwarta, Mawat and Qaladiza towns, it consists of about 30-500 m of indurate polygenetic conglomerates [13] (Figures- 3 and 4). The conglomerate, in the latter figure, consists of cobble-sized clasts of different colors, chert, and limestone. It rests unconformably on Shiranish Formation. In the proximal areas, at some places, there are 6-10 degrees of angularity between the two formations. In these areas, the conglomerate was tested by paleocurrent analysis of the imbricated pebbles, and the paleocurrent direction was found to be towards the SW.

#### 2.1.2. Kometan Formation

The Turonian–Middle Campanian Kometan Formation underlies Shiranish Formation in all sections and consists of 70-120 m of white well bedded chalky limestone. It contains chert nodules in addition to stylolites. In northwestern Iraq, it changes laterally to Mushurah Formation toward the northwest [2, 7] while in the northern Iraq it changes to Bekhme Formation [22, 23]. Its type locality is located in the Naudasht valley, 18 km to the north of Ranyia town near Kometan village in the Imbricated Zone.

In earlier studies [1, 2], the boundaries of the formation were assigned as unconformable. Conversely, some recent studies [22, 24, 25] conclude gradational boundaries with Shiranish Formation in their studied areas. Karim *et al*. [5] proved that the claimed conglomerate is made up of diagenetic chert nodules that are not related to terrestrial gravels.


**Figure 3-** Sampled section of Shiranish Formation showing calciturbidite in the Thrust Zone near 500 m east of Esewa village in the Bulfat foot hill area at latitude and longitude 35° 03' 28.70" N and 45° 18' 03.42" E.

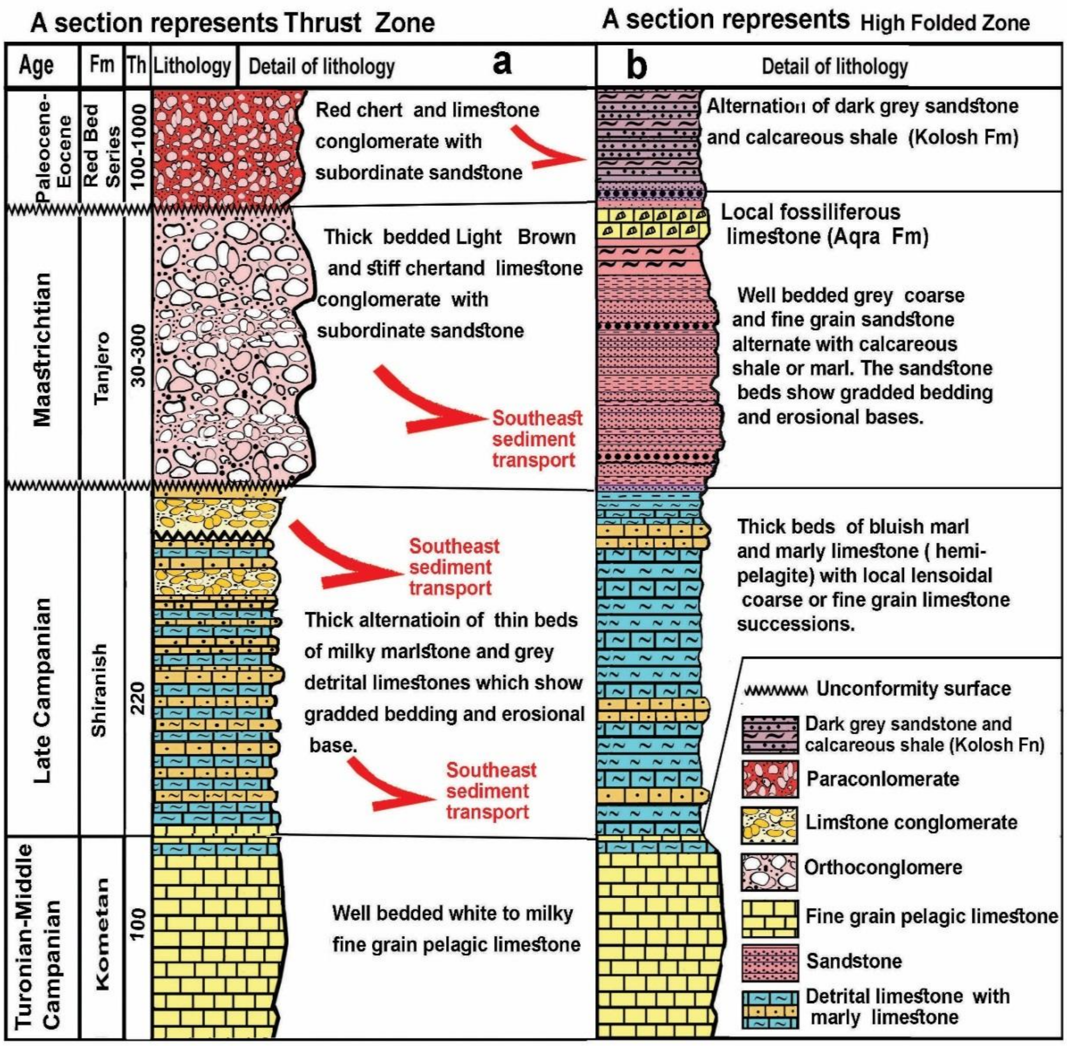


Figure 4-Two stratigraphic columns showing the position of Shiranish Formation along paleodip of later Cretaceous Zagros Foreland basin, a) 500 m east of Esewa village in the Bulfat foot hill area at latitude and longitude 35° 03' 28.70” N and 45° 18' 03.42" E. This column represents proximal area (outer shelf and slope), b) Basin plain column in the High folded Zone in area around Sulaimani city and Dokan area.

### 2.3. Calciturbitde in Shiranish Formation

### 2.3.1. Proximal calciturbidite in Qaladiza area

All the previous studies were achieved on deep facies of Shiranish Formation (marl and marly limestone) that deposited in distal area on the lower slope and basin plain. The continuous field inspection and mapping of the present study discovered the proximal facies of the formation near the border of Iran in the Thrust Zone. This facies is widespread and well developed from east of Qaladiza town to Iranian border near Qandol village. The same facies are found as well near Chwarta area in the foot of Kato Mountain. In the present study, the proximal area represents the closest available outcrops of the Shiranish Formation to the paleoshore line of the late Campanian Zagros Foreland basin.

In this area, the Tanjero Formation consists of 300 m of well sorted and rounded conglomerate which is made up of cobbles of chert and limestone (Figures-.3 and 4). It is underlain unconformably by Shiranish Formation, about 250 m thick, comprised of hundreds of thin beds of fine to coarse detrital limestone, and alternate with white marly limestone (Figure- 4). The detrital beds form sheet calciturdites and show thin bedding (3- 15 cm), very clear eroded bases, grading bedding, and rip up mud clasts (Figures.5 and 6). Most of the Bouma sequences [10] are incomplete since one or two units are absent (Figure-5b), but the complete ones are not rare (Figure-5a). The clasts of the detrital beds are calcitic carbonate grains which are sub-rounded and poorly sorted (Figure-6). Some samples, in addition to limestone clasts, contain plant debris (Figure-7) and 5-10% of detrital mafic igneous rocks, mostly of partially altered green fragments of augite and hornblende crystals.

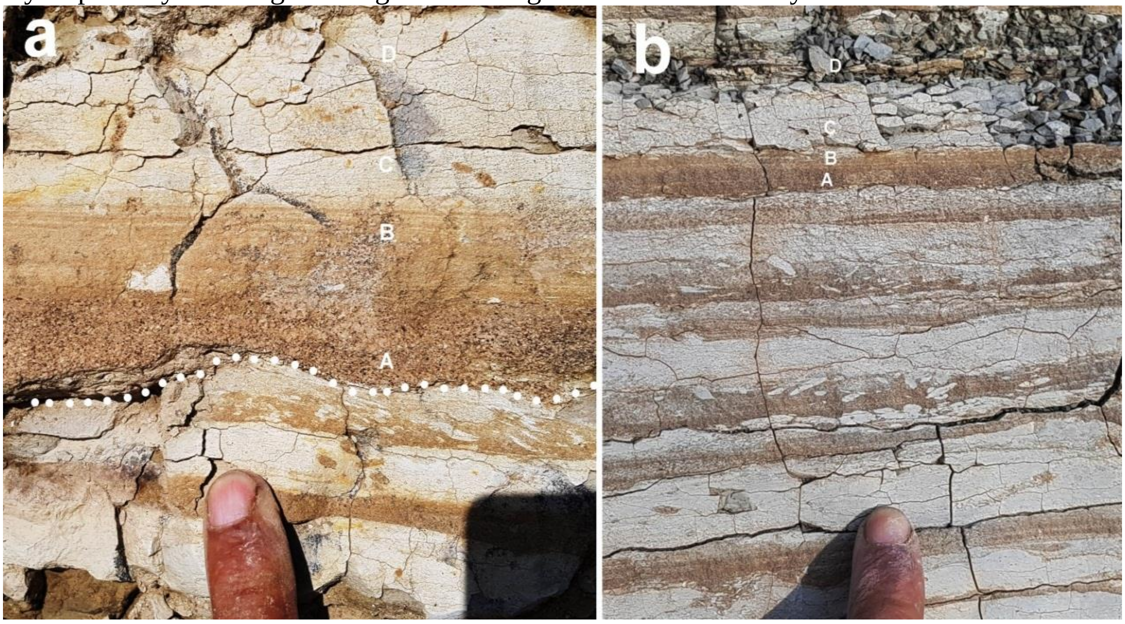


**Figure 5** a) complete Calciturbidite Bouma sequence in the proximal area 500 m east of Eswa Village in the Thrust Zone, b) incomplete sequence with imbricated rip up clasts

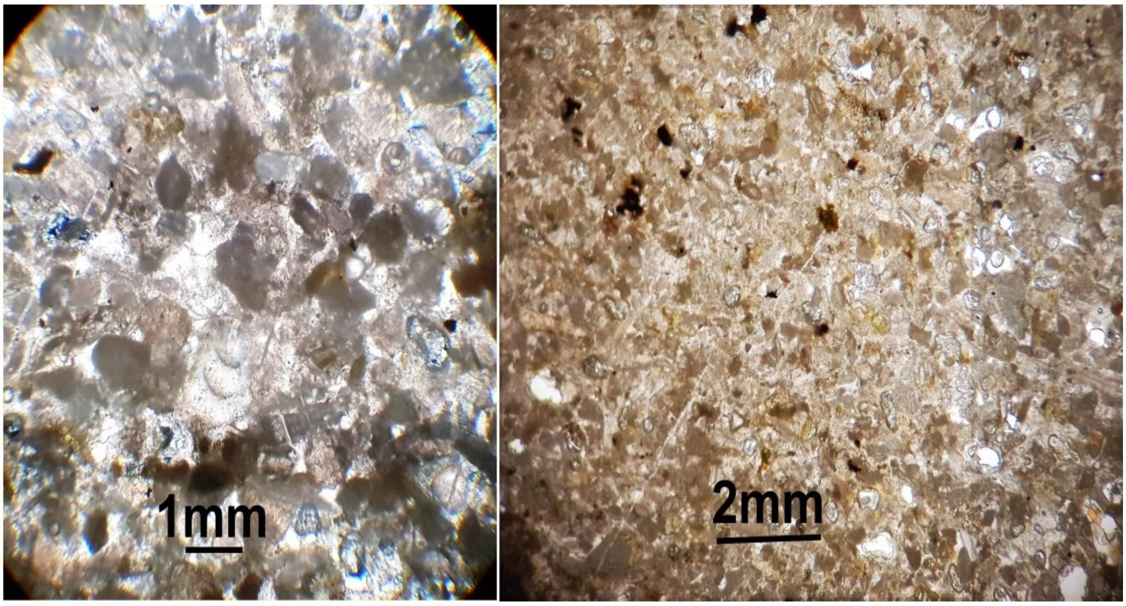


Figure 6- Two thin section of the calciturbidites (bioclasts and lithoclasts detrital limestone) of eswa section, a) under polarizer XP light, S.no.22, b) under stereoscope microscope, normal light, S. no. 22

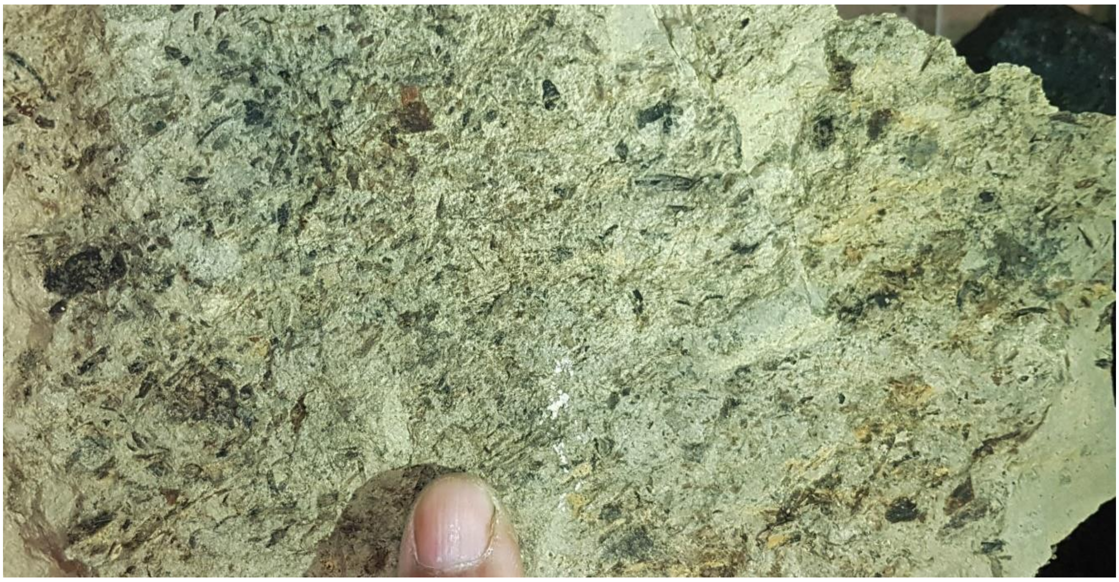

**Figure 7-**Carbonized plant debris in Shiranish Formation, 500 m of Esewa village at the proximal area. S. no.24

### 2.3.2. Chwarta area

The well-developed calciturbidite can be observed at 5 km south of the Chwarta town around Suerala, Dolla Tu and Harmela village. In this area, the features of the calciturbidite are the same as those of Qaladiza (Esewa) area but the beds are thinner and exist as several parasequences, each one is about 7 m thick and consists of tens of calciturbidite thin beds (Figure-8). The grain sizes of beds are finer than those of Qaladiza area and the carbonate grains are all calcitic and barren of siliciclastic grains and plant debris. Another difference is the presence of both sheet and channel calciturbidates. The most well developed turbidite features in this area is lensoidal channel fills in the middle part of Shiranish Formation. These channel fills have light brown (grey fresh) color and are composed of sorted and rounded medium grain limestone clasts. They can be seen along three horizons, and each channel is about 0.4- 1.5 m thick and 2-3m long (Figure-9). The channel fills are surrounded by green marl beds (hemipelagite) whereas their laminae ends against (truncated by) the walls of the channel fills (Figure-10). In this area, a previous study [26] found lensoidal, pelecypod rich limestone body, which is about 10 m thick inside Shiranish Formation (Figure-11). The author considered it as a local limestone mound in deep water. The present study restudied this limestone and concludes that it is a calciturbidte channel fill.

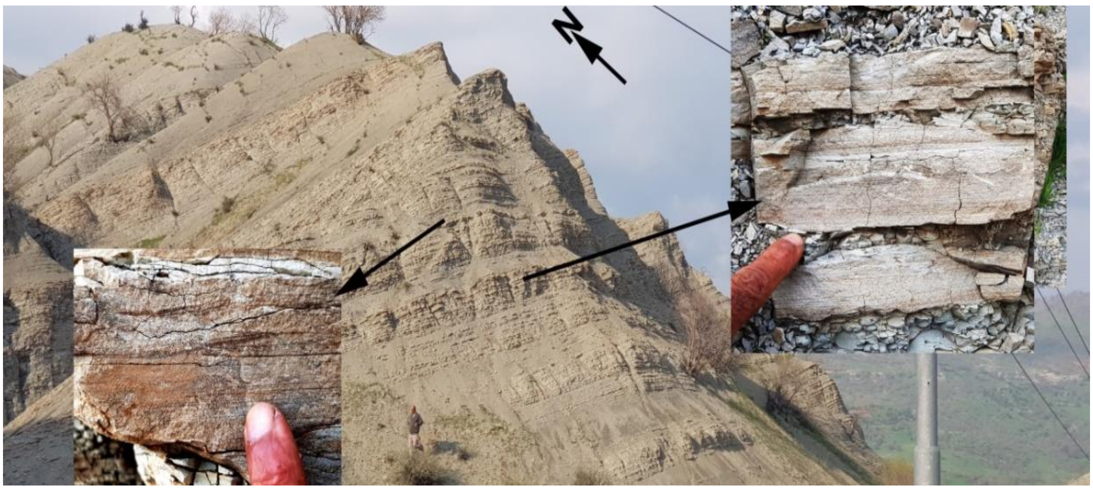


**Figure 8-** Well developed calciturbidite parasequences in Shiranish Formation, about 7 m, between the Dolla Tu and Harmela villages at the latitude and longitude 35° 40' 32.38" and 45° 37' 38.92", respectively. The small scale cross lamination (lower left corner) along with erosional surface and rip up clasts (right upper corner) can be seen

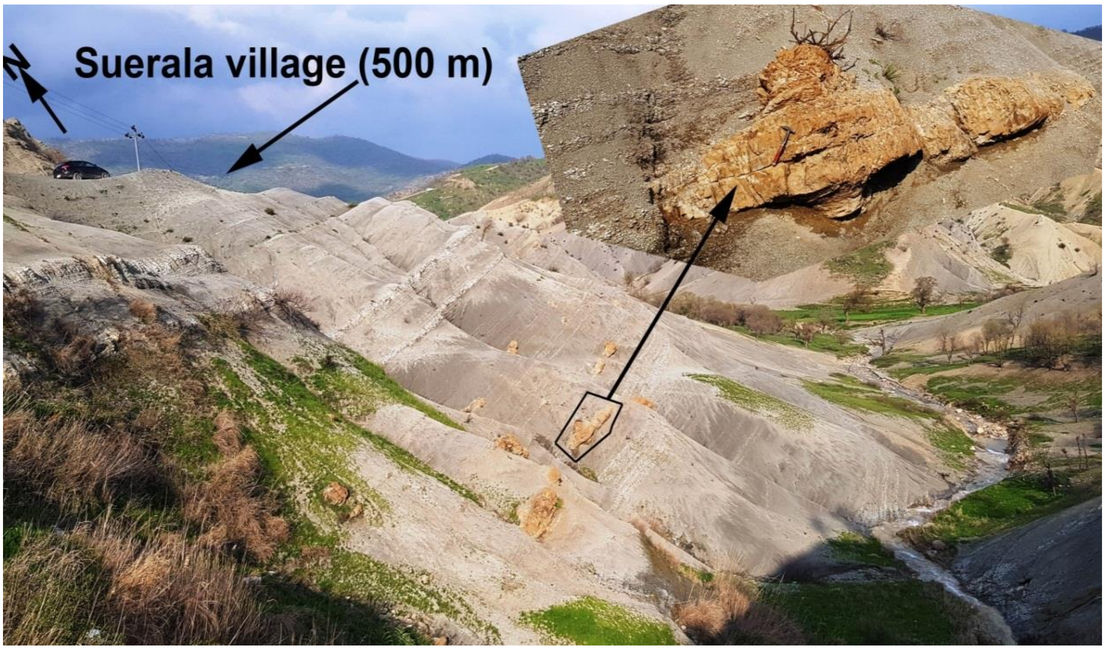


Figure 9- Calciturbidite lensoidal channels in the middle part of Shiranish Formation between the Dolla Tu and Suerala villages at the latitude and longitude 35° 40' 29.46" and 45° 37' 39.20", respectively.

**Figure 10-**Lensoidal single channel fill (calciturbidite) surrounded by green marls bed the lamiae of which end against the channel wall.

**Figure 11-** Northeast side of the Kato mountain between Dolla Tu and Suerala villages, at the latitude and longitude 35° 39' 50.03" and 45° 36' 52.14", respectively. 1- Tanjero Formation (composed of conglomerate in this area), 2- Shiranish Formation which consists of green marl containing several calciturbidites parasequences (s), 3- Lensoidal 10 m thick pelecypods-rich limestone body, about 10 m thick (T). This body was first found by [26].

**2.3.2. Evidence of calciturbidites in the distal area (basin plain)**

In the distal area, the bedding pattern has the characteristics of rhythmic bedding, abundant faint lamination, general uniformity of thickness and lateral persistence to several hundreds of meters. The lithologies are mainly consisting of marlstone (hemipelagite), mixed with fine sand and silt-size detrital grains, in addition to pelagic influx of foraminfreas and radiolarias. The hemipelagite in most places contains channel fills and sheets of fine grain calciturbidites, while the ammonite fossils are very rare.

The distance between proximal and distal calciturbidites is more than 40 km, which extends along the pleodip of the Zagros foreland basin. The basin plain includes the area around Sulaimaniya city and Dokan area in addition to Sharazoor plain. In these areas, the calciturbidite occurs as frequent lensoidal bodies, but the sheet detrital limestones are not rare inside Shiranish Formation. The grain size of these limestones varies from silt to coarse sand . It is possible that the lensoidal bodies represent channelized submarine passages for the transport of turbidity current and detrital limestone from shelf to basin plain. While the sheet bodies, such as those in Dokan area (Figure-12), represent coalesced shallow submarine channels. The lateral migration of the shallow channels are attributed to lateral erosion in the soft hemipelagite sediment of the slope and basin plain.

**2.3.3. Dokan area**

In Dokan area, Shiranish Formation is about 220 thick made up of bluish grey marl and marly limestone and has the age of Late Campanian. The formation is relatively well studied in this area, both paleontologically and lithologically [8, 27, 28, 29]. Among these studies, one found three new and uncommon conclusions about the formation in Dokan area [8]. The first conclusion is the Early Campanian-Maastrichtian age of the formation and that *Globotrancan calcarata* biozone is located at the middle of the formation. This conclusion contradicts the results of the other above authors who concluded the late Campanian age of the formation. Around Sulaimaniya city and in Sirwan valley, previous works [30, 31, 32] found *Gobotrancana calcarata* inside Kometan Formation. Therefore, the present study supports only conclusion of the age of late Campanian for the formation in Dokan area.

The second conclusion is the direct overlying of the Turonian succession by the Shiranish Formation in Dokan area. This conclusion implies a major unconformity between the two formations above which sediments of Conacian and Santonian (7 million years) are missing. This conclusion also opposes the results of other studies [5, 25, 33] who discussed in detail the absence of unconformity between Kometan and Shiranish Formations and proved the claimed conglomerate diagenetic chert nodules.

The third unusual conclusion reported by an earlier work [8] is the division of the Shiranish Formation into three depositional sequences, which is neither supported by the present study nor by the previous ones due to the absence of sedimentary expressions of the three sequences. Unfoundedly, the latter author neither indicated the GPS location of the three sequences nor showed the photos of sequences and system tracts. It is worth to mention that other reports [12, 34] put the Shiranish Formation in a high stands system tract.

Therefore, in Dokan area, the Shiranish Formation consists nearly of monotonous marl and marly limestone, but in its top it contains two types of limestone. The first type is located exactly at the boundary with Tanjero Formation and consists of 2.5 m thick fine grain succession of the detrital limestone with barren of fossils Figures-(12 and 13). These limestones are well bedded and laminated, which shows sophisticated bending, but it is not known exactly if the bends are the result of deposition or stress deformation (Figure-12). They can be traced for 3 km laterally and show variable grain sizes and allochems. The grain size changes from silt to coarse sand limestone, and toward the east it changes to coarse grain pelecypod bioclasts and whole skeletons (Figure-14). The lateral migration of the channels in the soft hemipelagite sediment of the slope and basin plain appear as sheet bodies.

**Figure 12-** Basinal signs of calciturbidite in upper part of Shiranish Formation at 3 km west of Dokan Dam at the latitude of 35° 56' 58.36" and longitude of 44° 55' 41.99". The succession consists of well bedded fine grain detrital limestone showing bedding truncation and bending due to channel migration and its cut and fill.

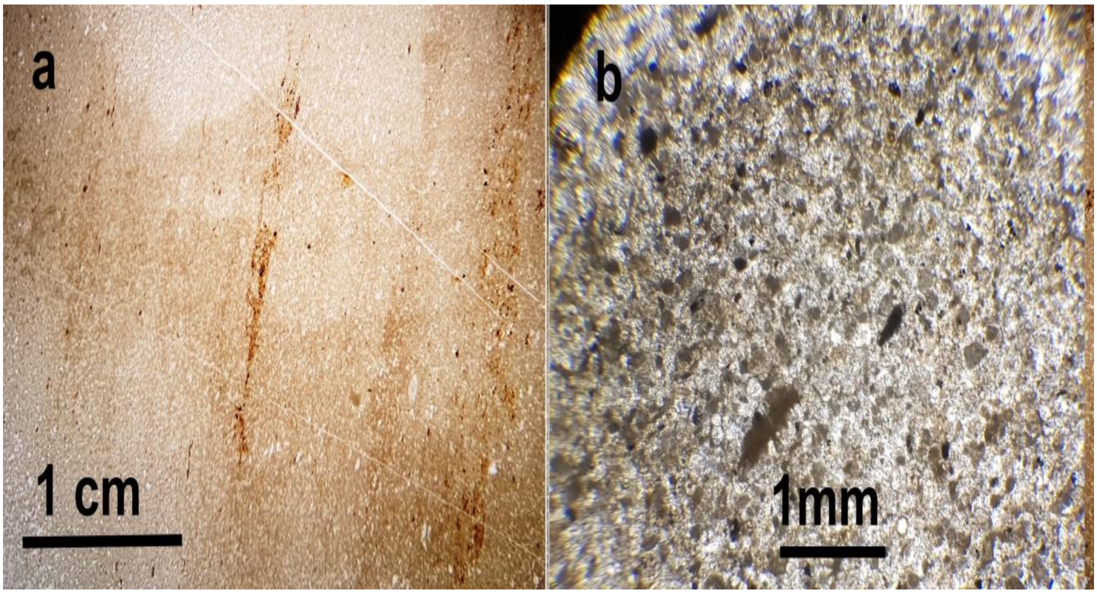


**Figure 13-**Two thin sections of the fine grain calciturbidites in Dokan area, a) under stereoscope microscope which shows crude laminations, normal light S. no.33, b) sample under polarized microscope, XP light.

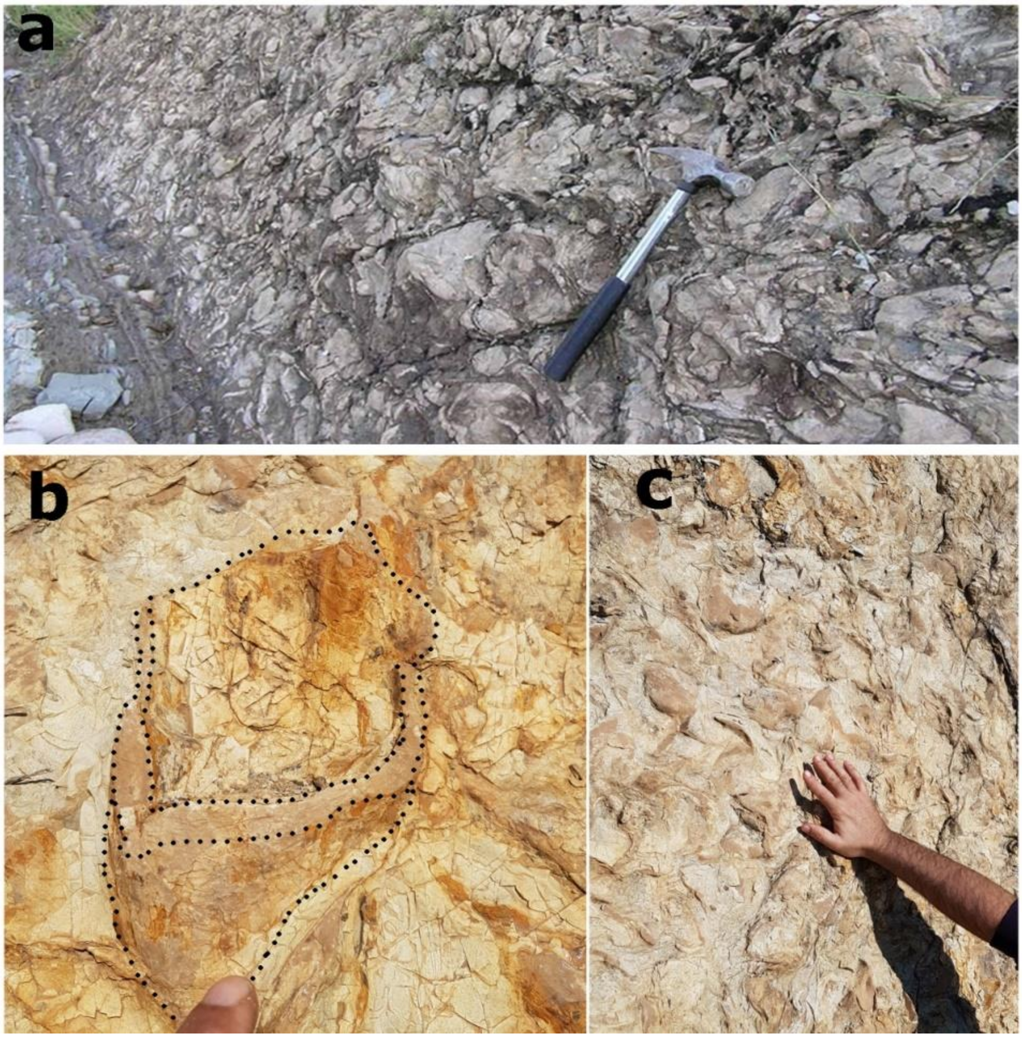


**Figure-14** Reworked, rudists and other pelecypods at the upper part of Shiranish Formation in Dokan area at latitude of 35° 56' 12.50" and longitude of 44° 57' 42.87".

**2.3.3. Shukey (Kani Dirka) village section**

This section is located 16 km southeast of Chwarta town between Kani Dirka and Shukey villages. In this area, the Shiranish Formation is only partially exposed and its lower part includes well developed and well bedded succession of coarse grain detrital limestones, about 12 m thick. The beds are laminated and grey in color, and their callochims are badly sorted and have a sub-rounded shape. These grains can be seen by naked eyes and consist mainly of limestone lithoclasts with sparse benthonic foraminifers tests. The succession is discontinues laterally and ends at the distance of 150 m in both sides. It is possible that the succession is an unconfined channel scored at the toe of the slope during minor regression, and later filled with sediment during subsequent sea level rise. Most possibly, the channels were feeding (transporting) detrital limestone to the basin plain (Unconfined channel of the calciturbidite).

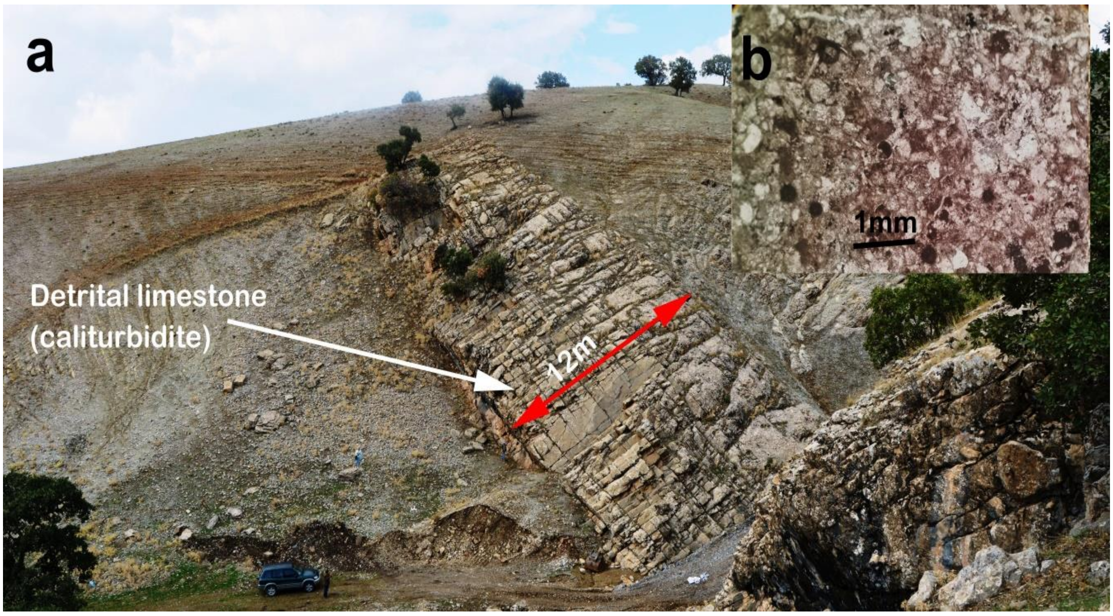


**Figure 15-** a) A succession of coarse grain detrital limestone (unconfined channel calciturbidite), 12 m thick in the lower part of Shiranish Formation at 500 m east of Kani Dirka village at the latitude of 35° 34' 43.72" and longitude of 44° 37' 22.81". b) Thin section of the same succession showing lithoclast and bioclasts grainstone, S.no.4, PPL.

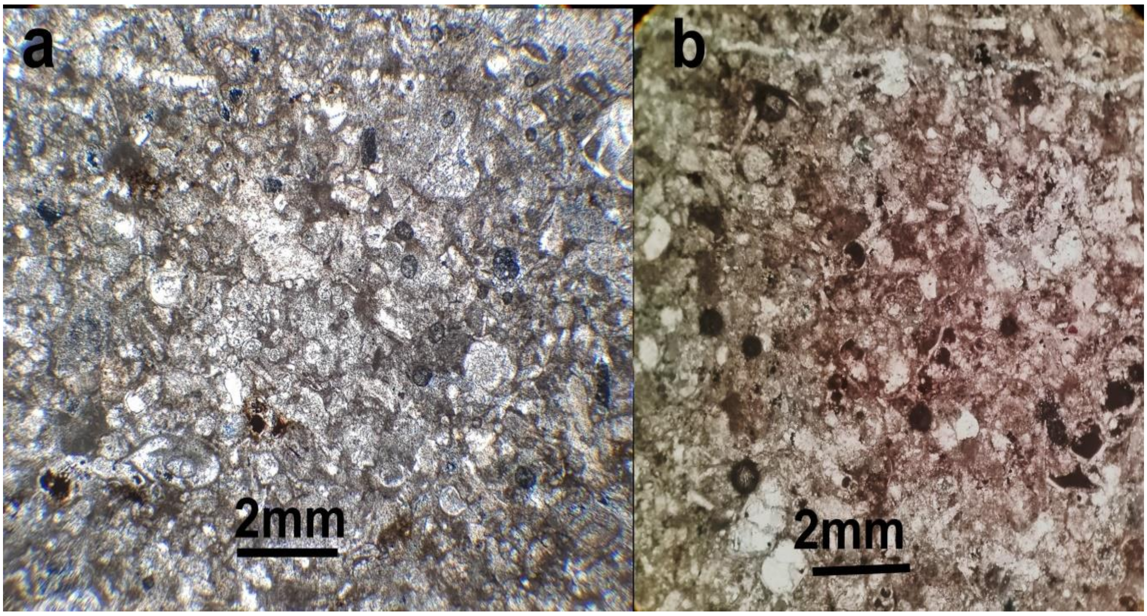


**Figure 16-**Two thin sections of the calciturbidites (bioclasts and lithoclasts detrital limestone) of Shukey section, S.no. 6. PPL.

**Demirkan Section (Sharazoor plain section)**

This section is located at the western part of the Sharazoor plain 14 km southeast Sulaimaniya city between Damirkan and Yakhy Mali villages (Figure-17). In this area, Shiranish Formation is similar to Dokan area whereas its upper part (near the contact Tanjero Formation) contains a lensoidal body of 2 m thick laminated detrital limestone that persists only for about 30 meters (Figure-17). The body is highly deformed as demonstrated by the folding of laminae (Figure-17b and c).

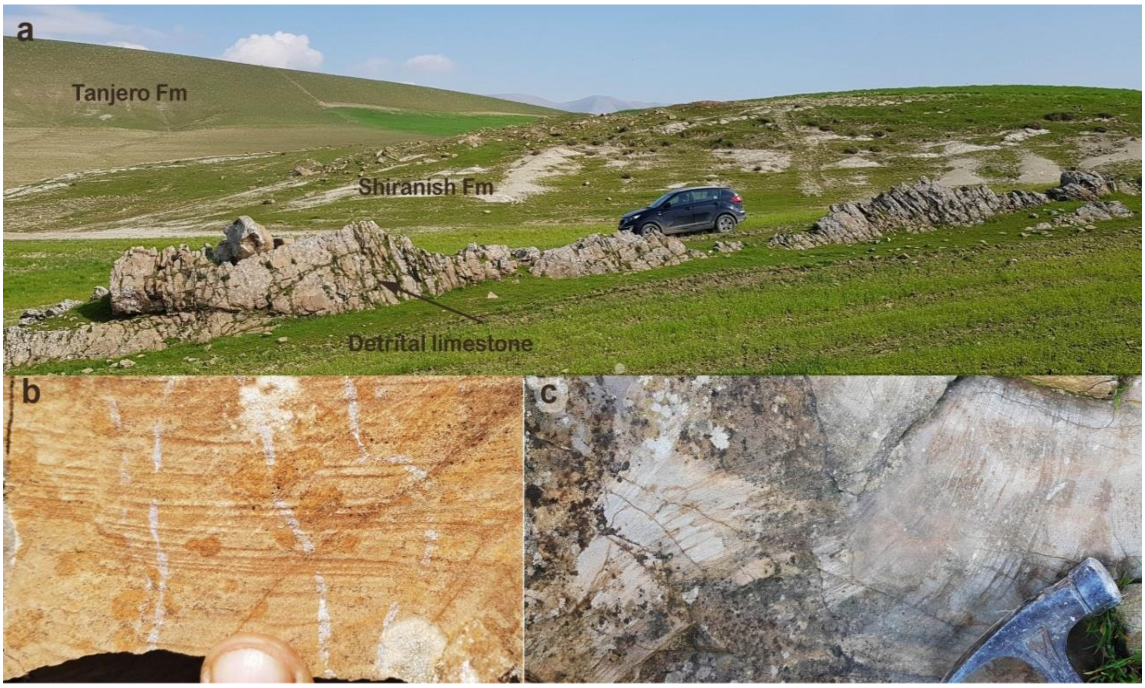


**Figure 17-** a) Laminate lensoidal detrital limestone (caliciturbidite) inside the upper part of Tanjero Formation at the mid distance between Damirkan and Yakhimali villages in Sharazoor plain, 4 km west of Arbat town at the latitude of 35° 26' 30.05" and longitude of 45° 31' 31.51", b) Planar lamination, c) Bended lamination

## 3. Discussion

### 3.1. Recorded Late Cretaceous Zagros calciturbidite

The present study is the first to document calciturbidite in the Zagros orogenic belt during the Late Cretaceous. All the previous literatures defined Shiranish Formation as of pelagite origin characterized by microfaunas and ammonites [1, 2, 9]. The present study has five significant outcomes; the first is the introduction of caliciturbidite facies which indicated transportation of carbonate sediments and deposition in deep basin by turbidity currents. The second is changing the lithology of the formation to hemipelagite which is mediated by fine channelized caliciturbites at distal areas. The third indicates the paleogeography and tectonic setting of Late Cretaceous Zagros Foreland basin (Figure-18). This setting is of high topography with newly uplifted terrestrial land that is inhabited by plants ((Figure-7). The fourth is the limestone source area of the Shiranish Formation; this limestone was a main first rock that was uplifted during the colliding of the Arabian and Iranian plates at the beginning of the Campanian. No evidence of volcanic lithoclasts either in Shiranish Formation or in Tanjero Formation was found in Sulaimaniya Governorate. There are two sources of the limestone clasts, the first is the possible Avroman Formation (Triassic reefal limestone) which might had been uplifted and eroded during the Late Campanian. The second source is the possible shelf limestone (reefal limestone) inside the basin of Shiranish Formation. The evidence for this source is the presence of pelecypods bioclasts in the calciturbidite of Esewa section. This reefal limestone was far to the northeast inside the present Iranian territory. The fifth is the direction of the submarine paleocurrents by which the calciturbidite was delivered from the source area to the basin via the shelf and slope. These currents transported huge amounts of terrestrial sediments to deep basins and its direction was toward southwest (Figures-1, 2, and 18). The southwest direction of the paleocurrent is inferred from the shape of the channels which have minimum length in the direction of paleocurrents. The direction of the coarsest sediment caliber decrease can also be used to indicate the paleocurrent for Shiranish Formation; this decrease is toward southwest (Figure-18). Many authors such as Karim (2004) and Karim (2005) documented the development of Zagros geodynamics during the late Cretaceous and indicated that the Early Cretaceous Arabian platform margin was changed to foreland and foreland basin during the Campanian. They added that during this age, the paleocurrent was reversed from northeast to southwest due to the foreland basin generation.

Another problem is the age of the Shiranish Formation as it changes from a place to another. Several studies [1, 7, 36, 37] assigned the late Campanian age for the formation, while others [8, 38] indicated the Campanian-Early Maastrichtian and Early-Late Campanian as the age of the formation, respectively.

All of these age determination attempts were performed in the distal area (basin plain) where the sedimentation continuous, barren from submarine erosion and stable environments. In the proximal area (the slope and the outer shelf), an age determination by the present study, using nannofossils, indicates the Early Campanian age (Figure-19). This age difference between the basin and slope might be attributed to three factors; the first is the environmental instability in the proximal area due to frequent flow of turbidity currents and high rate of clatics input, which dilute or prevent revival of certain index fossils. The second is possible the diachrony of the facies of the formation, by which it become younger toward the basin plain (southwest). In this regard, an earlier work [2] suggested that the age of the formation is older than that of the Upper Campanian in some places. Kaka [39] assigned the age of Maastrichtian to the formation in Dimerdagh, well-1, in Erbil area.

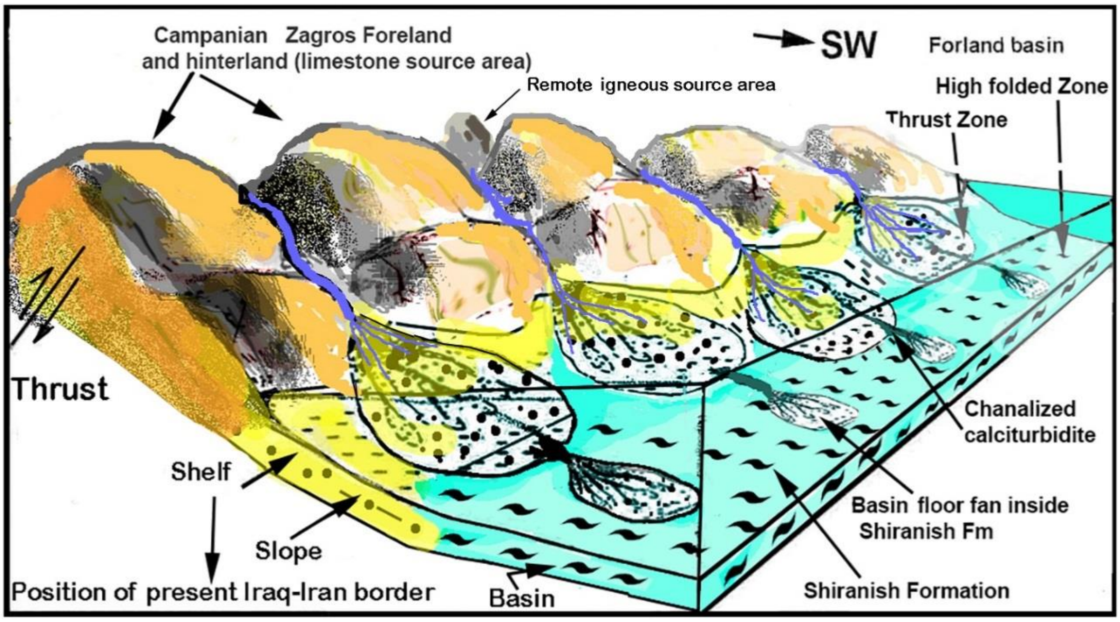


**Figure 18-** Reconstruction of tectonic and paleogeographic setting of the newly generated Late Cretaceous Zagros Early foreland basin. The setting shows the location of the calciturbidite fan system with a direction toward south west. In the model, the present location of Iraq-Iran border is indicated which indicates that the source area and shelf were located in Iran.

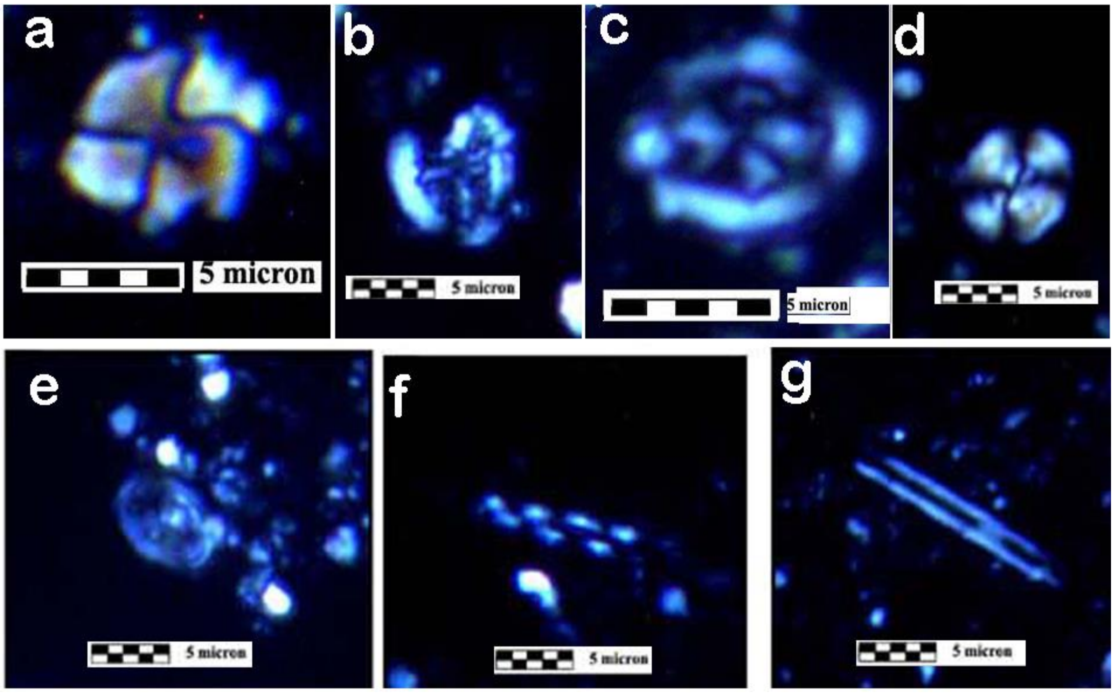


**Figure 19-**Species of Nannofossils incating Early Campanian in the Esewa section in Thrust Zone, a) *Calculites obscurus,* b) *Arkhangelskiella cymbiformis,* c) *Calculites obscurus,* d) *Watznaueria bipoeta,* e) *Tranolithus phacelosus,* f) *Lithraphidites camiolensis,* g) *Microhabdulus decoratus*

## 4. Conclusions

This study has the following conclusions:

1. An extensive calciturbidite is recorded during the Late Cretaceous in Zagros Fold-Thrust belt which links the initial nucleus of Zagros Orogenic Belt with the basin plain.
2. The lithology of Shiranish Formation is changed from Pelagite to hemipelagite and calciturbidite
3. The calciturbidite is very clear in the proximal area which consists of a thick sequence of coarse detrital limestone that shows Bouma units, while in the distal area it consists mainly of channelized detrital limestone and hemipelagite .
4. The source of limestone clast was derived from either Avroman Formation or from peripheral shelf reefs of the basin of the Shiranish Formation.

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