Possible Effect of Storm on Sediments of Upper Cretaceous Foreland Basin: A Case Study for Tempestite in Tanjero Formation, Sulaimanyia Area, NE-Iraq

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ABSTRACT

Previously, the basin of Tanjero Formation (Campanian-Maastrichtian) has been given the setting of trench or miogeosyncline in which turbidite sedimentation had occurred. In the present study, conversely, many sedimentary structures are found that shows shallow environment of the lower and upper part of Tanjero Formation.These sedimentary structures revealed that during deposition of these parts the sea level is so lowered that the sediments are affected repeatedly by storms surges. These storms reworked sediments to form storm deposits (Tempestite) or to be transported to deeper water and deposited as turbidite. The recoded sedimentary structures are such as hummocky- cross stratification, interference and longitudinal ripple marks, plant debris and grass body fossils in addition to clean sandstone (Arenite).

التاثير المحتمل للعواصف على رسوبيات حوض مقدمة القارة في الكريتاسي العلوي: حالة دراسية خاصة للتعرف على رسوبيات العواصف في تكوين تانجرو، محافظة السليمانية، شمال شرق العراق

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الملخص

اعتبر سابقا تكوين تانجيرو (الكامباني-ماسترختي) كخندق او مايوجيوسنكلاين و تجمعت بداخله التعكرات. ولكن في هذة الدراسة تم أيجاد العديد من التراكيب الرسوبية في الجزئين السفلي والعلوي للتكوين حيث تشير هذه التراكيب الى ضحالة هذين الجزئين اثناء الترسيب خاصة اثناء انخفاض مستوى سطح البحر الى حد تأ ثر الرسوبيات بامواج وتيارات العواصف. هذه الامواج والتيارات ادت الى اعادة الترسيب بشكل رسوبيات العواصف او نقل الرسوبيات المذكورة الى مناطق اكثرعمقا و من ثم ترسيبها بشكل ترسبات العكورة. التراكيب الرسوبية المسجلة في هذة الدراسة والدالة على رواسب العواصف الشديدة (Tempestite) عبارة عن: تطبق متقاطع محدب وعلامات تموج متداخلة و طويلة، فتات نباتي و متحجرات نباتية كاملة و رواسب رمل نظيفة.

INTRODUCTION

Tanjero Formation is an Upper Cretaceous (Campanian-Maastrichtian) unit, which crops out within the Imbricated and High Folded Zones in Northeastern Iraq Buday (1980) and Buday and Jassim (1987). It stretches as narrow northwest-southeast belt near and parallel to the Iranian border (Fig.1). The formation mainly consists of alternation of sandstone, calcareous shale and marl with occurrence of very thick conglomerate and biogenic limestones (Karim, 2006b, Karim and Surdashy, 2005b and 2006b). These authers inferred that the basin of the formation developed during Campanian as foreland basin due to collision of Iranian and Arabian plates.

On the basis of main lithological distribution, Karim (2004b) has divided the formation into three parts (lower, middle and upper parts). The lower part consists of thick succession of conglomerate (20-500m) and sandstone (100-400m) at proximal and distal area respectively. The conglomerate and sandstone represent near shore and slope sediments. The middle part is composed of 100-300m of bluish white marl and calcareous shale. The upper part consists of alternation of biogenic (skeletal) limestone and calcareous shale with miner amount of sandstone and conglomerate. He cited that the lower and upper parts were deposited in relatively shallow water while the middle deposited in deeper water.

Tanjero formation is previously suggested as deposit of deep marine (trench) environment (see Buday, 1980; Jaza, 1991 and Jassim and Goff, 2006). But Karim (2004b, 2006b) and Karim and Surdashy (2005a and 2006) showed that both lower and upper parts were deposited in shallow water environments while the middle part deposited in deep one. Therefore, in these shallow environments (in the shelf environment) the sea level is so lowered that the sediments are repeatedly reworked by storms and deposited on the slope and basin plain. These sediments are sandstone in the lower part while in the upper part consisted of bioclast with large forams. The sections of the upper part that contain cross bedded bioclastic limestone are studied by Lawa et al., 1998 and Karim 2004b.

TEMPESTITE SEDIMENTS IN THE LITERATURE

Tempestite is storm deposit, which shows evidence of violent disturbance of pr-existing sediments, followed by their rapid re-deposition in shallow environments (Ager, 1974). Walker, (1984) showed by diagram that storm can rework sediment of the shelf and redeposited it either as tempestite (in shallow water) or as turbidite in deeper water (Fig.3). According to Einsele (2000) tempestites are sheet-like sand, silt and mud beds on considerable lateral extension. They are formed by storm wave, which have strong impact of subtidal sediments by stirring up sand and pebbles, seaweed, various shells debris and fine grain materials. After the storm has waned, the suspended material is re-deposited either directly at the site of wave erosion (site of reworking as tempestite) or transported by suspension into deeper water and deposited as turbidite. He adds that, the grain size of tempestite varies greatly. They range from coarse-grained sand and gravel to silt and mud. The same grain sizes also appear in reworked carbonate sediments such as bioclast sandstone, wackestone and packstone. According to the same author tempestite requires either terrigenous sediment influx or significant biogenic carbonate production, which must not be diluted by siliciclastic. Tempestites probably are formed during sea level fall and well preserved when deposited at the lowest sea level stand.

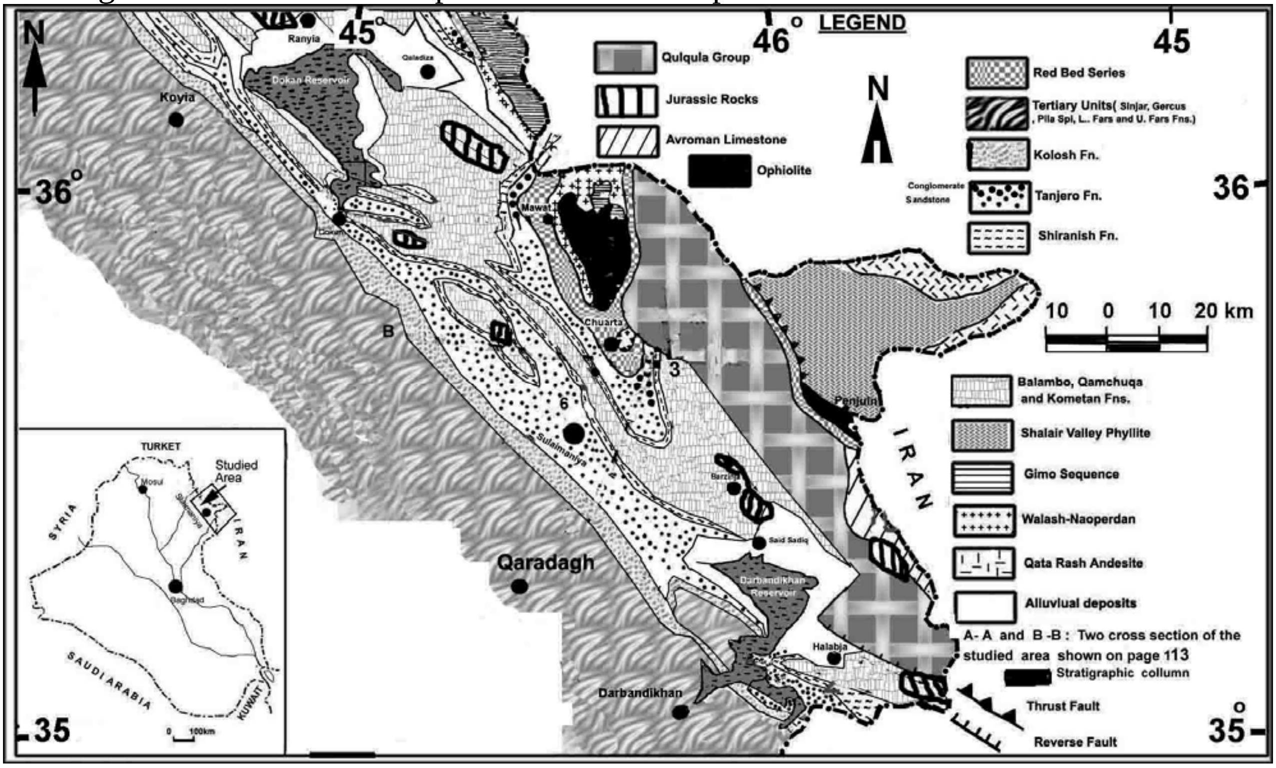


Fig. 1: Location and geological map of the studied area

According to Einsele (2000) tempestites deposited close to the coastline are called proximal tempestite. Those deposited basin ward at great distance from their sediment sources are called distal tempestite. The proximal tempestite facies contains large scale hummocky cross stratification and has no muddy interbeds. In Tanjero Formation this type of tempestite is located at the area to the north of Sulaimaniya city including Chuarta area where coarse sandstone and boiclast where available during upper Cretaceous. According to Einsele (2000), the intermediate tempestite is characterized by thick and often amalgamated bedform with increase of muddy intercalation. In Tanjero Formation, the areas that located around (lower part of both limbs of) Azimr, Goizha, Daban and Sara anticlines have this type of tempestite. But the distal ones are thin, fine grain and show the same inorganic sedimentary structures as distal turbidite in their faunal characteristics and vertical facies trend (differing by existence of hummocky cross stratification). Distal tempestites are seen at Dokan and south of Sulaimanyia area (Fig. 1 and 2). Mohseni and Al-Aasm (2004) are studied tempestite in the carbonate-siliciclastic succession of Paleogene of Zagros basin from southwest of Iran.

FIELD EVIDENCE FOR TEMPESTITE IN TANJERO FORMATION

Many lines of evidence exist in the lower part of Tanjero Formation proving that this part had been deposited in shallow, storm dominated, water (originally deep basin that changed to shallow water by sea level fall) located above storm wave base. These are:

1. The most important line of evidence for tempestite is the extensive occurrence of plant debris (leaf and trunk fragments) on the top or inside the sandstone beds (Fig.8). On these beds, the debris are scattered in about 1 to 5cm thick. In some localities more than 15 horizons are found at interval of 20 m of the lower part (lowstand wedge) of the formation. The sizes of these fragments decrease across depositional strike. The source of these debris are derived from terrestrial near shore plants which destroyed to small pieces (1cm to more than 25 cm in length) and then carried by water or wind to the shallow water and deposited there by settling after the storms or stream floods have waned.

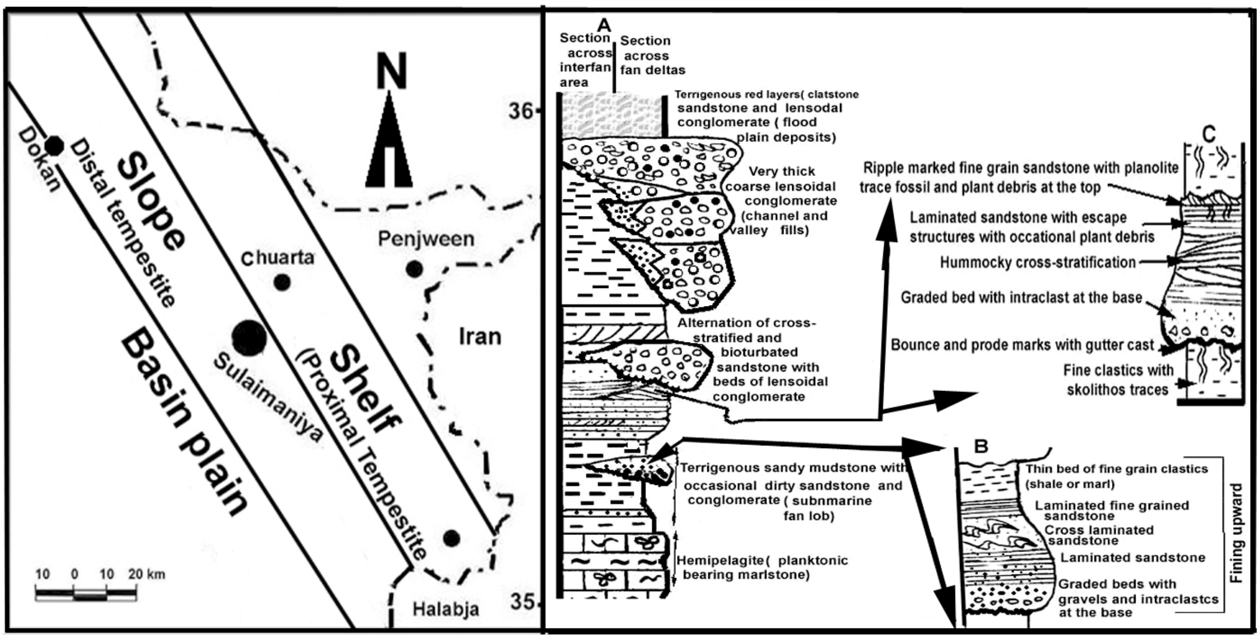


Fig. 2 Left: Position of shelf, slope and basin plain of Tanjero Formation during lowstand system tract. The position of proximal and distal tempestite is indicated. Right: A) General Facies model for the formation, B) facies model for turbidite, C) Facies model for tempestite.

2. Existence of hummocky cross stratification (Fig.3). According to Tucker (1991) this structure is characterized by gently curved, low angle(less than15 degrees) cross laminations. The lamine are arranged in convex-upward (hummock) and concave downward (swale) pattern with the erosional lower boundary of the sets. The laminae are nearly parallel to the erosional surface and thicken laterally which giving fan-like shape (Fig.5). All these characteristics only can be seen when three-dimension exposures are available. In the Tanjero Formation similar structures are found in the lower part. This part is deposited in the basin, at an area that is located between distal and proximal area (Fig.2 and 4). In Dokan area at 450m to the west of Joblakh village and near tourist village, a three-dimensional sample is found which has most prerequisites of HCS (Fig. 3).

Walker, (1984, p.150)mentioned that in core samples, the criteria for distinguishing hummocky cross stratification are the intersected low angle laminations (Fig.5 and 7) and bioturbated mudstones. These lamination and bioturbation are very common in the lower part of Tanjero Formation at the north of Sulaimaniya city at the east and west of checkpoint. Moreover, Walker, (1984, p.200) mentioned association of *Skolithos* and *Cruziana* ichnofacies with Hummocky cross stratification (see Karim

200b). He added that reworking of pre-existing sediment by storm form escape trace fossil. The same thing is found by Smith and Jacobi (200, p.341) in upper offshore of Caneadea Formation of Canadaway Group, USA. In Tanjero Formation and in the lower part similar structures are found near each other in clean sandstone.

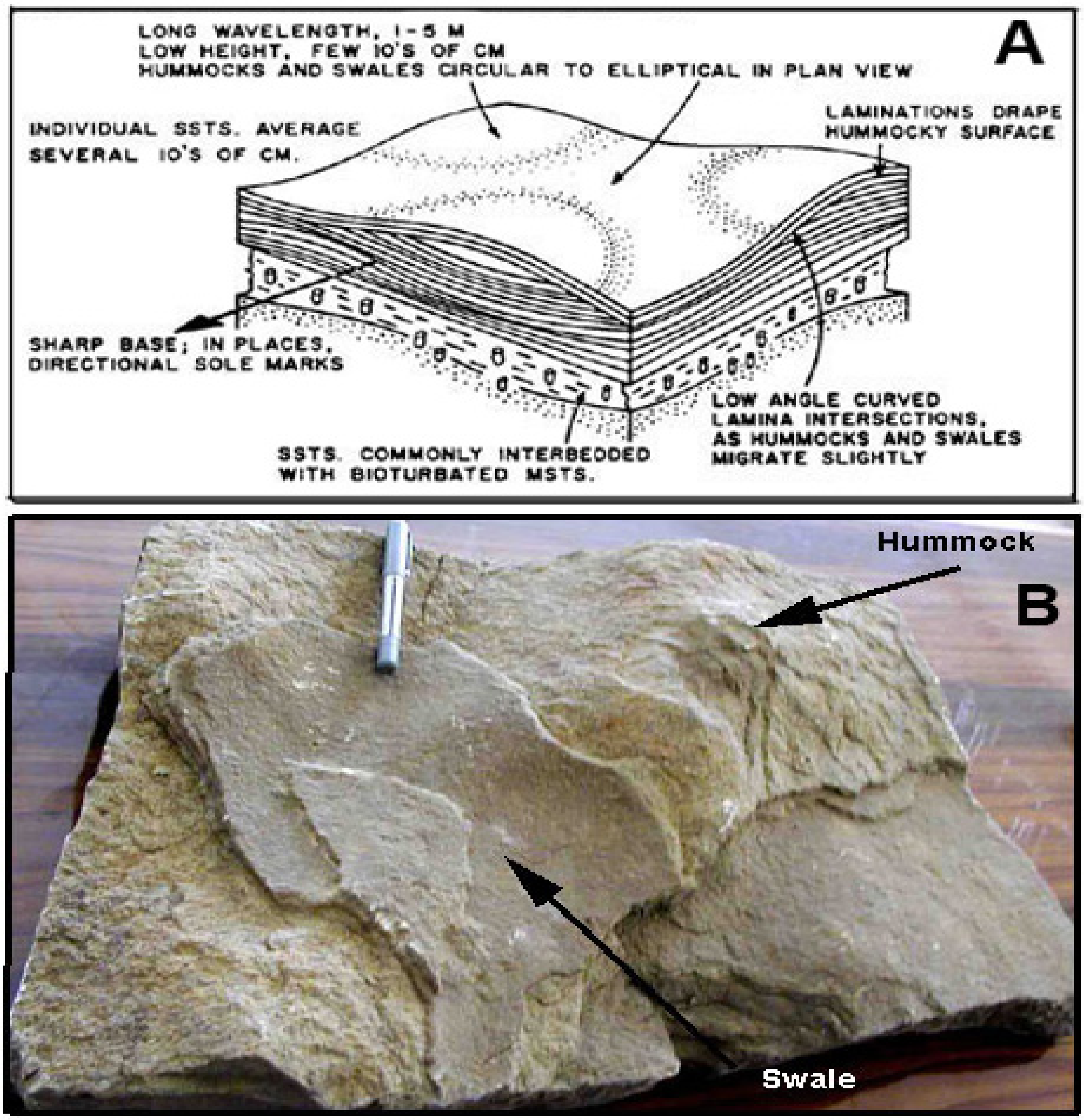


Fig. 3 A: Comparison between sketch of hummocky cross stratification by f Walker(1984) and Photo of hummocky cross stratification structure found at Dokan area near Joblagh village, 2km east of tourism camp. One can observe the parallism of the lamina covering the surface of hummock and swale.

3. Many vertical escape burrows are oftenly recorded in thick and thin sandstone beds of the lower part of the formation (see Karim 2004b and Karim 2006b). They possibly represent the escape burrow of organisms that became buried during the storm event and represent doomed pioneers of disturbance regime.

4. Some sandstones of the lower part are clean and well sorted. In this connection Emery and Myers (1996) mentioned that progradational; storm-dominated parasequences are generally simple, clean, and coarsening upward. Tanjero Formation contains such parasequences especially in lower and upper parts which represented by beds of lithic arenite and bioclast limestones respectively. In the lower part lithic arenite

5. The lower part of the formation, in many localities contains many thin and thick sandstone beds all end with small or large ripple marks. These ripples are more or less resembling linguoidal ripples (Fig.6). Pettijohn and Potter (1964) called these ripples interference ripples and Ainsworth and Crowley (1994, p.688) recorded the same type of ripple and attributed them to storm deposit (Tempestite).

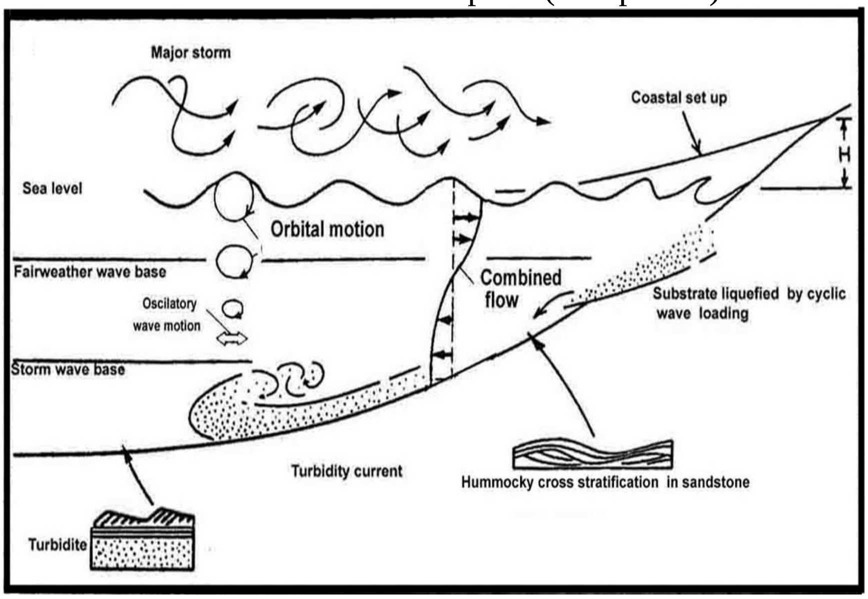
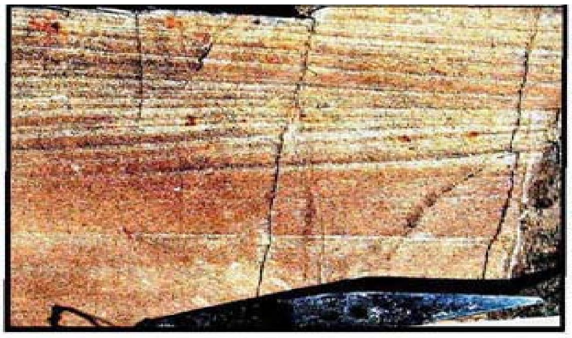
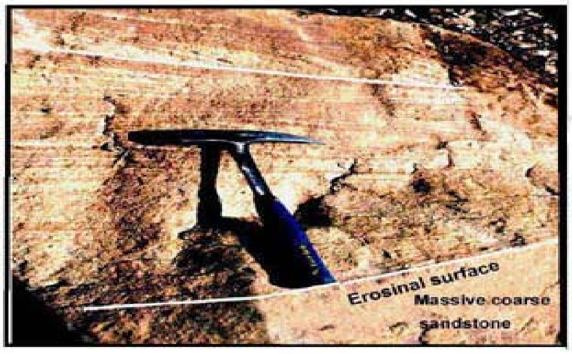


Fig. 4: Storm dominated shelf (Walker, 1984) used to illustrate the possibility of deposition of tempestite and turbidite by storm in shallow and deep part of the same basin.



(A) Low angle intersected lamination is supposed by Walker (1984)as an indicater for HCS. Lower Part of Tanjero Formation contain many of these lamination in the area between Arbat, - at the east, and Dokan at the west. This photo is taken at Malkandy Hill, 1km to the north of Sulimaniya. The hammer head is 16 cm long.



(B) An other low angle lamination which underlain by erosional surface which scored in massive sandstone bed. The whole photo possibly represents hummocky Cross stratification

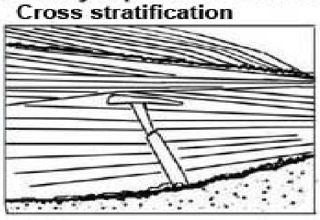


Fig. 5: Low angle cross lamination (A and B) found in the sandstone of Tanjero Formation possible represent part of hummocky cross stratification with their description at right side.

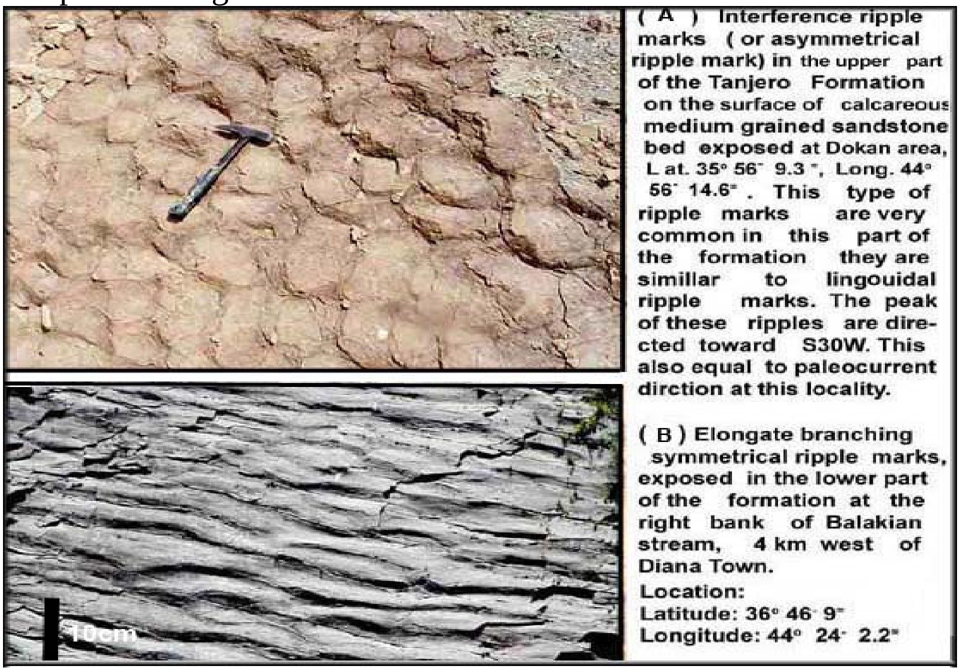


Fig. 6: Two types of ripple marks (A and B) found in the fine grain sandstone of Tanjero Formation with their description at right side.

FACIES MODEL OF TEMPESTITE

It is difficult to find a complete ideal facies model for tempestite in the Tanjero formation but from different styles of facies association, the ideal one can be established (Fig.2). According to Ensiele (2000) the difference between turbidite and tempestite model is that tempestite model contains hummocky cross-stratification. The siliciclastic facies model of tempestite mainly consists of the association of the following facies from base to the top of column of model:

1. Normally graded sandstone facies

This facies consists of graded massive sandstone (occasionally pebbly). The base of this facies consists of storm erosion surface, which may be undulatory or flat. This surface has sole marks and clasts of pebbles. It is deposited by upper flow regime by rapid events.

2. Hummocky cross-stratified sandstone

It is consist of clean and fine to medium grained sandstone with low angle cross-lamination dipping no more than 15 degrees which is called hummocky cross-stratification (Fig.4A). This structure initiated by combined flow of storm wave and storm induced geostrophic current.

3. Parallel laminated sandstone facies:

Located on the hummocky cross-stratified facies and consist of plane laminated fine grained sandstone with possible escape structures which is deposited by laminar upper flow regime.

4. Cross stratified sandstone facies

This facies contain wave ripple mark and current ripple marks showing cross lamination (See Karim 2004b). It is deposited by lower flow regime oscillatory currents due to waning effect of storm. The surfaces of this facies contain plant debris or *planolite* trace fossils.

COMBINING TEMPESTITE WITH TURBIDITE IN THE FORMATION

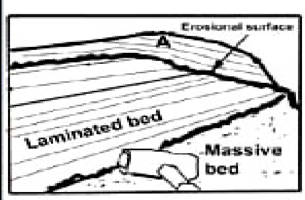
As mentioned before, the sediments of Tanjero Formation are deposited in different environments ranging from deep basin to shallow one (Karim, 2004b and 2006). According to these authors, the sediments were delivered to the delta by river flooding from the source area (Qulqula Formation) then deposit in prodelta environment (or clastic dominated shelf). From these places the sediments were reworked into deeper water by:

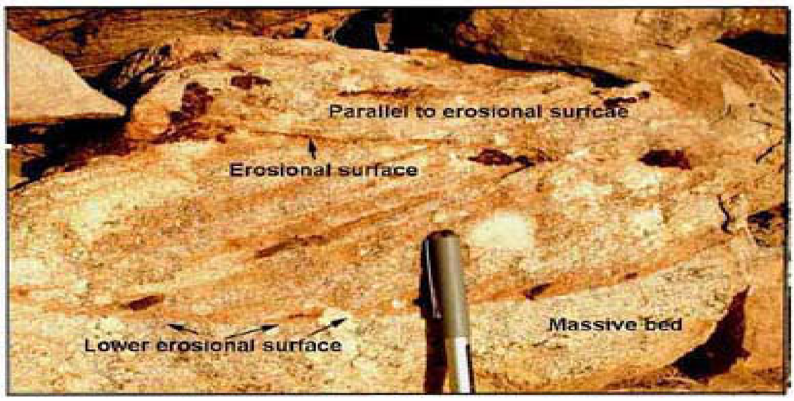
1-Reworking by stream and valley incision: During sea level fall the existed shelf and upper slope were exposed and incised by valleys and canyons. This type of reworking is more important in Tanjero Formation. The reworked sediment of the shelf and new sediment supplied by river were bypassed to lower slope and basin floor. It is possible that these sediments were again reworked

2-The storms and currents erode and mix sediment with water in prodelta area, then transport them to deeper water. This case is similar to that mentioned to Bhattacharya and Willis (2001, p.279) in their study of lowstand delta in Frontier Formation, USA. When the sediment rests below fair weather base and above storm wave base, this keeps the imprint of storm action in the form of hummocky cross stratification. The storm also generates turbidity current, which carries sediment to deeper water and deposit them as turbidite (Fig. 3).

3- Reworking by slumping, sliding and debris flow of the accumulated sediment on the delta front by effect of large storms and possibly earthquakes. These processes generate turbidity current, which transports sediments into different depth ranging from shelf to basin across the slope forming turbidite sediments.

(A)Hummocky cross-stratification, which is consisting of set of lamina (A) at the top overlying an erosional surface.
See the lower right sketch for more detail. Lower part of the formation 500 south of Chuarta check point.





(B) Possibly swale cross stratification consist of two sets of lamina forming trough. The two sets separated by an erosional surface, the upper set arranged parallel to erosional surface. This structure possibly formed by storm erosion and deposited , lower part of formation.

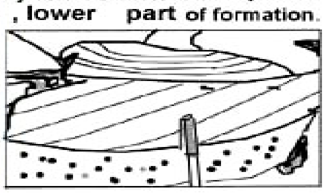


Fig. 7:Sedimentary structures supposed to be formed by storm found in the sandstone succession of the lower part. The descriptions of each photo are given at right side with graphic sketch of each one.

(A) Carbonized 50 cm long plant stem found in coares sandstone of Lower Part of Tanjero at 450m southeast of Qamar Telly village, the elongate axis is directed toward S-N which indicate southern direction of Paleo-current.

B) Petrified 15 cm long and 3cm thick plant stem found in thick conglom-erate bed of the lower part of Tanjero at 50m northeast of Nawar Village, Sirwan Valley, Halabja area, type section of the formation.

(C) Petrified grass body fossil found in thick pebbly sandstone of L.P of the formation at 2km to the south of Dokan Dam on the right bank of Little Zab River (Qashqully stream). The nedle is 2.5cm long.

Fig. 8: Plant debris and grass body fossils (A, B and C) found in the coarse sandstone of Tanjero Formation with their description at right side (taken from Karim, 2006b).

CONCLUSIONS

The following conclusions can be drawn:

1-Many sedimentary structures are developed in shallow water environments in the upper and middle parts the Tanjero Formation.

2-The structures are revealed reworking of the sediments by storms during accumulation of Tanjero Formation. The reworked sediments are either deposited as tempestite or transported to deep water by turbidity currents and deposited as turbidites.

3-The recoded sedimentary structures are: hummocky- cross stratification, interference and longitudinal ripple marks, plant debris and grass body fossils in addition to clean sandstone (arenite).
4-The Facies model of the tempestite is described and a norm of the depositional model is presented.

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