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ANATOMY OF CARBONATE BRECCIAS, TURBIDITE FACIES AND DEPOSITIONAL SYSTEMS OF GERCUS FORMATION IN DOKAN AREA, NORTHERN IRAQ

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ABSTRACT

Four facies associations are classified based on facies types, sedimentary structures and facies successions, these are; distal slope apron siliciclastic-calciturbidites (siliciclastic/ carbonate dominated), proximal marine siliciclastic-calciturbidites (carbonate/ siliciclastic dominated), distal basinal fan siliciclastic turbidites (siliciclastic dominated) and proximal basinal fan siliciclastic-calciturbidites (carbonate/ siliciclastic dominated). The most important characteristic representative facies types are; ball and pillows dolomite (reported here for the first time), thick fissile shale, slump/ slide limestone, slump/ slide sandstone, channeled sandstone, ball and pillow sandstone, slump sandstone, convolute sandstone, cross-bedded sandstone, sigmoidal channeled sandstone, disturbed sandstones, red argillaceous mudstone, gray massive claystone, flute scoured sandstone with slump carbonate breccias types. The carbonate breccias are the most important characteristic facies types observed in the formation and reported here for the first time and it is strong indication for marine environment. Examinations and anatomy of facies types and associations suggest developed marine environment, effected mainly by gravity flows and turbidity currents, forming sequences of submarine fans including high density turbidity currents in deeper margins.

Keywords: Gravity flow; Eocene; Gercus; Siliciclastic-calciturbidites; NE Iraq

INTRODUCTION

Middle Eocene Gercus Formation forms a part of the High Folded Zone in NE Iraq. Good exposures of the formation are cropped out in Dokan area (Jassim and Goff, 2006; Abbas, 2007; Aqrawi *et al*., 2010). The Gercus Formation composed basically rich in carbonate fragments arranged in fining upward cycles with predominant red beds. The main rock units are sandstones, mudstone and conglomerates and lacks fossils, in which

it is dated according to the stratigraphic position and palynological study as Middle Eocene (Al-Ameri *et al*., 2004).

METHODOLGY

In this study, typical stratigraphic section was selected in Kalka Smaq locality. The section is exposed in the SW limb of Hiebat Sultan Mountain (Fig. 1). More than fifty representative samples are collected from Kalka Smaq section. The sedimentary structures and lithologies are pointed on the log. Field photography was enforced for lithologies, sedimentary structures and facies types in the whole stratigraphic section.

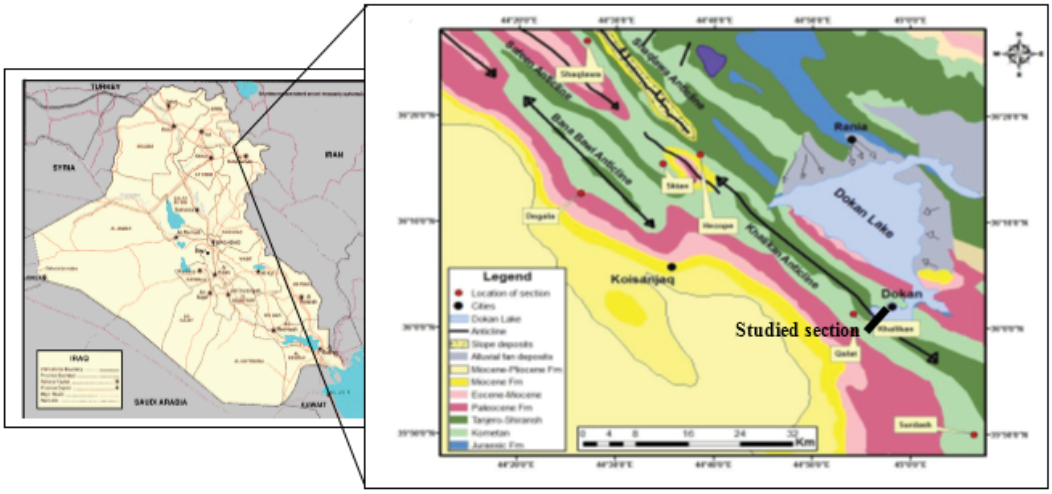
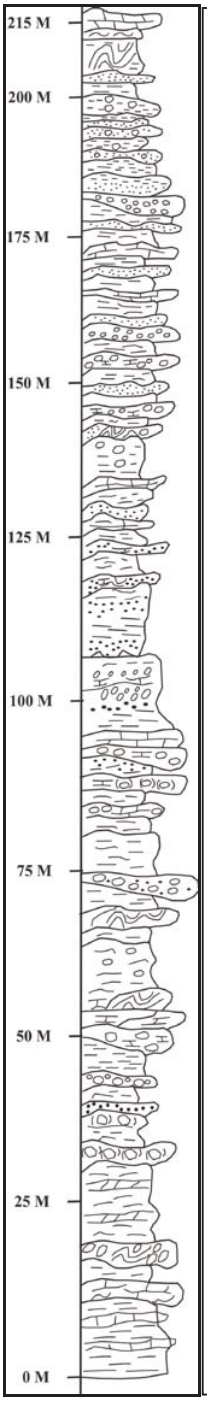


Fig. 1: Location and geological maps of the study areas show the location of the stratigraphic section (solid black lines) near Kalka village in Dokan area (the geomap adopted from Sissakian, 2000)

SEDIMENTOLOGY AND FIELD OBSERVATIONS

The out cropped Gercus Formation in the studied locality composed of mixed siliciclastic-carbonate rocks. It is composed of sandstone, shale, mudstone, claystone and conglomerate as a clastic portion. While the carbonate units are composed of dolomite, dolomitic limestone marl and carbonate breccias as well as debris flow beds. The siliciclastic and carbonate units are interbedded with each other's and are arranged in fining upward graded cycles. The thickness of the studied section attains more than 215 m (Fig. 2). The rock successions are characterized by specific types of sedimentary structures of turbidity origin c.f. sand and clay ball and pillows, rill, furrows, scour, load, flute and groove casts, slum, slide and convolute structures...etc. The main type of



Pila Spi Formation
Gradational contact with overlying Pila Spi Formation
50 m Slump and slide sandstone beds grade upward to red argillaceous-matrix, with convolute, load, scoured and flute casts. The most characteristics are sigmodal successive channels filled with fine-grained sandstones overlain successive beds of slumped and fragmented sandstones. These successions overlying with thin, lens and wedge carbonate beds.

55 m Successions of channeled fill carbonate breccias grades to red and dark gray mudstone/shale. Thick slump, scoured, fluted and load casted sandstones are grade upward to gray fissile shale. Successive slump beds of sandstones grade upward to black fissile shale. These successions are interbedded with slumping dolomites, scoured and load casted. The breccia includes large and small clasts. The color is dark gray, brown and reddish color

60 – 65 m Successive interbedded thick and thin slump sandstones and brecciated dolomite grades to claystone and shale beds. Most of the sandstone and carbonate beds are slumped and channeled, and arranged in turbidity cycles. The beds are scoured, flute and load. Beds are of dark gray, green and red color. These successions are interbedded with carbonate breccias. This part includes little sandstone beds

50 – 55 m Slumped dolomite with balls structures grades upward to dark gray fissile shale, carbonate breccia, matrix supported clast are carbonate, grades to gray shale interbedded with channeled bedded dolomite/shale couplet, scoured and load casted. In part, some beds are slump, slide and convoluted. This part includes little sandstone beds

Kolosh Formation of gradational contact with overlying Gercus Formation

Fig. 2: Stratigraphic section of the Gercus Formation in Kalka Smaq locality-Dokan area with description of different lithologic units

sedimentary structure is the graded beddings, which is characterized all the rock successions in the formation. The field works reveal dolomite balls and pillow structures and reported here for the first time, as well as slump, slide and convolute carbonate beds. Moreover, more than one type of carbonate breccias are recognized c.f. grain-supported, and matrix-supported breccias as well as tectonic and slump types. The carbonate units are ranging in thicknesses from 0.5 up to 5 m, the shale is about 1 m, the mudstones are of 0.5 to 2.5 m, and the sandstones are 0.25 up to 2.5 m. Some beds show un-uniform thickness, while others reveal lens-like or wedge beds. Most of the beds are undulated and scoured. All the carbonate units are grading upwards to shale or mudstone beds and associated with characteristic turbidity structures. On the other hand, the sandstones are grading upwards to shales or mudstones. One conglomerate bed of wedge shape is observed in the upper part of the formation, which represent channel fill conglomerate. The conglomerate reveals signs of slump and slide habit and is inter-mixing with sandstone beds.

FACIES ANALYSIS OF CLASTIC ROCKS

The classification of clastic facies types of the Gercus sediments as indicated here, follows the definitions of Stow (2012). Detailed field works reveal several siliciclastic facies types in the studied area, these are:

Slump/ slide laminated shale (F1): is observed in the lower part of the formation. The facies show slightly variation in thickness with undulated and scoured surface. It includes exotic dolomite balls in the lo wer part of the bed (Fig. 3A). It reveals dark gray to black color and ranges in thickness between 1 to 1.25 m.

Scoured and load casted sandstone (F2): is observed in the whole formation. Load casts are observed in the lower surface with undulation (Fig. 3B). It is massive and of gray to brownish gray in color and ranges in thickness between o.2 to 0.7 m.

Fissile shale (F3): is observed in the whole formation specifically in the middle and upper parts. It shows undulation and scouring in the upper surface and attains 0.5 to 1 m in thickness. The fissile shale is of gray to dark gray in color.

Flute casted sandstone (F4): is observed in the middle and upper parts of the formation. It is of undulated surfaces and the flutes are of variable sizes (Fig. 3C). The facies is of gray to pale gray in color.

Slump/ disturbed red sandstone (F5): it is observed in the middle and upper part of the formation. It is of undulated and scoured surfaces. The red bed sandstone shows disturbance in the internal structure and includes large faint sand balls. The thickness of the bed is 1.5 m and of red color.

Clay ball gray claystone(F6): it is observed in the middle part of the formation. It is disturbed, undulated and scoured surfaces with clay balls. The thickness of the bed is 1.5 m and of dark gray in color.

Convolute/ slump shale/ claystone (F7): it is observed in the middle part of the formation. It shows convolute laminations and disturbance with undulated surface. Some parts of the bed are hard bedded claystone and the others are fissile shale. The thickness of the bed is 1 – 1.2 m and of dark gray in color.

Bioturbated sandstone (F8): it is observed in the middle and upper parts of the formation. It shows bioturbation with various types of burrows c.f. slightly straight and y-shape burrows. The thickness of the bed is 0.25 – 0.5 m and of dark brownish gray in color.

Clast rich red sandstone (F9): it is observed in the middle part of the formation. It shows disturbance, bioturbation and rich in red clasts of the same bed. The thickness of the bed is 0.25 – 0.5 m and of red color.

Groove cast sandstone (F10): it is observed in the middle part of the formation. It shows striations on the upper surface of the bed with undulation. The thickness of the bed is 0.25 – 0.5 m and of brown color.

Thick red fragmented sandstone (F11): it is observed in the middle part and composed essentially of accumulation of red sandstone fragments and shows signs of slump and the whole bed is characterized by load casts. The thickness of the bed is about 2 m and of red color.

Red thick mudstone (F12): it is observed in the middle and upper parts of the formation. It is thick with faint lamination and includes thin beds of very fine red sandstone horizons. The thickness of the bed is about 2.5 m and of red color.

Channeled conglomerate (F13): it is observed in the upper part of the formation. It is thick. Lens-shape and shows convolution and mixing of conglomerates with red sandstone horizons. with faint lamination and includes thin beds of very fine red sandstone horizons. The thickness of the bed is about 2.5 m and of red color (Fig. 3D).

Rill and furrowed fluted sandstone (F14): it is observed in the middle and upper parts of the formation. It present as successive beds of thin sandstone characterized by rill and furrows with flute casts. The thickness of each bed is about 0.2 – 0.25 m and of pale gray color.

Convolute red sandstone/ mudstone (F15): it is observed in the upper part of the formation. It comprises high deformational structure composed of slump folded interbedded sandstone and mudstone beds. The thickness of the convolute beddings is about 10 m of brown color.

Cross-bedded sandstone (F16): it is observed in the middle and upper parts of the formation. It is a thick bed and includes successive sets trough cross-beddings. The thickness is about 1 m and of brownish gray color.

FACIES TYPES OF CARBONATE UNITS

Classification of facies types of the Gercus sediments, as indicated here, follows the definitions of James and Dalrymple (2010). Detailed field works reveal several carbonate facies types in the studied area, these are:

Ball and pillow dolomite (FC1): it is observed in the lower part of the formation. The facies is reported here for the first time and composed of large ball and pillow dolomite c.f. 0.3 m in diameter, which are supported with marly dolomitic materials (Fig. 3E). The thickness of the bed is 1 – 1.25 m and of dark gray color.

Carbonate breccias (FC2): it is observed in the lower and middle parts of the formation. The facies is reported here for the first time in this formation and composed of large and small clasts composed of dolomite and dolomitic limestone c.f. 0.1 – 0.3 (Fig. 3F). The thickness of the bed is 1 – 4 m and of dark to pale gray color. Two types of carbonate breccias are observed c.f. the grain supporter and matrix supported breccias.

Carbonate debris flow (FC3): it is observed in the middle part of the formation. The facies is reported here for the first time in this formation and composed of large and small clasts, dolomite and dolomitic limestone lithology c.f. 0.1 – 0.3 m in diameter. Debris flow is grain-supported type. The thickness of the bed is 1 – 3 m and of gray color.

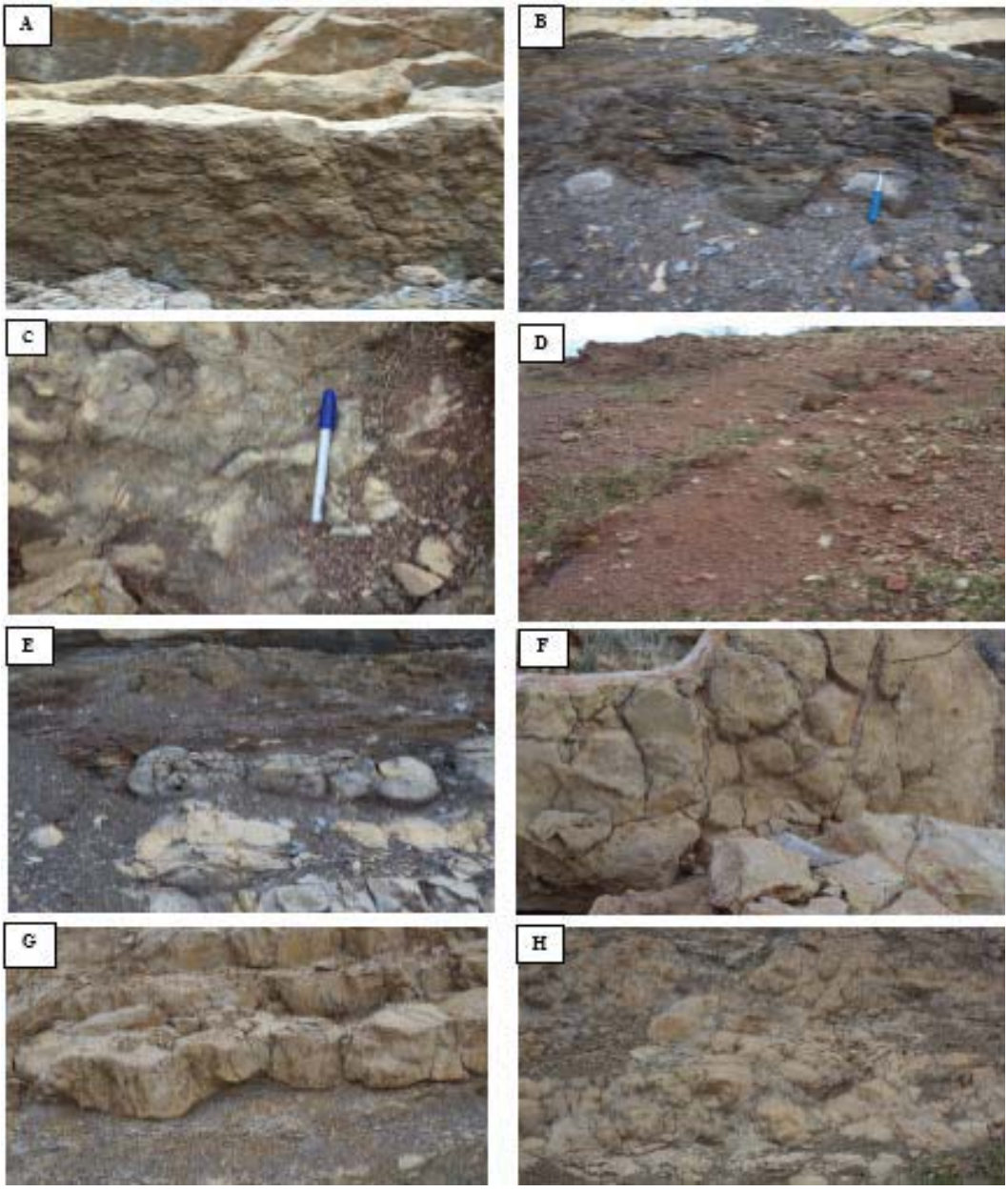


Fig. 3: Field photographs show clastic and carbonate facies types in the Gercus Formation (hummer= 30cm, pencil= 10cm)

A) Slump/ slide laminated shale, **B)** Scoured and load casted sandstone,
C) Channaled gonglomerate, **D)** Flute casted sandstone, **E)** Ball and pillow dolomite,
F) Carbonate breccia, **G)** Scoured/ undulated dolomitic limestone,
H) Slump/ disturbed dolomitic limestone

Scoured/ undulated dolomitic limestone (FC4): it is observed in the all parts of the formation. The facies composed of dolomitic limestone included various fossils types c.f. stromatolite, coral, forams…etc, (Fig. 3G). The thickness of the bed is 0.5 – 0.75 m and of dark gray color.

Wedge-shaped carbonates (FC5): it is observed in the middle and upper parts of the formation. It reveals lens-like or wedge shape beds almost refers to channel structure .The thickness of the bed is 1 – 1.5 m and of dark gray color.

Slump/ convolute limestone (CF6): it is observed in the middle and upper parts of the formation. It reveals shear folds due to slump of the sediments in the slope margin. The thickness of the bed is 0.25 – 0.3 m and of pale gray color.

Flute/ load casted limestone (CF7): it is observed in the middle and upper parts of the formation. It is observed in successive of several beds all reveals flute and load casts. It is characterized by undulated surfaces. The thickness of each bed is 0.1 – 0.2 m and of pale gray color.

Slump/ disturbed dolomitic limestone: it is observed in the middle and upper parts of the formation. The surfaces of facies are scoured and undulated and the bed is shows signs of slump and disturbance without any internal structures (Fig. 3H). The thickness of the bed is 3 – 4 m and of pale gray color.

ANTOMY OF DEPOSITIONAL REGIME

Anatomy of facies types and associations is based on Einsele (2000) and Reading (2000). Graded cycles of conglomerate lens, pebbly sandstone, mudstone and/or stratified or fissile shale refer to the control of turbidity currents. This idea is supported by the associated specific types of sedimentary structures of turbidity origin c.f. load, scour, flute and groove casts, slum, slide and convolute deformational structures, sand and clay mud and pillows, submarine channels…etc.

Suites of F2, F9, F10, F11, F13, F14 with F1, F3 and F6 are referring to Bouma turbidity cycles. The proximal and distal turbidites are controlled by the position of the suites of facies types with the submarine fan. This is evident from the thickness of sandstone and mudstone/ shale subdivisions in the turbidity cycles. The presence of channeled conglomerate refers to the beginning of the fan. Moreover, the presence of

interbedded carbonate breccias and debris flows between the turbidity cycles are referring to the proximal and distal setting in the fan.

The arrangement of various facies types in the Gercus Formation suggest to group in facies associations. The Gercus Formation can be subdivided into four distinctive stratigraphic units based on facies types, associations and successive arrangement of the rock units, these are:

FA1 Distal siliciclastic-calciturbidites (carbonate dominated), the lower unit, comprises distal setting in submarine fans. This evident from the observation of **FC1** and **FC2**, which are grading upwards to fissile and laminated shales (**F1** and **F3)**. The shale beds are slump, slide and convolute beddings refer to slump of the sediments upon slope margin. FA1 attains about 65 m in thickness, which characterized by specific type of sedimentary structures of turbidity origin c.f. slump, slide and convolute structures, load, scour, flute and groove casts as well as dolomite balls and pillows structures.

FA2 Proximal siliciclastic-calciturbidites (clastic dominate), the middle units, comprises proximal setting in submarine fans. Evidences comprise the presence of **FC2 and FC3**, which are grading upwards to mudstone and shales (**F12** and **F3**). Moreover, observation of interbedded of **FC4, FC5** and **FC7** with the turbidity cycles in graded beddings support the proximal setting. All these beds are characterized by specific type of sedimentary structures of turbidity origin c.f. slump, slide and convolute structures, load, scour, flute and groove casts as well as dolomite balls and pillows structures.

FA3 slope siliciclastic-calciturbidites (clastic dominated), the middle part, comprises slope margin sedimentation in submarine fans. Evidences comprise the presence of **FC1, FC2, FC3, and FC7**, which are grading upwards to thick, load casted, convolute and slumped mudstone and shales (**F3** and **F15**). The successive beds are characterized by specific type of sedimentary structures of turbidity origin c.f. slump, slide and convolute structures, load, scour, flute and groove casts as well as dolomite balls and pillows structures.

FA4 distal siliciclastic-calciturbidites (clastic dominated), the upper unit, comprises distal margin sedimentation in submarine fans. Evidences comprise the presence of **FC2 and FC7**, which are grading upwards to thick, load casted, convolute and slumped mudstone and shales (**F3** and **F15**). This unit is characterized by lens-shape channeled conglomerate (**F13**), which is grading upwards to sandstone (**F2, F9, F11** and **F16**). The

successive beds are characterized by specific type of sedimentary structures of turbidity origin c.f. slump, slide and convolute structures, load, scour, flute and groove casts as well as dolomite balls and pillows structures.

INTERPRETATION

The FA1 sediments are gradational with the underlying Kolosh Formation (of clastic deep marine turbidites) (Jassim and Goff, 2006). Subaqueous streams of gravity flows are displaying, which is the proposed origin for the debris flows, breccias, conglomerates and pebbly sandstones facies. These are locally preserved on the original bounding surface or in submarine channels (Einsele, 2000; Posamentier and Walker 2006). Submarine fans including streams are originated from annual turbidity currents created by most probably tectonic events. This interpretation is based on the presence of slump, slide and convolute structures and limited lateral extent of debris flows, breccias and conglomerate beds. It could be interpreted as submarine gravity flows originated by active turbidity currents (Einsele, 2000; and Reading, 2000). In addition, the Gercus Basin comprises a trough foreland basin situated in active subduction zone (Jassim and Goff, 2006; and Aqrawi *et al*., 2010).

Facies association units (FA1, FA2, FA3 and FA4) reveal evidences of Bouma turbidity cycles, these are:

1) Repeated cycles of fining upward sediments **2)** Upward grading of pebbly, massive, parallel laminated, rippled sandstones grades to thick shale/claystone, **3)** lateral extension. **4)** attains specific types of sedimentary structures of turbidity origin. Gravity flows mechanism represented the settle down sediments have been discussed and applied to deep marine fan models in great deal of literatures such as McCabe *et al*. (1984), Einsele (2000), and Reading (2000). Although, turbidite sediments have been reported in shallow marine environments. Mud flows and low to high density currents have been described in recently researches, either for ancient or recent formations (Eyles *et al*., 1985). Unstable sediments of marginal submarine fans, deltas and another build-up over steep slopes due to rapid sedimentation, increased overburden pressure, storm wave agitation or shocks of earthquakes are resedimented to deeper margins.

The sediments range from coarse to gravelly fully turbulent flow (subdivision Ta and subdivision Tb of Bouma cycle), to dilute and laminar sandy flow (Tc and Td) with

traction suspension of flat and occasional rippled cross laminations. The upper shale or claystone bed (Te of Bouma cycle) represents the final suspended load of turbidity currents (Einsele, 2000; Posamentier and Walker, 2006). Faint lamination in some gravelly basal horizons may refers to increase of shear rate under steady flows and developed depressive's pressures (Cook and Enos, 1977). However, Cook and Enos (1977) interpretation for deep marine carbonate breccias based on lithofacies relationships and sequence context. Intercalated of 1.5 – 3 m thick tabular body of carbonate breccias or conglomerate within undeformed turbidity sequences is referring to debris flow, which are supported by strength and buoyancy of sand-clay water fluid. Otherwise, the Gercus sediments are mainly generated by gravity flow processes, which are supported by the arguments of: **i)** successions of lateral continuation, **ii)** consist developed Bouma cycle subdivisions conforming more or less turbidity origin, **iii)** absence of angular cross-beddings, **iv)** repeated succession without fair weather deposit intercalations. Gercus sediment gravity flows may represent fore slope subaqueous fans fed by turbidity currents streams. The repeated successions reflect the episodic pulses of dense turbidity currents swept down the fan and may represent "turbidites". Thickness of the limestone bed in the start of FA2 appears exceptionally in size (2 – 2.5 m) when compared to modern sediments (Stubblefield *et al*., 1984) or ancient models (Shurr, 1984).

DISCUSSION

The study reveals cyclic repetitions of turbidity Bouma cycles, which was identified in all of the stratigraphic units, c.f. FA1, FA2, FA3 and FA4. These turbidity cycles are caped with limestone and dolomite horizons in all succession and are strong evidence of marine environment.

The Gercus Formation stratigraphically situated between the underlying deep-marine turbidites of Kolosh Formation and overlying Pila Spi Formation of marine environment. It is not logically accepted the fluvial environment for the formation bounded between two marine formations. It has a conformable contact with underlying Kolosh Formation. Field observations show gradation of lithologies and color form dark green and gray Kolosh sediments, to pale green to gray color of the Gercus Formation. Turbidity cycles of the Kolosh Formation are continuous in the units of the Gercus

Formation. Moreover, the Gercus Formation displays gradational boundary with the overlying Pila Spi Formation. The boundary is grading upwards form red mudstone to marl and marly limestone with calcareous debrites. The debrites bed extends for 3 to 5 m and laterally change to marl, and grading upwards to limestone. The Gercus Formation reveals characteristic sedimentary structures interpreted here as of turbidity and gravity flow origin, balls and pillows, load, flute, gutter, scour and groove casts, graded beddings, laminar stratifications, disturbed deformed beddings, slump, slide and convolute structures. The carbonate units in the lower part of the Gercus Formation is suggested here to belong to the Gercus Formation and not to Khurmala or Sinjar Formations. This due to:

A- The facies of the carbonate rocks composed of slump/ slide and convolute beds as well as ball and pillows dolomite beds. While in the Khurmala and Sinjar Formations are quite different.

B- There are several beds of carbonate breccias in the lower part of the Gercus Formation which are not reported in the Khurmala and Sinjar Formations.

C- The carbonate rocks in the Gercus Formation are arranged in siliciclastic-calciturbidite successions, which are grading upwards to thick beds of black and dark gray fissile shale. In which it does not match those in the Khurmala and Sinjar Formations.

D- The siliciclastic-calciturbidites reveal successive submarine channels with scour, flute, gutter and groove casts, a typical sedimentary structures of turbidity origin, which are also not recorded in both Khurmala and Sinjar Formations.

E- The presence of successive slump/ deformed black and dark gray shale in the lower part of the Gercus Formation are quite differ from the Khurmala and Sinjar Formation.

F- The suggested depositional environment of the Khurmala and Sinjar Formation is outer shelf, fore-reef, reef, back reef, lagoon and intertidal zones respectively. While the lower part of the Gercus Formation is deeper marginal environment.

G- The presence of planktonic forams, calcisphere and planktonic bivalve reject the idea of the Khurmala and Sinjar tongue, which are differ in fossils content.

H- Khurmala and Sinjar tongues of Early Eocene age are recorded in the upper part of the Kolosh Formation. While the carbonate units in the lower part of the Gercus

Formation are underlying with several red sandstone and mudstone beds and others are overlying it.

I- The reported thicknesses of the Khurmala and Sinjar Formations are very thick and reaches up to 20 m. While carbonate units of the lower part of the Gercus Formation are of 0.5 to 1.25 m thick.

J- The presence of submarine channels mostly associated with debris flow and carbonate breccias beds, which refer to the deposition in the mouth of the submarine fans.

The depositional model for the Gercus Formation is suggested in response to tectonic activity and volcanism. Volcanic arc volcanism at the northeastern border of the foreland basin of Iraq, comprising 3000 m thick sequences of Eocene pyroclastic and volcanic rocks (Mehdipour and Moazzen 2015; and Beygi *et al*., 2016). These volcanoes are the source of detrital volcanic fragments in the carbonate and siliciclastic rock units of the Gercus Formation. It is also the source of the red argillaceous matrix mudstones, which are interbedded with the siliciclastic-carbonate in graded turbidity cycles. These successive mudstones are most probably flows form the volcanic arc to the basin. Progressive subduction movements may act to create shock earthquakes that led to slump the over slope sediments to deeper margins. These are evidenced from volcanic fragments it is suggested that there is a rift movement acting perpendicular to the general direction of the subduction movement in a complex stress pattern, which is responsible to the deepening of the basin and forming the slump/ tectonic carbonate breccias, debris flows and turbidity cycles. The stratigraphic successions and sedimentological characters of the Gercus Formation may be suggest a marine environment in the stratigraphic column of Iraq. The Cretaceous – Paleocene – Eocene sequences of Tethys Sea represent continuous sedimentation in deep marine to deeper shelf environments under strong action of turbidity currents.

CONCLUSIONS

The Gercus Formation is cropping out parallel to the Zagros Thrust Belt in the High Folded Zone of north Iraq. It is stratigraphically distributed from NE to NW margins. The turbidites cycles composed of sandstones grade upwards to siltstones and fissile shales/mudstone beds. The graded beds reveal characteristic sedimentary structures of turbidity origin, these are; slump, slide and convolute deformed and disturbed beds,

balls and pillows, gutter, flute, scour, groove and load casts, and submarine channels. These turbidity cycles, sedimentary structures and the relationship between the Gercus successions could be displayed a marine environment which are supported by the presence of glauconite grains. Sixteen facies of the clastic and eight facies of carbonate rocks are identified.

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