 Iraqi Journal of Science, 2020, Vol. 61, No. 9, pp: 2293-2302
DOI: 10.24996/ijs.2020.61.9.16

ISSN: 0067-2904

Stratigraphic Analysis of Gercus Formation in Dohuk area, Northern Iraq

Karrar Hassooni Awad*, Hamid Ali Ahmed Alsultan
Applied Geology Department College of Science, University of Babylon, Baghdad, Iraq

Received: 26/1/2020 Accepted: 28/4/2020

Abstract

A surface section of the Gercus Formation (Middle-Late Eocene) was studied in Berafat area, Dohuk Governorate, Northern Iraq. The Gercus Formation consists of a mixed siliciclastic sediments, evaporates and carbonate sequences in the studied region, predominantly in the upper and middle parts. Nevertheless, it usually consists of upward-fining carbonate-rich sandstone cyclothems, marl, conglomerate and siltstone along with a gypsum lens and thin micrite carbonate beds. The Gercus Formation was deposited in delta and delta front of occasionally depositional environment which is represented by red-brown claystone and reddish-brown mudstone lithofacies. Cross bedded pebbly sandstone, trough cross-bedded sandstone and laminated cross-bedded sandstone lithofacies are deposited in braided delta environment. Marl lithofacies and gypsum lithofacies are deposited in intertidal and supratidal environments. The sea level fluctuation caused the river base level to occasionally rise and fall. In addition, the process changed from erosion to deposition, while the grain size also changed at different environments from gravel to sand and clays. The Gercus succession of northern Iraq was developed during the Middle-Late Eocene in an active margin basin, where the last stage closure of the New-Tethys and its collision with the Eurasian plate took place between the northeastern Arabian plate. It caused major episodes of uplifts and subsidence along with base level variations due to eustatic ups and downs. Within Gercus Formation, several fourth order cycles can be recognized, reflecting generally asymmetrical cycles, as well as the difference between sediment supply and accommodation space.

Keywords: Gercus Formation, evaporates, trough cross-bedded, braided delta, intertidal, supratidal.

التحليل الطباقي لتكوين الجركس في منطقة دهوك شمال العراق

كرار حسوني عواد * , حامد علي أحمد
قسم علم الأرض التطبيقي, كلية العلوم, جامعة بابل, بابل, العراق

الخلاصة

المقطع السطحي لتكوين الجركس (الايوسين الأوسط – المتأخر) دُرِس في منطقة بيرفات, محافظة دهوك شمال العراق. يتألف تكوين الجركس من تتابع خليط من الترسبات السيليكاتية و المتبخرات و الجيريات في المنطقة المدروسة, عموماً يتألف الجزء الأعلى و الأوسط من دورات من الحجر الرملي الغني بالجيريات و المارل و المدملكات و الحجر الغريني مع عدسات من الجبس و طبقات نحيفة من الجيريات المكرايتية. ترسب

*Email: g_karrar@yahoo.com

تكوين الجركس في بيئات الدلتا و الدلتا الأمامية المرافقة للبيئات الترسيبية المتمثلة بالحجر الطيني البني المحمر و سحنة الحجر الطيني البني المحمر , بينما سحنة التطبق الكاذب للحجر الرملي المحتوي على الحصى و سحنة التطبق الكاذب الخشن للحجر الرملي و سحنة التطبق الكاذب المترقرق للحجر الرملي ترسبت في البيئات الدلتاوية الظفائرية. سحنة كل من المارل و الجبس ترسبت بين بيئات المد و الجزر. التغاير في مستوى سطح البحر كان السبب في الارتفاع و الانخفاض في مستوى قاعدة النهر. بالإضافة الى ذلك, تغيرت العملية من التعرية الى الترسيب, كما تغير الحجم الحبيبي إلى بيئات مختلفة من الحصى إلى الرمل والطين. تتابع الجركس في شمال العراق تطور خلال فترة (الايوسين الأوسط – المتأخر) في حوض الحافة النشطة خلال المرحلة النهائية من انغلاق بحر التثس الجديد و التصادم مع الصفيحة الاوراسية الواقعة بين الصفيحة العربية الشمالية الشرقية. تسبب في حدوث مجموعة كبيرة من الارتفاعات والانخفاضات جنبًا إلى جنب مع الاختلافات في مستوى القاعدة بسبب الصعود والهبوط النحوي. ضمن تكوين الجركس ميزت العديد من الدورات الرسوبية رباعية الرتبة. بصورة عامة هذه الدورات كانت غير متناظره, بالإضافة الى ذلك الاختلاف بتجهيز الرسوبيات و الحيز المتاح.

Introduction

Gercus Formation is a Middle to Late Eocene group based on stratigraphy of the location cultivated in northern Iraq's High Folded Area. It extends as a narrow NW-SE belt from Dohuk to the Darbandikhan region [1]. Bellen *et al.* [2] were the first who identified the Gercus Formation in southeastern Turkey.

The Formation is comprised mainly of contrasting claystone, sandstone and marl clastic rocks with conglomerate and gypsum lenticels, particularly close to the top. Rock salt appears sporadically along with rare lignite in sandstone near the base [2,3]. A previous study [4] described the Halabja region's Gercus Formation at the base as the Lower Eocene and at the upper as the Middle Eocene. An earlier work [5] Indicated that Gercus Formation sedimentation in the Darbandikhan region was controlled by the block subsidence. In Shaqlawa and Darbandikhan areas, another group [6] studied the sedimentology and petrology of Gercus Formation. The source of red pigment that forms the Gercus Formation in NE Iraq is a fluvial series of related red beds deposited under arid to semi-arid conditions. Another study [7] investigated the petrography of Gercus Formation from the Shikhan-Sersang area, nearby the town of Swaratuka, and noted that the formation is composed of siltstone, red claystone, green marls, conglomerate and pale gray limestone accumulated in a relatively higher salinity shallow marine environment. A previous investigation [8] stated that Gercus Formation sediments should be accumulated in clastic tidal flat, whereas another report [9] separated the Gercus Formation into three parts, upper, middle and lower, based on the major distribution of lithology. In the Bozbel Formation in the Middle to Late Eocene in eastern center Turkey, the existence of Gypsum laminated and selenite in a shallow inner-lagoonal environment was reported [10]. A previous study [11] coupled the formation with Red Bed Series unit three (conglomerate) and concluded that both formed in proximal and distal regions, respectively, in one foreland basin. Another work [12] studied the Gercus Formation sequence stratigraphy in the area of Sulaimaniya, northeast Iraq, and supposed that the total formation involves main Lowstand tracts within Tertiary's stratigraphic history. A detailed sedimentological study [13] revealed that these rocks have a variety of sedimentary facies, which are organized into facies associations (FA). On the basis of characteristic sedimentary structures, they are interpreted to be formed by alluvial and aeolian processes with marine influence. The Gercus Formation was described [1] as a typical red molasse sequence resultant from uplifted north and northeastern regions. The present study aims to identify the depositional environment based on the facies assessment of the segment selected within the study area.

Geological Setting and Stratigraphy

The study area is situated within the Governorate of Dohuk in the High Folded Region in north Iraq in the village of Berafat, with High Folded Zone to the south of the North Thrust Zone, northwest of the Fold-Thrust Belt of Zagros. Middle-Late Eocene Gercus Formation was formed to the SW of an increasing plateau in a highly subsidizing area. It occurs through a very narrow NW-SE trending belt, extending from eastern Iran to northwestern wards, through northeastern and northern Iraq to southeastern Turkey. It was formed in the last stage of the Neo-Tethys Ocean subduction and closing,

in a relatively wide trough (Foredeep) along the northeastern edge of the Middle Eocene Basin, from the north and northeast uplifted regions [1].
Due to the basin configuration that was relatively deep in the shallow and middle peripheral region, th e formation thickness is very variable. The thickness of the formation in e Dohuk region is about 850 m, according to one study [14], while another [2] reported a thickness of 838 m for the same formation in type section. The former study stated that this thickness decreases to the southeast, close to the Iranian border on the river Diyala (Sirwan), where it rarely reaches 100 meters. The thickness of the selected section for this study is almost 631 m at the studied area. In the periphery of the basin in Dohuk region, the formation strata are incompatible with the Kolosh Formation and overlapping with the Pila Spi Formation; but the two formations were divided by a gypsum lens [2]. It was reported that the Gercus Formation overlays the Lower Eocene Khurmala Formation and the Avanah Formation in Dohuk region, and that the Pila Spi Formation overlays it [1]. These sediments are believed to represent a Middle-Late Eocene cycle fluvio-deltaic facies of northeastern Iraq [6, 12, 15].

Methodology and Study Area

The area studied is located in the Governorate of Dohuk, at Berafat village, northern Iraq (Figure-1). On every noticeable change for the Gercus Formation, detailed description and sample collection were carried out. The fieldwork involved testing of one composite section in the village of Berafat (36 ° 57 ' 53.51/N) (42 ° 56 ' 52.76/E). The sample selected from this section was focused on facies, changing colors and bed hardness.

The Gercus Formation consists of a mixed siliciclastic sediments, evaporates, and carbonate sequences in the studied region, mainly in the middle and upper parts. Nevertheless, it usually consists of upward-fining carbonate-rich sandstone cyclothems, marl, conglomerate and siltstone, along with a gypsum lens and thin micrite carbonate beds.

The formation is split into three parts, lower, middle and upper. The lower part thickness is about 265m, which contains thick bedded reddish brown sandstone, siltstone and claystone. The middle part, which has a thickness of 250 m, consists of ten complete sedimentary cycles, starting with the conglomerate and fining upward where sandstone and siltstone end with the claystone. The upper part consists of red claystone, gypsum and white marl alternations. Generally, both lamination and bedding represent the alternation of gypsum and red claystone, while the upper part thickness is about 110 m. The Gercus Formation’s lower contact is uncomfortable, taking place at the top of the Kolosh Formation, with claystone and sandstone bed and the conglomerate base. The formation's upper contact with the overlying Pila Spi Formation is sharp and characteristically identified by a thick conglomerate and breccia horizon.

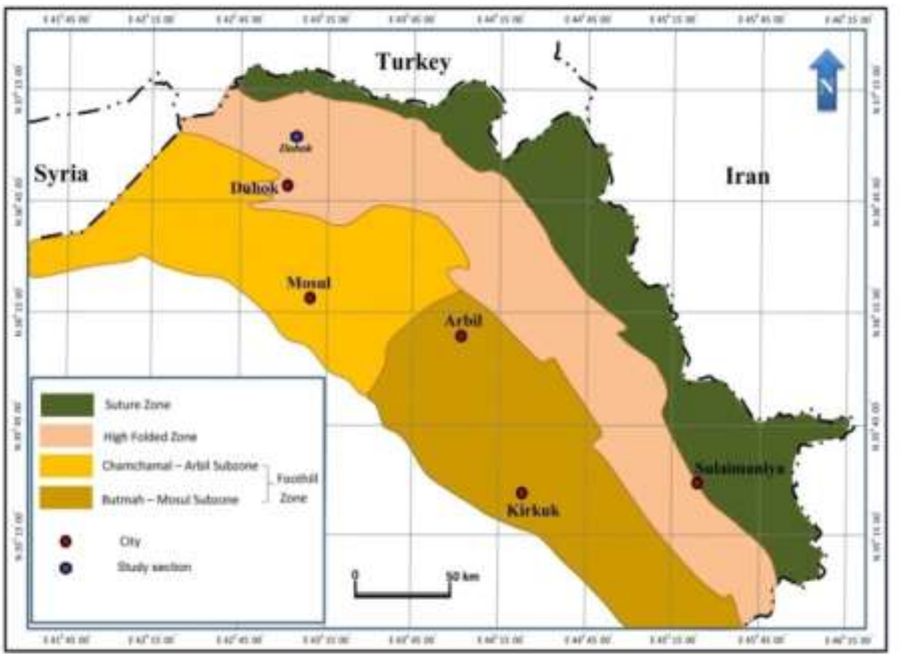

Figure 1- Location of the studied area, modified from [1]

LITHOFACIES

Eight lithofacies were recognized within the studied section. These are as follows.

- Grain-supported Conglomerate Lithofacies

This lithofacies consists predominantly of the conglomerate of gravel that has a reddish-brown or gray colour. The matrix is characterized by a broad alignment of the pebble and cross bedding, which is of medium or almost coarse sand. With the exception of small quantities of matrix-supported conglomerates, the texture is based primarily by clast. The conglomerate supported by the clast was mounted in sharp gradient fans in the river channel as bedload deposits [16]. It is clear from the size of clasts, thickness, fused shape, large scale crossbedding and erosional holes that the lithofacies are with high energy braided stream in alluvial fan. The alluvial fan then enters the sea water in the Paleocene-Eocene basin forming a fan delta. During a major drop in sea level, the alluvial fan was deposited in broad incised valleys (low system tract). An earlier study [17] described the deposition of sand with gravel, attributing the gravel supported by grains to the deposition by energetic aqueous flow from bedload sediments. The study found that sand is still suspended (which has been transferred to deeper water), but while the flow frequency decreases, the sand infiltrates into the particle frame gap. Another group [16] stated that, during the low water period, gravel interstices are later filled with sand (Figure-2.A).

- Cross bedded Pebbly Sandstone lithofacies

The thickness of a single bed ranges from 10 cm to 50 cm. The lower contact surface is irregular and sharp, while the upper contact is gradational. The size of the sand grain is less than 1 mm and that of the gravel ranges from 1 cm to 5 cm. Such lithofacies is deposited at the bottom of the channel as lag deposit fluvial or aeolian. In this study, the authors believe that this lithofacies is formed by river currents when they are in the higher runoff system. This lithofacies is the beginning of a new rock cycle and occurs over a scour surface, which is located above the older thick mudstone. The mid reach bar of the braided rivers can be represented by it (Figure-2.B). The braided rivers predominantly include thin mudstone layers**.**

- Trough cross-bedded sandstone lithofacies

The cross-bedded sandstone lithofacies consist of fine- to coarse-grained, moderately- to poorly-sorted sandstone sets varying from 15 cm to 50 cm in length. The set thickness is usually proportional to the size of the grain. This lithofacies occurs in sets or cosets characterized by thin siltstone or mudstone layers with sharp boundaries between individual sets and cosets. When mega-ripples migrate, this lithofacies occurs. Migration of straight-crested types is likely to form the tabular groups, while the trough cross-bedding is created by the migration of linguoid and lunate forms. The mega-ripples that migrate coincide with the top of the lower flow regime [18] (Figure-2.C).

- Planar cross-bedded sandstone lithofacies

This lithofacies consists of fine- to coarse-grained sandstone. The lithofacies external geometry is lenticular or irregular (wedge-shaped). Planar cross-beds may be existing as solitary sets or as cosets. Coset thickness ranges from 15 cm to a few decimeters. Such lithofacies interactions are gradational. It is created by the migration in the lower flow regime of straight crested dunes or bars. It represents bar and fluvial channels deposition (Figure-2.D).

- Laminated Cross- bedded sandstone lithofacies

The lamination in this facies is so developed that they resemble the pages of an open book; therefore it is called papery sandstone. On the surface of the sandstone sheets, one can see parting lineation. According to an earlier work [19], laminated sandstone is usually formed by the upper flow regime (laminar flow). Also, it occurs in diverse sedimentary environments ranging from fluvial channels to beaches and delta fronts. Another characteristic feature of this facies is the erosive base, which is associated with striation, drag cast (groove cast), flute cast and small channel. In rare cases, the sandstone is gravely at the base. The environment of this facies is probably of fluvial environment of sand-dominated distal braided river.

According to another report [20], this type of river is located at the distal area of alluvial fan, which is characterized by wide channel and linguoid sand bar. The claystone that is associated with this facies is attributed, in this study, to overbank fine distal braided plain and delta front environment. Low gradient, low relief channels and bars characterize this type of rivers. The main sediment types are massive, laminated and cross-laminated sandy silt [16] (Figure-2.E).

- **Reddish-brown mudstone lithofacies**

It comprises of massive and dense deposits of reddish brown claystone, sandstone, siltstone and occasional conglomerate lenses. The facies are most likely to appear on the floodplain of braided rivers and delta plains in the distal region of the alluvial fan, where the fan enters the shore. It is the most dominant in the Gercus Formation. Individual bed that ranges between 0.1 and 3m in thickness mainly consists of massive to parallel laminated. Thin claystone at the upper part of the channel sandstone cosets is diposited from suspension during channel abandonment.

- **Marl lithofacies**

This facies exists almost at the top of the formation. The pale grey and green marl facies is associated with the thin-bedded carbonate and interbedded with red brown claystone. Such general features of the studied succession indicate that the facies are deposited in a subtidal environment [21]. The gray marls are more likely to have marine impact, while the red mudstones display subaerial exposure.

- **Gypsum lithofacies**

Gypsum bed contains red claystone as a lensoidal (concave downwards) in the base of a coarse lamina, but at the top it was laminated , underlining and overlapping with sharp bed red claystone contact. Thick bed of gypsarenite (or brecciated gypsum) contains black bituminous lamina and fibrous secondary gypsum (stain spar) above this bed. Because of the natural deposition of red claystone and gypsum, the red bed claystone appears as a stripe (irregular line). The succession studied properties are shown in Figure-2.F. During high eccentricity, the sea level rises and the earth climate becomes warmer. Influx of seawater to the semi-coastal lake and evaporation are both increased and, consequently, evaporates are deposited in the peripheral lakes. But sea level’s fall is accompanied with decreased sea water influx and evaporation. This is associated with dilution of the lake by fresh water from source areas, which deposit red claystone or gypsarenite.

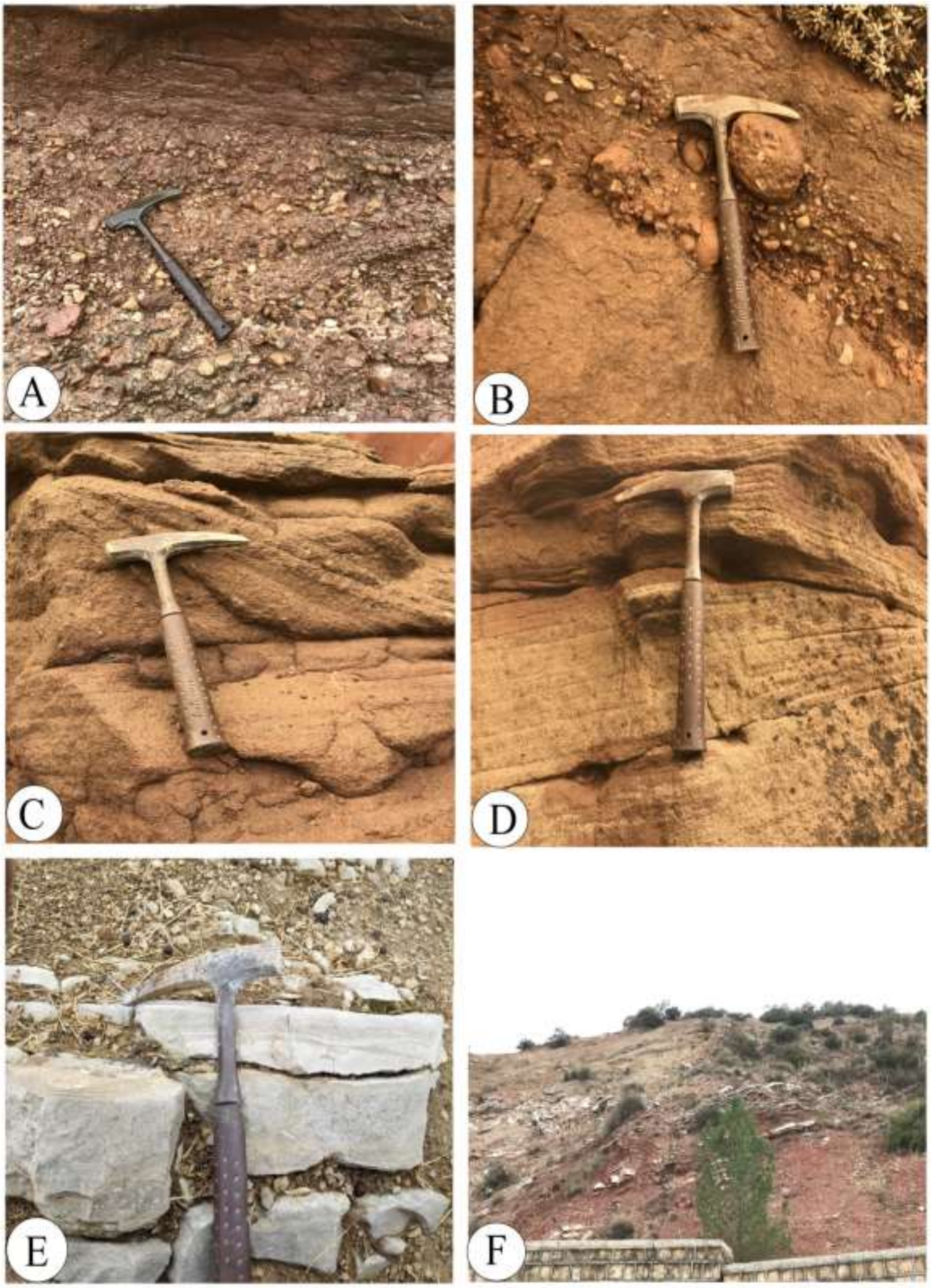

Figure 2- (A) Grain-supported Conglomerate, (B) Mud Ball in pebbly sandstone, (C) Trough cross-bedded sandstone, (D) Planar cross-bedded sandstone, (E) Laminated cross- bedded sandstone and (F) Gypsum interbedded with reddish-brown claystone.

Depositional Environment

From the above mentioned facies and sedimentary structures, it can be concluded that the alluvial environment system is the best depositional model for the Gercus Formation. This environment, according to a previous report [22], is divided into fan, delta and alluvial plain. Also, sand was found to be the component of all three parts but, in the fan, it may be inferior to the coarser debris and to the delta's generally fine silts and clays. Delta and alluvial fans are two depositional landforms that result in sudden loss of stream competencies. Alluvial fans are subaerial forms deposited when stream channel lose water by infiltration while the delta is mostly subaqueous, which decreases the gradient, or abruptly widens it. In addition, both the alluvial fan and the delta may mix (join) and several deltas may be capped by a low gradient alluvial fan [22].

A field study as well as a facies analysis showed that the above facts concerning delta and alluvial fans are applied to the Gercus Formation. This is because there is more evidence of lateral facies and sedimentary variations which showed that reddish brown claystone and red-brown mudstone lithofacies deposited in the delta and delta front are rare deposits, while trough cross-bedded sandstone, cross-bedded pebbly sandstone, and laminated cross-beddeding sandstone lithofacies are deposited in braided delta environments. In intertidal and supratidal environments, marl lithofacies and gypsum lithofacies are deposited. The sea level fluctuation caused the river base level to rise and fall. In addition, the process was altered from erosions to depositions, while grain size was also altered from gravel to clay and sand in different environments. The Gercus Formation environment was fluctuated over the total duration of the Middle to Late Eocene, as a result of changes in eustatic sea levels, tectonic subsidence, uplifting and sediment filling, in addition to the potential for climate change. As a result, the environment in the basin was changed both in space and time as a result of relative changes in the sea level.

Sequence development

The Gercus succession of northern Iraq was developed during the Paleocene Eocene in an active margin basin, where the Neo Tethys final closure and collision with Eurasian plate took place in the northeastern Arabian Plate. This caused major episodes of uplifts and subsidence together with base-level variations owing to eustatic ups and downs. Within the Gercus Formation, multiple fourth order cycles can be recognized. Such cycles represent a typically asymmetric BLTCs(Base Level Transfer Cycles), which often indicate fourth order relative sea level fluctuation, deposition in sediments and imbalance of building space. The highstand systems tract (HST), which is characterized by an aggradational to progradational parasequence set, was overlain by a sequence boundary and underlain by a maximum flooding surface. The transgressive system's tract, characterized by a retrogradational parasequence set, is overlain by a maximum flooding surface and underlain by a transgressive surface [23].

The lower portion of the formation starts with a fall in S.L. with a relatively little subsiding frequency, demonstrated in going through canyon incision, stream clustering and sediment. This was deposited in this lowstand episode and bounded under by a type) two of sequence boundary (SB2 developed in the early late lowstand system tract, where fluvial deposition took place, accompanied by a deposition of relatively thick gray conglomerate in the late lowstand system tract (LST). This conglomerate is known to be orthoconglomerate because it has a texture that is backed by rice. The product of forced regression was produce. This parasequence (LST), the relative fall in sea level is a direct result of mechanism and can be fairly supported by the effect of sediment influx [3]. After this, the transgressive system tract (TST) was alternated, with this system tract comprises of reddish brown siltstone and claystone. The system represented by highstand system tract (HST) and delta plain facies comprises of thick reddish brown sandstone with planner and trough cross bedding displayed by channel facies. The middle part of the section is represented by a thick succession of relatively thin BLTC cycles within the gravel conglomerate.

It has a matrix composed of medium to coarse sand, with gray or red color. It is distinguished across bedding on a large scale and pebble orientation (imbrication). The texture is provided predominantly with clast in addition to small quantities of matrix-supported conglomerates and fine- to coarse-grained, moderately- to poorly-sorted sandstone.

It reflected the transgressive system tract (TST) which is overlaid to gray claystone by garnish, along with siltstone which indicates the high-stand system tract (HST). Delta braided facies may reflect a balance between accommodation space and influx of sediments induced by relative fluctuation of the sea level, due to local subsidence rate change. Such successions are characterized by the transfer of thin cycles of symmetrical base level (BLTC: Base Level Transfer Cycles) representing a more balanced situation between reduced subsidence frequency and influx of sediments. Gercus

Formation's upper part consists of several asymmetric BLTCs with variable thicknesses (Figure-3). During high eccentricity, the sea level rises and the earth climate becomes warmer, while influx of seawater to the semi-coastal lake and evaporation are both increased. Consequently, evaporates are deposited in the peripheral lakes. But sea level fall is accompanied with decreases of sea water influx and evaporation. This is associated with dilution of the lake by fresh water from source areas, which deposits red claystone or gypsarenite, which represents the transgressive systems tract (TST), and reddish brown mudstone lithofacies which represents highstand systems tract (HST). This variation in thickness and cycle asymmetry reflects variability in subsidence rates and, hence, accommodation in a distal low gradient setting. This was interbedded with a thin marl and gypsum unit in the middle of the section, which reflected a sudden relative rise in sea level due to higher subsidence. This raises salinity by flooding sea water over the sill, which isolated the formation basin from the normal marine water.

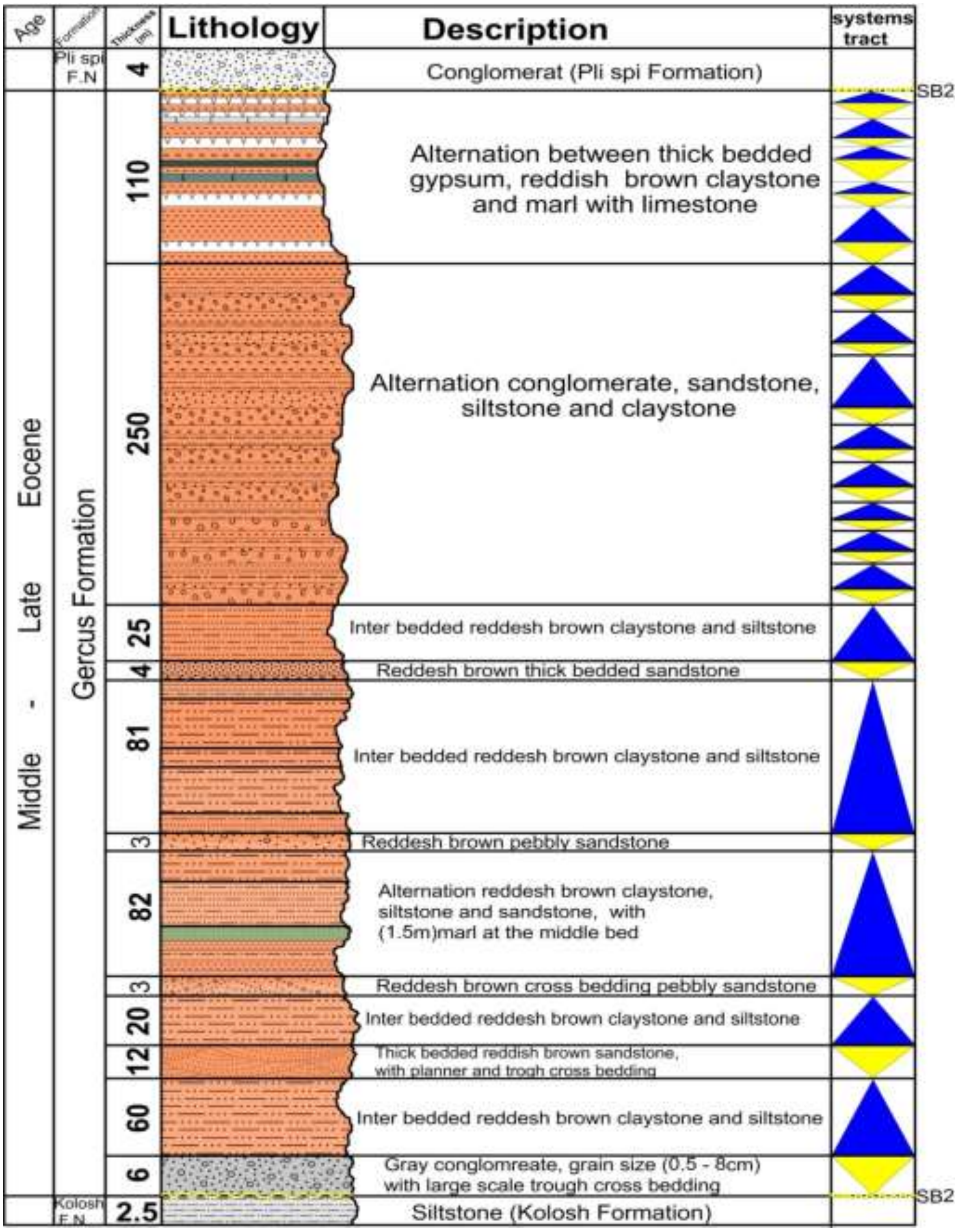

Figure3- Subdivision of Gercus Formation sequence stratigraphy in the study area.

Conclusions

The Gercus Formation in the study area comprises of clastic, carbonate and evaporated sequences. It consists of sandstone, conglomerates, siltstone, and marls upward, fining with a gypsum lens along with little thin micrite carbonate beds, especially at the upper and middle zones. This formation is divided into three parts: upper, middle and lower. The thickness of the lower part is about 265 m and consists of reddish brown thick bedded sandstone, claystone and siltstone. The middle part, which has a thickness of 250 m, consists of ten complete sedimentary cycles, starting with the conglomerate where sandstone and siltstone end with the claystone. Alternation of red claystone, white marl and gypsum formed the upper part of the formation. In general, both lamination and bedding represent the alternation of gypsum and red claystone, with the upper part having a thickness of about 110 m. The lower contact of Gercus Formation is uncomfortable with the upper part of Kolosh Formation. The formation's upper contact with the overlying Pila Spi Formation is sharp and characteristically identified by a thick conglomerate and breccia horizon.

The Gercus Formation comprises of red-brown claystone and reddish brown mudstone lithofacies formed in the delta and delta front of often depositional environment. While cross -bedded pebble sandstone, cross-bedded sandstone, and laminated cross bedded sandstone lithofacies are deposited in the braided delta. Within intertidal and supratidal environments, marl lithofacies and gypsum (or anhydrite) lithofacies are accumulated. The fluctuation in sea level caused the river base level to rise and fall. In addition, the cycle has been modified from abrasion to sedimentation, while the grain size has been also shifted in different environments from gravel to sand and mud.

Within the Gercus Formation, multiple fourth order cycles can be recognised. Both periods repres ent a generally asymmetric base level transfer cycle (BLTC); they often indicate fourth order relative S.L. The fluctuation and disparity between the lodging area and the deposition of sediments.

References

1. Jassim, S.Z. and Goff, J.C. **2006**. *Geology of Iraq*. Published by Dolin, Prague and Moravian Museun, Berno, 341p.
2. Bellen, R. C. Van, Dunnington, H. V., Wetzel, R. and Morton, D. **1959**. Lexique Stratigraphique, *Interntional. Asie*, Iraq, Vol. 3c. 10a, 333 p.
3. Jassim, S. Z., Karim, S. A., Basi, M. A., Al-Mubarak, M. A. and Munir, J. **1984**. Final report on the regional geological survey of Iraq. Vol.3, *Stratigraphy, GEOSURV, Baghdad, Lib*. Unpub. Rep., No.1447, 498p.
4. Bolton, C. m.G. **1958**. Geological Map-Kurdistan Series, Scale 1:100000 sheet K6 Halabja. Manuscript report *GEOSURV Baghdad*, No. 278.
5. Jassim, S. Z., Al Shaibani, S. K. and Ajina, T. M. **1975**. Possible Middle Eocene block movements in the Darbandikhan area, Northeastern Iraq, *J. Geol. Soc. Iraq.*
6. Al-Rawi, Y. **1980**. Petrology and Sedimentology of the Gercus Red Bed Formation (Eocene) NE Iraq. *Iraqi J. Sci*. **21**(1).
7. Basi, M.A. **1984**. Petrography of the formations exposed at Shikan-Sersink area, *SOM Library, Baghdad* No. 1396.
8. Al-Qayim, B. and Al-Shaibani S. **1991**. A bimodal tidal depositional system of the Gercus Formation, Shaqlawa area Northeastern Iraq. *Salahadin University, Jour. Sci*.
9. Ameen, B. M. **1998**. *Sedimentological Study of Gercus Formation in NE–Iraq* Un. Pub. M. Sc. thesis, Unv. Baghdad, 103p.
10. Tekin, E. **2001**. Stratigraphy, Geochemistry and Depositional Environment of the Celestine-bearing Gypsiferous Formations of the Tertiary Ulaş-Sivas Basin, East-Central Anatolia (Turkey). *Turkish J. Earth Sci*., **10**: 35-49.
11. Al-Barzinjy, S. T. M. **2005**. *Stratigraphy and Basin Analysis of Red Bed Series from Northeastern Iraq, Kurdistan Region.* Unpublished Ph.D. thesis, University of Sulaimani, 159p.
12. Ameen, B. M. **2006**. Sequence stratigraphy of Gercus Formation (Middle Eocene) In Sulaimaniya area, Northeast Iraq. *Iraqi Jour. of Earth Science*, 6(2).
13. Salim, H. H. **2012**. *Facies Analysis and Sedimentary Environments of Gercus Formation in Selected Surface Sections, Northern Iraq*. Ph.D. thesis, University of Mosul.
14. Buday, T. C, I. I. M Kassab and S. Z. Jassim **1980**. Regional Geology of Iraq: Stratigraphy, (Eds) D. G. *Geol. Surv*. Min. Invest. Pub. Vol. 1,445p.

15. Al-Qayim, B., Al-Shaibani, S. and Nissan, B. **1994**. A Bimodal Tidal Depositional System of the Gercus Formation, Shaqlawa Area, Northern Iraq. *Iraqi Geological Journal*, **27**(2): 75 – 95.
16. Einsele, G. **2000**. *Sedimentary Basin: Evolution, Facies and Sediment Budget*. 2nd ed. Springer-Verlag, Berlin, 792p.
17. Rust,B.R.and Koster,E.H. **1984**.*coarse alluvial deposits, in Facies Models*, 2nd Ed. Edited by R.G.Walker,ed. Geoscince Canada,Reprinal series No.1, p.54.
18. Tucker, M.E. **1991**. *Sedimentary Petrology, An Introduction to the Origin of Sedimentary Rocks*. Blackwell scientific publication: 260 p.
19. Selley, R. C. **1976**. *An introduction to Sedimentology*. Academic Press, London, New York, San Francisco.408p.
20. Mial.A.D.**1985** *principles of Sedimenary basin analysis*; NewYork,springer-verlag.
21. Omar.M and Al-Shamary, Th.A. **2018**. Sedimentology and Basin Development of the Middle Miocene Succession in the Zurbatiya Area, Eastern Iraq, *Iraqi Journal of Science*, **59**(3B): 1409-1418.
22. Pettijohn FJ, Potter PE, Siever R. **1987**. *Sand and Sandstone*. New York, NY, USA: Springer.
23. Obiageli.A.I, Adebowale.A.E, Uduma.O.E and Patrick.A.Ch **2018**. Integration of Seismic Facies and Seismic Sequence analysis for Depositional Environment Reconstruction of nandy Field, Niger Delta. *Iraqi Journal of Science*, **59**(3A): 1265-1276.