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Lithofacies Architecture of the Gercus Formation in Jabal Haibat Sultan, NE Iraq; New Concept of Lithostratigraphy and Depositional Environmental

Sa'ad Z. A.K. Al-Mashaikie(Corresponding author), Abbas T. Abbas Al-Azzawi and Ali K. Kadhum
Dept of Geology, Faculty of Sciences, University of Baghdad, Al-Jadriyah, Baghdad, Iraq.
E-mail of corresponding author: Kader3002@yahoo.co.uk

Abstract
Lithostratigraphic analysis of the Gercus Formation reveals four associations based on lithofacies types, petrography and sedimentary structures. The identified lithotypes are shale/claystone, sandstone, carbonate, conglomerate and debrite. Lithofacies association reveals four types arranged from bottom to top; FA1 proximal turbidite (sand dominated), FA2 distal turbidite (clay dominated), FA3 slop-apron turbidite (sand dominated) and FA4 distal deep turbidite (clay dominated). Lithofacies and associated sedimentary structures suggest sedimentation in marine turbidite regime followed the deep marine turbidites of Tanjero and Kolosh Formations in Tethyian foreland basin. The Middle-Late Eocene Gercus Flysch sediments composed of predominant litharenitic sandstones and interbedded mudstones, of turbiditic origin and mostly derived from a NE Arabian Plate margins. The sediments are well exposed in the NE side of Haibat Sultan Mountain, and provide excellent examples of fan sands associated with turbidites and related facies. The examined section indicates that the sandstones were deposited in larger channel complexes, which fed a mud-dominated slope. The more proximal facies have proportion of pebble conglomerates, shale-clast conglomerates and thick-bedded structureless pebbly sandstones, deposited by high-density turbidity currents, debris flows and slump. Other facies, either more distal or with a more uniform sand-rich are dominated by thick-bedded and amalgamated structureless sandstones. The massive sands are thought to originate from the gradual aggradations of sediment beneath or near-steady flows.
In this paper, new sedimentological and lithofacies evidences prove for the first time that the Gercus Formation was deposited in gravity-flow regime in marine environment. The identified sedimentary structures display alternative graded and fining upward cycles, load and flute casts, submarine channels, sand and clay balls and pillow structures, convolute and slump beddings, of turbidity origin, which is supported by index glauconite mineral in some sandstone horizons.
Keywords: Turbidites, Sedimentary structures, Gravity flow, Flysch, Gercus, Eocene, NE Iraq.

1. Introduction

The Gercus Formation was firstly described by Maxon in 1936 in the Gercus region of SE Turkey (Bellen *et al*. 1959). A supplementary type section for Iraq was described by Wetzel from Duhok area of N Iraq (originally referred to as Duhok Red Beds). It comprises 850 m of red and purple shales, mudstones, sandy and gritty marls, pebbly sandstones and conglomerates. It consists of brown clastics and limestones in the Demir Dagh area (Ditmar and the Iraqi-Soviet Team 1971). The formation is cropping out in the High Folded zones of the Unstable Shelf. In N Iraq, the formation is overthrust along the N Thrust Zone; the original depositional limit lay further to the north (Figure 1) (Jassim & Goff 2006). The thickness of the formation decreases towards the SE; near the Iranian border along the Sirwan (Diyala) River, it is usually less than 100 m thick. The Gercus Formation is present in Taq Taq (66 m thick) and Demir Dagh wells (117 m thick) (Jassim & Goff 2006). It consists of more than 200 m thick of red claystone with subordinate sandstone horizons. These sediments are believed to represent a fluvio-deltaic facies of the Middle-Late Eocene cycle of NE Iraq (Al-Rawi 1980, Al-Qayim *et al*. 1994; Ameen 1998). The formation was deposited in a relatively broad trough (foredeep) along the NE margin of the Middle Eocene basin, representing red molasse sequence derived from uplifted areas in the N and NE (Jassim & Goff 2006). The formation was dated as Middle Eocene age after Bellen *et al*. (1959) and Ditmar and the Iraqi-Soviet Team (1971), in which fossils are very rare and probably mostly reworked (Jassim & Goff 2006; Aqrawi *et al*. 2010). Al-Ameri *et al*. (2004) was dated the Gercus Formation as Late Lower Eocene using palynological data. The lower contact is with Sinjar Formation (in Derbandikhan area), and with Khurmala Formation (in Dohuk area) was unconformable (Jassim *et al*. 1975). While Bellen *et al*. (1959) was recognized an unconformity between the Kolosh and Gercus Formations. In the subsurface of NE Iraq. It is conformably overlain by Miocene Pila Spi Formation, which is previously marked by unconformity (Jassim & Goff 2006). This paper aims to make a new lithostratigraphic aspects based on detailed field study of lithofacies and sedimentary structures support with petrography to define a new stratigraphic concepts and depositional model.

2. Field works and methodology

For lithostratigraphic study, clear out cropped section in Chenarook area lies at NE limb of Jabal Hiabat Sultan locality was chosen . The section, lying along the main trough axis of the Paleogene Tethyian foreland basin, are exposed in Erbil district in NE Iraq. Examinations were carried out for the study on lithology, petrography, lithofacies, the stratigraphic sequences and associated sedimentary structures. Photographic documentation was enforced for the whole stratigraphic section, for lithologies, sedimentary structures and the different lithofacies types. Thirty three (33) rock samples were collected from the studied section and 33 thin-sections were prepared according to the procedure explained in Tucker (1988). To define the specific mineralogy and lithology, microphotographs were picking up for different mineralogical constituents.

3. Stratigraphy and sedimentology of the studied section

The studied section lies above Chenarook village, in NE side of Haibat Sultan Mountain of the Gercus Formation were sampled and discussed, which is situated 5 km NE of Koisanjak town, Erbil district (Figure 1). The lower and upper boundaries were identified as gradational with underlying Kolosh and overlying Pila Spi formations, which reject the previous idea. The lower boundary is separated by well marked 20 m successive pebbly sandstones and marls, which grades upwards to siltstone and shale beds, in fining upwards cycles, with gradual color change from olive green beds below, to grey, yellowish grades to brownish beds above. This criteria was observed by Bellen *et al*. (1959), who referred to gradational contact between the Kolosh and Gercus Formations. No basal conglomerate was observed. The upper boundary was reported at the base of Pila Spi Formation and marked by slump deformed carbonate debris flow bed, composed of various sizes of carbonate pieces support with marly materials, which is laterally grades to marl rich in mud clasts of underlying beds, and later to marl. It is grading upwards to Pila Spi limestones. The previous workers referred to conglomerate in the upper contact, which was not found in Chenarook in this study. The thickness of the Gercus Formation in the studied section was determined to reaches about 205 m (Figure 2).

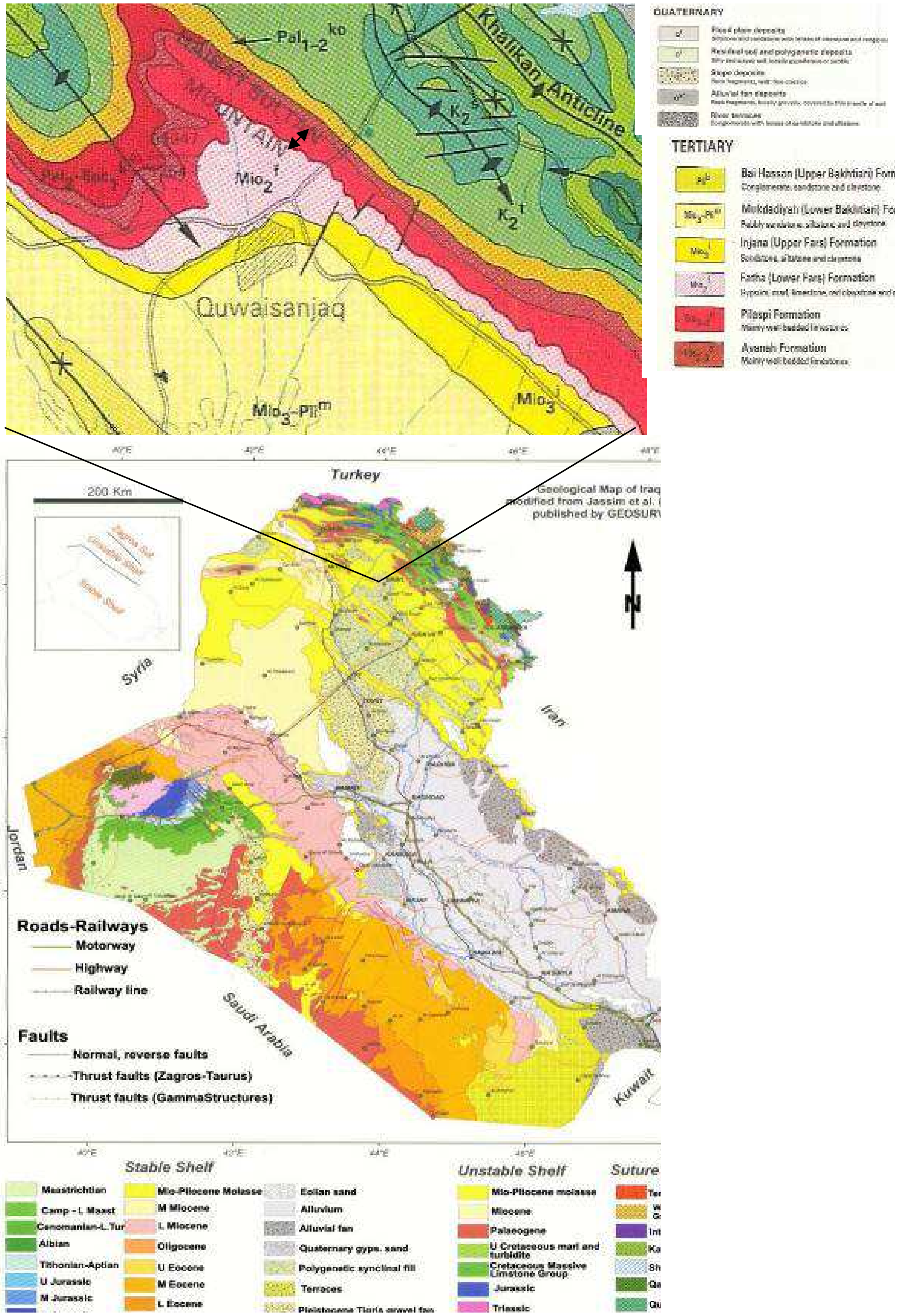


Figure. 1 General geological map of Iraq and the geological map of the studied area in Haibat Sultan Mountain, NE of Koisanjak city, NE Iraq. Arrows refer to the studied section (after Sissakian 2000).

3.1 Lithology and cyclothems

The stratigraphic log of the Gercus Formation is shown in (Figure 2, 3). It is composed basically of clastic rock units of sandstone, siltstone, shale and claystone cyclothems, arranged in fining upwards cycles. Lens like conglomerate beds were identified in the base of some turbidity cycles. The clastic cyclothems are interbedded with subordinate thick and thin carbonate beds (limestone and marl) in a mixed siliciclastic-carbonate successions. Cyclothems of Gercus Formation consists of about 60% shales, claystones and siltstones, 20% sandstones, 10% limestone, 5% marl, and 5% debris flow and conglomerate beds. The shales are gray to black, claystones and siltstones are of grey and reddish color. The beds range in thickness form 0.2 to 15 m. Two distinctive irregular black shale beds were identified in the upper part of the formation, and attains 0.3 to 0.5 m thick. The idea of turbidites in Gercus Formation is supporting with associated sedimentary structures of turbidity origin. The very fine-argillaceous rocks display sand and clay balls and pillows and slump bedding structures, load and flute casts, as well as convolute deformation. The sandstone beds are 1 to less than 2 m thick, reddish to gray in color, and reveals specific turbidity sedimentary structures e.g. slumping deformed beds, ball and pillows, slump channel levees, submarine channels…etc. The marl is of yellowish white, ranges in thickness form 0.5 to 2 m, and identified in the lower most and upper most parts of the formation. The limestone beds are white to dark grey and attains 0.1 to 1m and less more in thickness. The debris flow and conglomerate beds attains thicknesses of 1 to 2 m. The conglomerate is lens like, wedging out laterally and recognized in a sub-aquatic channel like structure. Four alternative groups of gray and red rock units were identified, representing mixed siliciclastic-carbonate successions (Figure 3).

3.2 Sedimentary structures

Varieties of sedimentary structures of characteristic turbidity and gravity flow regime origin were identified in the Gercus Formation, these are; graded beddings, cross stratifications, slump-convolute deformed and slump-disturb beds, load and flute casts, clay and sand balls and pillows, subaquatic channels, longitudinal ripple marks and burrows. These structures were classified and described according to Selley (1976), Reineck & Singh (1980) Collinson & Thompson (1982), Stow (2012) and Walker & James (1998). Graded beddings are the most common structure represents characteristic structure of the turbidity Bouma cycle (Figure 4a). All subdivisions of the turbidity cycle (Ta, Tb, Tc, Td, Te) were present in part of the sequence, and in the other part some of these subdivisions (Tc, Td and Te) were identified. Debris flow and conglomerates are recognized in the lower subdivision of the graded cycles. while the pebbly sandstone grades upwards to fine-argillaceous siltstone and thick fissile shale and claystone beds. Planner and cross stratifications were identified in the subdivision (Tc) of the cycles, generally associated with normal and tabular cross stratifications (Figure 4b), Slump deformed bed and/or group of beds with slide implying internal deformation of coherently beds to totally disturbed strata (Walker & James 1998). Thicknesses range from 0.5 to 2 m. The distinct slump facies may have environmental significance (Figure 4c,d). Ball and pillow structures of various sizes of sand and clay lithologies were identified in random disturbed manner (Figure 4e). The structure was recognized in the sandstone and in fine-argillaceous claystone and shale beds. Submarine channels were identified in the successive sandstone beds confirm high energy gravity flow and turbidity currents and reveals submarine outwash fans (Figure 4f). Small and large size channels were recognized in the lower and middle parts of the formation, and are commonly associated with the graded beddings, debris flows, ball and pillows, slide and slump disturbed structures. Load and gutter casts, the erosional characteristic structures of the turbidity current (Figure 4g), were identified at the upper surface of the fine-argillaceous shale and claystone beds. Flutes are heel-shaped hollows, scoured into mud bottoms. Ripple marks were identified in the upper surface of the sandstone horizons and mostly of longitudinal type (Figure 4h). The wavy type is of small scale. Biogenic structures are varieties of burrows and animals activity in the sandstones horizons and identified in the surface contact with fine-argillaceous sediment e.g., siltstone and shales.

3.3 Petrography

According to the classification of Mcbride (1963) and Pettijohn (1975) the sandy lithofacies of the Gercus Formation is classified as lithic arenites with total chert fragments of (5-20%) and carbonate lithic fragments (50-65%). The main cementing material is carbonates, with subordinate ferruginous cement (Figure 5). Noticeable glauconite content was identified in some of sandstone horizons (Figure 5 b, c). The glauconite is less than 1% and was reported here for the first time. The size of the sandy particles can be generally characterized as fine sands. Other lithic fragments like metamorphic are rare abundance as well as quartz, feldspars and argillaceous fragments. The main content of the heavy mineral fractions are opaque (magnetite, hematite, illmenite and chromite), zircon, tourmaline, hornblende and garnet. The limestone beds are mainly composed of micrite, micro-sparite, fossiliferous and/or dolomite (Figure 5d, e). The limestone with terrigenous elements contain carbonate bioclasts as shells and foraminifer fragments supported with carbonate mud (Figure 5f) (Tucker 1991; Scholl & Scholl 2003). The terrigenous grains do not exceed 10 %, and composed of rare

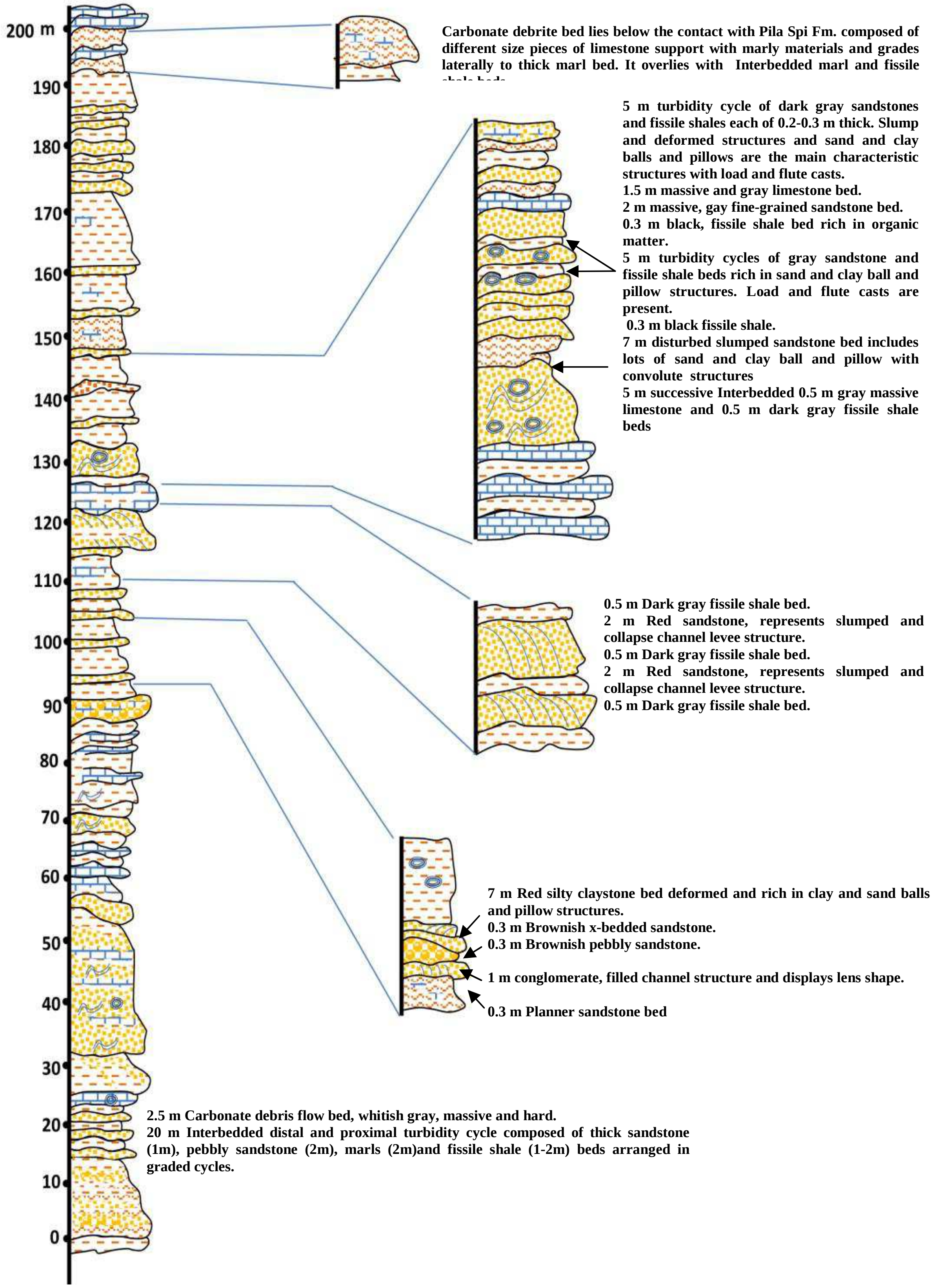
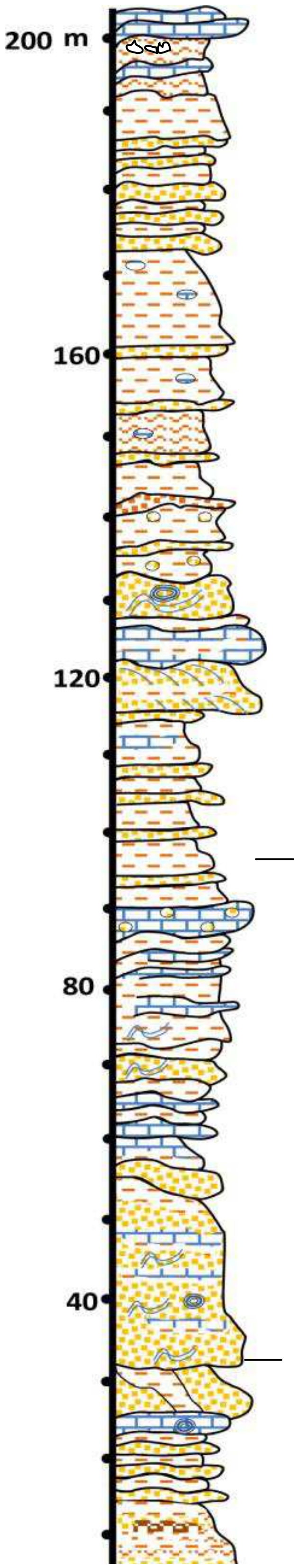


Figure. 2 The stratigraphic log of the Gercus Fm. shows the characteristic lithotypes and the identified sedimentary structures.



Pila Spi Formation, composed of bedded limestone rocks.

10 m (Transitional beds) Interbedded thick yellowish marl (1-1.5m thick) and dark gray fissile shale (1-.15m thick) beds overlie with thick debrite composed of large and small carbonate boulders support with marly materials. These succession represents the transitional beds between the Gercus and Pila Spi Formations (Yellowish &gray color)

FA-4, Distal (deep-shelf) turbidites (clay dominated)(Red color)

55 m Fining upwards and graded turbidity cycles, each cycle composed of 1 m of massive and sometimes pebbly sandstone, brownish to red color, grades to planner stratified and x-bedded sandstones. The sandstones grades to thick, red siltstone and claystones bed (5-7 m thick). The successive cycles display specific turbidity sedimentary structures e.g. sand and clay balls and pillow structures, slumping deformed beds, flute and load casts.

FA-3, Deep-marine turbidites (sand/shale successions)(Gray to black color)

35 m Fining upwards, graded turbidity cycles; each cycle composed of 0.2-0.3 m of massive gray sandstone, , grades to 0.2-0.3 m dark gray to black fissile shale beds. The successive cycles display specific turbidity sedimentary structures represents by sand and clay balls and pillow, slumping deformed beds, flute and load casts.

FA-2, Distal turbidites (clay dominated)(Red color)

30 m Fining upwards, graded turbidity cycles; each cycle composed of 1 m of massive and sometimes pebbly sandstone, brownish to red color, grades to planner stratified and x-bedded sandstones. The sandstones grades upwards to thick, red siltstone and claystones bed (5-10 m thick). The successive cycles display specific turbidity sedimentary structures e.g. sand and clay balls and pillow, slumping deformed beds, flute and load casts, burrows and slumped /collapse channel levee structure.

FA-1, Proximal turbidites (sand dominated)(Red and gray color)

65 m Fining upwards, graded turbidity cycles; each one composed of 1 m of massive and sometimes pebbly sandstone, brownish to red color, grades to planner stratified and x-bedded sandstones. The sandstones grades upwards to thick, red siltstone and claystones bed (5-7 m thick). The claystone beds are Interbedded with very thin limestone horizons of 0.1 m thick. The successive cycles display specific turbidity sedimentary structures e.g. sand and clay balls and pillow, slumping deformed beds, flute and load casts, and burrows. The sequence reveals successive submarine channel structures filled with conglomerates and/or pebbly sandstones.

2.5 m carbonate-debrite limestone bed, drab and thick, composed of different size pieces of limestone support with carbonate materials.

23 m (Transtional beds) fining upwards graded turbidity cycles composed of thick (1m), massive and fine-grained red sandstone with thick (1m), dark gray fissile shales, Interbedded with yellowish, thick (1-2m) marl beds. The sequence reveals specific turbidite structures represented by, slumping deformed beds, convolute deformed beds, flute and load casts and sand and clay balls and pillow structures.

Kolosh Formation, turbidites successions of green sand and dark gray shale beds.

Figure 3. The stratigraphic log of the Gercus Fm. shows the lithostratigraphic units in the Gercus Fm.

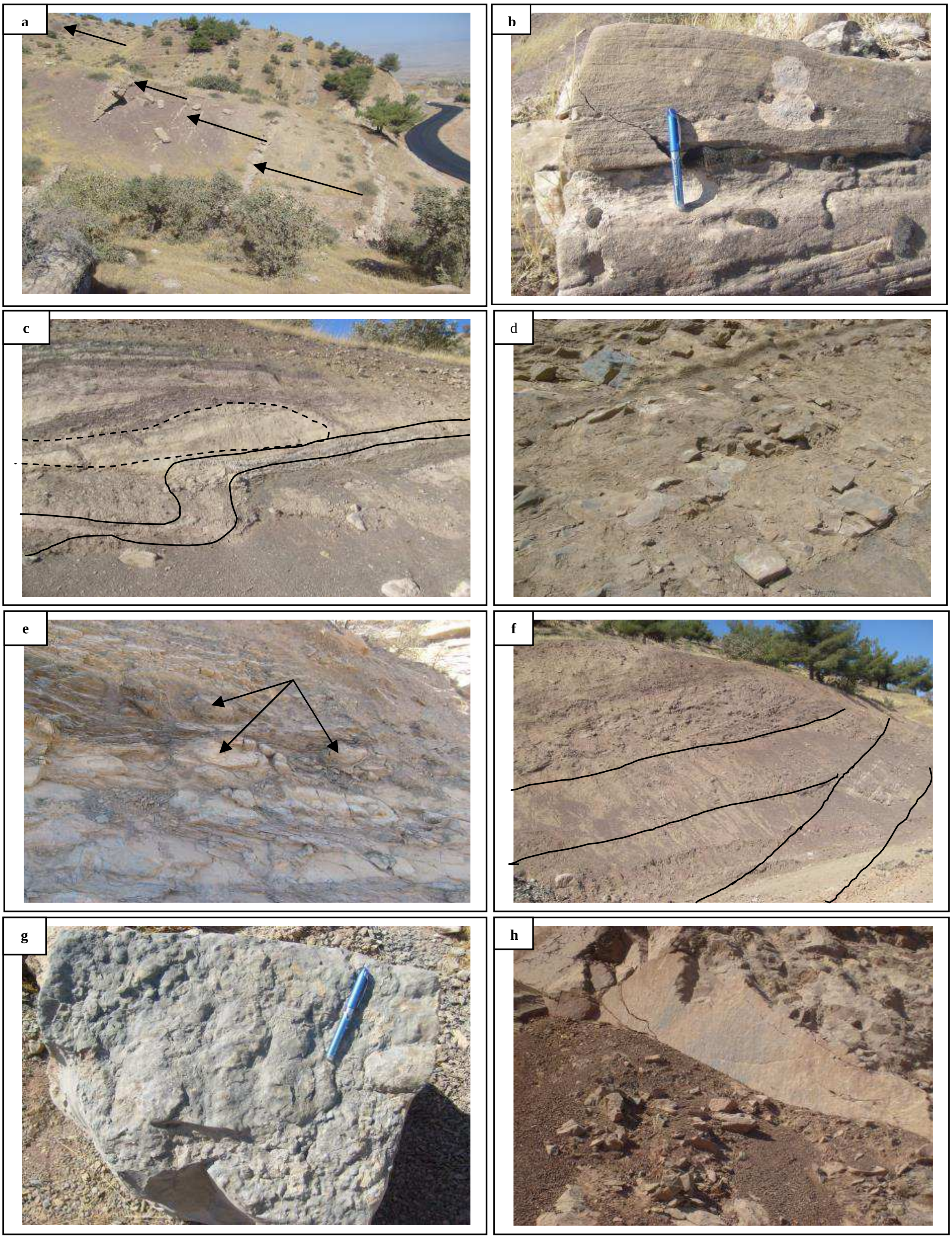


Figure 4. the identified varieties of sedimentary structures in the Gercus Formation; (a) graded turbidity cycles of 5 to 7 m thick cycle, (b) normal and tabular cross-bedded sandstone in 1 m thick sandstone, (c) slump and slide deformed (convolute) beds in 1 m thick beds, (d) disturbed deformed sliding bed in about 2 m thick bed, (e) sand and clay, ball and pillow structures in sandstone and shale beds, (f) large submarine channel structure in the sandstone beds filled with disturbed and ball sandstones, (g) load and flute casts in the upper surface of gray shale, (h) longitudinal ripple marks in the upper surface of reddish sandstone bed (pencil=10cm).

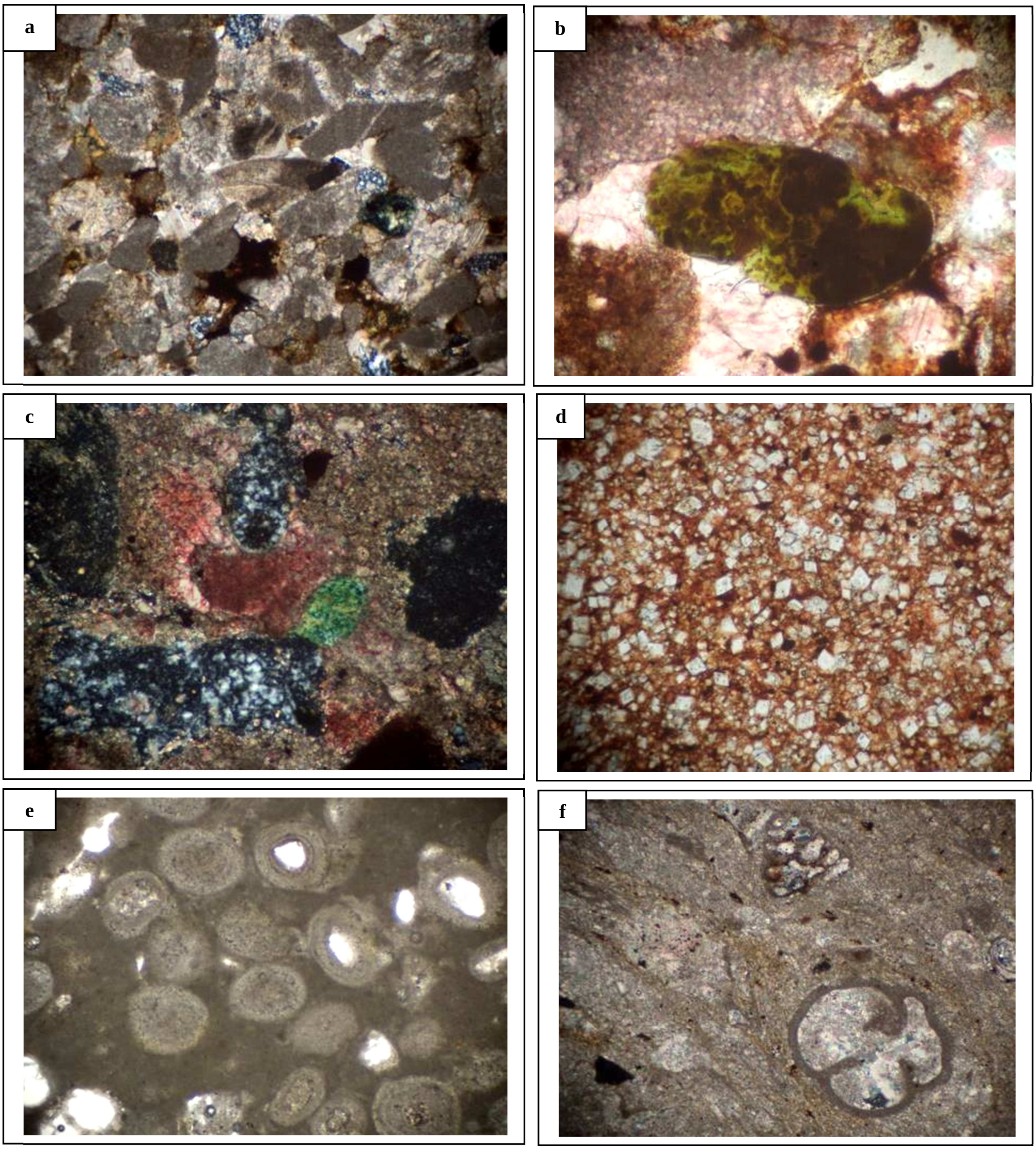


Figure 5. Photomicrographs explain the type of rocks and mineralogical composition of the Gercus rock units, (a) general composition of the sandstone lithotypes, which composed basically of carbonate and chert lithic fragments supported with carbonate and terrigenous cement (CNx40X), (b) glauconite pellet in sandstone in the lower part (CNx100X), (c) glauconite grain in sandstone of the upper part (CNx40X), (d) dolomitic limestone from the lower part (CNx40X),, (e) oolitic limestone from the middle part (CNx40X), (f) fossiliferous limestone from the upper part of the formation (CNx40X).

quartz, metamorphic “green clasts” with sedimentary lithoclasts of carbonates and chert fragments. The marl beds consisting of carbonate, clays and subordinate terrigenous fragments e.g. chert, lithic carbonates, iron oxides and rare detrital quartz.

4. Lithostratigraphy

Lithologically, the Gercus Formation consists of gray, yellowish brown, pinkish and red, massive, cross-bedded, medium to fine-grained sandstone, sometimes pebbly, which is interbedded with thick, fissile and stratified siltstone/shale beds and claystone of gray to red color (Figure 2, 3, 4). Field observations have revealed the presence of five lithofacies types, which are distinguished and classified based on the differences of certain sediment characteristics such as grain size, color, sedimentary structures and changes in lithological composition if any. The boundaries between lithofacies types are defined based on such characteristics, however they are generally transitional. The classification of the Gercus sediments, as indicated here, follows the definitions of Walker (1984), Reading (1986), Einsele (1992), Walker & Johns (1998), Posamentier & Walker (2006). The identified lithologies and lithofacies types are repeated through the stratigraphic section, these are; shale/claystone, sandstone, carbonate, conglomerate, and debris flow. Each of these lithotypes can be subdivided into several characteristic lithofacies types.

4.1 Shale/claystone lithofacies

The shaly lithofacies composed the main constituent of the Gercus Formation, which characterized by thick and thin bedding, 0.5 up to several meters in thickness (Figure 4a, c, e, f). Concerning grain size, it is a mixture of predominant clay with subordinate silt fraction. The present sedimentary structures are horizontal laminations, resulting from the presence of silty lamina. The geometries are strata like and the upper boundaries are sharp and flat and the lower are gradational. Sand and clay ball structures were reported in this lithofacies, which are repeated along the stratigraphic section. Load and flute casts were identified in the upper surface of the beds. The shaly lithofacies was identified as upper subdivision (Te) of turbidity cycle. Several lithofacies type were recognized and discussed below;

4. 1.1 Massive claystone, comprise very thick and massive claystone beds. It is red in color and ranges in thickness from less than 1 meter to more than 10 m. Massive claystone lithofacies represents the (Te) subdivision of the turbidity cycles. Clay and sand ball and pillow structures are the most characteristic feature with load and flute casts. No fossils was observed in this lithofacies.

4.1.2 Interbedded claystone and siltstone, composed of thin and very thick, massive red claystone bed, interbedded with thin siltstone horizons. Thick claystone beds attain thicknesses ranges between 3 and 10 m, while the siltstone beds range in thickness from 5 to 10 cm and almost inter mixing with the claystones. This lithofacies represents the subdivision (Te) of the turbidity cycle.

4.2 Sandstone lithofacies

The sandy lithofacies mainly include sand and silty sand. The thickness of the sandy beds is usually 1 to 2 m. Frequently, graded beddings in fining upwards turbidity cycles were encountered, but subordinately, massive beds could be observed, as well as planner and cross-laminated beds. The lower boundaries of individual beds are mainly sharp and flat, irregular, with scours, while the upper limit is grading into the shaly lithofacies. Several lithofacies types were recognized in the sandy lithofacies;

4.2.1 Fine-grained sandstone, represents (Tc) subdivision of Bouma cycle. The sandstone grains are angular to subrounded, fine-grained, supported by carbonate and ferruginous cement, which classified as litharenite. It is massive, sometimes stratified, hard and ranges in thickness from 0.5 to less than 2 m. These sandstones have fining upward grain sizes. In some beds, normal and tabular cross-stratification, sand and clay, ball and pillow structures and disturbed slump beds as well as glauconite grains were identified. Variations in color is noticeable from light-brown, red and pink to grey color. No fauna was distinguished except some marks of bioturbation and burrows.

4.2.2 Massive sandstone, is almost medium to fine-grained (grains subangular to rounded) and supported mainly by carbonate cement. This lithofacies comprises (Tb) subdivision of the turbidity cycle. Ferruginous cement shows variable occurrences, in which it concentrated in some beds and decreases in others. The sandstone is classified as lithic arenite. The sequence displays irregular shape, almost massive, lacking any structures and attains thickness of 2 m or less more. It is yellowish brown, red and grey to green in color and hardly cemented. No faunal content can be observed.

4.2.3 Pebbly coarse-grained sandstone, represents the basal subdivision (Ta) of the turbidity cycles and classified as lithic arenite. It is composed of coarse to medium-grained (angular to subrounded), which is supported by carbonate and subordinate ferruginous cement. The pebbles are fine, angular to subrounded, composed of carbonate and chert lithologies. The lower boundaries of the sandstones are sharp, irregular and displays scours and load casts . It is pale-gray to drab in color and ranges in thickness from 0.5 to 1m. The pebbly sandstones are grading upward to planner and cross-stratified sandstones respectively. Disturbed and deformational structures can be observed. It is lacking any faunal content, either some trace fossils were identified in the upper and lower surfaces of the bed.

4.3 Conglomerate lithofacies

Based on sedimentological criteria, the conglomerates is composed of pebbles and cobbles, support with sandy argillaceous matrix. It is usually 1 to 2 m thick and reveals lens like geometry. Frequently, graded beddings in fining upwards turbidity cycles were encountered, and subordinately, massive habit was observed. The lower boundary of the individual bed is mainly sharp and flat, less irregular, while the upper limit is grading to pebbly and/or planner laminated sandstone lithofacies..

4.4 Carbonate lithofacies

Based on sedimentological and petrographical criteria, two carbonate lithofacies were separated; (i) limestone, and (ii) marl. The limestones display thicknesses range from 0.3 to 1 m of white to dark gray in color. The internal structures are faint parallel laminations, massive and thin beddings and sometimes reveals distorted deformation. The limestones with terrigenous material are visible in less than 1 m thick beds. The marl was identified in the lower and upper most parts of the formation, whitish to yellowish in color and attains 2 to 2.5 m thick. Inner structures are massive, sand and clay balls and pillows but primary faint parallel laminations were preserved. Several carbonate lithofacies type were identified in the Gercus Formation, these are;

4.4.1 Massive limestone, is thick, drab, grey to dark grey color. It is structureless and of 0.5 to 1 m thick. Three types of Microfacies were identified in thin-sections petrography of this lithofacies these are; (i) carbonate mud-micrite, (ii) bio-spary-micrite, and (iii) dolomitic micro-sparite (Folk 1974; Tucker 1991; Scholl & Scholl 2003). Sometimes, the micritic groundmass includes foraminifer and fossils shells. Patches of carbonate mud was recrystallized to sparite and micro spary calcite. The dolomite Microfacies composed of dolomite rhombs and micro-sparite. The massive limestones are interbedded with dark grey to green shales in mixed carbonate-siliciclastic succession.

4.4.2 Thin-bedded limestone, is drab to dark grey, and each bed attains 0.1 to 0.2 m thick, grouped in a bed not exceeds 1 m thick. It is almost structureless and sometimes show ripples and faint laminations. It is interbedded with thin to thick shale horizons in a mixed carbonate-siliciclastic succession. This lithofacies reveals three types of microfacies, these are; (i) carbonate mud-micrite, (ii) sandy micrite, and (iii) bio-spary- micrite (Folk 1974; Tucker 1992). The sandy micrite composed of terrigenous clastic grains e.g. lithic carbonate, chert, iron oxides grains, embedded in micrite groundmass. The bio-spary-micrite composed of predominant foraminifer with less spicules and shell fossils in micritic groundmass. Some of micrite was recrystallized to spary calcite.

4.4.3 Marl, is yellowish white to drab in color, and attains about 2 m thick bed. It was identified in the lower and upper most parts of the Gercus Formation. In the lower part of the formation, marl was interbedded with turbidity cycles. While in the upper part, marly debris flow bed grades laterally to marl, overlies with green shale, which interbedded with whitish gray limestone and marl beds in the transitional zone to the Pila Spi Formation.

4.5 Debris flow lithofacies

The sedimentological criteria of the debris flow beds reveals accumulation of different size pieces of carbonate lithology (boulders to pebbles), supported with marly carbonate materials. The thickness of debris flow bed is 2 m and was identified in the upper most part of the formation. It is gradually changed (laterally and vertically) to marls rich in mud clasts and later to marl were observed. The lower boundary are sharp and irregular according to the gravity flow and slumping effect.

5. Lithostratigraphic classification

Lithofacies analysis of the Gercus Formation shows major effect of turbidity currents on the sediment, which are classified according to lithotypes, sedimentary structures and the stratigraphic arrangement of the litho-units in the formation. The identified lithofacies types can be grouped into facies associations, each of which comprises certain depositional system and environment. The classification of lithofacies associations was depend on Reading (1986), Einsele (1992), Mutti (1992) and Walker & James (1998). The lithofacies associations discussed form bottom to top;

5.1 FA-1, Proximal turbidites (sand dominated)

Description

This association reveals group of lithofacies types arranged in fining upward turbidity cycles and of thickness reaches up to 65 m (Figure 6a). This association displays gray, red, drab and yellowish color. These cycles are deposited in proximal margin, which is evident from;

(i) Thickness of sandstone and claystone horizons. The sandstone horizons of FA-1 are thick, massive, faint laminated and sometimes cross laminated. The thickness of the sandstones is about 1 m or more less, while the claystone beds range in thickness form 1 to 1.5 m, (ii) The graded bedding cycles are small in thickness and not exceed 2-3 m. It is composed of thick beds of sandstone and claystone. The thickness of the sandstone are about 1 m, while the claystones are 1-1.5 m in a cycle, (iii) Sedimentary structures in FA-1 reveals specific types of turbidite origin, these are; subaquatic channels, graded beddings, load casts, slump deformational structures, balls and pillows…etc. The succession of sandstone and claystone beds are interbedded with thin to less thick limestone beds. Limestones are whitish yellow to gray color and attains 0.1 to less than 1 m thick, which are interbedded with the graded cycles.

5.2 FA-2, Distal turbidites (clay dominated)

Description

This association reveals group of lithofacies types arranged in a fining upward turbidity cycles. The thickness of FA-2 reaches up to 30 m (Figure 6b) and of red color. while the carbonate horizons are of whitish and gray color. These cycles are deposited in distal margin, which is evident from;

(i) Thickness of sandstone and claystone horizons. The sandstone horizons of the FA-2 are thick, massive and sometimes cross laminated and are less than 1 m thick. While the claystone beds range in thickness form 3 to 10 m. The lower surface of the sandstone horizon is irregular and erosive. While the upper surface is gradational and fining upward to siltstone and silty claystone lithologies.

(ii) The graded bedding cycles display large thickness and exceed 4 to 11 m. Each cycle is composed of less thick bed of sandstone (less than 1 m) and very thick claystones horizon (more than 3 to 10 m).

(iii) Sedimentary structures of FA-2 confirms graded turbidity cycles associated with types of sedimentary structures of turbidity origin, these are; graded bedding, planner and cross stratification, graded beddings, load casts, slump deformational structures…etc. Burrows of animals were identified in the boundaries of the sandstones horizons. Sometimes, the very thick claystone beds are interbedded with very thin limestone beds (5-10 cm thick). The sandstone and claystone beds are interbedded with thin to less thick limestone beds of yellow to gray color and attains 0.1 to less than 1 m thick.

5.3 FA-3, Slope-apron turbidite (sand dominated)

Description

Slope-turbidite facies association is characterized by a lot of slumping and deformed beds. It is sands dominated lithofacies characterized by thin bedded slump sandstone successions. The successive beds are mainly of green and gray color with subordinate black shales. The sandstones are thick, massive, fine-grained, and of green to gray in color, which attains about 2 m in thickness. While the shale beds are thin, fissile of green to black color, and attains 0.2 to 0.5 m thickness. The thickness of FA-3 is about 35 m . The beds of lithofacies types are arranged in fining upward turbidity cycles (Figure 6c, d). The successions reveals turbidity types of sedimentary structures e.g., graded bedding, slump structures, load casts, slide deformed beds, disturbed beds…etc. The carbonate horizons are absent.

5.4 FA-4, Distal (deep) turbidite (clay dominated)

Description

This lithofacies association attains thickness reaches up to 55 m (Figure 6e, f). It was started with thick disturbed, white carbonate horizon of 1 m in thickness. Only this carbonate horizon was identified in this association. FA-4 composed mainly of deep marine turbidity cycles, in which the sandstones are very thin (0.1 to 0.5 m thick), while the claystone beds are very thick (5 to 7 m). The whole successions are of red color. The claystone beds are interbedded with very thin horizons of siltstone and limestone, each of 10 cm in thickness. FA-4 reveals sedimentary structures of turbidity current origin e.g. graded bedding, load casts, flute casts, deformed slump beds, disturbed beds…etc.

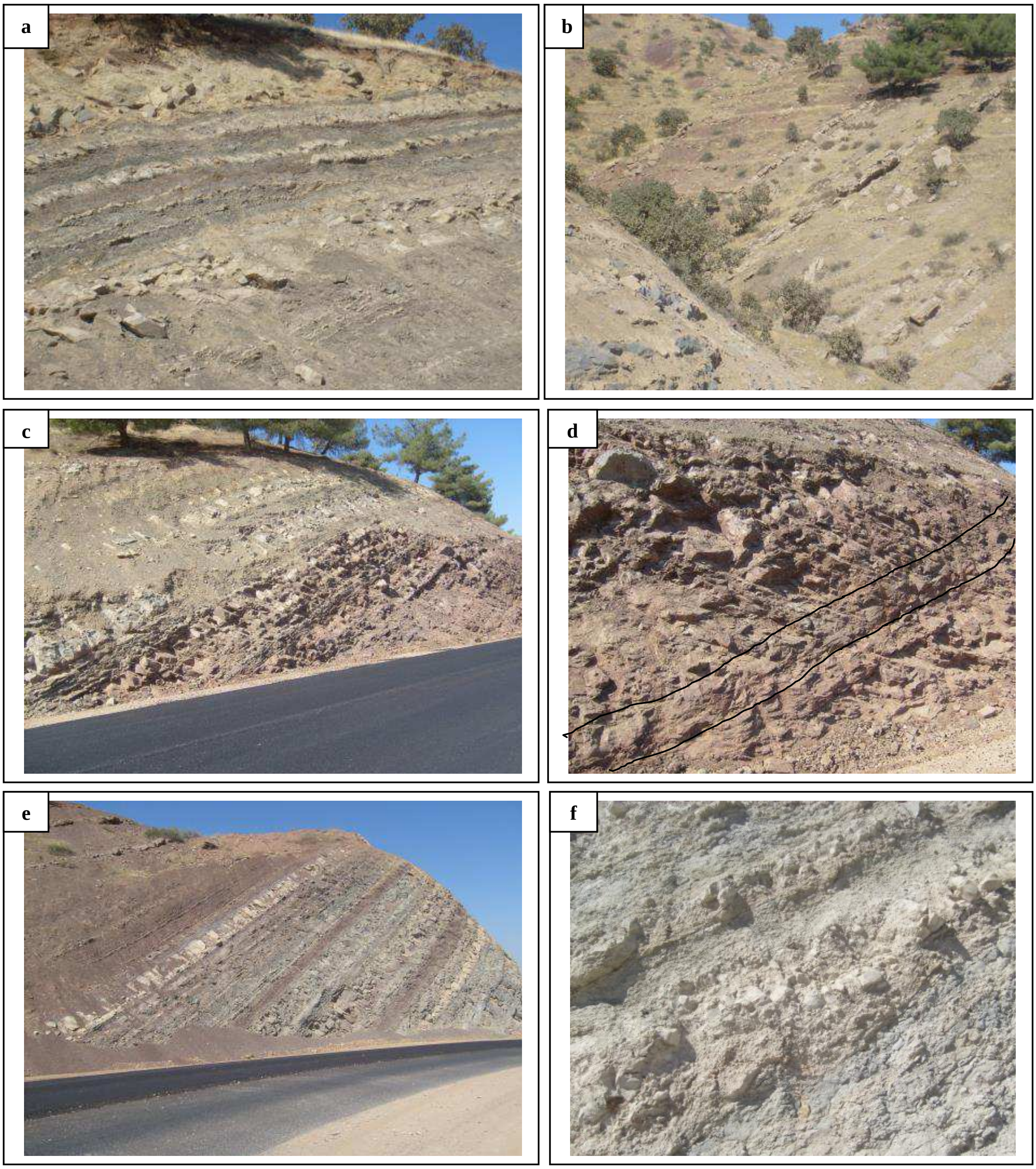


Figure 6. Field photographs show lithological features and lithostratigraphic associations in the Gercus Formation in Jabal Haibat Sultan Mountain; (a) FA-1, sand dominated, proximal turbidites (thickness about 25 m), (b) FA-2, clay dominated, distal turbidites, (thickness about 50 m) (c) FA-3, sand dominated, slope-prone turbidites, (thickness about 20 m) (d) thin-bedded slump and sliding beds in FA-3, which displays successive sandstone beds, (thickness about 10 m) (e) FA-4, clay dominated, distal-deep turbidites, (thickness about 45 m) (f) carbonate debrites in successive marl-shale-debrites alternatives in FA-4 (thickness of succession is about 5 m).

6. Interpretation

The arrangement of Bouma turbidites represented by lens like pebbly sandstones, fine-grained sandstones and fissile shale/claystone lithofacies in fining upwards cycles, are associated with deformed slump beds and other sedimentary structures of turbidity origin as reported in all of lithofacies association units in the studied section.
Proximal marine turbidite sediments are preserved between the underlying gradational retrogressive surface of

the upper Kolosh Formation and the overlying regressive surface of marine turbidites of the lower FA-1 unit. The latter surface is on lapped by proximal turbidity cycles, which were deposited in marine conditions. This displays subaqueous streams of gravity flows, which is the proposed origin for the conglomerates and the pebbly sandstones lithofacies, and is locally preserved on the original bounding surface or in submarine channels (Demarset & Kraft 1987; Nummedal & Swift 1987; Deynoux *et al*. 1991; Einsele 1992; Walker & James 1998; Posamentier, & Walker 2006; Octavenunuo 2006). The subaqueous streams originate from annual turbidity currents according to the most probable tectonic events. This interpretation is based on the presence of rough cross-stratifications, pebble imbrications, pebble shape and the limited lateral extent of the conglomerate beds. It could be interpreted as submarine gravity flows originated by the active turbidity currents (Kurtz & Anderson 1979; Walker 1984; McCabe *et al*. 1984; Reading 1986; Deynoux *et al*. 1991; Einsele 1992; Walker & James 1998). Moreover, the Gercus Basin (Paleogene sediments in Tethys Sea) comprises a trough foreland basin lies in active subduction zone (Jassim & Goff 2006; Aqrawi *et al*. 2010). The units FA-1, FA-2, FA-3 and FA-4 successions display analogies with the Bouma turbidity sequences as evidenced by:

(i) Repetition of fining upward successions, (ii) Upward succession of pebbly sandstone and massive, parallel laminated, rippled sandstones grades to thick shale / claystone, (iii) Good lateral extension, (iv) Presence of sedimentary structures types of turbidity origin e.g. slump and slide beds, disturbed deformed beds, load and flute cats, graded beddings, sand and clay balls and pillows…etc.

The occurrence of sedimentary gravity flows comprise continuation from the underlying Kolosh Formation might appear quite surprising at first glance. Mechanisms by which sedimentary gravity flows are settle down have been discussed and applied to deep sea fan models in a great deal of literature (e.g., Bouma 1962; Bouma & Brouwer 1964; Carter 1975; Middleton & Hampton 1976; Kurtz & Anderson 1979; Nardin *et al*. 1979; Lowe 1982; McCabe *et al*. 1984; Reading 1986; Einsele 1992; Mutti 1992; Walker & James 1998; Posamentier & Walker 2006). Turbidity cycles have also been reported in shallow marine environments (Thompson 1972; Scott 1975; Homewood 1983). Mud flows and high to low density currents have been extensively described in recent papers, either in ancient or modern sequences (e.g., Evanson *et al*. 1977; Rust 1977; Hicock *et al*. 1981; Gazdzick *et al*. 1982; Domack 1982; Visser 1983a-b; McCabe *et al*. 1984; Eyles *et al*. 1985).

All these resedimentation processes take place when submarine marginal fans, deltas, and other build-ups become unstable from over steepening and/or slopes due to either rapid sedimentation, increased overburden pressure or load, storm wave agitation or active tectonic. If the mechanisms which caused the coarse to fine sand sized sediments of FA-1, FA-2, FA-3 and FA-4 sequences are related to sediment gravity flows, the following high density current process could be envisaged according to the terminology of Lowe (1982). The sequences range from coarse to gravelly fully turbulent flow (pebbly sandstone/ division Ta & Tb in BOUMA cycles), to more dilute and laminar sandy flow (fine grained sandstone and silty argillaceous sandstone/division Tc & Td) with traction suspension deposition shown by flat laminations and occasional rippled cross laminations. The upper capped shale or claystone bed (division Te) represents the final suspension load of turbidity currents (Einsele 1992; Walker & James 1998; Posamentier & Walker 2006). The crude lamination, which appears in some gravelly basal horizons may reflect an increasing shear rate and under steadiness of the flow and the development of depressives pressures (Aalto 1976; Lowe 1982), which remained active in the overlying laminated sandstones of (Tc/division).

However, as emphasized by Eyles *et al*. (1985), realistic interpretations of conglomerate genesis must be preliminary based on lithofacies relationships and sequence context. The intercalation of a meter thick tabular body of conglomerate within undeformed turbidity sequences is representative for a debris flow in which the clasts were supported by strength and buoyancy of sand-clay water fluid.

Several authors described shallow water graded sand-beds with a vertical succession of structures that resemble those of deep water turbidites as related to storm effects (Kelling & Mullin 1975; Brenchley *et al*. 1979; Hamblin & Walker 1979; Walker *et al*. 1983; Walker 1984). Two phases overlapping in time are recorded in storm deposits: (a) An initial phase of transport and deposition which emplaces the sand on the shelf, (b) Second phase during which the sand is reworked by storm waves (Brenchley 1985). Among others (wind-forced currents and storm-surge ebb currents), turbidity currents have been postulated to be responsible for the initial phase (Hamblin & Walker 1979; Walker *et al*. 1983; Walker 1984).

In FA-1, FA-2, FA-3 and FA-3 units, no typical HCS or wave related ripple marks have been found, but the following characteristics may suggest rejection of the storm sequences as defined by Walker et al. (1983) or Brenchley (1985):

(i) The presence of the erosional base of apparently oriented gutter-casts or even flute and load casts, (ii) The massive and graded aspect of the basal pebbly sandstone and massive sandstone beds, (iii) The non-frequent un-undulatory aspect of the lamination in Tc horizon, and (iv) The absence of the complex polygonal ripples, which may represent small scale HCS as described by Guillocheau (1983), Brenchley et al. (1986) or Guillocheau & Hoffert (1988).

Otherwise, these are probably mainly generated by gravity flow processes as supported by the following arguments:

(1) The laterally continuous aspect of the sequences, (2) The consistent development of internal divisions conforming more or less to the Bouma sequences, (3) The absence of angular cross-beddings, (4) The repetitive aspect of the sequences without fair weather deposit intercalations.

The facies association units sediment gravity flows may represent the fore slope deposition of subaqueous fan fed by turbidity currents streams. The repetitive sequences reflect the episodic pulses of dense sediment laden turbidity currents swept down the fan and most probably represent “turbidites”.

The later surface between FA-1 and FA-2 units is on lapped by thick conglomerate bed of FA-2 unit, which are interpreted as the start of another main submarine fan deposits. The size of these conglomerates appear exceptionally thick in size (1 t0 2 m) when compared to modern (Swift *et al*. 1978; Kurtz & Anderson 1979; Swift & Field 1981; Stubblefield *et al*. 1984) or ancient models (Boyles & Scott 1982; Rice 1984; Shurr 1984). They have neither been studied and nor reported in the Koisanjak/Chenarook area. but the proposed origin is based on:

(i) Their geometry and relationship, (ii) The well sorted nature of the sediments, (iii) The lack of fine-grained deposits (argillaceous silt or clay), (iv) The nature of sedimentary structures associate with the turbidity sequences include this bed (planar laminations, faint hummocky cross stratification), which are characteristics of a shallow water high energy environment.

7. Discussion

The sedimentological and lithostratigraphic analysis of the Gercus sediments and successions (in Haibat Sultan location)suggest new stratigraphic aspects, which are not reported previously, these are;

- The study documents (for the first time) marine environment for the Gercus Formation, which was previously suggests fluvial environment, probably mixed with deltaic prone in the upper most part. One of most important evidence is the identifiable glauconite grains in some sandstone beds (Scholl 1979; Kerr 1985; Tucker 1992; Chaftez & Reid 2000; Scholl & Scholl 2003; Chaftez 2007; Relu *et al*. 2012).
- The identified limestone (contains marine fauna) and marl beds, which are interbedded with the turbidity cycles in the whole successions, refer to marine environment and default the fluvial idea.
- The study presents that the Gercus Formation composed essentially of cyclic repetitions of turbidity Bouma cycles, identified in all the lithostratigraphic units, e.g. FA-1, FA-2, FA-3 and FA-4. These turbidity cycles considered as strong evidence of marine environment.
- The Gercus Formation shows conformable contact with the lower Kolosh (flysch-turbidites) and upper Pila Spi (carbonate) Formations. This is evident from the gradation and transition in lithology and color. Moreover, the cycles of turbidites still continuous from the underlying Kolosh Formation and in all stratigraphic units of the Gercus Formation. The previous workers suggest that carbonate debrite in the upper most part of the Gercus Formation comprises a basal conglomerate between the Gercus and Pila Spi Formations.
- The successions of the Gercus Formation displays varieties of sedimentary structures, interpreted here as of turbidity and gravity flow origin. It includes, sand and clay balls and pillows, load and flute casts, graded beddings, laminar stratifications, slump and slide beds, disturbed deformed beds.
- The carbonate horizons is belonging to the Gercus Formation and not a tongue of the Khurmala Formation as reported previously. The carbonate beds composed of marl, fossiliferous and dolomitic limestones. Moreover, these limestones are of little thickness and ranges between 0.1 to less than 1 m. While the Khurmala tongue was reported as about 15-20 m thick in the adjacent area. Furthermore, the limestone beds were identified in all lithostratigraphic units in the formation.
- The presence of submarine channels associated with debrite-turbidite beds refer to the deposition in the mouth of the channels in submarine fans.
- Farther, north toward to the Turkey-Iraqi frontier in the area of Hakkarie, the Eocene develops a thickness of 2000 m or more in sediments interpreted as marine "flysch".
- The study was subdivided the Gercus Formation into four lithostratigraphic units, according to their lithologies, facies context, color of the rocks, sedimentary structures and stratigraphic sequences.

The stratigraphic successions and sedimentological characters of the Gercus Formation suggests an interesting marine environmental indications in the stratigraphic column of N Iraq. The Cretaceous-Paleocene-Eocene sequences of Tethys Sea in northern Iraq represent continuous sedimentation in deep marine to deeper shelf environment under the effect of strong turbidity currents.

In NE Iraq, the proximal (NE) part of the Late Cretaceous foredeep basin was started uplift in Paleocene-Oligocene time. A NW-SE trending basin, was continued to the SW in which up to 2000 m of sediments was deposited. Continuous uplift of the thrust sheets that had been emplaced in NE Iraq led to progradation of clastic wedges in a foreland basin, where the old Upper Cretaceous thrust belt was uplifted and shed clastics of Kolosh and Gercus Formations were deposited. As the Neo-Tethys progressively closed, the molasse basin merged with the accretionary prism of the Paleogene subduction zone (Jassim & Goff 2006).

This paper suggest two new stratigraphic aspects as discussed above;

Firstly, the study suggest that the Gercus Formation was deposited in marine environment. This suggest that the foreland basin was still continuous and closure was carried out in a later stage after the deposition of the Gercus, Pila Spi and most probably Lower Fars Formations.

The second suggest that the Gercus Formation represents continuous sedimentation of the Kolosh Formation in deeper margins but in an oxic/anoxic environment, which are evident from the presence of alternative red and dark gray groups of rocks in the formation. This suggestion needs more detailed studies to define the origin of the red color in turbidites successions as well as the presence of two black shale horizons in the dark gray successions.

8. Conclusion

The Gercus Formation is cropping out in a narrow belt of the high folded belts, which is distributed from NE to NW margins and encountered in several oil wells in N Iraq. It is composed of litharenitic sandstone of red beds, green, gray and yellow with few black horizons. The Gercus successions show cyclic repetitions of the turbidity Bouma cycles and gravity flow sediment. The turbidity cycles composed of graded pebbly sandstones, planner and cross stratified sandstones, siltstones and fissile shales/claystone beds. These cycles reveal varieties of sedimentary structures of turbidity current origin, e.g. sand and clay balls and pillows, convolute beddings, flute and load casts, planner and cross stratifications, slump and slide beds, deformed disturbed beds, and submarine channels.

The relationship between turbidity cycles, sedimentary structures and the Gercus successions confirm the suggestion of marine environment, which supports with the presence of glauconite mineral grains.

Ten lithofacies types were recognized in the Gercus Formation: Massive claystone, interbedded claystone and siltstone, fine-grained sandstone, massive sandstone, pebbly sandstone, massive limestone, thin-bedded limestone, marl, conglomerate, debrite. These lithofacies types can be grouped in four distinctive lithostratigraphic association, from bottom to top;

FA-1, Proximal turbidites (sand dominated), FA-2, Distal-shelf turbidites (clay dominated), FA-3, Slope-marine turbidite (sand dominated) and FA-4, Distal (deep) turbidite (clay dominated).

The lower FA-1 represents the proximal turbidites characterized by thick pebbly sandstone beds filled a lot of submarine channels. This represents the sedimentation of the gravity flows and turbidity currents in submarine fans, which display graded beddings, ball and pillows, slump, slide and disturbed beds. FA-1, represents continuation of the turbidity cyclic repetitions of the Kolosh and Gercus Formations with gradual boundary in between. The above FA-2 represents distal turbidites sedimentation in the basin plane. It is composed of thick beds of fine-grained sandstone and claystone arranged in fining upwards cycles, which reveals characteristic structures of turbidity origin e.g. slump disturbed beds, graded beddings, ball and pillow structures,…etc. The overlying FA-3 represents sedimentation of sand dominated rocks of gravity flows in slope prone. It is characterized by sets of slump beds associated with types of turbidity structures e.g. ball and pillows, disturbed deformed, graded beds…etc.

The last FA-4 confirms sedimentation in deeper margins with clay dominated beds. The sequence composed of fining upwards of thin sandstones and thick claystone beds, which are alternative in repeated turbidity cycles. The claystones of the upper most cycle is gradually changed to marly debrite and marl. The marl is overlying with limestone beds of Pila Spi Formation.

The interbedded thin and thick limestone horizons with siliciclastic turbidites in the whole log of the Gercus Formation is most probably carried out after the end of each turbidity pulses and confirm mixed siliciclastic-carbonate sediment. This needs more studies to detail it.

The previous studies were reported the carbonate beds in the lower part of the Gercus Formation as a tongue of Khurmala Formation of lagoon origin. This idea needs more specific studies to prove. Thick of 1.5 m limestone bed is directly overlies disturbed slump and thick successive beds rich in sand and clay balls. This is not scientifically convince with the deep marine turbidity sandstone successions.

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