Depositional Environment of the Gercus Formation in Jabal Haibat Sultan, NE Iraq; New Sedimentological Approach

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Abstract

Sedimentary structures of Gercus Formation in NE Iraq was little studied in the last decades. In this study 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 marine turbidity origin. The foreland part of Tethys basin characterized by deep marine Tanjero and Kolosh Formations followed by the Gercus formation with conformable relationships. The Eocene aged Flysch comprises predominantly litharenitic sandstones and interbedded mudstones, both of turbiditic affinities and most likely derived from a NE Arabian Plate source. The sediments provide excellent examples of distal fan sands associated with turbidites and related sedimentary structures. The overall sedimentological characteristics of the examined section indicate that the sandstones were deposited in larger channel complexes that fed a mud-dominated slope. The more proximal sediments have a proportion of pebble conglomerates, shale-clast conglomerates and thick-bedded structureless pebbly sandstones, deposited by high-density turbidity currents, debris flows and slumping. Otherwise, more distal or more uniform sand-rich source are dominated by thick-bedded and amalgamated structureless sandstones. The massive sands are thought to originate from the gradual aggradation of sediment beneath steady flows.

In this paper, new sedimentological evidences prove for the first time that the Gercus Formation was deposited in gravity-flow regime in marine environment. This is supported with identified glauconite index mineral in some sandstone beds.

Keywords: turbidites; massive sands; Flysch; Gercus Formation, Eocene, NE Iraq.

بيئة ترسيب تكوين الجركس في جبل هيبت سلطان، شمال شرق العراق : نظرة رسوبية جديدة

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الخلاصة:

ان التراكيب الرسوبية في تكوين الجركس في شمال شرق العراق لم تدرس بشكل مفصل سابقا . تظهر هذه الدراسة ان التراكيب الرسوبية تتمثل في تعاقب دورات التدرج الطبقي، وطبعات الثقل والأبواق والقنوات التحت بحرية والكرات والوسادات الطينية والرملية وتراكيب التطبق المشوه والزاحف والتي تشير ال ى الاصل البحري المتأثر بتيارات التعكر. ان الجزء الخلفي لحوض التيثس يتمييز برواسب بحرية عميقة متمثلة بتكويني التانجرو والكولوش والتي يعقبها تكوين الجركس المتوافق معها طباقيا. ان رواسب الفلش لعمر الايوسين تتمثل بغالبية من الصخور الرملية (الارينايت الصخري) والتي تتداخل مع الصخور الطينية الم توافقة مع رواسب التعكر

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والتي تكون غالبا قد اشتقت من مصادر في شمال شرق الصفيحة العربية . ان رواسب الجركس تعكس مثالا جيدا لرمال المراوح البعيدة والمصاحبة لرواسب المتعكرات وتراكيبها الرسوبية . ان الصفات الرسوبية للمقطع المدروس تشير الى ان الصخور الرملية قد ترسبت في مجموعة قنوات تحت بحرية كبيرة والتي قد تكون مصدرا لرواسب الطين في المنحدرات البحرية البعيدة . ان الرواسب القريبة في الرف القاري تحتوي على كميات من المدملكات الحصوية والاخرئ الحاوية على قطع طينية والصخور الرملية الحصوية السميكة والخالية من اية تراكيب والتي ترسبت بفعل تيارات التعكر العالية الكثافة والفتات الصخري الزاحف. وان الرواسب الاكثر بعدا والغنية بالرمال تكون في غالبيتها ذات تطبق سميك خالي من التراكيب . ويعتقد ان الرمال السميكة الصماء قد اشتقت من التقدم التدريجي للرواسب تحت الجريان الثابت او القريب من الثابت.

لقد وجدت ادلة رسوبية جديدة في هذه ألدراسة تثبت لأول مرة ان تكوين الجركس قد ترسب في نظام جريان متأثر بتيارات التعكر في البيئة البحرية وهذا الرأي قد دعم بوجود معدن الكلوكونايت في بعض طبقات الحجر الرملي.

Introduction

Gercus Formation formed a part of the Paleogene successions in northern Iraq, which is represented by a thick section of clastic sediments of Middle-Late Eocene age. A complete and good section of these rocks are cropping out in Chenarook area, NE side of Hiabat Sultan anticline, which lies in the Unstable Folded zone. [1-4]. The formation composed of clastic sediments consist of fining upwards cyclothems. It consists of carbonate-rich sandstones, marls, siltstones and some conglomerates with some carbonate units. The formation is dated on the basis of its stratigraphic position and palynological study to be of middle Eocene age [5,6]. It occurs along a relatively narrow NW-SE trending belt, extends from eastern to northern Iraq figure-1 and extends northwestwards into SE Turkey [7], to the southeast, the Kashkan Formation in Iran [8] seems to be similar in most aspects to Gercus Formation including age. The type section of the Gercus Formation lies at Gercus locality in Turkey and a supplementary type section was chosen in Iraq at Dohuk [5]. It shows a great deal of lateral variation and it interdegitate and passes laterally westwards and southwestwards (basin wards) into lagoonal limestones and marls [9,5]. Northeastwards the formation wedges out against the landmass, but these limits of the formation are now hidden beneath large overthrust sheets. Gercus Formation, thus, also shows great variations in thickness from one place to another but at its supplementary type section in Duhok area reaching up to about 850 m [according 5] and 480 m [according 1]. This paper aims to discuss and interpret new evidences of sedimentary structures with detailed petrographic investigation to define a new hypothesis for depositional model of the Gercus Formation.

Field and lab methodology

For the investigation in this study, clear out cropped section in Chenarook lies at NE limb of Jabal Hiabat Sultan Mountain was chosen. The section lying along the main trough axis of the Paleogene foreland basin, are exposed in the Erbil district in NE Iraq. Examinations were carried out for investigation on lithology, petrography and sedimentary structures. Photographic documentation was enforced for the whole stratigraphic section, for lithologies and sedimentary structures. [33] Rock samples were collected from the studied section and thin-sections [perpendicular to the bedding plane] were prepared according to the procedure explained in Tucker [11]. To define the specific mineralogy and lithology, microphotographs were picking up for different mineralogical constituents.

Stratigraphic description of the studied section

Location: The studied section of Gercus Formation lies above Chenarook village, in NE side of Haibat Sultan Mountain were sampled and discussed figure-1.

Formation boundaries: Gradational lower and upper boundaries of Gercus formation were identified with underlying Kolosh and overlying Pila Spi formations. The lower boundary with the underlying Kolosh Formation, is separated by well marked successive pebbly sandstones and marls, which grades upwards to siltstone and shale beds, in fining upwards cycles. The sequence reveals 20 m thick of gradual color change from olive green beds (of the Kolosh Formation) below, to grey, yellowish grades to brownish beds above. This criterion was observed by [5], 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 and disturbed carbonate debris flow bed, which composed of various sizes of carbonate pieces support with marly materials. Debris flow bed is laterally grades to marl rich in mud clasts of underlying beds, and later to marl. It is grade upwards to limestone of Pila Spi Formation. The previous workers referred to conglomerate bed, which was not found in Chenarook in this study.

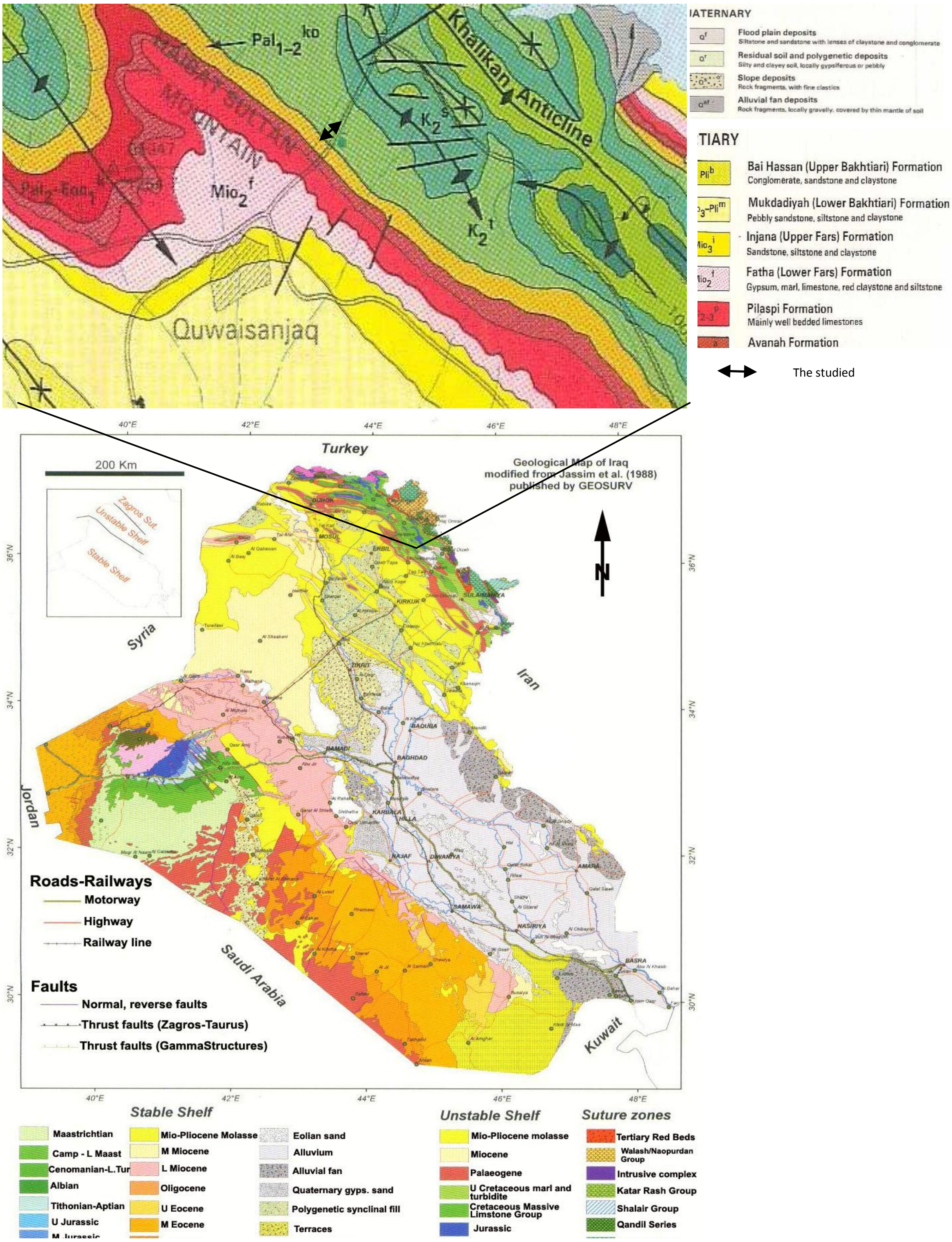

Figure 1- General geological map of Iraq shows the geological map of the studied area in Haibat Sultan Mountain, NE of Koisanjak city, NE Iraq. Arrows refer to the studied section [after 10].

Thickness: The determined thickness of Gercus Formation in the studied section reaches about 205 m figure-2. It is important to say that the thickness of Gercus Formation varies from location to another. It reaches about 90-100 m in Derbandikhan area [SE Sulimaniya] and about 800 m in Dohuk area north Iraq [2].

New Sedimentological Aspects

Lithology

The stratigraphic log of Gercus Formation is shown in figure-2, which composed basically of clastic rock units of sandstone, siltstone, shale and claystone cyclothems, arranged in fining upwards turbidity cycles. The surface between each Bouma cycles is sharp, irregular and attains load and flute casts. Subordinate rock units of limestone, marl and few conglomerate beds are interbedded with turbidity cycles in a mixed siliciclastic-carbonate successions, which was identified in the whole section of the formation. Sandstones are grading upwards to silty claystone/shale in fining upwards cycles. It consists of about 60% shales, claystones and siltstones, 20% sandstones, 10% carbonate, 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 10 m. Two distinctive irregular black shale beds were identified in the upper part of the formation, which attains 0.3 to 0.5 m thick. The sandstone beds are of 1 to 2 m in thickness, reddish to gray in color. The marl is of yellowish white color and ranges in thickness form 0.5 to 2 m. It was recognized in the lower most and upper most parts of the formation. While the limestone beds are white to dark grey in color and attains 0.1 to 1m and less more in thickness. The debris flow and conglomerate beds attains thicknesses of 1 to 2.5 m. The conglomerate contains small pebbles, lens like, wedging out laterally and recognized in a sub-aquatic channel.

Sedimentary structures

Characteristic varieties of sedimentary structures were identified in the stratigraphic section of Gercus Formation. These are, graded beddings, cross stratifications, slump deformed beds, load and flute casts, clay and sand balls and pillows, subaquatic channels, collapse channel levees, longitudinal ripple marks and burrows. These varieties are typical structures of turbidity current and gravity flow regime, which are classified and described according to Bouma [12,13]; Selley [14], Reineck & Singh [15] Collinson & Thompson [16], Walker & James [17] and Stow [18] and are discussed below;

Graded beddings, are the most common structure identified in Gercus Formation [pl/1.a]. It comprises characteristic structure of the Bouma cycles. In part of the sequence, all subdivisions of the turbidity cycle [Ta, Tb, Tc, Td, Te] were present and in the other part some of these subdivisions [Tc, Td and Te] were identified. Few debris flow and conglomerate beds are recognized in the lower limit of the graded cycles. while the pebbly sandstone grades upwards to fine-argillaceous siltstone and thick fissile shale/claystone beds.

Planner and cross stratifications. Planner stratifications were identified in the subdivision [Tc] of the sandstone beds in the turbidity cycles [pl/1.b], which is overlain with cross stratifications. Several types of cross laminations were recognized in the sandstones the most characteristic is the normal, and tabular stratification. Each bed set of cross stratification attains 0.1 to 0.2 m thick.

Slump deformed sandstone beds, Slump deformed bed and/or group of beds implying a little less internal deformation of coherently deformed beds to totally distorted strata [17]. Thicknesses range from 0.5 to 2 m. The distinct slump beds reveal convolute folding and flowage in the bed shape, which refers to turbidity environmental significance [pl/1.c].

Slump convolute-folded beds, contains few beds of thin interbedded sandstone and mudstones characterized by many subtle soft-sediment convolute-folds and deposited in slope-apron into the basin [pl/1.d]. Slump-folded turbidite succession may shows internal dislocated thrust, due to turbidity currents.

Ball and pillow structures, of sand and clay lithologies reveals balls and pillows and present in random distribution in the beds due to the slump of semi-coherent sediments [pl/1.e]. The structure was recognized in the sandstone and in fine-argillaceous beds.

Load, and gutter casts, are erosional characteristic structures of the turbidity current [pl/1.e]. It was identified at the upper surface of the fine-argillaceous beds.

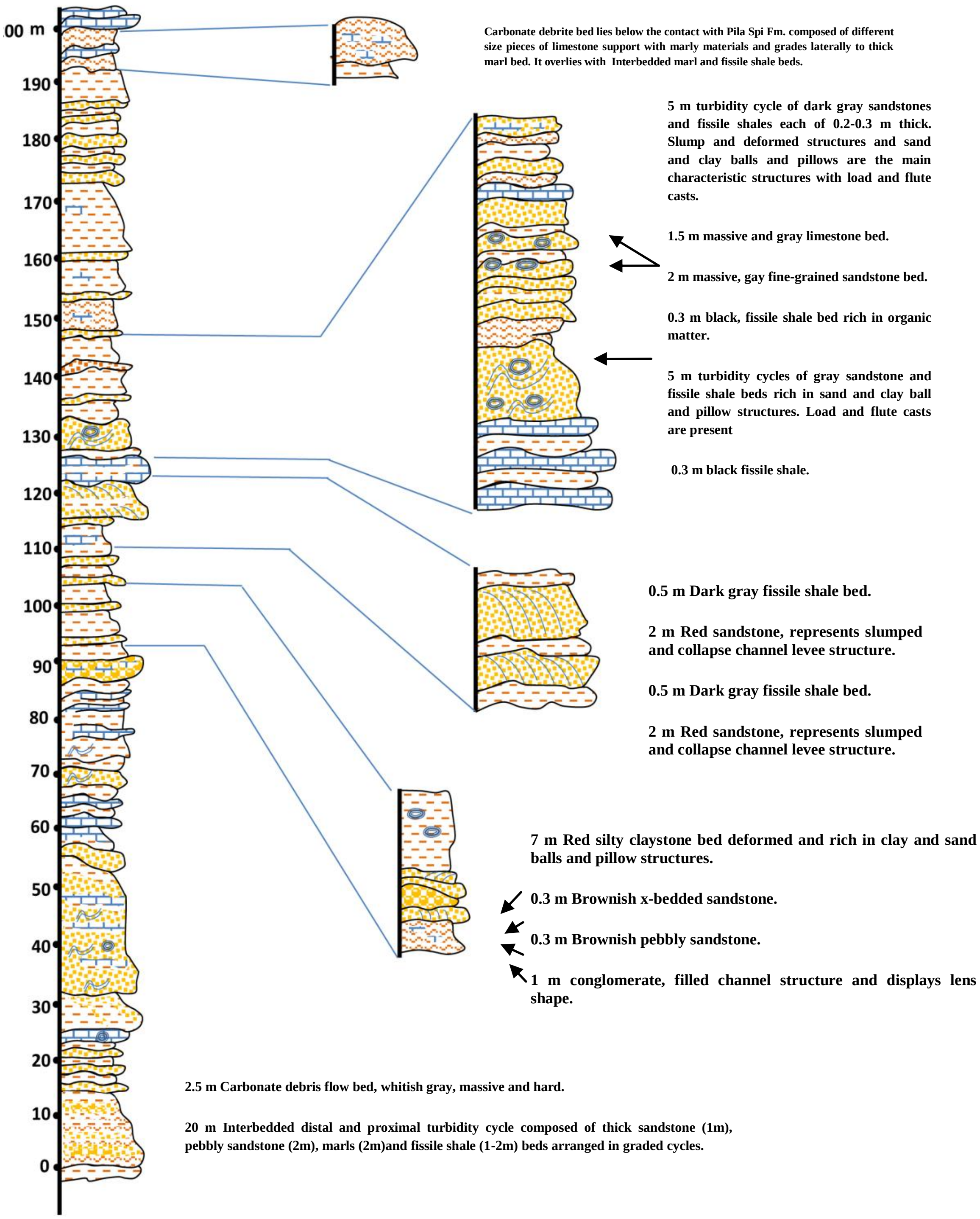

Figure 2- The stratigraphic column of the Gercus Formation show details of the characteristic lithologies and sedimentary structures.

Submarine channels, are characteristic structure of the high energy gravity flow and turbidity currents, which leads to form submarine channels and outwash fans [pl/1.f]. Small and large size channels were recognized in the lower and middle and upper parts of the formation, filled with sandstones. On the small channels was identified filled with conglomerate. The submarine channels are commonly associated with graded beddings, load and gutter casts, and slump deformations

Slump thin-bedded sandstones, are identified as sets of thin-bedded sandstones, which were identified as tilted successions interbedded with slump deformed sandstone beds and were originally deposited on submarine channel levees. The collapse of the levees lead to slump the coherent sets of thin beds on a slope to the basin, which considered the characteristic structure of turbidity currents [pl/2.a].

Flute casts, Flutes are heel-shaped hollows, scoured into mud bottoms, each hollows is generally infilled by sand, contiguous with the overlying bed. It was identified in the upper surface of dark gray shale bed from the upper part of the formation [pl/2.b].

Ripple marks, are identified in the upper surface of the sandstone horizons and almost of longitudinal type [pl/2.c]. The wavy type is of small scale.

Biogenic structures, represented by varieties of burrows and animals activity in the sandstones horizons and in the surface contact with fine-argillaceous sediment e.g., siltstone and mudstones. Large and small burrows were recognized as well [pl/2.d].

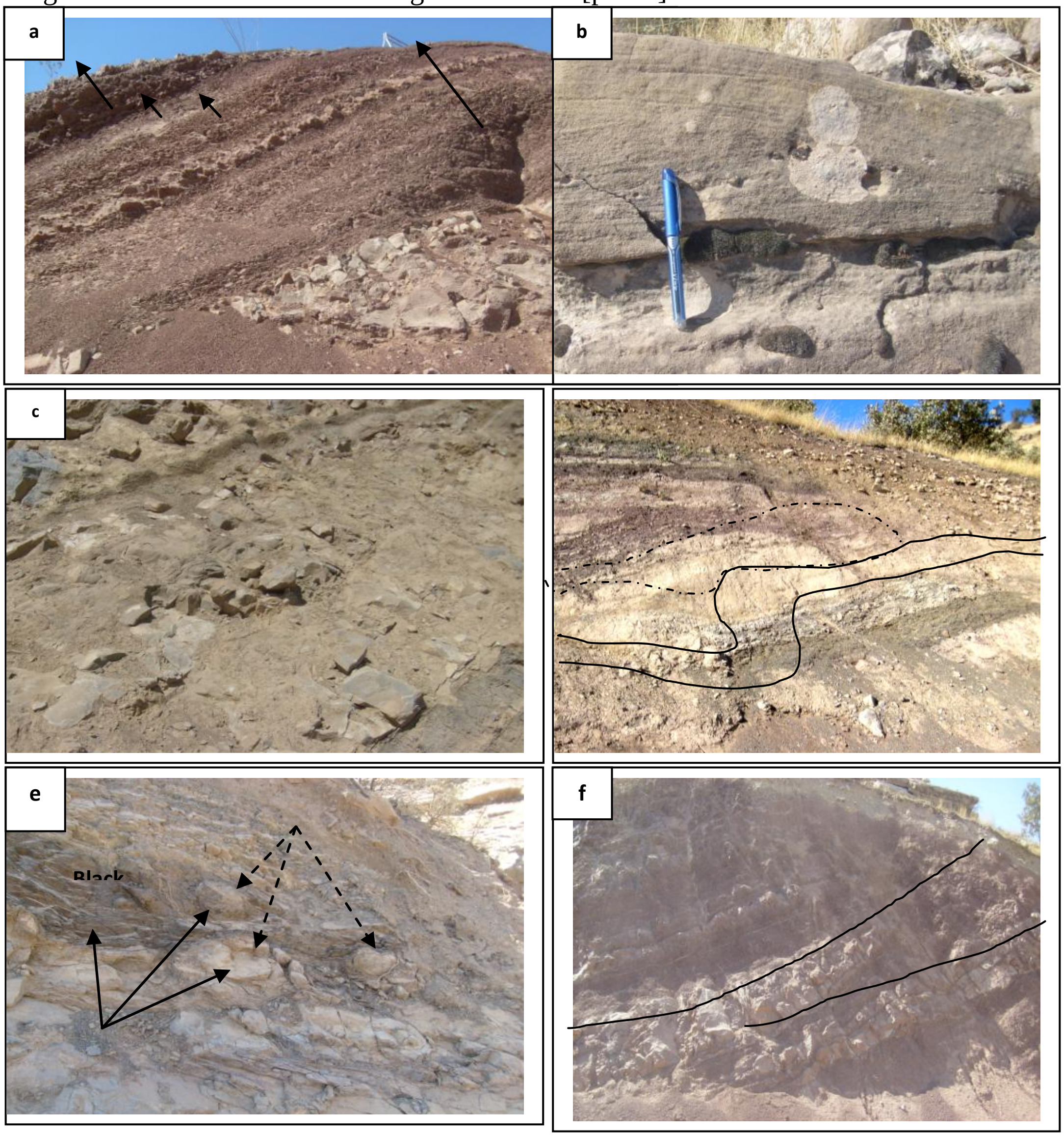

Plate 1- Field photographs show identified varieties of sedimentary structures in the Gercus Formation, **[a]** graded beddings sows fining upwards sandstones siltstone and mudstones identified in the upper part, **[b]** cross-stratifications in sandstone horizon identified in the middle part, **[c]** slump deformed thick distorted sandstone bed identified in the lower part, **[d]** slump convolute-fold deformed beds of sandstones and mudstones interbeds (sold arrows refers to the slump convolute-fold, and the dash line refers to the deformation in the thickness of the beds), **[e]** sand and clay ball and pillows [dash arrows] associated with load and gutter casts, identified in the upper part, **[f]**

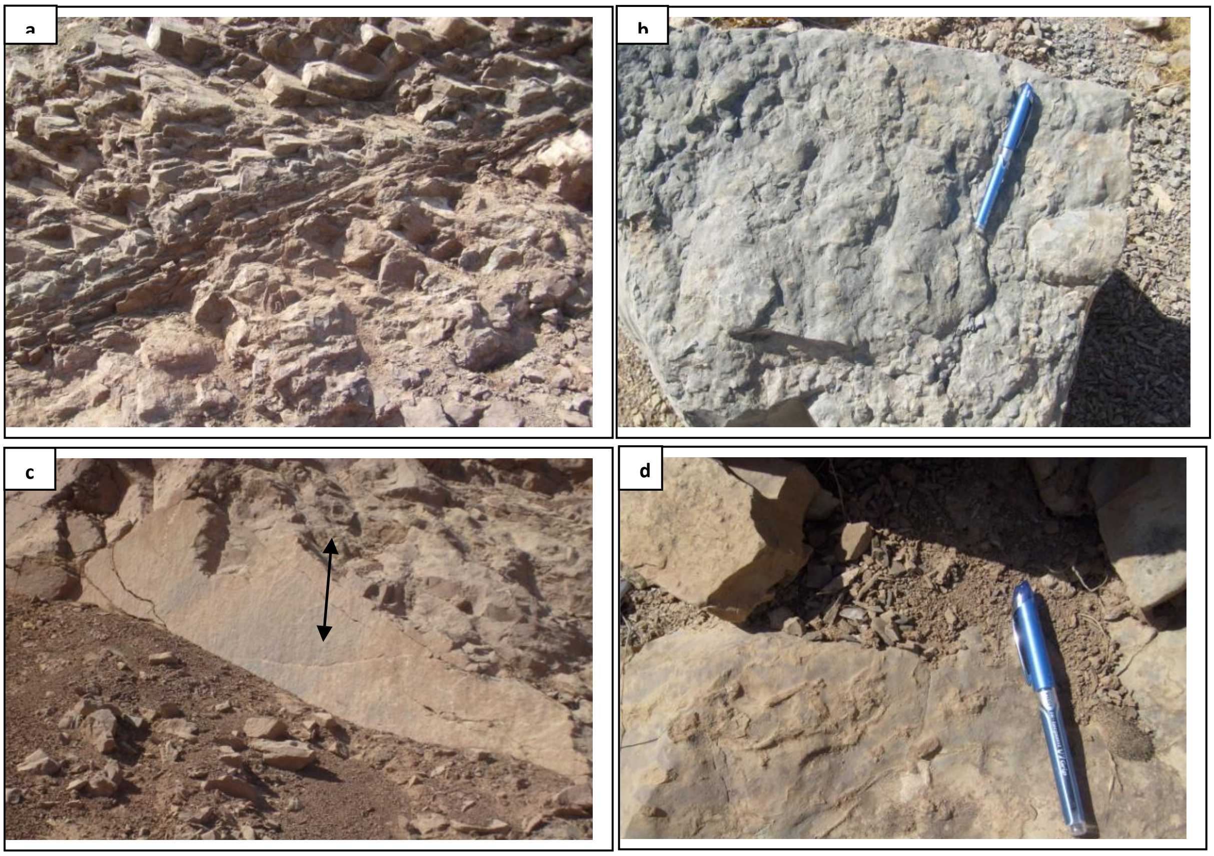

Plate 2. Field photographs show identified varieties of sedimentary structures in the Gercus Formation; **[a]** Slump thin-bedded sandstone bed sets interbedded with slump disturbed sandstone beds, which was identified in the middle part, **[b]** flute casts identified in the upper surface of gray shale in the upper part, **[c]** longitudinal ripple marks identified in the upper surface of fine-grained sandstone in the middle part [arrow refers to the elongation of the ripples] **[d]** biogenic structures- burrows identified in the upper surface of red sandstone bed in the middle part of the formation.[pencil=10cm].

Environmental evidences of sedimentary structures

The identified varieties of sedimentary structures confirms the sedimentation in turbidity and gravity flow regime. Characteristic sedimentary structures of turbidity origin are distributed in the stratigraphic section, and their environmental indication are discussed.

Graded beddings and associated sedimentary structures support the idea of turbidity origin [14-19]. The cyclic repetition of pebbly sandstone and/or sandstones, planner/cross bedded sandstone, siltstone and shale/claystone represents the ideal Bouma cycle deposited under the influence of turbidity currents. The thicknesses of each of sandstone and shale/claystone beds in the turbidity cycles refers to the proximal and distal turbidites [14,15,19]. Furthermore, these currents lead to form several associated structures as a direct influence. The load, gutter and flute casts were identified on the upper surfaces of shale and mudstone beds at the contact with the overlying sandstone beds are characteristics of turbidity currents as well as sand and clay balls and pillow structures. These structures are associated with slumping deformed beds and submarine channels. Moreover, collapse of thin sandstone bed sets identified here as channel levee and identified in the middle unit of the formation. It is most probably originated by successive pushing up of strong turbidity currents in the same submarine channels. The slump convolute-folded thin beds of sandstones/mudstones couplets are originated as a direct influence of the pushing force of the turbidity currents. Distortion and deformation of thick sandstone beds, both in internal habit as well as thicknesses reveal strong evidence of turbidity current influence.

The overall examined sedimentary structures indicate that the sandstones were deposited under the influence of turbidity currents and gravity flow regime, which create sets of submarine channel complexes that fed a mud-dominated slope. The more proximal facies in these subaquatic channels have high proportion of pebbly sandstones, and thick-bedded structureless sandstones, deposited under the action of high-density turbidity currents, debris flows and slumps. The thickness of sandstone and shale/claystone beds refer to the proximal and distal turbidites in the succession. The massive sands are thought to originate from the gradual aggradation of sediment beneath steady or near-steady flows of turbidity currents, with rapid deposition from final-stage modified grain flows [14-19].

Petrography.

According to the classification of Mcbride [20] and Pettijohn [21] the sandy beds are basically classified as lithic arenite. In several samples from the sandstones, the matrix content is very low and less than 2%, considering the total chert [5-20%] and the total carbonate lithic fragments [50-65%]. The main cementing materials are carbonates, with subordinate ferruginous cement [pl/3].

For the first time, noticeable glauconite grains and pellets were identified in many of sandstone horizons, [pl/3.b,c]. The glauconite contents is less than 1%. 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, oolites and/or dolomite. The limestone with terrigenous elements contain carbonate bioclasts as shells and foraminifer fragments supported with carbonate mud [pl/3,d,e] [22,23]. The terrigenous elements do not exceed 10%, and represented by rare quartz, metamorphic fragments such as "green clasts" as well as sedimentary lithoclasts as fragments of carbonates and chert. The marl beds consisting of carbonate, clays and subordinate terrigenous fragments e.g. chert, lithic carbonates, iron oxides and rare detrital quartz.

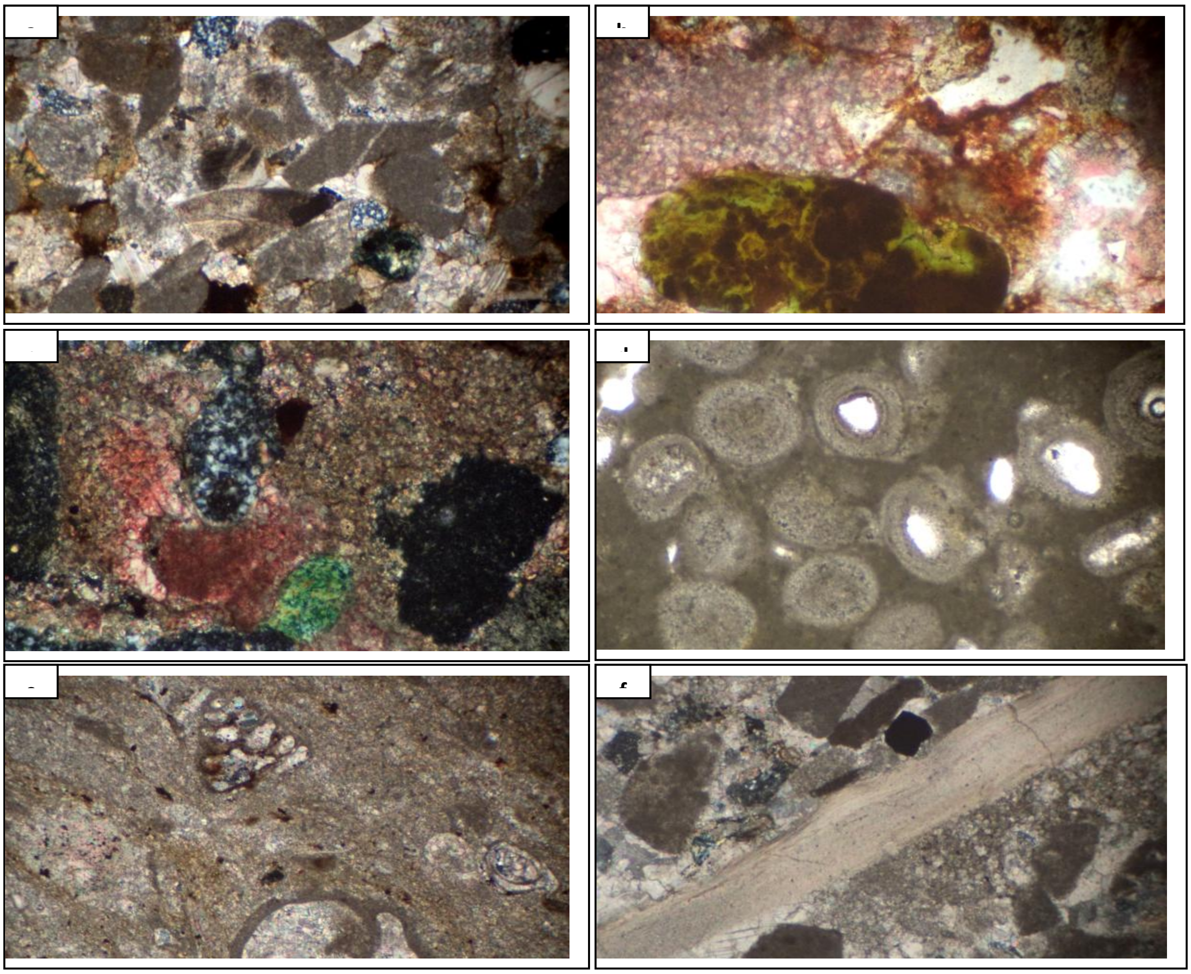

Plate 3. Photomicrographs show the mineralogical composition of the Gercus Formation; **[a]** general composition of the sandstones show the majority of carbonate and chert lithic fragments, which is support with carbonate and ferruginous cement [X 40CN],**[b]** glauconite grain identified in sandstone of sample [G-5] from the lower part [X 100PP], **(c)** glauconite grain identified in sandstone of sample [G-22] from the middle part [X 40CN], **[d]** oolitic limestone identified in a thick carbonate bed from the middle part [X 40PP], [e] fossiliferous limestone identified in thin carbonate bed from the upper part [X 40CN], **[f]** lithic and fossils shell fragments identified in sandstone bed from the upper part of the formation [X 40CN].

Paleo-environmental interpretation

The arrangement of Bouma turbidites, which are represented by lens like pebbly sandstones, fine-grained sandstones and fissile shale/mudstones lithotypes in a fining upward cycles. These are associated with deformed slump beds as reported in all of litho units in the studied section, and confirms developed marine environment.

Proximal marine turbidite deposits preserved between the underlying gradational surface with the underlying Kolosh Formation and the overlying marine turbidites of the lower part of Formation [24,25,26,19,17]. 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 few conglomerates and pebbly sandstones, and is locally preserved on the original bounding surface or in submarine channels [19,17,27,28]. The subaqueous streams originate from annual turbidity currents, which are most probable originated due to tectonic events. This interpretation based on the presence of rough cross-stratifications, pebble imbrications, pebble shape and the limited lateral extent of the identified conglomerate bed. It could be interpreted as submarine gravity flows originated by active turbidity currents [29-32,26,19,17]. Moreover, Gercus Basin [Tethys Sea] comprises a trough foreland basin lies in active subduction zone of Zagros belt [2,4]. The rock successions display analogies with the Bouma turbidity sequences as evidenced by:

[i] Repetition of fining upward successions e.g. graded beddings, [ii] Upward succession of pebbly sandstone and massive, parallel laminated, rippled sandstones grades to thick shale and mudstone bed, [iii] Good lateral extension and [iv] Presence of types of sedimentary structures of turbidity origin e.g. slump and slide beds, disturbed deformed beds, load and flute cats, graded beddings, sand and balls…etc. The occurrence of gravity flows comprise continuous sedimentation of 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 margin fan models in great deal of literatures [13,17,19,27,31-38]. Turbidites have also been reported in shallow marine environments [39-41]. Mud flows and high to low density currents have been extensively described in recent papers, either in ancient or modern sequences [31,42-49]

Furthermore, some authors have stressed the role of turbidity currents in the formation of rhythmites questioning the annual significance of varve [very fine sandstones and/or siltstone/mudstone couplets] [50-57]. 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 sequences are related to sediment gravity flows, the following high density current process could be envisaged according to the terminology of Lowe [37]. The sequences range from coarse to gravelly fully turbulent flow [horizon 1-2 pebbly sandstone / division Ta & Tb in BOUMA cycles], to a more dilute and laminar sandy flow (horizon 3 & 4-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 [horizon 5-fissile shale and laminated siltstone-shale / division Te] represents the final suspension load of turbidity currents [19,17,27]. 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 [58,37]. Depressive pressure remained active in the overlying laminated sandstones of horizon 3 [Tc-division]. However, as emphasized by [49] realistic interpretations of conglomerate genesis must be preliminary based on lithofacies relationships and sequence context. The intercalation of a meter thick tabular and lens like conglomerate body within undeformed turbidity sequence confirms debris flow in which clasts were supported by strength and buoyancy of sand-clay water fluid. Otherwise, the generated successions by gravity flow processes are supported by the following arguments:

[i] The laterally continuous aspect of the sequences, [ii] The consistent development of internal divisions conforming more or less to the Bouma sequences, [iii] The absence of angular cross-beddings, [iv] The repetitive aspect of the sequences without fair weather deposition intercalations.

The sediment gravity flows may represent the fore slope deposition of subaqueous fan fed by turbidity current streams. The repetitive sequences reflect the episodic pulses of dense sediment laden turbidity currents swept down the fan and most probably represent “turbidites”. The presences of the surface on lapped by thick conglomerate bed, which is interpreted as the start of another submarine fan deposits.

They have neither been studied and nor referred in the Koisanjak district 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 in the turbidity sequences includes this bed [planar laminations, faint hummocky cross stratification], which are characteristics of a shallow water high energy environment.

Discussion

Gercus Fm. is exposed in a narrow belt in the unstable high folded zone of N and NE of Iraq, have thickness of about 200 m in the studied section in Chenarook/Erbil district. The study proves new stratigraphic aspects based on sedimentological evidences, which are not discussed and reported by the previous workers. These are;

- This study newly report that Gercus Formation was deposited in marine environment. One of important evidences is the presence of glauconite grains in some sandstone beds [23,59-63].
- The identified limestone [includes marine fauna] and the marl beds, which are interbedded with the turbidity Bouma cycles in the formation refers to marine environment and reject the idea of fluvial environment.
- The study presents that Gercus Formation composed essentially of cyclic repetitions of turbidity Bouma cycles, which is strong evidences of marine environment.
- Gercus Formation reveals conformable contact with the lower Kolosh [flysch-turbidites] Formation. This is evident from the gradation and transition in lithology and color form the underlying dark green and gray sediments, changed upwards to pale green to gray and later to drab in color. The cycles of turbidites still continuous in the all successions in the Gercus Formation.

Moreover, Gercus Formation displays gradational boundary with the overlying Pila Spi Formation. The boundary is grading from red claystone to marl and marly limestone with calcareous debrites. The debrites bed extends for 2 to 3 m and is laterally changes to marl, which is grading upwards to limestone rocks. The previous workers pointed that the debrite bed is a basal conglomerate between the Gercus and Pila Spi Formations.

- Gercus Formation displays varieties of sedimentary structures, interpreted here of turbidity current and gravity flow origin. These varieties include, sand and clay balls and pillows, load, flute and gutter casts, graded beddings, laminar stratifications, disturbed deformed beddings, slump beds…etc
- The studied limestone beds, is suggested belongs to Gercus Formation and not belongs the Khurmala Formation tongue as reported previously. Moreover, the limestone beds of the Formation is of little thickness, ranges between 0.1 to 1 m. While the Khurmala tongue was reported of about 20 m thick in the adjacent area. Furthermore, the limestone beds were identified in the all successions in the formation.
- The age of the Khurmala Formation is Paleocene while Gercus Formation is Middle to Late Eocene. Who can the tongue of the Paleocene comes within the Middle-Late Eocene.
- The presence of submarine channels associated with debrites and conglomerates refer to the deposition in the mouth of the channels in submarine fans.
- Further, north toward 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 stratigraphy and the sedimentological characters of Gercus Formation suggest new interesting marine evidences. The Cretaceous-Paleocene-Eocene successions in the Tethys represents continuous sedimentation in deeper marine margins under the effect of turbidity currents. In NE Iraq, the proximal NE part of the Late Cretaceous foredeep basin was uplifted in Paleocene-Oligocene time. A NW-SE trending basin, was continued to the SW Turkey in where up to 2000 m of sediments was deposited. Continuous uplift of the thrust sheets that had been emplaced in NE Iraq lead 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).

Two ideas were suggested in this study;

Firstly, the study suggests that Gercus Formation was deposited in marine environment in relatively deeper margins and the closure of the foreland basin was carried out in a later stage after the deposition of the Gercus Formation.

The second is Gercus Formation confirms continuous deposition of Kolosh Formation in the same margins but in an oxic/anoxic environment. These are evident from the presence of alternative red and dark gray successions in the sequence. This result needs more detailed studies to define the origin of the red color in the deeper margins as well as the presence of two black shale horizons in the dark gray successions of the formation.

Conclusion

Gercus Formation is cropping out in a narrow belt of the high folded belts in N Iraq. It is stratigraphically distributed from NE to NW margins and encountered in several oil wells in the oil fields of N Iraq. The formation is mainly composed of lithic arenite sandstone of red, green, gray and yellowish in color. The Gercus successions represent cyclic repetitions of turbidity Bouma cycles and gravity flow sedimentation. The turbidites cycles composed of pebbly sandstones graded upwards to planner stratified sandstones, cross-bedded sandstones, siltstones and fissile shales or claystone beds. The graded successions reveals varieties of turbidity sedimentary structures, these are; slump and deformed disturbed beds, sand and clay balls and pillows in sandstone and claystone beds, convolute beddings, gutter casts, flute and load casts, planner stratifications and submarine channels. The presence of glauconite pellets and grains in some of the sandstone beds support the idea of marine environment of Gercus deposits. The previous workers suggest that the carbonate beds in the lower part of the Gercus Formation represent tongues of Khurmala Formation. This suggestion mostly rejected according to the age of the Gercus and Khurmala Formations.

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