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Geology of recently recognized lithologies inside the Red Bed Series in the Chwarta-Mawat area, Kurdistan Region, NE-Iraq

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ABSTRACT

The sequence of the coastal siliciclastic facies of the Paleocene-Eocene Zagros Foreland Basin is well exposed in the Chwarta-Mawat area, north of Sulaimani Governorate, northeastern Iraq. According to previous studies, this sequence is designated as Red Beds Series (RBS), consisting of more than 2000 m of fine and coarse red and grey clastics. The present study found recently recognized lithologies (RRLs) about 100 thick inside the series and encompassed green marlstone with subsidiary detrital limestone which has significant tectonic and paleogeographic results. The petrography, biostratigraphy, and boundary conditions studies are applied to uncover their origin. The new lithologies are deposited in the subsiding basin in the Imbricate Zone during the Middle Eocene. During this age, the Tertiary Foreland Basin was separated by a paleohigh into two basins, (northern and southern basins). In the northern basin, the RRLs have deposited as deep facies of the Naopurdan Formation while in the southern basin the Pila Spi Formation was deposited as lagoonal facies. The former formation was deposited as reefal facies in the shelf area of the northern basin to the northeast Chawrta and Mawat Towns. The RRLs, units one and two of the series (in the Thrust Zone) are correlated respectively with Pila Spi, Sinjar and Gercus formations in the High Folded Zone. These correlations are shown on the stratigraphic columns and paleogeographic models with the aid of nannofossil and benthonic foraminiferal studies. This study is the most important step for solving the tectonic and paleogeographic setting of northeastern Iraq and for a better understanding of the Zagros Collisional belt.

Keywords: Red Bed Series, Coastal facies, Pila Spi Formation, Naoperdan Formation, nannofossils, Foreland Basin

1. Introduction

The Red Bed Series crops out as a narrow and long belt in extreme northeastern Iraq and consists of more than 2000 m of red claystone, sandstone, and conglomerates. The present study focused on those outcrops that are located in the north of Sulaimani city in the Sulaimaniyah Governorates in Kurdistan Region, in the High and Thrust Zones of[1] (Figure 1a) which is a part of Zagros Collisional Belt in northern Iraq and at the margin of the Zagros Suture Zone. The history and geological setting of the area are controversial in Iraq's geological literature[2, 3,4] concluded the separation of the basin of the series, inside the Imbricate Zone, by a paleohigh from the basins of the Tertiary units in the High Folded Zone[4] depicted by sketch deposition of the Red Bed Series during Paleocene and Eocene in the intermountain basin and separated by mountain ranges from the basin in which Kolosh Formation is deposited[2,5] divided the Red Bed Series (RBS) into four units while[6] divided it into six units which are alternating vertically as red claystones, conglomerates, and sandstones succession. [7]re-studied the fossil content of Qulqula Radiolarian Formation in Qandil area and proved that what is previously called "Qulqula Radiolarian Formation" is nothing except Red Bed Series. [8] studied geochemical, tectonic, and provenance aspects of the RBS and concluded derivation of its sediments from a volcanic arc. [9] concluded the resting of Red Bed Series (Suwais unit) unconformably on the Arabian foreland and structurally below the Main Zagros fault. They added that its deposition was aged b middle Oligocene (ca. 26 Ma) maximum depositional age. This age was refuted by[10] and stressed that this age is due to tectonic disturbance between Red Bed Series and underlying formations.

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[11] renamed unit one of the series, the Kolosh Formation which consists of dark grey sandstone and conglomerate with interbeds of shale and is located between the Aqra and Tanjero formations. The present study found, in the Chwarta-Mawat area and inside

the Red Beds Series, a succession of lithologies, which are abnormal and were not mentioned previously. The study introduced the new age, stratigraphy, boundary condition, and tectonics of the recently recognized succession via finding recently recognized lithologies (RRLs) for which a correlation chart and tectonic model are prepared.

1.1 Location and geomorphology

The studied area is located in the north of Sulaimani city at the south of Mawat and Chwarta towns in the High and Thrust Zones (Figure 1) and in the part of the Zagros collisional Belt that is located in Northern Iraq. In this area, the Red Bed Series' outcrops extend for about 40 km along the northern bank of the Mokaba-Gugasur stream as a narrow belt with a width of 1-3 km. We sampled two sections that hosted the best representation of the recently recognized lithologies along this belt. The first one is situated 500 m west of the Barda Pan village and 4.5 km east of Mawat town at 35º 51' 47.25" N and 45º 25' 58.61" E (Figure 2). The second section is located 900 m southeast of Shamsawa village at the northern side of the paved road between Chwarta and Mawat towns at the latitude and longitude 35º 421' 53.18" and 45º 31' 03.241" (Figure 3). The area is a large valley which can be called Mawat-Chwarta valley in which the latter stream, as a large tributary of the Lesser Zab River, flows toward the northwest which is the first watercourse that flows in this direction in Iraq. According to[15], the valley was a large lake before 50 ka (Late Pleistocene). They found about 15 m laminated white fine grain calcitic sediment with botryococcus, scattered plant debris, leaves, and pollen grains mainly of herbaceous plants.

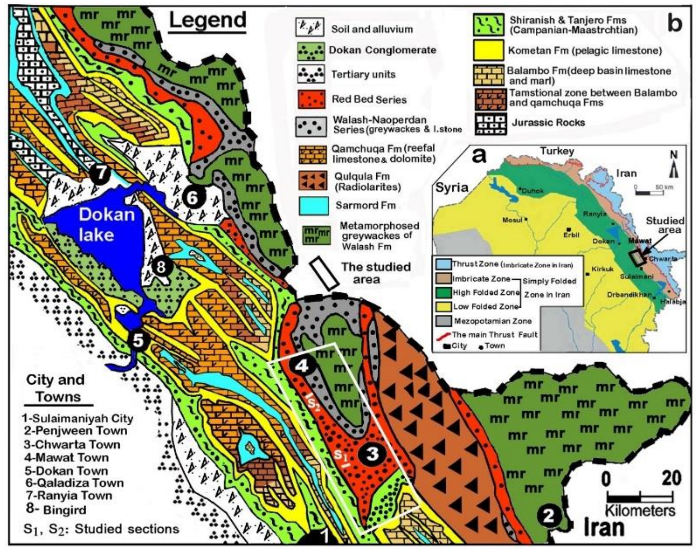

Figure 1: Tectonic classification of north Iraq[1] shows the studied area, b. A Geological map of northeastern Iraq (modified from[12, 13, 14].

Figure 2: Barda Pan section 3 km east of Mawat town which is sampled along the road between the Dashti Tle and Gabarwa villages, the letter S1-S22 are the locations of the samples.

Figure 3: Nannofossils rich marlstone interval (about 40 m thick) topped by sandy detrital limestone of RRLs at 900 m southeast of Shamsawa village between units two and three of the Red Beds Series. Sh1-Sh6 are the locations of the samples.

1.2 Geological setting of the area

According to the tectonic classification of[1], the investigated area is located inside the Imbricate Zone where the synclines and anticlines are overturned toward the southwest or reversely faulted and thrusted (Figure 1). Overturning and faulting of the folds stacked the sedimentary successions over one other and the apparent thickness of the formations doubled in many places and they mainly dip about 20-50 degrees northeastward. Due to these processes, the studied area is characterized by a complex geological setting showing highly deformed outcrops. These outcrops include all kinds of rocks such as shallow-deep carbonates (the Aqra Formation) and siliciclastic in addition to felsic and mafic (greywackes) sedimentary rocks (see[16]) with varieties of metamorphic rocks. These metamorphic rocks are exposed in the northern part of the studied area which includes different kinds of metamorphic rocks in the grade of phyllites and schists. The sedimentary rocks are exposed only in the southern part which includes the carbonates of the Early and Late Cretaceous ages in addition to turbidite and hemipelagite of the Tanjero and Shiranish formations that are exposed at the southwest of Mawat and Chwarta towns (Figure 1). In the studied area, the Aqra Formation has a reefal setting and it changes to turbidities facies towards the south where it interbedded with the upper part of the Tanjero Formation in an area around Sulaimani city and Dokan Town[17,18].

The studied area is located between two large normal faults at its southeast and northwest boundary, these faults transformed the area into a graben (Karim, 2006)[19]. The geological complication of the area is due to its location at the boundary between Thrust and Imbricated Zones of[1] (Figure 1a). The studied area was part of the continental margin of the Arabian Plate during the Jurassic and Early Cretaceous while it was transformed into the foreland basin during the Late Cretaceou[17, 14]. This transformation was due to either the ophiolite obduction[1]or to the Iranian and Arabian plate continental collision[20, 21].

The area represents the northeastern margin of the Arabian Platform where the continental collision between the Arabian and Iranian plates occurred during the Eocene[22, 23] and Early Miocene[24]. The thrust sheets of Ophiolite Complexes and Qulqula Radiolarite Formation occupied the northern part of the area[25- 29]. This tectonic feature is called Mawat Nappe by [5] who showed its thrusting over the Red Bed Series and Cretaceous rocks**.** In contrast to the Ophiolites Complex ideas of the previous authors such as[29, 30] changed the area to the metamorphic core complex of a sedimentary origin.

2. Material and Methods

The main used materials of the study is a recently recognized marl and detrital limestone beds inside the Red Beds Series in the Mawat -Chwarta area for the first time in what was previously called Red Bed Series. Two sections (Barda Pan and Shamsawa) are found and selected in the field and sampled for investigation. A total of 36 samples are collected from the two sections for petrographic studies and nannofossil-benthonic foraminifera aging. Twelve thin sections are prepared from the detrital limestones in the laboratory of the Department of Geology, University of Sulaimani. The thin sections are studied under petrographic microscopes and stereoscopic microscopes. The percentage of the allochems is estimated using the chart of[31]. Eighteen samples of the marl are collected for identification of nannofossils by the standard simple smear slide. The nannofossils are extracted using the method of the authors[32] and identified by the nannofossil experts at the University of Mosul (Dr Omer Badrani and Sulaimani (Dr. Soran Othman) for age determinations.

3. Results

3.1 Exterior and interior boundary conditions of the recently discovered succession

3.1.1 Exterior boundary condition of the Red Beds Series (RBS)

[2, 33]first described this series on the Qandil Mountain, and according to[5], it consists, in the study area, of a thick succession of sandstone, conglomerate, and red claystone (Figure 4). The RBS overlies either on the Kolosh Formation or the Tanjero Formation and its upper boundary is erosional or tectonic, while the lower boundary gradation with the latter two formations in some places while in others unconformable[34]. Recently[11] found the Kolosh Formation in the Chwarta-Mawat area between the Aqra Formation and Red Bed Series. In this area, the thickness of the Kolosh Formation is about 100 m and is comprised mainly of dark grey sandstones and conglomerates with interbeds of black shales. The crytalloclasts (partially and mechanically wearied crystals by reworking) of igneous minerals such as pyroxene, hornblende, plagioclase, and olivine in addition to lithoclasts of metamorphic rocks are the main constituents of the rocks of the formation

[6]divided the RBS at the Chwarta area into six units and referred to the equivalence of the lower three units and upper ones to the Kolosh (Paleocene) and Gercus formations in time and basin occupation. Nearly all sandstones and conglomerate clasts of the lower and upper parts of RBS consist of chert and limestone terrigenous detritus. While the upper part (unit five of [6] and unit three of[5] involves, in addition to the mentioned two clasts, igneous and metamorphic ones. Below the unit of latter author three, an unusual succession of marl and detrital limestone (called RRLs in the present study) occurs with two beds of pebbly calcareous sandstone (Figure 5). These lithologies are relatively soft, therefore, intensely deformed and most of its outcrops are covered by soil leading to spotty exposures.

Figure 4: Middle part of (sandstone and conglomerate unit) of RBS at 3 km southwest of Qalachwalan village which stratigraphically equivalent to the Gercus Formation in high Folded Zone. The photo shows the succession of sandstone beds near Shakhasur mountain.

3.1.2 Interior conditions (properties) of RRLs

The RRLs contain plentiful abiogenic and biogenic components that are described in the below subsections

Non-biologic components (litholoclasts)

The RRLs, in the Barda Pan section, are comprised, of a thick succession of well-bedded detrital limestone and massive green marl. The limestone beds and marl build up about 20 and 80 percent of the succession. The detrital limestone beds are well-sorted and comprised of packstone-grainstone and upward changes to fine-grained wackestone. There is a bed of pebbly detrital limestone (conglomerate) in the middle part and another one of coralline limestone in the middle part (Figures 5 b, c, and 6).

The detrital limestone contains some siliciclastic clasts of igneous and metamorphic rocks, mostly subangular quartz crystalloclast. The pebbly limestone consists mainly of sand-size detrital limestone with a few rounded pebbles of limestone, igneous and metamorphic rocks. Therefore, the detrital limestone can be called sandy detrital limestone (Figure7). The percentage of the siliciclastic clasts is not more than 15% and the share of quartz, feldspar, volcanic fragments, and metamorphic clasts are 9, 4, 2, and 1% respectively. The beds of the RRLs dip nearly 70 degrees toward the northeast and their total thickness is 120 m (Figures 5a and 2).

The Shamsawa section is slightly different from the previous section since the sandy detrital limestone succession has a lesser thickness and is finer in grain sizes. The beds are thin and dipping 30 degrees toward the northeast and most of the green marl is covered by soil. These two sections are located in the same stratigraphic position and, in the field, they can be connected along the strike. they contain nearly the same nannofossils

Figure 5: a. Sandy detrital limestone in the middle part of the RRLs which is photographed from the Parda Pan village shows the locations of samples, **b.** the conglomerate bed and its white and dark pebbles are limestone and igneous rocks, c: coral bearing limestone.

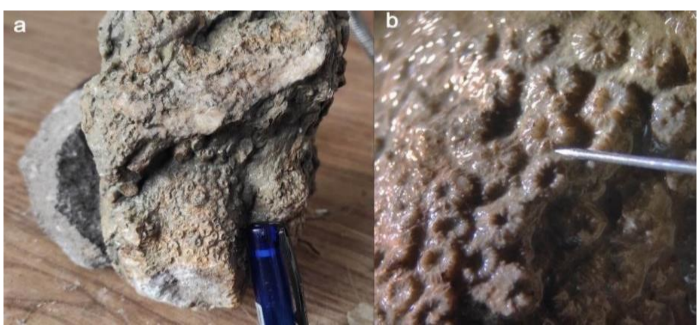

Figure 6: coralline limestone in the middle part of the RRLs of Red Bed Series at the base of detrital limestone, **a.** hand specimen, **b.** a close-up image of the part of the specimen.

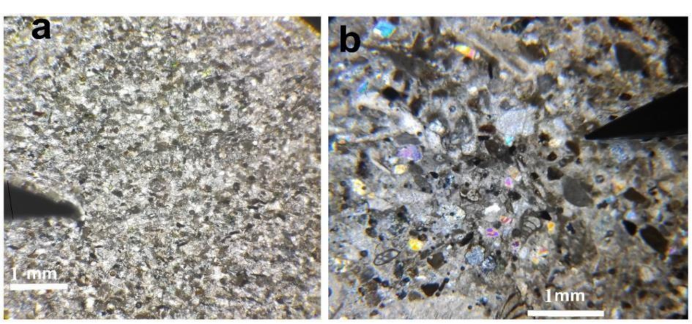

Figure 7: sandy detrital limestone (packstone), mainly consists of limestone clasts with subsidiary quartz grains **a.** under normal light, **b.** under crossed polarized light s.n.12.

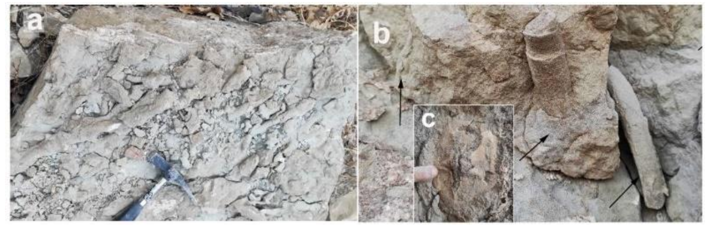

Figure 8: trace fossils (Thalassinoides) in the sandy detrital limestone Parda Pan section, **a.** horizontal traces, **b.** vertical trace, c: echinoderm body fossils, all located at the middle part of the section near s.n.14 (see figure 2).

Biologic components of the RRLs

Although the RRLS contains two beds of coralline limestone in the middle part of the section, the first one is made up of pure limestone of coralline limestone, and the second one consists of fragmented (detrital) coral debris in the middle part of this section. They also contain a variety of fossils and their traces. The first bed is comprised of a massive colony inside the marl and the second is located 2 m above the second bed and consists of fragments of branching coral (Acropora) (Figures 5c and 6).

In addition to coral, the detrital limestone is rich in pelecypod, and their thalassinoides trace fossils which include horizontal, inclined, and vertical forms in the size of 2-5 cm in diameter (Figure 8). Moreover, the middle part of the detrital limestone contains plant debris and echinoderm shells at a size of a chicken egg (Figure 8c). The detrital limestone of the Shamsawa section is barren of the above biologic components due to its possible deepness and most of its parts are covered by soil while green marl is very rich in nannofossils. Some beds of the Parda Pan detrital limestone are rich in Heterostegina benthonic foraminiferas such *as Operculina hardei*, *Operculina gomezi*, *Assilina schwargeri-Alpina* (Figure 9) which indicate the Upper Eocene age of deposition of the middle part of the RRLs.

Most of the thickness of the RRLs of the Red Bed Series in the Shmasawa section consists of pure and silty-sandy marl which contains nannofossils such *Ericsonia formosa* (Kamptner, 1963[35], Haq, 1971[36]), *Coccolithus pelagicus* (Wallich, 1877[37], Schiller, 1930[38]), *Discoaster sublodoensis*[39], *Discoaster lodoensis*[40,41], *Blackites inflatus*[39], Discoaster deflandrei[40], *Toweius callosus*[42], *Dictyococcites scrippsae*[43], *Reticulofenestra dictyoda*[44], *Sphenolithus spiniger*[45], *Sphenolithus editus* [40, 46], *Helicosphaera compacta* , *Discoaster mirus*), These fossils indicate the Middle Eocene (Lutetian) age (Figure 10).

The marl in the Shamsawa section contains nannofossils same as the nannofossils of Bard Pan section such as *Reticulofenestra dictyoda*, *Sphenolithus orphanknollensis*, *Reticulofenestra minuta* (Figure11), which indicate the Middle Eocene age.

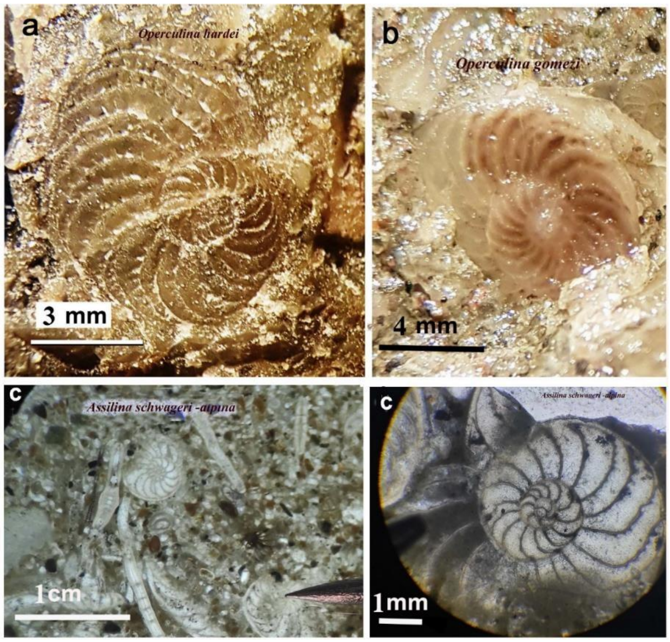

Figure 9: benthonic foraminifera species of the Upper Eocene in the detrital sandy limestone
succession, **a.** *Operculina hardei*, **b.** *Operculina gomezi,* **c.** *Assilina schwargeri-alpina.*

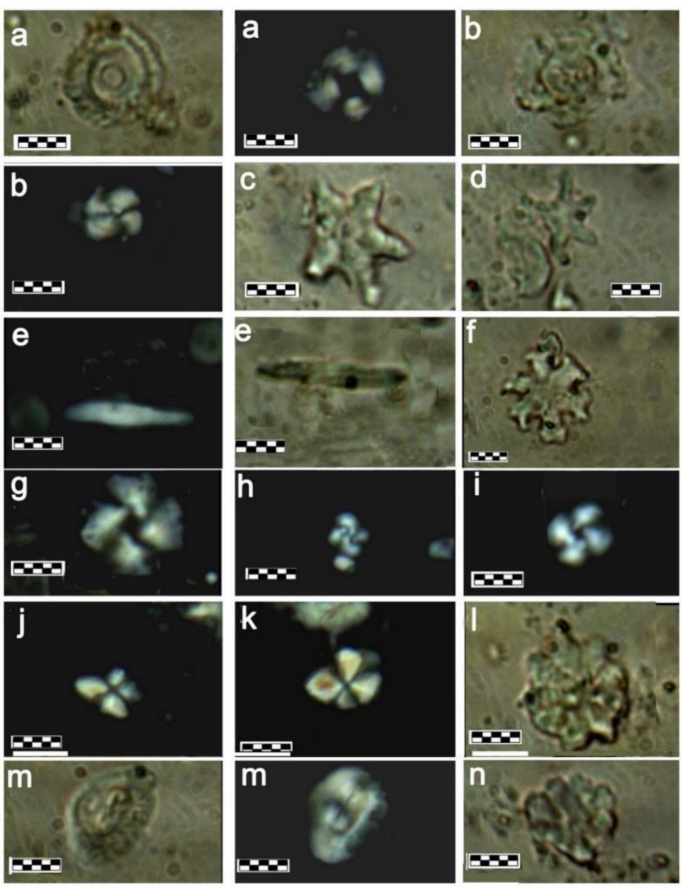

Figure 10: Nannofossils of the Barda Pan section, indicate the Middle Eocene (Lutetian), **a.** *Ericsonia formosa*, s. n. R9, **b.** *Coccolithus pelagicus*, s. n. R9, **c.** *Discoaster sublodoensis* S.N.R9, **d.** Discoaster lodoensis, S. n. R2, **e.** *Blackites inflatus* s. n. R2, **f.** Discoaster deflandrei, s. n. R9, **g.** *Toweius callosus*, s.n.R2, **h**. *Dictyococcites scrippsae*, s.n.R1, **i.** *Reticulofenestra dictyoda*, s.n.R1, **j.** *Sphenolithus spiniger* , s. n. R2, **k.** and l) *Sphenolithus editus*, s.n.R2, **l.** *and* s.n.R9, **m.** *Helicosphaera compacta*, s.n.R9, **n.** *Discoaster mirus*, s.n. R9. The bar is 5 microns, the photos with dark and light backgrounds are under ppl and normal lights respectively.

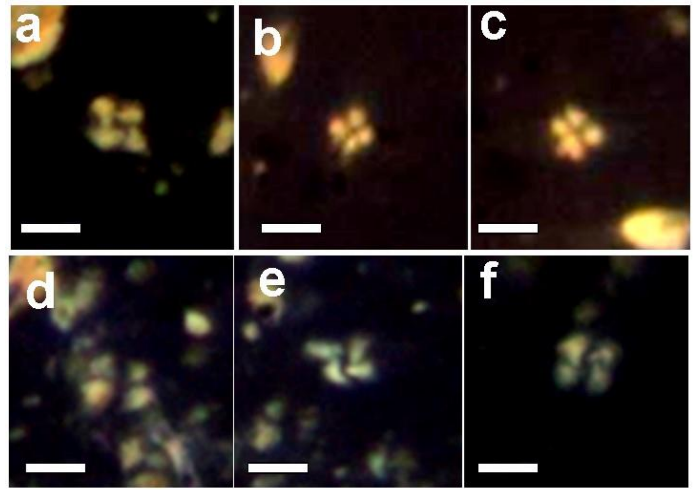

Figure 11: Extraction of index Nannofossils from marlstone of the Shamsawa section. These fossils indicate the Middle Eocene age, **a.** *Reticulofenestra dictyoda*, s. no. Sh3, **b, c.** *Sphenolithus orphanknollensis*, s.no. Sh4, **d, f.** *Reticulofenestra minuta,* s.no. Sh2. All bars are four microns.

3. Discussion

The finding of the coastal area of the Zagros Foreland Basin, as an active depositional basin, is very important for drawing its realistic paleogeographic and tectonic models in addition to spatial and temporal facies mapping. Previously, many pioneer works have been achieved in this context such as[5,20,34] who considered, in their models, the Chwarta and Mawat region as a coastal area during the Late Cretaceous and Tertiary. They refused the previous idea about the separation of the Imbricate and High Folded zones by a paleohigh during the whole Tertiary (except Upper Eocene). They also argued facial and basinal relations between the High Folded and Imbricate zones of northeastern Iraq.

The present study, however, is the first that proves this relation between the two zones and adds new data about the relation between the two zones. This is achieved via fossil age determination, in addition to the recognizing of several changes in the geological setting of the coastal area and linking of the two zones with the Thrust Zone of[1].

The coastal area of the Zagros Foreland Basin was dynamic since it was prone to shallowing and deepening and includes several unconformities. The location of the coastal area was not fixed, but it was wandering (moving) northeast-southwest according to uplift and rebounding of the Zagros Orogenic front which manifested extensive facies changes; vertically. As the authors are aware, the geologist cannot find articles treating this important issue either in Iran or Iraq. The description of the Zagros Foreland Basin without a coastal area is similar to finding a Dinosaur skeleton without a head. That is why the present study has concerned the coastal area of the Zagros Foreland Basin by expanding the previous studies and drawing a more accurate correlation between coastal facies and their deep marine equivalents.

During the field study, it is very difficult to find the equivalent of Kolosh, Sinjar, Gercus, and Pila Spi formations (in the High Folded Zone) in the Imbricate and Thrust zones. This is due to high tectonism and deformations in these two zones, in addition to the probability of the presence of several unconformities inside the Kolosh Formation and the Red Bed Series in which, two unconformities were found in the present study (Figure 12). This study tries to introduce significant changes in the equivalent of the forgoing formations in the two zones inside the RBS and Walash-Naopurdan groups which were deposited during the Tertiary.

The study correlated the above units in the three tectonic zones (Thrust, Imbricated**,** and High Folded Zone) (Figure 12) which is based on the occupation of the above three tectonic zones by a single foreland basin during the Upper Cretaceous, Paleocene, and Lower Eocene where most parts of the RBS (in the Thrust and Imbricate zones) and its time equivalent formations of the High Folded Zone are deposited (see[34]). Previously[5] found incised valley inside the RBS and discussed in detail the correlation of the later series with the Kolosh Formation, and proved that both deposited in one foreland basin.

The most recent study by[47] indicated that the Red Bed Series as an active margin and repeated the conclusion of the latter study about proximal and distal fans in addition to river sediments. They mentioned nothing about the foreland basin and connection to the other units in High and Low Folded zones. Another recent paper that is a serious challenge to the results of the present works is the study of[9] in which they indicated the depositional age of the base of the RBS using detrital Zircon. They deciphered Oligocene as the age of the deposition of the base of the Red Bed Series which neither agrees with previous studies (see[28]) nor with the actual stratigraphy of the series as revealed in the present study (Figure 12). All the previous studies and the present one confirms the late Paleocene as the depositional starting of the RBS.

This is because detrital Zircons cannot indicate the age of deposition of their host sediments due to their crystallization in great depth and then exhumed or uplifted to the surface and transported to the site of deposition. These Oligocene zircons are most likely related to Upper Miocene-Pliocene Metamorphic Core Complexes described by[11, 48] where the zircons are reset by metamorphism during former age and uplifted.

Another Challenge to the result of the present study is the finding of the Middle Eocene unconformity by [49] who depended on the 40Ar–39Ar aging and literature for indicating this unconformity in the Imbricate Zone of the study area. However, the present paleontological study doesn't aid this large unconformity of several million years during the Middle Eocene, previously[34] indicated deepening of the study area during the mentioned age (Figures 12d and 13).

Another contradiction to the current study is the study of[50] who studied similar lithologies in slightly metamorphosed marl and sandstone) as the Naopurdan Group in the Thrust Zone between Mawat Ophiolite and conglomerate beds of the RBS in the Chwarta-Mawat area near Bitwat and Waras villages.

Recently[11] found the Kolosh Formation in the Chwarta-Mawat area in the Imbricate Zone for the first time above the Aqra Formation. It has 20-100 m thickness in the mentioned area and is comprised of dark color sandstone (greywacke), conglomerate, and shale, therefore, we correlated it with its equivalent in the High Folded Zone as lateral facies change of the Paleocene Foreland Basin in the two zones (Figure12). In the mentioned area, above the Kolosh Formation, unit one of the Red Bed Series has, in some places, 200 m thickness and consists of relatively soft clastics such as red claystone, fine-grain sandstone, and a few beds of the conglomerate (Figures 13 and 14). This unit is correlated with Sinjar Formation in the High Folded Zone depending on two facts, the first is its stratigraphic position above Kolosh Formation. The second is the softness of its lithology which is significant hydraulically which means a low energy environment was unable to deliver turbidity, except intermittently, to the location of the Sinjar Formation in the foreland basin (present days High Folded Zone) during its deposition in the Early Eocene. In contrast to turbidity, the flourishing nutrient was able to reach the location and ensuing typical reef growth.

Above the fine clastic occur unit two which has 50-200 m thickness and consists of a thick succession of sandstones and conglomerate with interbed of red claystone. The sandstone beds have clear erosional bases with many imprinted tool marks and small channels (Figure 14b). The imbricated pebbles and flute casts indicate the southwest paleocurrent direction and high energy of sediment transport. Therefore, the high energy and paleocurrent indicated transportation of turbidity to the High Folded Zone in the form of coarse siliciclastic sediments and led to the deposition of the Gercus Formation which is correlated with unit two of the RBS (Figure 14). Above, sandstone and conglomerate unit, the rocks (RRLs) of the present study occurs and consists mainly of silty and sandy green marl and sandy detrital limestone (grainstone and packstone) which is described in the previous sections of the result chapter of this study (Figures 3 and 15).

When the hydrodynamic of the basin is considered, these RRLs are deposited in a relatively deep and low-energy forereef environment which is highly bioturbated and holds echinoderm (Figure 8c) and plant debris. According to[34], these characteristics indicated the deepening of the area (Imbricate and Thrust zones as the northern basin) and separated from the High Folded Zone (as the southern basin) during the Middle Eocene by a paleohigh. The Walash-Naoperdan groups were deposited in this basin in addition to the RRLs during Paleocene-Eocene, in the same basin, and nearly in the same time the Kolosh, Sinjar, Gercus, formations were deposited in the High Folded Zone while Pila Spi Formation is separated from the northern basin by paleo high (Figures 12 and 13) but can be correlated with RRLs timewise. This separation is justified by the absence of clastic sediments inside the Pila Spi Formation while the Sinjar Formation, in many localities, contains terrigenous siliciclastic sandstones and conglomerates [34].

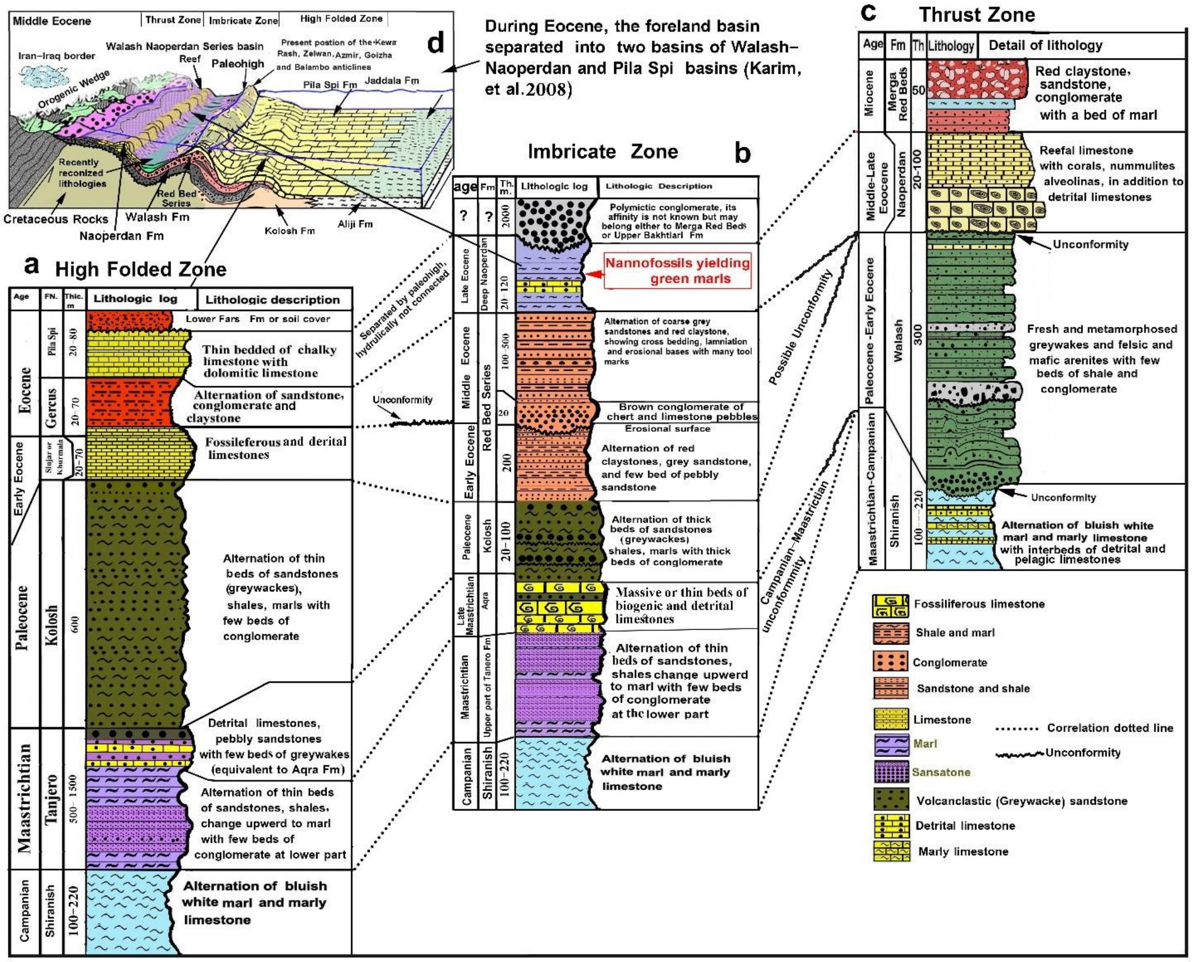

Figure 12: Stratigraphic columns showing correlation of the units of the Red Bed Series including the RRLs inside the Imbricate Zone with the formations in the High Folded Zone and Thrust Zone with the paleogeographic, environment, and tectonic model of the RRLs during the Upper Eocene. The stratigraphic columns are **a**: High Folded Zone, **b**: Imbricate Zone, **c**: Thrust Zone, **d**: Paleogeographic model (modified from [34]).

The age of the RRLs is slightly different when estimated by nannofossils and benthonic foraminiferas since they indicated Middle Eocene and Upper Eocene, respectively (Figures 9 and 10). The nannofossils of the previous studies in northern Iraq yielded slightly older age than that of foraminifera. This difference in age between the two fossils is possibly due to the very small sizes of the former which are more prone to reworking and mixing than the latter one. Therefore, the most convenient age is the late Middle Eocene-early Upper Eocene.

The preservation of soft sediment such as green marl in coarse clastics of RRB is very difficult due to erosion by high-energy sediment transport of conglomerate and sandstone. Therefore, it does not occur in all outcrops of the RBS but only in three places, southeast of Shamsawa, west of Para Pan village, and near Tagran village. The stratigraphic position, age, and detrital limestone content, of the RRLs , are an indication of their stratigraphic relationships in the foreland basin as the distal facies of the Naopurdan Formation which was deposited in the northeast during the Middle-Late Eocene. These facies (RRLs) were deposited in the northern basin after its separation from the main foreland basin while (in the southern basin the Pila Spi Formation was deposited as can be seen in (Figures 12 and 13). The Walash and Naopurdan groups' basin (northern basin) was survived up to the end of the Eocene since it compressed and roofed by uplifted older rocks such as radiolarite and volcaniclastics sediments. These processes are associated with well-known Oligocene unconformity. The compression and uplift were coeval with the opening of the Red Sea during the end of the Eocene.

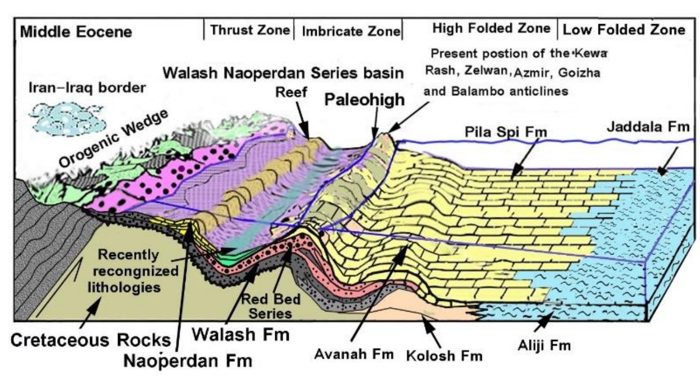

Figure 13: Paleogeographic and environmental model of northeastern Iraq during the Late Eocene. shows the location of the formations and separation of the foreland basin into two subbasins (modified from[34]).

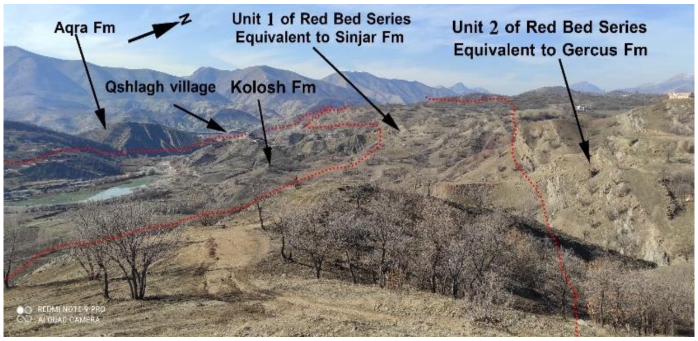

Figure 14: Aqra and Kolosh formations in addition to units one and two of RBs at 6 km west of Chwarta town near Ashlagh village,

Figure 15: units one and two of Red Bed Series directly to the west of Tagaran village, Chwarta area, RRls are located at the top of the latter unit. **b.** base of a sandstone bed in unit two shows flute cast. Tool marks and two small, sediment transport direction.

Conclusion

1. A succession of RRLs are found in the middle part of the Red Beds Series in the Imbricate Zone and studied petrographically and biostratigraphically. The succession consists of green marl and sandy detrital limestone.

2. The nannofossils and benthonic foraminiferas indicated the Middle and Late Eocene ages.

3. The stratigraphy and age of the RRLs are used as a key for correlation of units of Red Bed Series and formations of the Imbricate and Thrust zones with those of the High Folded Zone during the Late Cretaceous and Tertiary.

4. The RRLs belong to relatively deep facies (Forereef) of the Naopurdan Formation and they are correlated with the Pila Spi formation in age while their basin was separated by paleohigh.

5. Unit one of the Red Bed Series is equivalent to Sinjar Formation while unit two is equivalent to the Gercus Formation.

6. The Tanjero, Kolosh, Walash, Sinjar and Formations in addition to Red Bed Series are deposited in one Foreland Basin while the new lithology and both Naoperdan and PilaSpi formations were equivalent in age but were deposited in two different basins. This is a great change in the geology of Iraqi Kurdistan

Conflict of interests

None

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