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Lithology and Diagenetic Processes of the Baluti Formation (Upper Triassic) from the Amadyia Area, Kurdistan Region, North-Iraq

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Abstract

Lithologic characteristics and diagenitic processes of the Baluti Formation (Upper Triassic) from two well-exposed sections are studied. The sections are located northwest (Sararu village) and southeast (Sarki village) of Amadyia district, within High Folded Zone, in the Iraqi-Kurdistan. The Baluti Formation consists of intimately interbedded green, gray to black shale and gray limestone with subordinate greenish gray marlstone; those do not alternate in a repeated fashion and are not strictly described as cyclic.

Bioclastic limestone, intraclastic limestone, and peloidal limestone interbedded with invasively yellowish-gray shaley mudstone and fissile shale lithologies which are interpreted as slope and basinal units deposited in deeper water. Storms were a dominant factor in initializing down-slope transport from shallower-water settings. Polymictic limestone conglomerate and shallow-water-derived limestone, fossils and siliciclastic grains indicate that depositional slopes were steep enough at times to allow considerable transport from up-slope areas. The bioclastic and peloidal limestones then locally turn into the nodular limestone through early diagenetic modification in deep water. Petrographic evidences indicated that these deposits have undergone both shallow and deep-marine diagenesis with slightly influence of vadose and meteoric diagenesis. Following shallow-marine diagenesis, these intra- and bio-clasts were transported to the deeper part and were exposed to deep-marine water, which appear to have initiated deepmarine diagenesis. The evidence of deep-marine diagenesis is reprecipitation of the small amount of carbonate generated by dissolution of unstable grains (presumably aragonitic) into newly opened molds and partially filled primary pores as clear, fine to medium, equant calcite spar.

Introduction

The type section of the Baluti Formation is located in the Baluti village, south of Amadyia, in the core of the Chia Gara Mountain. A supplementary type-section, in which the full formation is exposed, was discovered later in southeast of Amadyia, near Sarki village, 9 km east of Baluti village (Fig. 1). The samples from this section and from additional section in the Sararu village, northwest of Amadyia, reveal the shale to be a distinct lithologic unit within the Baluti Formation intercalated with few thin-bedded limestones. Stratigraphically, the area of the Amadyia includes several rock units extending from Late Triassic, which represents the oldest rocks cropped out in the core of the anticlines in the area, to the

Pliocene which represents the youngest rocks exposed in the area. The upper Triassic Baluti Formation was first introduced by Wetzel in 1950 and amended by Morton in 1951 as gray and green shales, calcareous, dolomitic, with intercalations of thin-bedded dolomitized limestones and silicified limestones ***[1]***. They considered it to be equivalent to the Zor-Hauran Formation and that the Baluti and Zor-Hauran are the only sedimentary units of Rhaetic age (upper Triassic) in the Iraq. No changes were introduced since the original description was published. The Baluti Formation is a distinctive lithologic unit distributed in the Balambo-Tanjero and High Folded Zones from northern Iraq. The last reported outcrop of the formation at southeastern part of IraqiKurdistan is found in the Shawry valley at Ranya area ***[2]***. In Sirwan Gorge section the succession presents strata set, comprising greenish gray shale units similar to those of the Baluti Formation outcrop; but they are not clear enough to including within the formation. A succession of limestones, anhydrites, and shales, in other localities in Iraqi-Kurdistan, can also be considered a facies of the Baluti shale Formation but the low proportion of shale was seen in that outcrops ***[1]***. Both lower and upper boundaries of the Baluti Formation are conformable and gradational except in well Tharthar-1 ***[1]***.

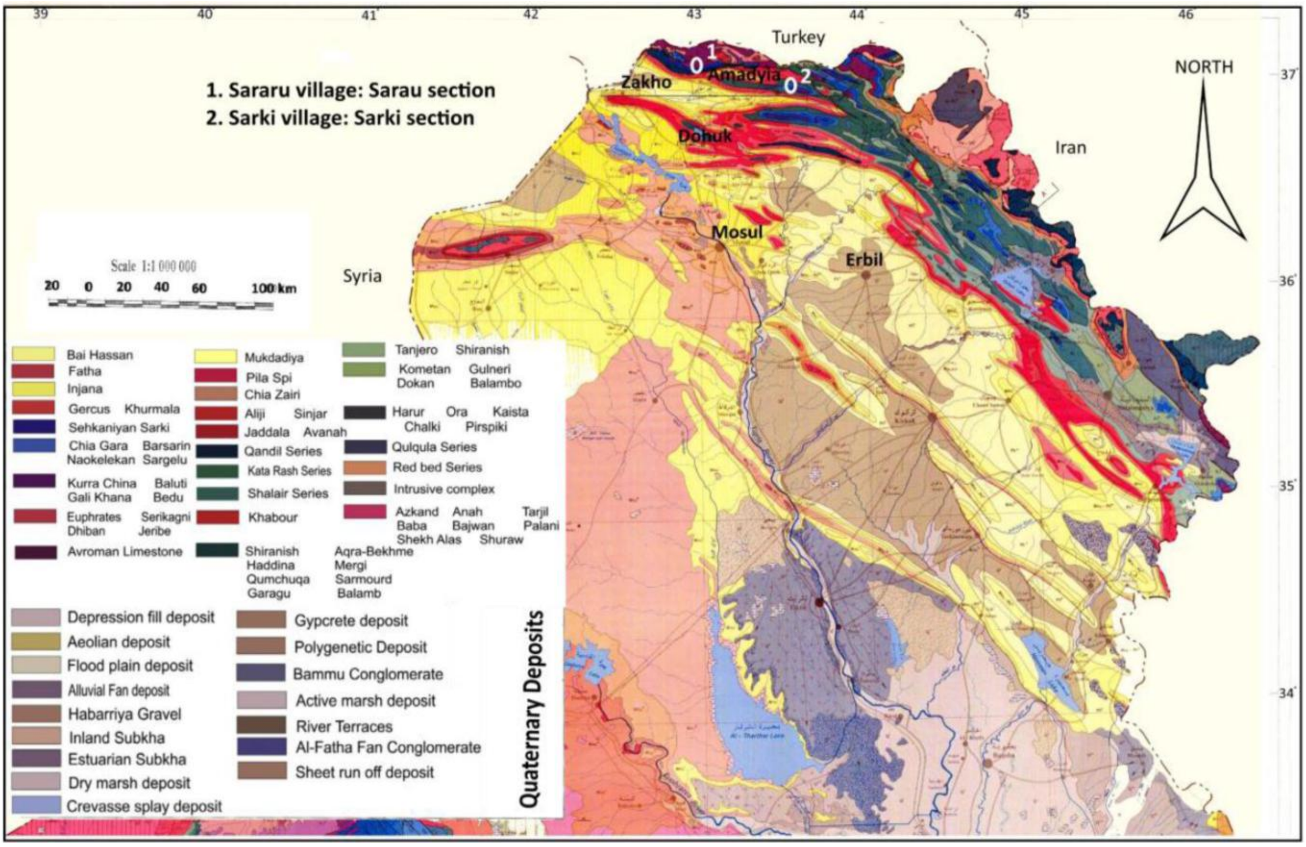

Figure. 1: Location and Geological map of the study area (from GEOSURV Library2002, Iraq)

The Baluti Formation conformably overlies the Kurra Chine Formation and also conformably underlies the Sarki Formation. The conformable nature of upper contact with Sarki Formation in some areas of Iraq seems to be uncertain, due to the ascertained break between Triassic and Liassic, and the widespread and well known break between Triassic and Liassic in Saudi Arabia, southwestern Iran and other areas ***[2]***. Fossils are rare and not age diagnostic ***[1]***, therefore, the age of the Baluti Formation is determined arbitrarily from its position within the stratigraphic succession between the proved upper Triassic Kurra Chine and the overlying Sarki formations of supposed Liassic age. Consequently, the Rhaetic age for the Baluti Formation should be considered ***[1]***. From above it is obvious that no detailed work on sedimentology of the Baluti Formation was carried out in the area of Amadyia, Iraqi-Kurdistan. Therefore a detailed lithologic analysis and diagenetic interpretation of the Baluti Formation were undertaken.

Fieldwork and outcrop observations were undertaken for two detailed stratigraphic sections of the Baluti Formation in the type section near Sarki village and in the Sararu village, around Amadyia area (Fig. 1). The other parameters have been taken into consideration for this work are field photography, samples collection, preparation and study of petrographic and carbonate thin sections using petrographic microscope, chemical staining with Alizarin-Red S and Potassium Ferricyanide and digital photomicrography.

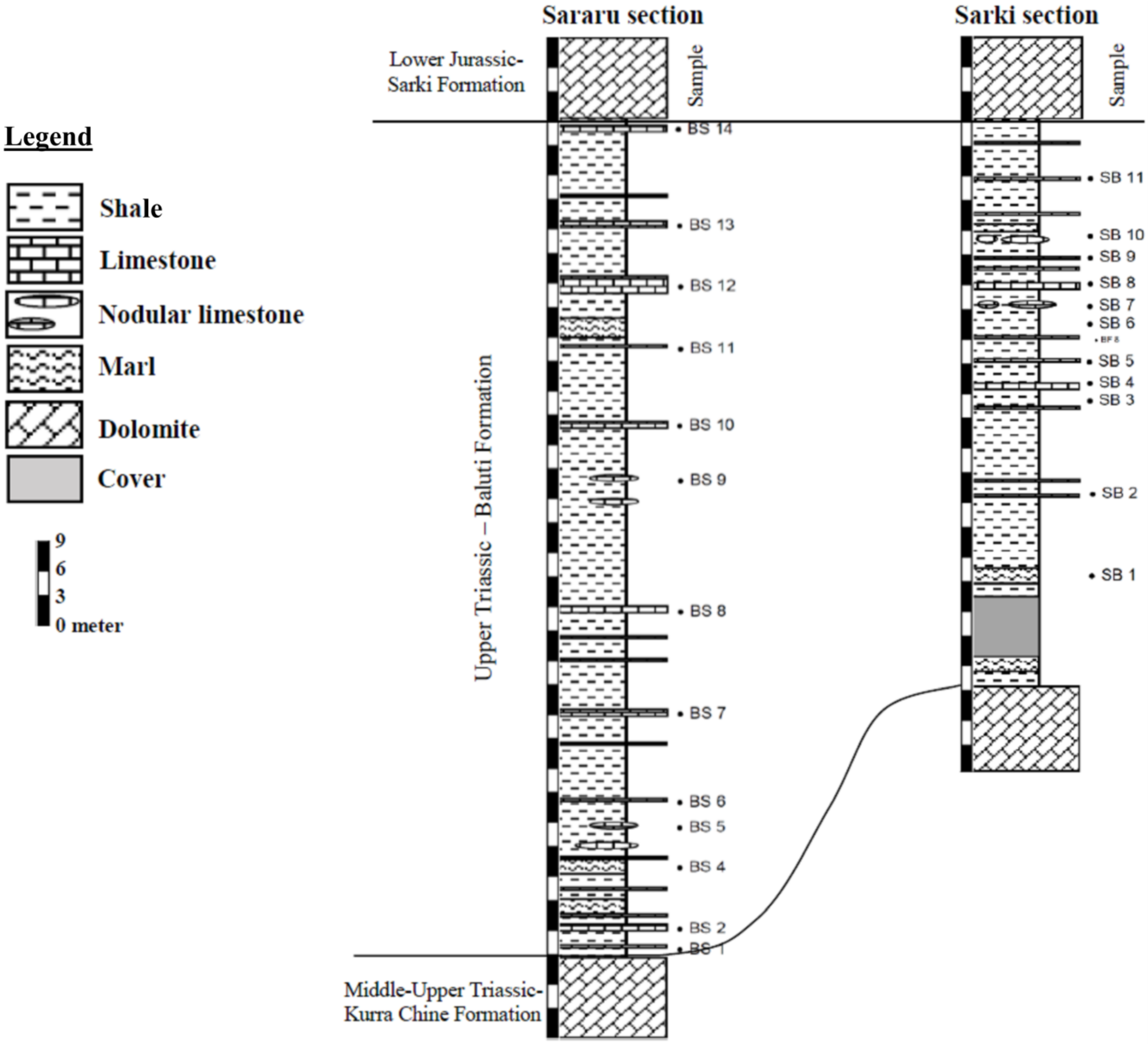

Figure 2: Stratigraphic sections of the Baluti Formation from the Sararu and Sarki locations.

Lithologic Characteristics:

Here, the author presents the new detailed lithostratigraphy, sedimentary petrography and paleontology of the upper Triassic Baluti Formation exposed in the Amadyia outcrops, in Kurdistan Region, Iraq.

A. Lithostratigraphy

Wetzel in 1950 and Morton in 1951 named the Baluti Formation at the type section in Baluti village and a supplementary type-section at Sarki village ***[1]***, show a total thickness of 58.5 m, and they briefly described it as a gray and green shales, calcareous, dolomitic, with intercalations of thinbedded limestones, silicified limestones and solution-recrystallization breccias. Thin beds of solution-recrystallization breccias suggest the one-time presence of thin interbedded anhydrites ***[1]***. ***[3]*** reported the Baluti Formation as 66.5 m thick and he divided the lithostratigraphy of the formation into the lower part consisting primarily of light olive to gray shales and marls intercalated by few thin marly limestone beds and dark grey dolomites, and the upper part which is consisted almost entirely of black shales intercalated by thin beds of dolomitic limestones grad lithologically to the thick dark gray medium to thick bedded limestones with voids filled by olive green marls.

The author remeasured the Baluti Formation at Sarki section, and it is a well-exposed and rarely fossiliferous section with clear lower and upper contacts. The additional section at the Sararu village was also taken (Fig. 1) for displaying more data. Therefore, the Baluti Formation near its type section at Sarki village is 62 m thick and at Sararu section is 93.5 m (Fig. 2), which is largely shale. Limestone is the next most common lithology, and marls are also present in the lower part. Therefore, the lithologic framework of the Baluti Formation is proportionally consisted of shale, limestone and marl, respectively.

- *Shale*

The proportion of shale in the Baluti Formation at both sections is almost equal, comprising 75.8% of the total thickness at Sarki and 73.8% at Sararu (Fig. 2). This shale is typically a dark-gray or a greenish gray in color (Fig. 3a). The massive yellowish-gray and thin beds of reddish-brown colored shale could be called a mudstone, due to its massive blocky character (Fig. 3b). However, the most part of this mudstone is consistent with true fissile shale (Fig. 3c), as defined by ***[4]***. The darker shales are considerably more fissile. In both sections of the Baluti Formation, shales are interbedded with variety of limestone lithologies including bioclastic limestone, intraclastic limestone and nodular limestone. These nodular limestones are embedded in shale (Fig.3a). Such interbeds give large assumption for sporadic, storm-generated sedimentation ***[5]*** and ***[6]***.

Petrographically, shale in the Baluti Formation is composed dominantly of clay, fine-silt size particles, and trace amounts of sand. Silica (clay- to silt-size crystalline quartz) is the dominant mineral in this shale; carbonate (clay- to silt-size crystalline calcite and dolomite) is also locally common, along with lesser amounts of pyrite and phosphate particles. No fauna was noted within the shale itself, with the exception of rare brachiopod clasts. Some miospore species and few acritarch, prasinophyte genera are reported by ***[3]***. Lack of fauna noted is probably due to small sample size and to conditions within the shale which may not have been conducive to life at the time of deposition or to the preservation of fossils following deposition. The author made no attempt to pick samples for microfossils.

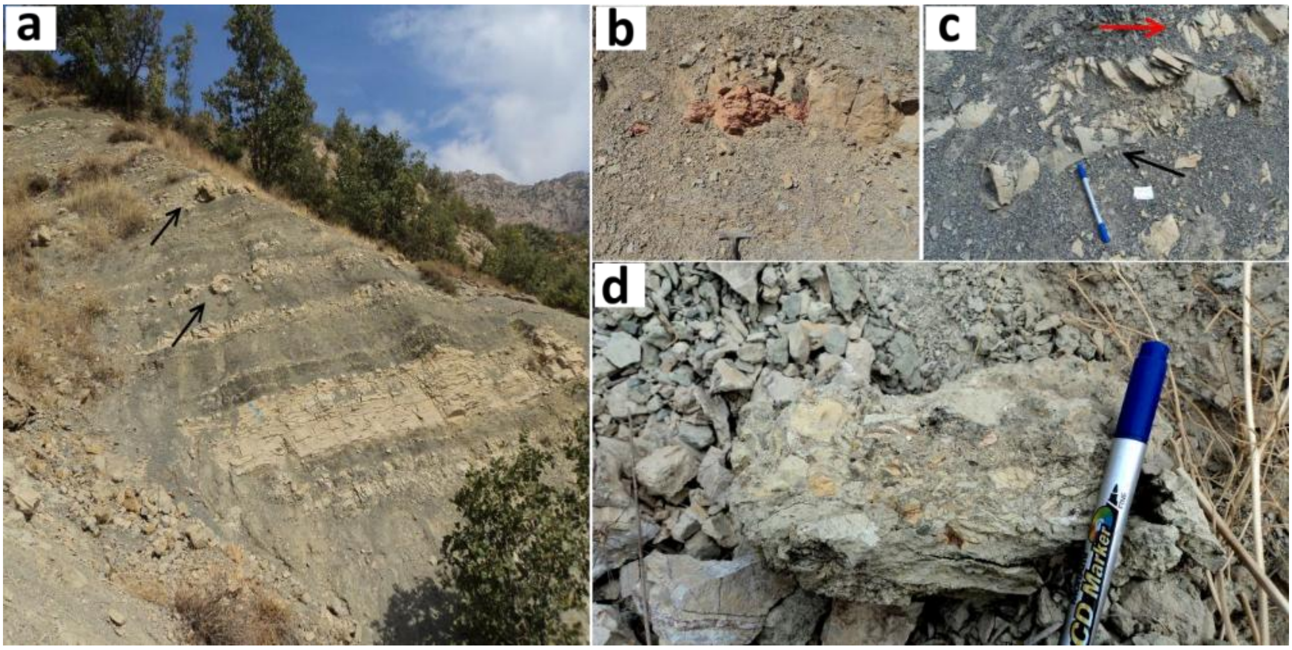

Figure 3: Field photographs from Baluti Formation. a) Yellowish white limestone beds and nodular limestones (arrows) interbedded with dark gray to greenish gray shale (Sarki section). b) Yellowish-gray to reddish-brown colored mudstone undergone hematitization (Sararu section). c) Thin limestone bed (red arrow) and marlstone (black arrow) is embedded in dark gray-fissile shale (lower Sarki section). d) Thin bed of polymictic limestone conglomerate (Sarki section).

- *Limestone*

Limestone comprises 16% at both sections of the total Baluti Formation thickness (Fig. 2) and occurs as intercalated thin limestone beds to thicker limestone units (Fig. 3a, c). Thickness commonly ranges from 0.1m to 2m. These limestone beds are present throughout the occurrence of the shales in the Baluti Formation. Lithologically, the beds of limestone are described as biosparites and biomecrites, intrasparite and calcisiltite (pelmicrites) lithologic units. Polymictic limestone conglomerate and other depositional slope grains are also reported (Figure 3d).These limestone, in addition to skeletal grains, intraclasts and peloids, contain some glauconite, phosphate and detrital quartz, (Fig. 4a). Phosphatic grains appear to have been transported along with the shell materials. Nodular limestone are common in the middle of the Baluti Formation, the beds of nodular limestone are 0.2–0.5 m thick embedded in shale (Fig 4b). Internally, the nodular limestones preserve uncompacted bedding indicating that they formed early and prior to compaction. Petrographically, the limestone beds in the Baluti Formation are yellow to yellowish gray in color, hard and fractured, fine grained with local polymictic limestone conglomerate, and composed of abundant bioclasts, intraclasts and peloids, a few detrital quartz grains and phosphates are also present (Fig. 4a). The nodular limestones are generally composed of bioclastic, mixed fine siliciclastic-carbonate siltstone, which is partly laminated and partly bioturbated (Fig. 4c). The most common bioclasts are of planktonic and smaller benthic foraminifera (such as rotalides and miliolids), fusulinids, ammonite, gastropods, echinoderm, ostracods, and brachiopod (Fig. 4d). Some clasts of calcareous algae are also present in some limestone beds (Fig. 5a). Pyrite and phosphate grains, also present, are generally less than 2 millimeters in size (Fig. 5b). The matrix is commonly micrite and microsparite (Fig. 5c), and locally, large amounts of yellowish carbonate cement are present (Fig. 5d). However, the Baluti Formation yields fossils of foraminifera, bivalves, gastropods, ammonoids, bryozoans, echinoids, brachiopods, and clasts of algae.

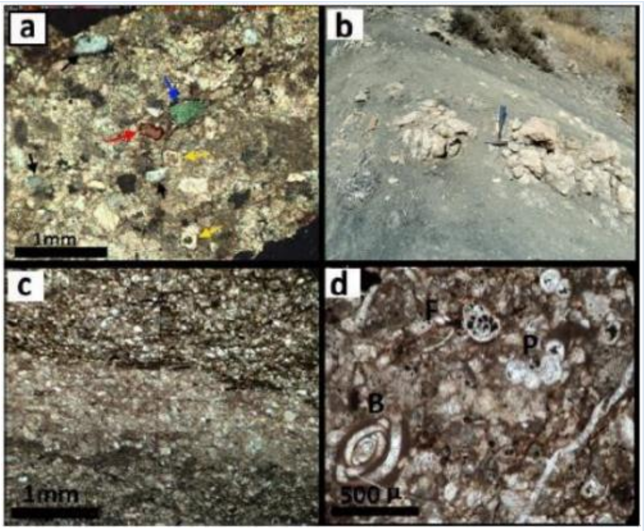

Figure 4: Lithologic characteristics in Baluti Formation.
a) Photomicrograph of intrasparite limestone bedcontains some detrital grains of quart (black arrows), glauconite (blue arrow), phosphate (red arrow) and dolomite rhombus (yellow arrows) (Sararu section). b) The nodules of limestone are embedded in dark gray shale (Sarki section). c) Photomicrograph of partly laminated and bioturbated nodular limestone (Sarki section). d) Photomicrograph of bioclastic limestone contains fusulinids (F) undergone pyritization, planktonic (P) and small benthic (B) foraminifera with micritic envelope in the limestone bed (Sararu section).

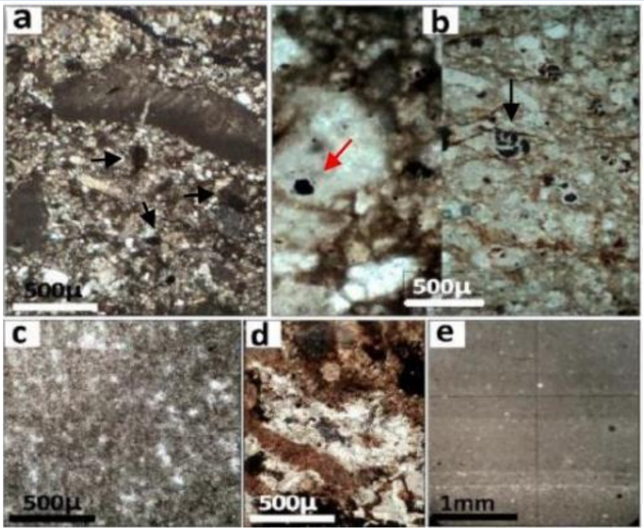

Figure 5: Lithologic characteristics of Baluti Formation.
a) Photomicrograph of calcareous algae in limestone undergone micritization with some micritizated peloids (arrows). b) Photomicrograph of pyrite grain (red arrow) and diagenetic pyrite (pyritization) replaced bioclasts (black arrow) in limestone. c) Photomicrograph of neomorphism of micrite to microsparite. d) Photomicrograph of locally carbonate cement. e) Photomicrograph of laminations in marlstone containing minor clay and carbonate particles. All samples from Sarki section.

- *Marl*

The proportion of marl is about 8% at Sarki section and 10% at Sararu section, of the total thickness of formation (Fig. 2). Marlstone is concentrated at the lower part of the Baluti Formation (Fig. 3c). It is also present as thinner intervals in the upper part of the formation. In a weathered outcrop, the marl beds would appear as shale. Calcite is the dominant mineral in this beds, but dolomite (in the form of 30-µ crystals) also, is locally present. Silt-size quartz grains are present, along with silt-size peloids. Laminations in these rocks are the result of interbedded layers of carbonate particles containing minor clay and carbonate particles with abundant clay (Fig. 5e). Pyrite and phosphate are relatively rare in the marl. Fossils include planktonic foramineferas, echinoderm, ostracode and some brachippode fragments.

B. Diagenetic Processes:

Diagenesis can occur in vadose, meteoric water, shallow and deep-marine and in the deep burial environment in the subsurface ***[8]***. Each of these environments will produce different diagenetic textures and fabrics. The various diagenetic processes including micritization, dissolution, cementation, recrystallization (neomorphism), compaction, fracturing and vein filling, and locally pyritization, hematization, silicification and dolomitization have been recognized in the Baluti Formation.

- *Micritization*

Micritic envelopes occur around fauna such as echinoderm, pelecypod, brachiopod and foraminiferal fragments which have original aragonitic mineralogical composition (Fig. 4d). In this study micritization takes two forms: first is micritzation of the outer portions of grains (Fig. 5a); second is the complete transformation of the skeletal grains into peloids (Fig. 5a). Some peloids were probably originated from micritization of other allochems such as bioclasts or ooids (pseudopeloids). This process is the first diagenetic phase, which takes place in the marine diagenesis of limestones ***[7]***, and it is observed commonly in the Baluti Formation.

- *Dissolution*

Dissolution is not a common diagenetic process found in the studied formation and it can be traced on both macroscopic and microscopic scale. Dissolution may effect on the matrix and faunal grains having aragonitic mineralogy ***[8]***. The size of pores varies from few microns to several centimeters (Fig. 6a). The pore spaces produced during dissolution were later filled up by calcite cement during deeper burial diagenesis (Fig. 6b).

- *Cementation*

The cementation occurs where there is the potential for a large flux of calcium carbonate-saturated waters through porous sediment ***[9]***. Only minor amounts of calcite cementation are observed in the samples from Baluti Formation. Fibrous, bladed, granular (equant spar) calcite, drusy calcite and locally blocky cement are the most common cement types observed in Baluti limestones (Fig. 6 c, d, e, f, g). The CaCO3 needed for these cements is provided directly from supersaturated marine and evaporated marine waters, or indirectly, with the $CaCO_3$ coming from the dissolution of metastable carbonates phases ***[9]*** and ***[10]***. Aragonite is a metastable carbonate mineral and it is dissolved in the very early phase of diagenesis of carbonate sediments, and then subsequently replaced by calcite.

- *Recrystallizaion (Neomorphim)*

Although, the original depositional features and early diagenetic textures of limestone are often altered or changed by recrystallization, a neomorphism, which is the most important form of recrystallization in the carbonate rocks, may led to preservation of the original structure of skeletal material ***[10]***. Neomorphism appears to be a relatively unimportant process in a shallow marine diagenesis zone; however, it in this zone seems to be uncommon ***[8]***. On the other hand, skeletal and non-skeletal grains transported into deeper water or pelagic shells settling into such water may undergo aggrading neomorphism, which commonly involves alteration of aragonite to low Mg-calcite. Neomorphism also occurs in matrix and produced microspars (Fig. 5c), but the distinguishing between aggrading neomorphism and sparite representing carbonate cement is often difficult. A considerable portion of skeletal materials of the Baluti Formation were altered into low Mg-Fe-calcite. This type of neomorphism normally produced a non-ferroan microspar mosaic (Fig. 6 b, h).

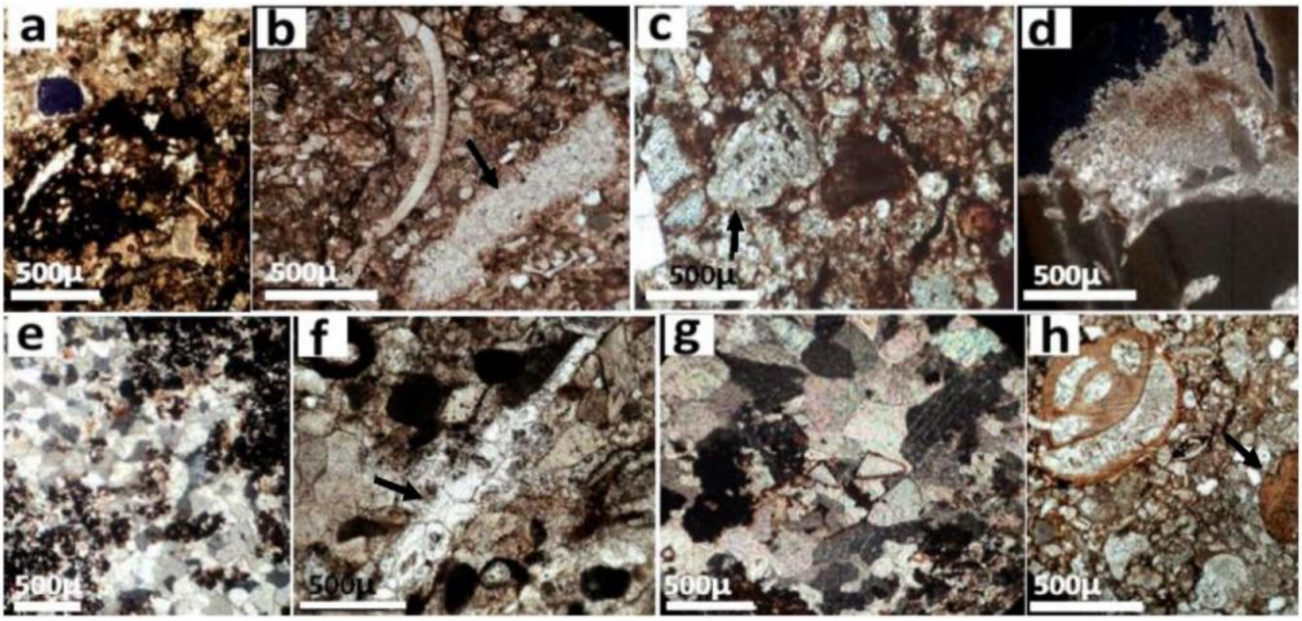

Figure 6: Diagenetic features of Baluti Formation. a) Photomicrograph of dissolution influence on the faunal grain and matrix which is filled later with hematitizated pyrite. b) Photomicrograph of pore space filled up by neomorphised calcite cement (arrow) during burial diagenesis. c) Photomicrograph of fibrous-calcite cement (arrow). d)

Photomicrograph of bladed-calcite cement. e) Photomicrograph of granular-calcite cement. f) Photomicrograph of drusy-calcite cement (arrow). g) Photomicrograph of blocky-calcite cement. h) Photomicrograph of foraminiferal fragment undergone neomorphism and micritization diagenesis, see also the grain of phosphate (arrow).

- *Compaction*

Compaction of sediments is the process of volume reduction and it took place in the limestones under both physical and chemical influence ***[10]***. Both physical and chemical compaction have recorded in the Baluti Formation. Flattening, grain breakage and sutured contacts between grains within carbonate beds is the only evidence for physical compaction in this Formation. Some of the skeletal (such as pelecypod, brachiopod, gastropod) and non-skeletal (such as intraclast) grains were brittle and ductile which is related to compaction processes (Fig. 7a). Chemical compaction would appear to have been more dominant process, with the development of the different shapes of stylolite and dissolution seams in the limestone beds (Fig. 7b).

- *Fracturing and Vein Filling*

The presence of different types of fractures, veins and broken allochems display the imprints of both tectonic stresses and overburden pressure pre-and-post cementation phases. Fractures are relatively common and are partially filled by ferroan-calcite or non-ferroan calcite cements (Fig. 7a). They are recorded in various limestone beds of Baluti Formation and are vary from elongated thin to thick ones with width of about 1mm and length of about several millimeters (Fig. 7a).

- *Pyritization*

Pyritization is observed in most beds of limestone, but it most common in lime-mudstone and bioclastic limestone of the Baluti Formation (Fig. 5b). Pyritization forms patches in limestone samples filling some voids with different shapes and sizes as a subsequent diagenetic process (Fig.7c). Pyrite is sometimes scattered and replaces bioclasts and silica cements. Authigenic pyrite commonly forms under reducing conditions replacing organic material, or form penecontemporaneously in fine-grained marine sediments through reduction of sulfate from the seawater ***[10]*** and ***[11]***.

- *Hematitization*

Hematitizated materials are suggested to be originated by the oxidation of iron-bearing minerals (pyrite and glauconite) and are an indicator of dominant oxidizing conditions during the deposition of the sediments ***[12]***. Hematitization process can be documented in Baluti Formation within reddish brown mudstone (Fig. 3b) and within the fine grain groundmass of the lime-mudstones along stylolites and fractures (Figs. 6a and 7b). The oxidation of pyrite and glauconite either found as detrital components or that replaces the skeletal particles.

- *Silicification*

Silicification of carbonates involves both the replacement of carbonate by silica and the precipitation of porefilling silica cement. Silicification of some bioclasts and matrix, together with silica filling pore spaces is documented in the samples of Baluti Formation (Fig. 7d,e), but it is not common. Silica replacement is either selective or pervasive (Fig. 7d). Various bioclasts such as echinoderms and brachiopods and non-skeletal grains were replaced by different types of microquartz (Fig. 7e).

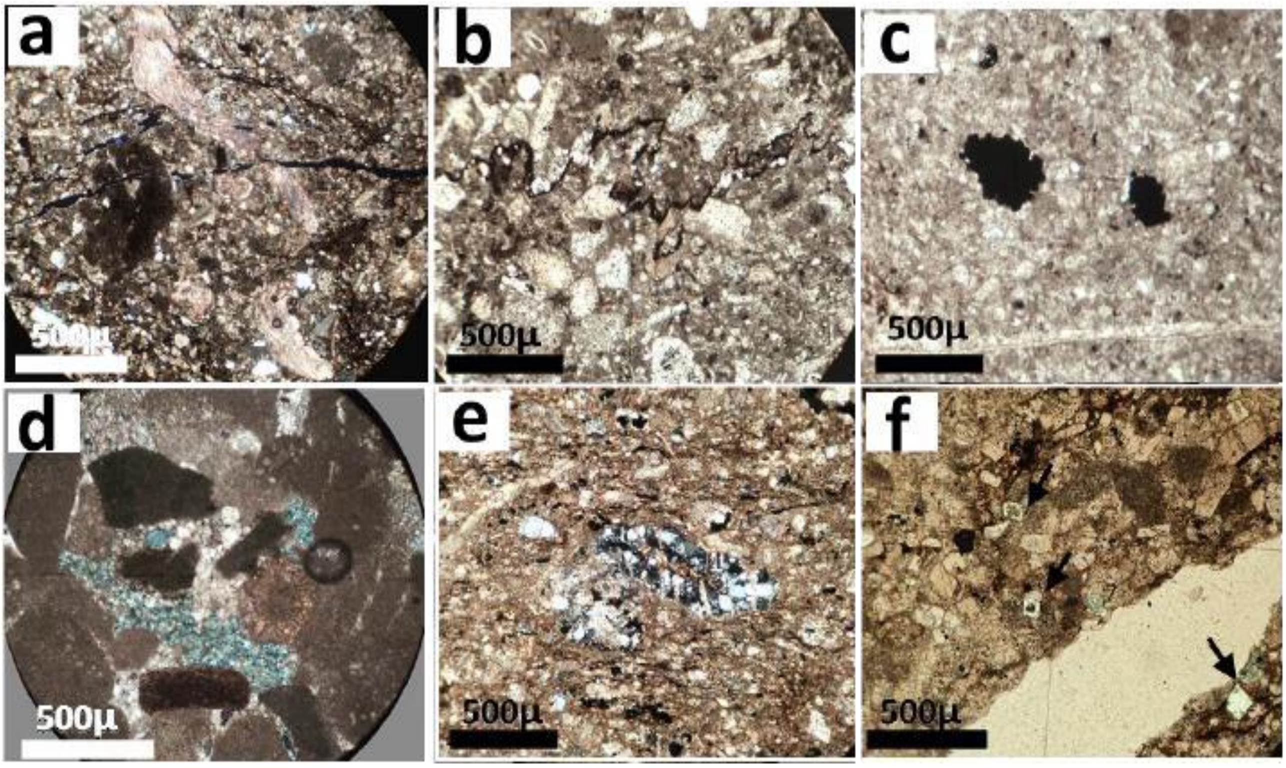

Figure 7: Diagenetic features of Baluti Formation. a) Photomicrograph of ductile-brachiopod grain undergone physical compaction, see also the fracturing in sample. b) Photomicrograph of stylolite filled up with Fe-oxides in the limestone sample. c) Photomicrograph of pyrite patches filling some voids in limestone sample. d) Photomicrograph of pervasive silica cement filling pore-space in intraclastic-limestone sample. e) Photomicrograph of skeletal grains replaced by different types of microquartz. f) Photomicrograph of fine-grained dolomite rhombus (arrows) present along pressure dissolution seam.

- *Dolomitization*

Scattered, fine-grained dolomite rhombs have been recognized within the thin-bedded limestone (Fig. 4a). The presence of dolomites along styolites and pressure dissolution seams and their fine grain-size nature (Fig. 7f) is suggestive of dolomite forming during burial with early- diagenetic origin. ***[13]*** pointed out that scattered dolomite rhombs along veins and stylolites, and late dolomite cements are all common features of burial dolomite in many limestones.

Discussion and Conclusion:

The formation of Baluti sediments requires corresponding climatic and palaeogeographic conditions. ***[14]*** proposed a storm belt on the north and northeastern side of the Tethys during the Late Triassic. During Mid Triassic-Late Triassic time further extension occurred around the northern and eastern margins of the Arabian Plate, then deposition of open-marine shallow-water carbonates occurred along the northern and northeastern margin of the Arabian Plate ***[15]*** and ***[14]***. Strata of the Baluti Formation are may be used as a sedimentary record of the opening NeoTethys and tectonic activities in that time (see also ***[15]*** and ***[14]***). Sediments of the Baluti Formation mainly represent deposits of a deep shelf environment, comprising about 75% shale, 16% limestone and 9% marl (Fig. 2). The succession is thus described as a slope-and basinal-forming succession of gray, green or black shale, intercalated with limestone beds that are mostly biosparites and biomicrites, intrasparites and nodular limestone. Undulations of dark-gray and nodular limestone beds were the result of oscillatory currents produced by major storms. The base of the formation at the studied sections is shaly marlstone or marl containing silt-size quartz grains and carbonate clasts. Other marlstone beds are a minor lithology in the formation. These beds do not alternate in a repeated fashion and are not clearly displayed as cyclic (Figs. 2 and 3). The interbedded nature of the strata of Baluti Formation requires an environment in which the supply of carbonate fragments was occurred. Explanation of the depositional environment of the shale intervals is difficult due to the lack of diagnostic features. Fossils are extremely rare and scattered within the shale, which is mostly weathered and locally covered in the studied sections. The author interprets the shale to represent deposits of the marine deeper shelf environment below storm wave base ("offshore shale"). Based on the lithostartigraphy, petrography and diagenetic processes, and the presence of polymictic-carbonate conglomerate bed (Fig. 3d), the succession was probably deposited on the deep basin during and/or after the limestone facies were deposited on the shelf margin. Periodic influxes of fine carbonate clasts washing off the shelf were interspersed with periods of reduced influx which allowed carbonate deposition to occur. Marin shale, limestone and marl units, together with skeletal clasts and some intervals of well-preserved fossils, provide evidence for an open, normal marine deeper shelf environment below fair weather wave base but slightly above the storm wave base as indicated by the presence of biosparite layers that can be interpreted as distal tempestites ***[5]*** and ***[6]***. The alternating of these limestones and shales in the Baluti Formation appears consistent with diagnostic features of carbonate storm layers or tempestites. Carbonate storm layers or tempestites can be recognized by a combination of features including: a) intra- and bioclasts, b) flat-pebble carbonate conglomerate, c) sharply defined lower surface with sole marks, d) internal sedimentary structures, including parallel and crosslamination and ambiguously grading bedding, e) rippled upper surface, and f) lack basal lags ***[16]***, ***[5]*** and ***[6]***.

The strata of the Baluti Formation have undergone both shallow and deep-marine diagenesis with slightly evidences of vadose and meteoric diagenesis, as inferred from lithologic characteristics and petrographic analysis. The diagenetic processes and their relative timing in the Baluti Formation can be divided into two main groups: 1) marine diagenesis, and 2) burial diagenesis, occurring prior to, and after lithification. Micritization, dissolution, cementation, neomorphism, dolomitization, silicification, compaction, pyrite growth and hydrocarbon migration are the main diagenetic processes which have modified the formation. Micritization is one the first stages of diagenesis seen in the Baluti Formation and it occurred commonly in marine environment soon after deposition since it predates all other diagenetic features ***[17]*** and ***[18]***. Dissolution process is responsible for the creation of large volumes of secondary porosity within the Baluti Formation. Dissolution of aragonitic bioclasts is most common in platform to or shallow marine-water deposits. A burial origin is inferred for dissolution which postdates micritization and where fractures are infilled by calcite cement. Fibrous, bladed, granular (equant spar) calcite, drusy calcite and locally blocky cement are common types of cement in Baluti Formation. Calcite cements postdate the formation of micrite envelopes and is commonly reported from marine and burial diagenesis. This suggests that the dissolution of bioclasts occurred near contemporaneously or slightly post-dating the precipitation of some granular and drusy cement ***[19]*** and ***[20]***. The rare occurrence of early marine cementation in the sediments of Baluti Formation indicates that during deposition and near surface burial the sediment was affected by very little early marine cementation. ***[21]*** however, showed that granular-equant spar precipitated from deep-marine water. This evidence together with the planktonic fauna occurrence support the interpretation that most of the sediment was deposited in deeper water setting. The evidence of deep-marine diagenesis is reprecipitation of the some carbonate generated by dissolution of unstable grains (presumably aragonitic) into newly opened spaces and partially filled primary pores as fine dursy and equant calcite cement. Further burial processes have produced late stage calcite cementation represented by large crystal calcite of drusy and blocky cements followed, locally, by dolomitization. Neomorphism postdates micritization and early cementation in Baluti Formation. Depending on water chemistry and rates of flow, micrite and early fine calcite cements may recrystallize and neomorphose to coarse grains. Both physical and chemical fractures, stylolites and vein fillings are later diagenetic features and are inferred to have occurred in a burial environment. Pyritization, hematitization, and glauconite clearly predate the calcite cements. Finecalcite cements commonly have inclusions of pyrite, iron-oxide and glauconite, which are of marine origin. Glauconite is an authigenic marine clay ***[22]*** and can thus be used as a point of reference by which to constrain marine diagenesis. From characteristics of the cements, their relationship to glauconite, pyrite and their relationship to other diagenetic features, it is apparent that glauconite, iron oxide, fibrous and bladed cements, were all products of the marine diagenetic environment. The effect of silicification and dolomitisation processes on the Baluti Formation is limited. ***[13]*** argued that scattered rhombs, dolomite crystals along stylolites and pressure dissolution seams, and late cavity-filling dolomite cements are all common forms of burial dolomite in many limestones. Silicification of some bioclasts and matrix, together with silica filling pore spaces by silica is common in some limestone beds in Baluti Formation. This suggests that silicification is likely to have taken place during burial diagenesis. Nodular limestone and carbonate concretions, a product of early diagenesis ***[23]***, are also present.

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