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DEPOSTIONAL ENVIRONMENT OF EARLY CRETACEOUS ARABIAN PLATFORM: AN EXAMPLE FROM KURDISTAN REGION, NE-IRAQ

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Abstract

The field study on outcrop of the Early Cretaceous Arabian Platform (as represented by Qamchuqa Formation) in the northeastern Iraq revealed many fossils and lithologic constituents that can be used for establishment of a new environment of platform in the studied areas. For this purpose the facies analysis of the previous studies are used and reinterpreted. These showed that the evidences of barrier reef environment are stronger for Qamchuqa Formation than previously assigned ramp environment. The facies such as mudstone, miliolid–bioclastics wackstones are deposited in relatively deep lagoon while the branched coral, oncoid, rudist; stromatolites bearing lithofacies are deposited in the reef core. The bioclast packstone to grainstone (coquina), rudstone and orbitulina bearing lithofacies are deposited in the fore reef. Qamchqa formation is laterally toward north and northeast changes to Balambo Formation which is deposited in the deep part of the Southern Neo-Tethys) and represented by planktonic forams bearing mudstone. The ooids and bioclast are deposited in the sand flats that located directly at the back reef. Generally the environment of the formation is characterized by relatively low energy, which was of normal marine circulation during Aptian while toward and deposition of high mg-calcite.

البيئة الترسيبية للرصيف العربي خلال الكريتاسي المبكر: مثال من منطقة كردستان ، شمال شرق العراق

الخلاصة

اظهر الدراسة الحقلية على مكاشف لرصيف العربي(المتمثلة بتكوين القمجوقة) خلال الكريتاسي المبكر عديد من المتحجرات و المكونات الصخارية مفيدة لاستنتاج البيئة الترسيبية منطقة الدراسة. و قد استعلمت التحاليل السحنية السابقة لهذا الغرض حيث ظهر بان دلائل ترسيب لتكوين قمجوقة في بيئة حواجز الحيدية أقوى من دلائل ترسيب في بيئة المنحدر المتعين سابقا . وقد ترسب سحنات مثل : الحجر الجيري الطيني و الحجر الجيري الواكي المليوليدي في البيئات الاكوني العميقة نسبيا، بينما سحنات حاوية على المرجان المتشعب و الاونكويد و الرودست والستروماتولايت قد ترسبت في بيئة الحيد . اما الحجر الجيري الفتاتي الحياتي المرصوص–الحبيبي(Coquina) و Rudstone و والسحنات الصخرية الحاوية على اوربيتولاينة قد ترسبت أمام الحيد . يتغير لتكوين قمجوقة جانبيا نحو الشمال و شمال الشرق إلى تكوين البالامبو حيث ترسبت الجزء العميق و الانتقالي من حوض التيثس الجنوبي الجديد (Southern Neo-Tethys) و المتمثلة الحجر الطيني حاوي على الفورام الطافية . إما السحنات

الحاوية على السرئيات والفتات الحياتية قد ترسبا في المسطحات الرملية (sand flats) والتي تقع مباشرة خلف الحيد . وبشكل عام فان بيئات التكوين تميزت بالطاقة الواطئة نسبياً ، والتي كانـــت مياهـــاً بحريـــة اعتيادية خلال الابتيان ، وقد ازدادت الملوحة واالحرارة خـــلال الـــسينومانيان والتـــي تعكـــس ترســـب الدولومايت التحويري الاولي او الكالسايت الحاوي على نسبة عالية من المغنيسيوم .

Inroduction

The Early Cretaceous Arabian platform is consisted of thick succession of dolomite and limestone. This succession covers, most of Iraq including the studied area and some part of southwestern Iran, Arabian Gulf and Saudi Arabia. The Early Cretaceous Qamchuqa, Suaiba and Mauddud formations are main constructing units of this platform. These units are assumed as important reservoir for oil in Middle East (Buday, 1980, Alavi, 2004, Jassim and Goff, 2006. In the studied area among these units, only Qamchuqa Formation occurs which has thick and relatively well exposed outcrops. The description of the formation is cited in detail by Bellen et al, (1959) as 650 meters of alternation of well-bedded to massive, grey colored, dolomite and light grey limestone or dolomitic limestone. The name of Qamchuqa Formation is derived from the name of Qamchuqa village, which is located directly to the southwest of the type section, about 45 Km northwest of Sulaimani city in the High Folded Zone. According to Furst (1970 in Buday, 1980), the Upper and the Lower Qamchuqa Formations have been renamed Mauddud and Shuaiba formations, respectively in the middle and southern part of Iraq. The same author mentioned that, in Iran, the correlative formations are Dariyan (Aptian) and the Albian part of Sarvak Formation of the East Zagros Mountains in Iran.

Geological Setting

The studied area is located within Sulaimani and Arbil governorates in northeastern Iraqwhich is bounded by latitude (35^{0} 51^{-} $12^{=}$ and 36^{0} 31^{-} $51^{=}$) N and longitude (44^{0} 45^{-} $49^{=}$ and 45^{0} 12^{-} $25^{=}$) E. According to (Stocklin, 1968; Buday, 1980; Buday and Jassim 1987; Mc Quarrie 2004 and Jassim and Goff, (2006), the studied area constitutes a part of Western Zagros Fold-Thrust belt, directly to the southwest of the main Zagros Suture Zone. Structurally, the area is located within the High Folded and Imbricated Zones (Buday, 1980 and Buday and Jassim, 1987) where the anticlines are in northwest–southeast direction. The formation crops out mostly in High Folded Zone along the summit and sides (limbs) of many mountains (anticlines) such as Piramagroon, Sara, Asos, Asingaran, Zhelwan, Kosrat, Qarasard, Safeen, Kewa Rash, Karokh and Makok (Fig.1).

Studied sections

Five sections are chosen and sampled in the Sulaimani and Arbil Governorate, for detailed study (Fig.2). The selection of these sections is based on yielding maximum obtainable information such as facies change and fossils content. However, the process of the selection has suffered from three constrains. The first is that the formation, in many places, form vertical erosional and fault cliffs, which cannot be sampled and even inspected. The second is that, due to high thickness, the lower boundary and even thick intervals of the lower part is not exposed in the many parts of the studied area. The third is that the formation is effected by thrust and reverse faults, especially in the Imbricated Zone, which most possibly have caused repetition of some intervals. In opposite to other formations, the facies change is so rapid, in some places, that when stepping on, several different facies could be recognized in a distance of about 5kms. The detail of the sampled sections can be seen in Ameen (2008).

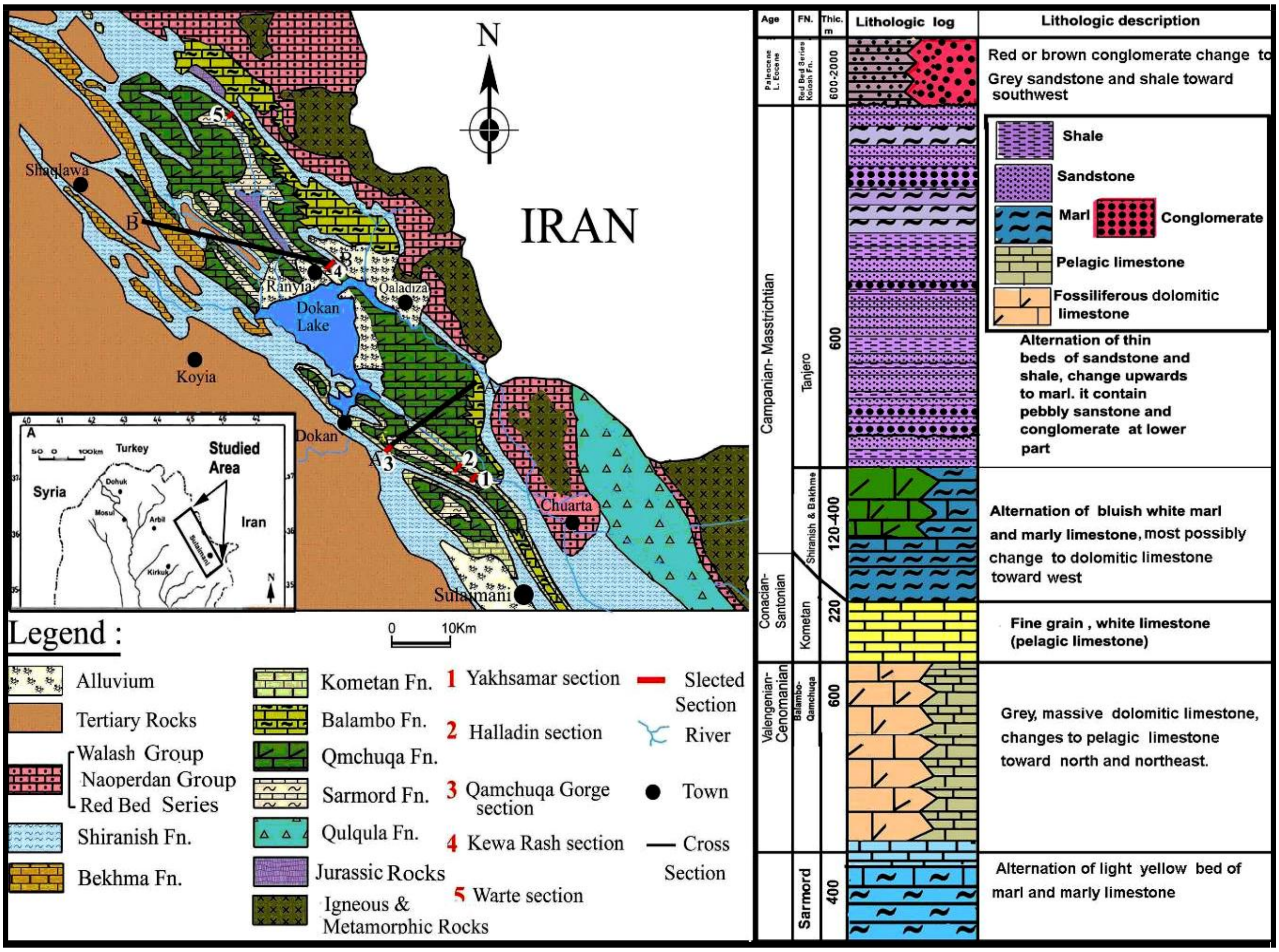

Fig.1: Geological map (modified from Sissakian, 2000) northern Iraq showing location of the studied section and stratigraphic column (not to scale).

Depositional Environment

It is generally known that the depositional environment of the formation is platform but three facts are important to be clarified. The first is that it is not known if the platform was totally attached, or it has suffered from more or less intermittent isolation. The second is if the platform consisted of ramp, rimmed shelf or barrier. The third is the problem of climate; prevailing wind direction, temperature of the basin during different time.

For solving one or all the above facts, the field and petrographic studies had achieved which revealed some positive sign of solving them. In the study, different types of fossils and facies are found, which change both laterally and vertically. All these fossils are indicating shallow depositional water of platform environments. Some of the lithofacies and fossils are discussed by Ameen(2008). These fossils and other allochems, are very helpful for environment indication. These facies are such as oolitic packstone–grainstone, boundstone (planar, wavey and oncoidal stromatolite of green algae and bacterias) (Fig. 3), tabular scaleritarian and branched corals (Fig.4B and 5) bearing lithofacies. Most intervals contain radiolitids rudists (Fig.6) while orbitulina and miliolids forams can be seen occasionally. These facies and fossils give specific environment.

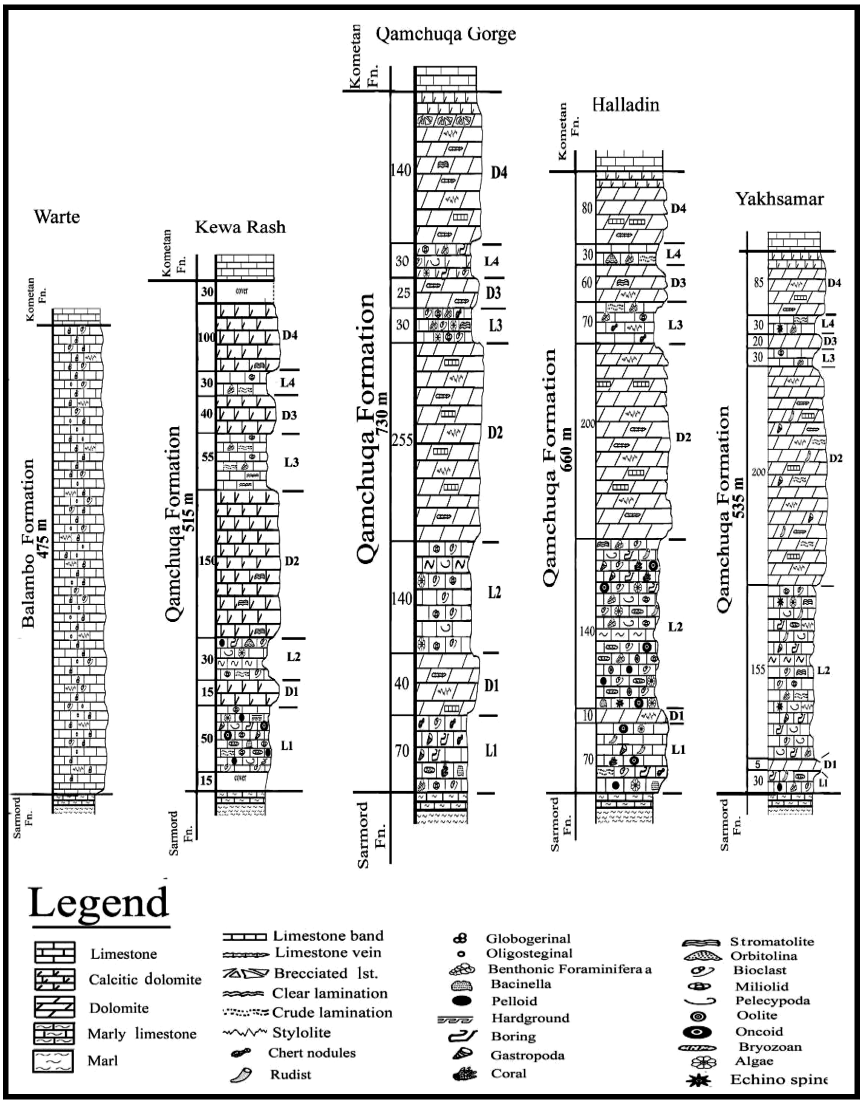

Fig.2: Studied outcrop sections and their lithological constituents (Ameen, 2008). L: limestone units, D: Dolomite units.

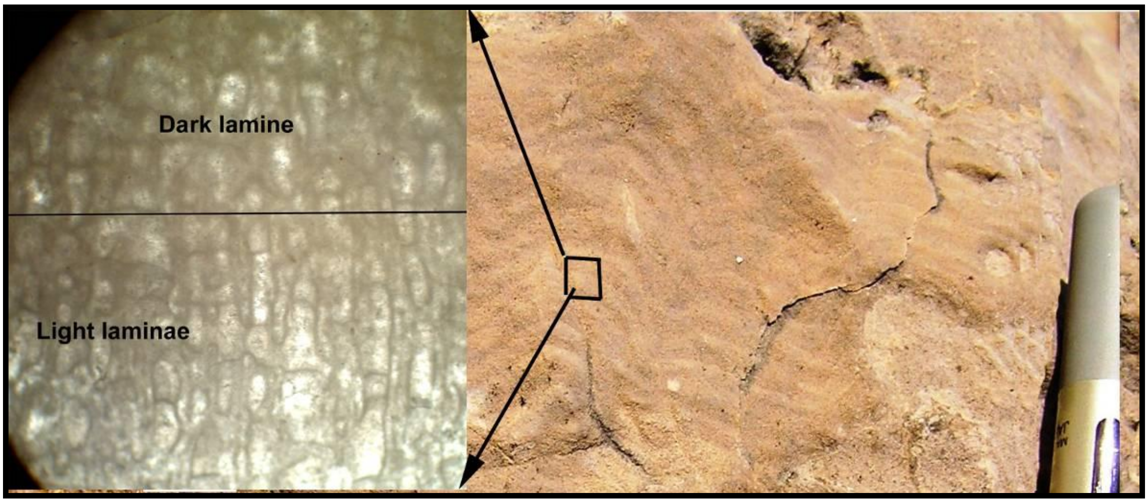

Fig.3: wavey stromatolite of green algae in the lower part of Haladdin section (Babo mountain) of Arabian Platform (Qamchuqa Formation).

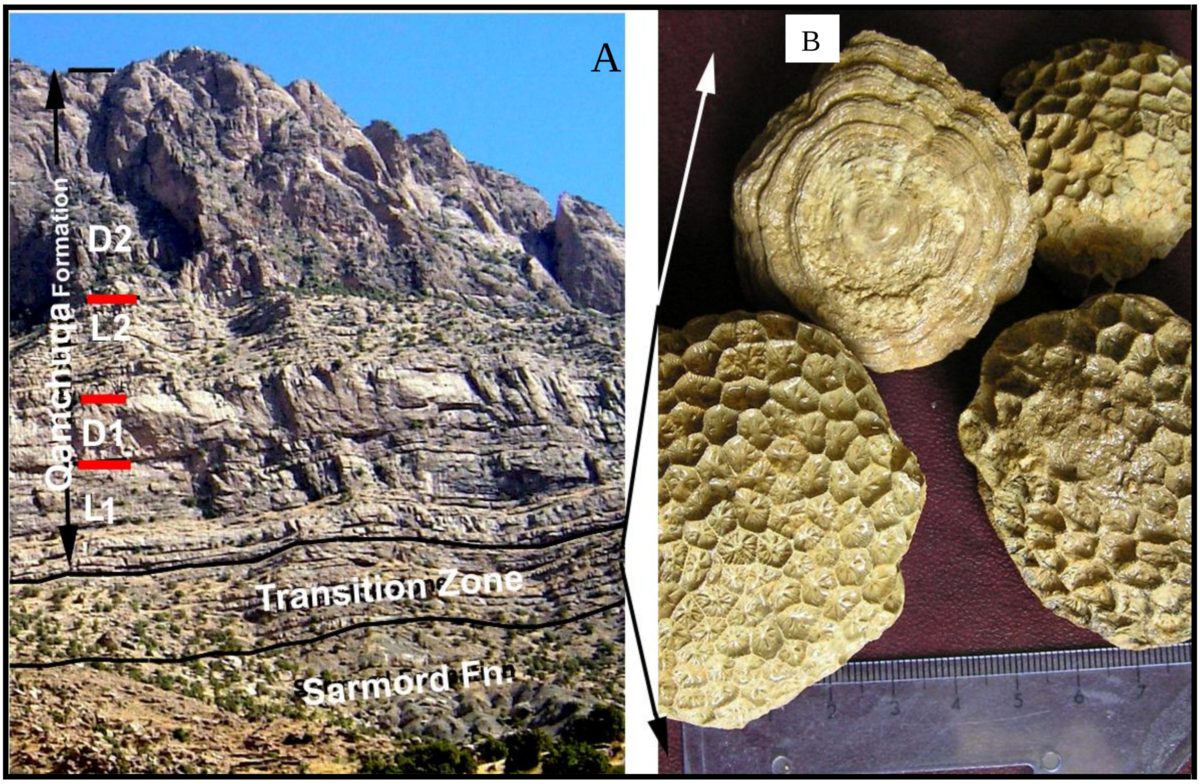

Fig.4: A) A section of Early Cretaceous Arabian Platform near Qamchuqa Village showing transition zone between Qamchuqa and Sarmord Formations in addition to limestone and dolomite units. B) The single coral colonies in the transition zone with Sarmord Formation which found in the Qamchuqa and Bardashan sections.

Fig.5: Branching Coral of Arabian Platform (Qamchuqa Formation), A) coral in outcrop in the lower part of the Halladin section, B) coral of Kewa Rash section under binocular microscope (taken from Ameen, 2008).

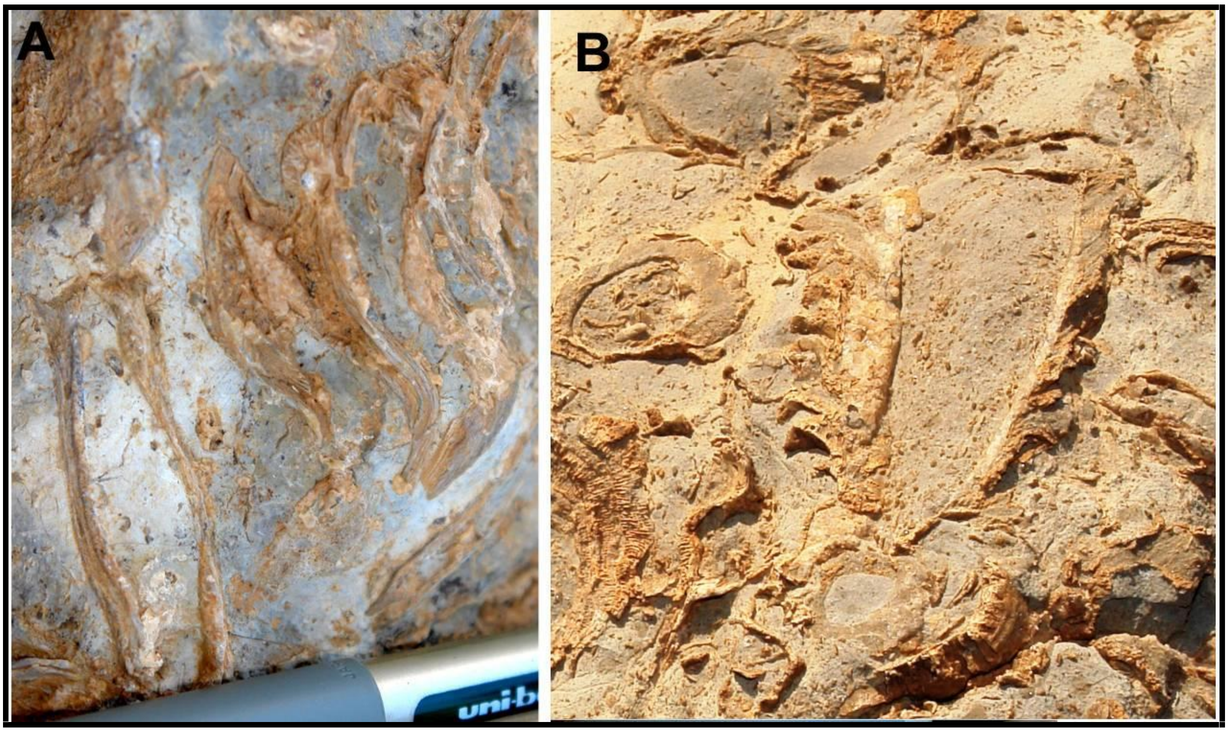

Fig.6: In situ Radiolitid rudists in Yachsamar and Haladdin sections in the lower part of the formation.

Reef Environment

Seven evidences are observed in the studied area which indicated that the platform is consisted of barrier reef instead to ramp that assigned previously by Al-Sadoony (1978) and Al–Shakry (1977), Jassim and Goff (2008) and Bawa(2008). The first is alternation of thick limestone and dolomite successions in the studied area. The vertical facies change from limestone to dolomite rapid and the contact is relatively sharp. This sudden change of facies is more common in reefal setting than in ramp because there is more isolation between different parts (lagoon, core, sand flat and fore reef) of the reef than ramp (See models of reef in Lehrmann *et al*, 1998 and Ensile, 2000). In the Halladin section, 50m of algal bounstone is overlain by three meters of oolitic packstone-grainstone and the contact is sharp. This sharpness can be observed between miliolid and coral bearing successions in Qamchuqa section too and between dolostone and limestone successions in all section (Fig.2 and 4A).

The second is that there are two thick limestone successions (L1 and L2) of reefal and lagoonal limestone at the lower part of the formation both at Qamchuqa and Haladdin sections respectively. In the Haladin section, the L1 is about 50m thick and consist of massive algal boundstone and coral bufflestone which makes reef core (Fig.7). Reijmer and Immenhauser(2005) have mentioned that the coral-rudist-microbolite (algal) boundstone is related to episodes of reef development at the platform margin (which is applicable for the studied area). The L2 is about 140m thick and contain index fossils of lagoonal environment such as miliolid and Dacyculadacy green algae. This thick succession of lagoonal facies is more suitable for reefal environment than ramp since in the ramp, there is more sediment dispersal than reef and the vertical and lateral facies change are more or less gradational. The third is that the reefal environment is clear in Qamchuqa Formation from outcrop and thin section study. In outcrop, all sections contain thick alternation of massive limestone or dolomite. These successions form high cliffs, in some palace, about 300m high (Fig.4A). They consist of light grey coral, algal and stromatolitic limestone (Fig.3 and 5) with various types of rudist gastropods and pelecypods (Fig.6).

The fourth fact is that the cross sections that are drawn by Dunnington (1958) for the north eastern Iraq during Lower Cretaceous show topographies that more resemble reef than ramp (Fig.8B). When the ramp considered on these topographies, it doesn't agree with facies distribution from the southwest toward the northeast. If the platform was ramp, the deep facies must be in the northeast of the platform not in the southwest or west. But the actual facies distribution is opposite. This is because, the shallowest facies such as oolitic grainstone, stromatolite bounstone and rudist rudstone are located in the extreme northeast near the border with Iran. When the angle of the slope of the ramp is assumed to be 0.5 degree the depth of the water will change from zero to 800m if the distance is about 100km (for example the distance between Ranyia town and Kirkuk City(Fig. 8C). This distance was longer during Lower Cretaceous than present due to absence of shortening that is resulted from later folding. But the actual depth estimation by facies shows no such change of depth from southwest towards northwest and nearly a fixed depth along 100km distance can be inferred from facies. To the north of Ranyia town and east of Qladiza town, the relatively sudden facies change to pelagic limestone (Blambo Formation) can be observed which passes through fore reef facies (bioclast grainstone and rudstone).

The fifth evidence is that, in all sections, there are no important terrigenous clastics. Ameen (2008) and Bawa (2008) recorded a bed (about 15cm thick) of limestone that contains disseminated quartz grains. These grains are angular and do not show any sign of roundness (Fig.9). Therefore, the origin of these grains is not clear. Qaradaghi, *et al* (2008) mentioned that quarz grains of Nahr Umr Formation (as equivalent of Qamchuqa Formation) are sub-rounded to well round. Therefore, the terrigenous source (Western Desert) of these grains is excluded but the intraformational source is not excluded as reworked early authigenic quartz grain or may be transported by wind. In the Qamchuqa Formation many horizons contain chert nodules in the Halladin and Qamchuqa Sections (Fig.1), so the growth of early diagenetic quartz and reworking is not impossible.

The seventh fact is that when the ramp setting is considered, the boundary of Arabian Platform is not clear which is indicated in the fore reef area of Qamchuqa (Mauddud or Shuaiba) Formation. In contrast to this, this boundary is not clear in case of ramp setting since the boundary of the inner, mid and outer ramp is not indicated previously. Rreigers and Hisu, (1986) not included ramp in the definition of a platform and gave it separate definition. Many authors mentioned or recorded patchy reef in the Qamchuqa Formation, among them are Al-Sadoony (1978) and Al–Shakry (1977). The attribution of the deposition of the Qamchuqa Formation to patchy reef is not ascertained in the present study, due to two points. The first one is the patchy reefs are commonly associated with terrigenous influx which does not exist in Qamchuqa Formation, at least in the studied area. During studying of the outcrops these patchy reefs were not recognized and could not be missed because they are clear for their massiveness and resistance to erosion and appear as mound. However, their occurrence is not excluded in the lagoonal or forereef areas.

Therefore, according to these observations it is clear that the platform was reef not ramp as signed previously and use of platform is more suitable than ramp. When the platform is used it means it may contain both ramp and shelf either spacially and temporally. Rreigers and Hisu (op. cit) and (Bosence, 2005) mentioned that ramp and shelf are interchangeable with time.

Therefore, a reef (barrier reef) model is drawn for the depositional environment and topographic relief of the basin of Qamchuqa Formation. By this model the position of nearly all facies are indicated in which the thick and massive dolomite successions are located at the back reef and derived from dolomitiztion of sand flat(Fig.8). According to the model, this flat consists of wide area behind the reef (between the reef core and lagoon). The sediments, in this flat area, were porous bioclastic (mostly high Mg) and were in contact with Mg-rich water of the lagoon for early dolomitization when the wind and sea level changes was supportive for invasion of lagoonal water. The dolomitization is aided by bioturbation organism, which may have stirred the sediments several times and then enriching with high Mg lagoonal water, during each stirring phase.

The prevalence of mudstone and dolostone lithofacies and occurrence of rare oolitic and bioclastic grainstone reveal calm environment while it was winnowing for some short interval time. In this connection, Einsele (2000) showed by diagram that association of green algae, coral; and others are survived in wet tropical seas. These fossils and lithofacies indicate that the environment of the lower part was consisted of low–latitude circulated normal marine platform environment as typical algal and coral reef is developed (Fig.7). Toward the upper part thick and massive–bedded succession of dolomite increases, this might be attributed to increase of temperature, salinity and isolation (relative restriction). This may be related to the green house phenomena that prevailed during Early Cretaceous (Barremian–Aptian) as mentioned by Friedrich (2003) and Hillgärtner *et al.* (2003). The former author added that the mid-Cretaceous (nearly coincide with deposition of upper part of the Qamchuqa Formation) was the extremely warm while the Late Cretaceous (Campanian–Maastrichtian) interval marks the onset of waning greenhouse conditions. This warm condition and restricted circulation was favored by high evaporation and early dolomitization of the sediments in the upper part. In this connection, (Millman and Muller, 1973, and Sartori, 1974, in Reading, 1991) mentioned that high Mg calcite precipitated during high-elevated temperature. Evidence to the warmness of the climate during Albian–Cenomanian is the deposition of the evaporite concurrently with deposition of upper part of Qamchuqa Formation in the western Iraq as Jawan Formation (Buday, 1980, Dunnington, 1958 and Jassim and Goff, 2006).

Another possible reason for occurrence of thick dolostone in the upper part is the narrowing of the Southern Neo-Tethys in which Balambo and Qulqula Radiolarian formations were depositing during Mid Cretaceous. The cause of narrowing is attributed to the southwest advance of Iranian Plate (Fig.10) (see Ameen, 2008) which led to limited circulation and decrease of the tidal current in the southern Neo-Tethys. These currents, are generated (now days) by gravitational interaction between earth and both moon and sun.

The scarcity of large forams, except orbitolina, can be signal for the restricted and some higher degree of salinity than normal marine water. According to Pittet, *et al.,* (2002), orbitolinid beds and carbonates formed by microbolites and microencrusters seem to be the shallow-water carbonate response to global changes, affecting Late Barremian to Aptian palaeoclimate and palaeocean-ography. When one compare between the rudists of Upper Cretaceous (Aqra Formation) with that of Qamchuqa Formation, he realize the relative intolerable environment of the latter formation as compared to the former one. The rudist of Aqra Formation gained sizes

larger three times than that of Qamchuqa Formation for same genus (Fig.4).
Prevailing wind has great role in accumulation of the bioclastic or lithoclastic sediments in the backreef area and either supplying food (aiding growing of reef) or increasing turbidity preventing reef growth. This is can be seen in both northeastern and southwestern coastal area of the Arabian Gulf respectively now. As concerned to the prevailing wind direction in the Qamchuqa basin it is possible that the nearly same wind system (northeasterly and south westerly winds) of the present was prevailing during Early Cretaceous as topography and main water body similar to present time if the northeast and southwest of the present is reversed 180 degrees. This mean that the main water body was to the northeast during Early Cretaceous while the topography was at southwest (western desert) but now this geography is reversed as the main body of sea consist of Mediterranean and Arabian Gulf.

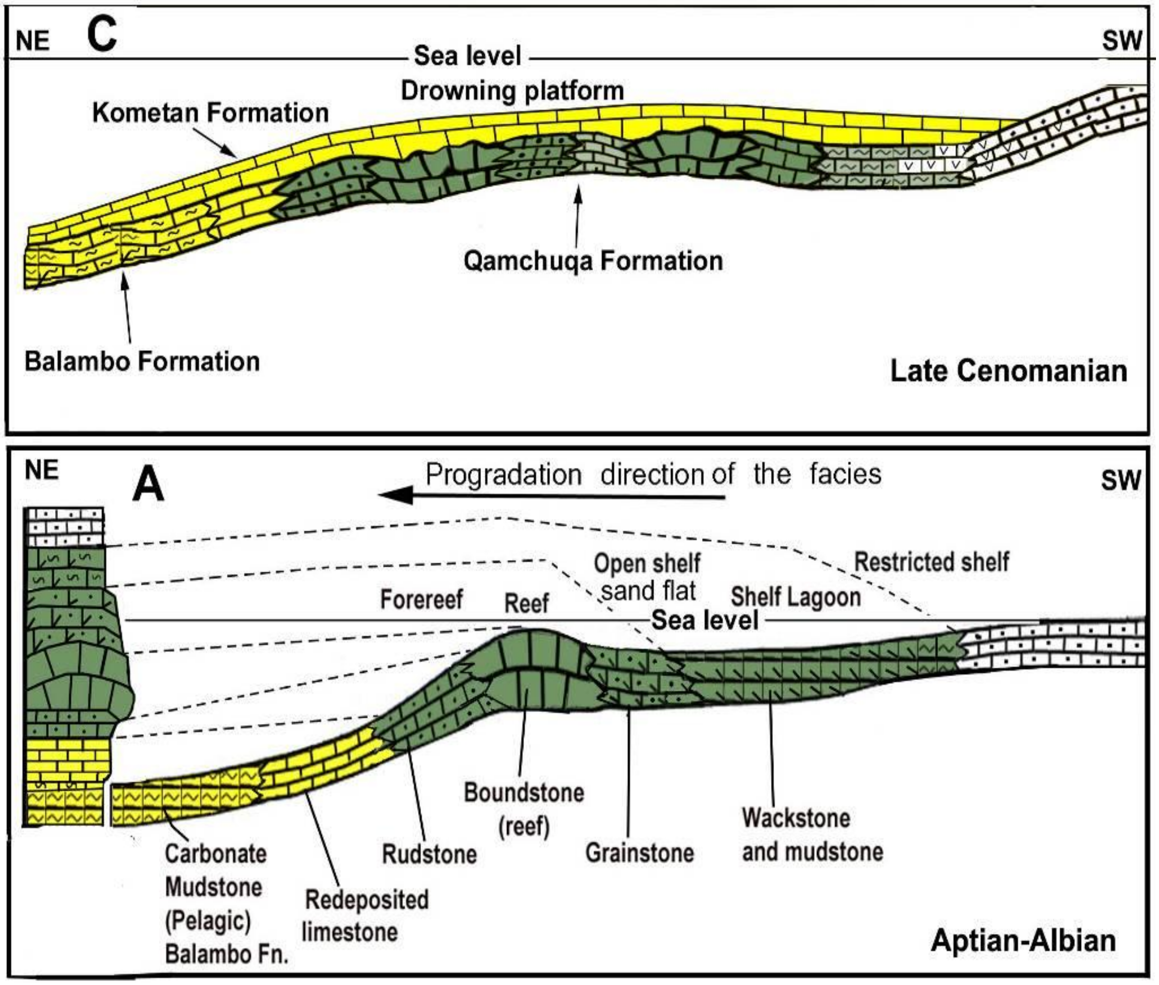

Fig.7: Two depositional models for Qamchuqa Formation. A) After drowning (local subsidence of Arabian platform) during Late Cenomanian. B) Before drowning which shows reef topographic setting and observed facies distribution. (Taken from Ameen, 2008).

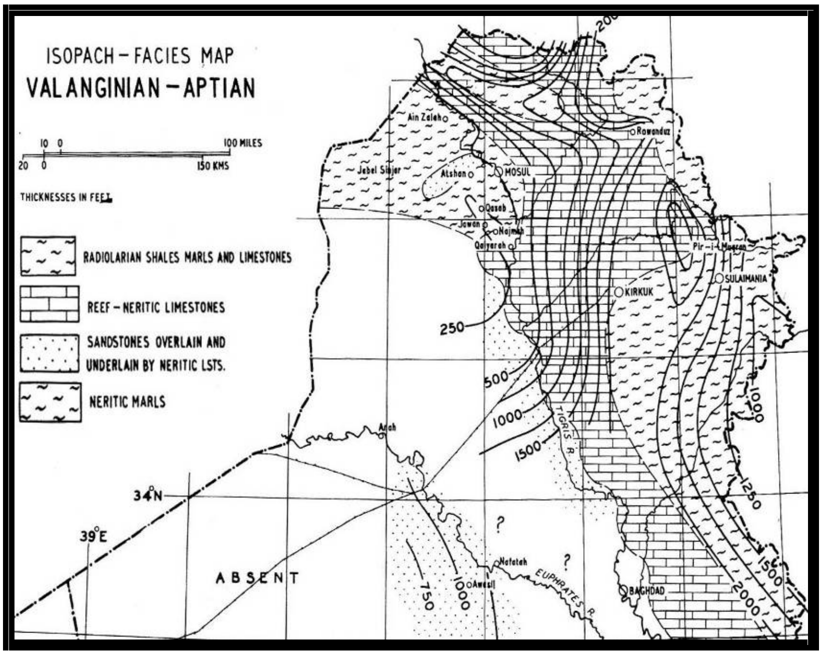

Fig. 8A: Isopach facies map of Valanginian–Aptian (Dunnington, 1958) shows position of reefal limestone. The reefal limestone is surrounded from several sides by deep facies (marl), which may be ascribed to isolated platform setting.

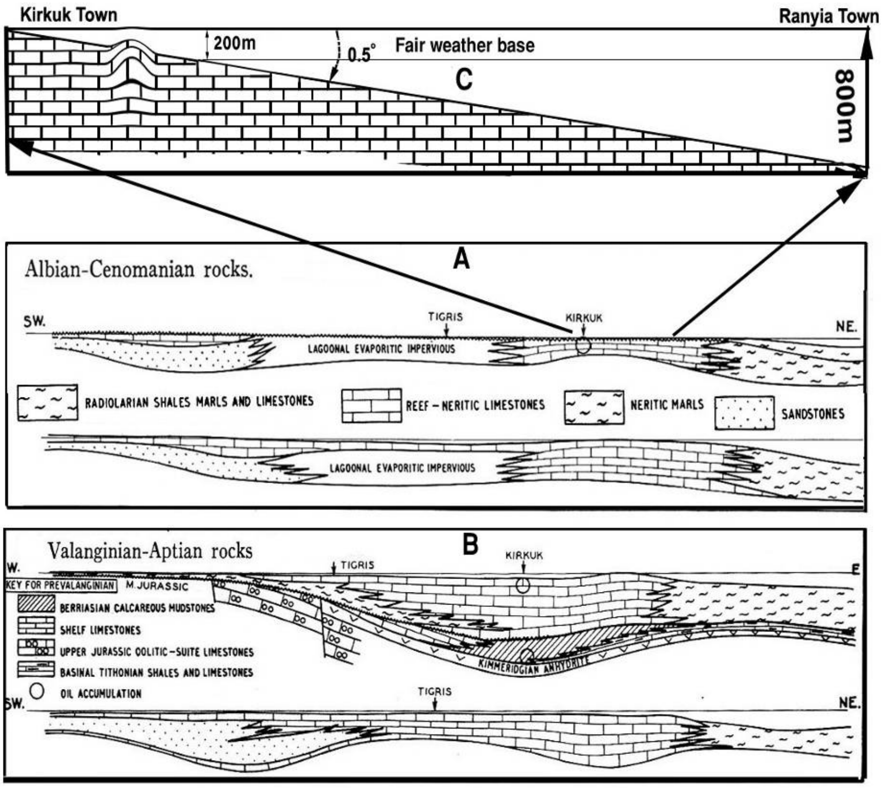

Fig. 8B: Diagramatic cross section of Iraq(NE-SW direction) during: A) Albian-Cenomanian, and B)Valanginian–Aptian (Dunnington,1958) show topographies that better fit shelf(reef) than ramp. C) Calculation of depth (in the present study) when the suggested ramp has the slope of 0.5 degrees. The depth is about 800m which doest agree with existed observed facies.

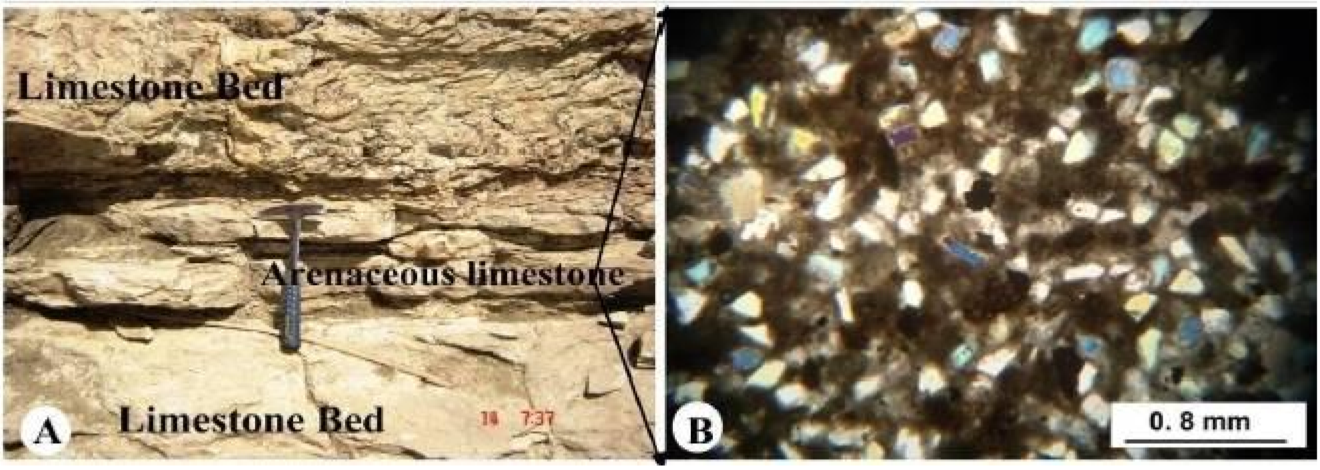

Fig. 9: Disseminated angular quartz grains in the arenaceous limestone as bed of 15cm thick position showing alternation of different environment of the type section of Qamchuqa Formation. (Taken from Bawa, 2008).

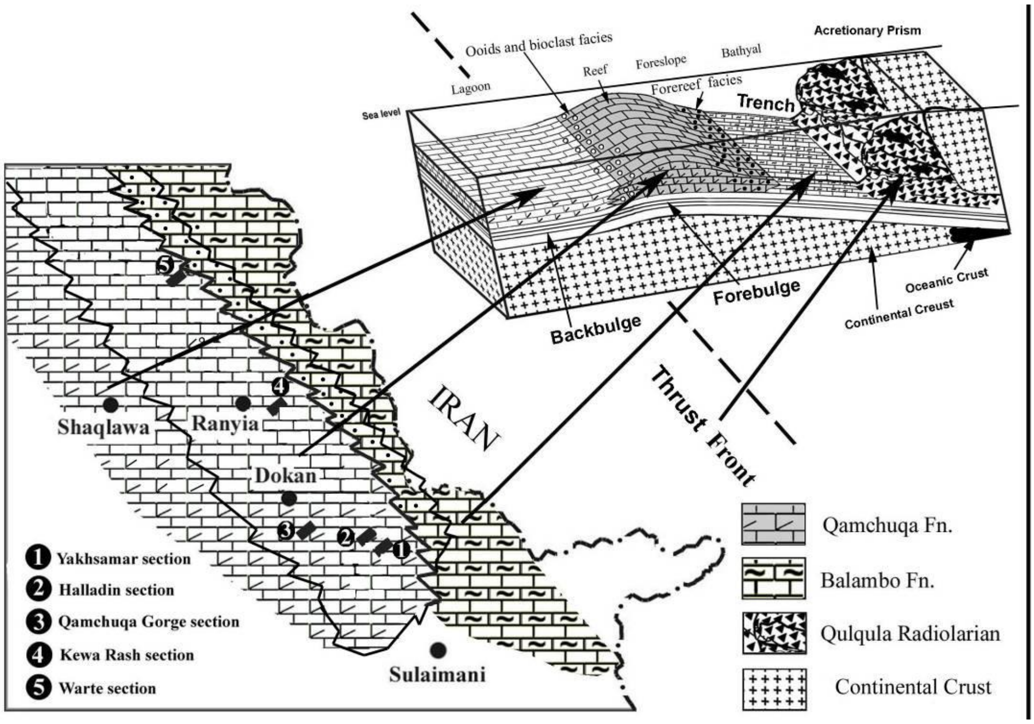

Fig. 10: Position of different environment in the tectonic model of the Arabian Platform during Aptian in the Northeast Iraq. The Shaqlaw area was changed to reef during Albian.

Conclusions

1- The Formation was deposited in reef, forereef and back reef environments. The reef was barrier reef.
2- The environment of the Qamchuqa Formation was relatively quiet and warm with short interval of agitation.
3- The upper part of the formation shows more restriction of the circulation than lower part.
4- The reef body consists of reef builders such as coral, rudist, algae and stromatolite. The environment was changing in response to sea level change and tectonic subsidence and uplift.

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