Sedimentary Environments and Age Determination of the Chia Gara Formation, Northern Iraq

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Abstract

The rock successions of the Chia Gara Formation were studied at two surface sections (Barsarin and Rania) from North-Eastern Iraq. The detailed sedimentological study reveals that the formation consists basically of thin-bedded black limestone, dolomitic limestone, marly limestone, bituminous shales, and Ammonitic limestone. The petrography results showed that the formation consists of various petrographic components as Ammonites, calcispheres, radiolarian, and silicate sponges in addition to the groundmass of micrite. Ammonite taxa are examined in the upper part of the Chia Gara Formation to find Ammonite species, of which seven species have been identified. One biozone is postulated based on the above assemblages, in order of age: Berriasella Jacobi, from a regional perspective, this biozone was connected with other Ammonite assemblages, leading to the conclusion that the Formation age is Early Cretaceous in age. The facies analysis demonstrates that the rock succession consists mainly of three microfacies. The main microfacies include lime mudstone, wackestone, and packstone. At the same time, the lithofacies comprise limestones and shales. The overall characteristics of these facies show that the Chia Gara Formation was deposited in three different environments; (1) the Lower part of the Upper bathyal (2) the Middle part of the bathyal, and (3) the Upper part of the outer shelf environment.

Keywords: Ammonite; Chia Gara; Cretaceous; Iraq

1. Introduction

The Chia Gara Formation is one of the important carbonate formations found in Iraq. It is located within the range of the High Folded Zone and the Foothill Zone and Imbrication Zone of tectonically unstable mountains (Jassim and Buday, 2006). The Chia Gara Formation Deposited during Late Jurassic-lower Cretaceous. The type section of the Chia Gara Formation is located in the north of Iraq, Duhok City, South of Amadiya, specifically At the Chia Gara anticline, in the high folded zone. This location was studied by Wetzel (1950). The thickness of the formation at its type section is 232m consists of alternating sequences of thin-bedded limestone and shale, the upper part consists of more ammonite faunas, about 20 meters thick, and grading upwards to yellowish marly limestone and shale. The lower part contains the "phacoid" beds, about 25 meters thick. The lower boundary of the Formation within the Barsarin Formation located below it is conformable and the the upper boundary of the Formation with the Garagu Formation located above it is conformable. The aims of this study are to determine the
petrography and microfacies to investigate the sedimentary environments for the Formation and identify the ammonite species to determine the age of the formation.

The Chia Gara Formation in the Rania section, is located in the north of Iraq, Sulaymaniyah, Rania city, Shawli anticline, at the intersection of latitude (36° 17’19.3” N) and longitude (44° 51’11.1” E) (Fig. 1). The lithostratigraphic description of the Rania section consists of limestone with thin shale rock, brownish to dark color, about 100 m in thickness(Fig. 2). The lower part of the Formation contains layers of phacoid bed which indicates the beginning of the Chia Gara Formation and is interspersed with dark-colored shale layers. While the middle part consists of a succession of limestone and shale rocks and the which color is light. The upper part contains ammonite fossils and its traces. The overlying Balambo Formation is conformable with the Chia Gara Formation, while the lower contact is a sharp conformable boundary with the Barsarin Formation.

The Chia Gara Formation appeared in the Barsarin area, Erbil, Zozak anticline, near the course of Rawanduz River, at the intersection of latitude (36°37'46.50"N) and longitude (44°39'13.65"E) (Fig1). The lithostratigraphic description of the Chia Gara Formation in Barsarine section also consists of a succession of well-bedded limestone of dark brown color intercalated with thin dark black shale layers. The thickness of the Chia Gara Formation in the barsrine section is about 87 m. The lower part contains the layers of phacoid bed characterized by dark colors because contains bituminous organic materials. The middle unit shows an increase in limestone with decreasing shale beds, while the limestone beds of the upper part, are interbedding with laminated shale and contain ammonite fossils. The overlying Sarmrod Formation, which is bounded from the top by a sharp conformable surface and the lowering contact it is conformable with the Barsarin Formation(Fig. 3).

![Fig. 1. A geological map showing the locations of the studied areas (Sissakian, 2001)](image-url)
Fig. 2. The lithostratigraphic column of the Rania sections

<table>
<thead>
<tr>
<th>Formation</th>
<th>Thickness (m.)</th>
<th>Lithology</th>
<th>Sample no.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balahbo</td>
<td></td>
<td></td>
<td></td>
<td>The upper part consists of limestone which color is light brown and Alternation with shale beds. This part contains ammonite fossils</td>
</tr>
<tr>
<td>Chia Gara</td>
<td></td>
<td></td>
<td></td>
<td>The middle part consists of a succession of limestone and shale rocks which color is brown</td>
</tr>
<tr>
<td>Barsarin</td>
<td></td>
<td></td>
<td></td>
<td>The lower part consists of Alternation limestone with thin shale beds, the color is dark brown of limestone, and black shale. The lower part contain layers of phacoidal structure</td>
</tr>
</tbody>
</table>

Legend:
- Limestone
- Shale
- Dolomite
- Marly Limestone
- Ammonitic Limestone

Scale 1cm:5m
Fig. 3. The lithostratigraphic column of the Barsarin sections.

The deposition of the Chia Gara Formation take place during a long period of time, during two eras (Jurassic_Cretaceous) (Fig. 5) that is, at the end of AP7 and the beginning of AP8 during this era, the New-Tethys sea began to form, in the Northern and Eastern parts of the Arab plate (Buday, 1980). The Arabian plate was divided into the Arabian shield and the Arabian shelf, as the Arab shield represents
the area that was characterized by sediments belonging to the pre-Cambrian era to the present time. The Arab shelf forms a deep sedimentary basin to the east (Geert et al., 2001). According to Buday and Jassim (1987), the Arabian shelf was divided in the northern part of Iraq into two regions: the stable region, in which there are no or few folds, and the unstable region, the region in which there are folds, which were distinguished during the Jurassic period in the areas of creeping faults with a thin sedimentary cover interspersed with some interruptions (Fig. 4). As a result of the activity of tectonic plates in the north and northeast of Iraq, during the Jurassic to Cretaceous periods, the rocks usually occur at some eroded cores and limbs of anticlines in High Folded, and Thrust Zones.

![Image](image.png)

**Fig.4.** Paleogeography for Tithonian to Berriasian in Iraq (Jassim and Buday, 2006).

Wetzel (1950) in Bellen et al. (1959) originally identified the Chia Gara Formation (M. Tithonian-Berriasian) in the Chia Gara anticline, south of Amadia city in the High Folded Zone of northern Iraq. At its type section, the formation is about 232 m thick consists of thin-bedded limestone and shales that are rich in ammonite faunas. The Formation grades upward to yellowish marly limestone and shales that have a zone of phacoid beds that is 21m thickness at the base (Belen et al., 1959). On the ammonites of this formation, Spath (1950) conducted a thorough examination. The Tithonian-Berriasian layers were referred by Dunnington (1958) as basinal euxinic radiolarian shale-limestone. The Chia Gara Formation sediments were regarded by Buday (1980) and Jasim and Goff (2006) as a representative of the deep marine facies. According to Total’s (1990) study the area west of the Tigris River had a high average rate of sedimentation for the Chia Gara Formation. Al-Qayim and Sadala, (1992) investigated the Formation in the Rawandoz region and Bekhma Gorge. They came to the conclusion that the Formation depicts characters from the deep ocean. Salae (2001) studied the Chia Gara Formation in the Rania area and documented to the first occurrence of brown shale layers of the Chia Gara Formation over the stromatolites beds of Barasarin Formation. Al-Ameri and Al-Obaidi, (2004) considered the Chia Gara Formation is a source rock. Mohyaldin (2007) studied the formation in the Rania area and concluded that the upper bound of the Chia Gara Formation is not compatible with the Balambo Formation (Mohialdeen et al., 2013). Al-Abbasi (2017) studied the sedimentological and stratigraphically of the late Jurassic to early Cretaceous (Tithonian to Aptian) successions from selected section in north Iraq (Mamaseni et al., 2019). Mustafa & Tobia (2020) studied geochemical applying in unraveling...
paleoweathering, zones and environmental setting of the shale from the Chia Gara Formation, Kurdistan Region. The goal of this study is to classify the ammonite taxa that collected from the Formation and age determination for stratigraphic successions that deposited in Jurassic period and determined the sedimentary environment by using the facies and microfacies.

![Figure 5. Schematic chart for Iraq Mesozoic Formations including the Chia Ghara Formation (After Sharland et al., 2001).](image)

### 2. Materials and Methods

Two areas were chosen for field work including an accurate description of all field phenomena that are clearly visible in the rock detectors of the studied sections and the collection of rock in the two sections based on the differences in the characteristics of the rocks and determine the upper and lower formations. 100 rock samples were prepared and taken from the study sections.

The Laboratory work (80 thin sections of rock) (slides) were made in the geological workshop and laboratory study under a polarizing microscope in order to identify the petrographic characteristics of
the Chia Gara Formation rocks and to precise the biological content, in addition to identifying and studying the diagenesis processes affecting the rocks.

3. Results

3.1. Skeletal Components

Ammonite: The Cephalopods are shows bilaterally symmetrical marine carnivore mollusks that include a large number of Genera since the Paleozoic, these are the larger group after Arthropods. They are active marine predators that we’re able to swim within the marine. They are also the most intelligent, moving, and largest of all the mollusks. Gradually, three forms of ammonoids (Goniatites, Ceratites, and Ammonites) evolved, over geologic time. The cephalopod shell shapes are varied, ranging from coiled-shaped in one plane (planispirally coiled), to open spirals, called Heteromorphs shells. Species

Radiolaria: the Radiolaria fossils were identified in the rocks of the Chia Gara Formation in the middle part. Two types of Radiolaria skeletons were identified, a cultivar of Spumeellaria and Nassellaria. As shown (Armstrong and Brasier, 2005) the Radiolaria are found from the photic zone to the abyssal depths, meaning that the Radiolaria increase with depth from the shelf area to the bathyal area in the sedimentary basin.

Sponges: Spiny sponge fossils were diagnosed in the rocks of the Chia Gara Formation in the middle and upper part. their walls are made of either calcium carbonate (such as calcite, aragonite) or of Silica (opal_A) found in the pre-Cambrian era to the recent era and have the ability to adapt and it sparsely presenced in fresh water in most of the sponges of the Paleozoic and early Mesozoic eras. It is found in shallow to deep marine environments (Scholle and Ulmer Scholle, 2003).

Calcispheres: They have been found at very high rates in the rocks of the Chia Gara Formation, indicating that the Calcispheres found in the usual carbonate deposits of the Jurassic-Cretaceous period are deposited in the deep marine environment (Pelagic) (Flugle, 2010).

3.2. Groundmass

The groundmass of the Chia Gara Formation rocks contains micrite (Fig.8g) and it is recrystallized to the microspar (Fig.8h). the presence of micrite require low energy and a calm environment (Folk, 2004).

Diagenesis Processes: The Chia Gara Formation's petrography shows diagenesis processes and their effects on rocks and their compenents, such as grain types (Allochems) and groundmass (matrix). There are many diagenesis processes that affect the Chia Gara Formation, cementation is a common process in Formation. Many types of cement are recognized including blocky cement (Fig. 7a). Granular cement (Fig. 7b), fibrous cement (Fig. 7c), Drusy cement (Fig. 7d). Recrystallization has affected the rocks of the Chia Gara Formation, particularly in the lower and middle parts of the Rania and Barsarin sections (Fig. 7e). The other digenesis process is silification which is identified in the skeletons of the radiolaria fossils (Fig. 7f). There are other types of the digenesis process that are accompanied by a change in the mineral and chemical, such as dolomitization. According to Randazzo and Zachos (1984), two types of dolomite textures were diagnosed, the aphantopic fabric (Fig.7g) and the Floating rhomb fabric (Fig. 7h). Fractures filled with sparry calcite cement generated from pressure solution of post-compactional diagenesis are prominent criteria for identifying chemical compaction or physical compaction(Fig. 8a) in the Chia Gara Formation. Such chemical compaction forms include Hummocky Stylolite (Fig.8b), irregular Stylolite (Fig. 8c), Peak low amplitude (Fig.8d), parallel Stylolite (Fig. 8e), and Peak high amplitude (Fig.8f), (Flugel 2010). Also, the process of dissolution that occurred for the structural and non-structural grains in the rock as a result of factors of carbon dioxide pressure,
temperature, acidity, hydrostatic pressure, and the degree of saturation with solutions (Milliman, 1974; Flugel, 1982)(Fig.6a).

3.3. Facies Analysis

The microscopic study of the rocks of formation revealed that it consisted of three main microfacies according to Dunham classification, (1962): the lime mudstone microfacies, lime wackestone microfacies and Lime packstone microfacies, then they are divided into submicrofacies according to the components grains. and two lithofacies: Limestone lithofacies and Shale lithofacies. The submicrofacies compared with the stander microfacies of Wilson (1975) and Flugle (2010).

3.3.1. Lime mudstone microfacies (M)

This microfacies is located in the lower and middle part of the formation of the study area in both sections, Its contain less than 10% of the components of the skeletal grains (Radiolaria, Calcspheres, and Ammonite), groundmass, with a small percentage of organic matter. This microfacies divided to three submicrofacies :

- Radiolarian lime mudstone Submicrofacies (M1)

  This microfacies consist of skeletal grains of the Radiolarian with a percentage less than or equal to 10%. This microfacies is common in the middle part of Chia Gara Formation (about thick 6-10 m) and their molds are sometimes filled with calcite. The groundmass consists of brown micrite (Fig.6a). This submicrofacies affected by silicification, cementation and compaction. The features of this submicrofacies resemble to the stander microfacies of (SMF1)

- Calcspheres lime mudstone Submicrofacies (M2)

  this facies consists of calcspheres with a percentage of less than 10%, with a brown micrite groundmass (Fig.6b). This microfacies is common in the lower part of Chia Gara Formation (about thick 7-23 m). This microfacies affected by silicification and compaction. The features of this submicrofacies resemble to the stander microfacies of SMF3.

3.3.2. Lime wackestone microfacies(W)

This facies is widespread in the middle to upper part of Chia Gara Formation in both sections, contain more than 10% of the components of the skeletal grains (Calcareous balls, Radiolaria, and Sponges), and the micrite groundmass dark brown, with a good percentage of organic matter, and in some areas, it is subjected to a diagenesis process of re-crystallizing micrite to microspar as well as a process of chemical and physical dissolution and compression. These microfacies are divided into sub microfacies, which are:

- Calcspheres lime Wackstone Submicrofacies (W1)

  This facies consists of calcspheres with a percentage of more than 10%, with a brown micrite groundmass in addition to organic matter. This microfacies is common in the upper part of the Chia Gara Formation (about thick 15-25 m). This microfacies affected by compaction diageneses (Fig.6d). The features of this submicrofacies resemble to the stander microfacies of (SMF3).

- Radiolarian lime Wackstone Submicrofacies(W2)

  These facies consist of radiolarian fossils and that are widespread in the middle part (about thick 5-10 m), and less than it in the upper part, and the lower part is very little, which is also subject to several
diagenesis processes silification, cementation and compaction processes (Fig. 6c). The features of this submicrofacies resemble to the stander microfacies of (SMF1).

- **Sponge lime Wackstone Submicrofacies (W3)**

  These facies consist of the skeletons and fragments of (sponges), which are found in the middle and upper part (about thick 5 m) and are also subject to diagenesis processes silification (Fig. 6e). The features of this submicrofacies resemble to the stander microfacies of SMF1.

3.3.3. **Radiolarian - Calcispheres lime Packstone Microfacies (P)**

  This facies consist of granules of about 50-60% (Calcispheres-radiolaria) and a microspar or a little micrite groundmass with the presence of organic matter. This facies is found in both sections in the middle part of the Formation (about thick 5-10 m) and subjected to diagenesis processes such as silification and physical compaction, vein of calcite presence. Calcispheres-Radiolaria indicates that it was deposited within the central bathyal areas (Armstrong and Braseier, 2005).

  The microfacie compared with the stander microfacies of Wilson (1975) and Fugally (2010) which refers to the FZ1 and SMF1 which is called the deep sea environment (Fig. 6f).

3.3.4. **Lithofacies**

- **Limestone lithofacies (L)**

  This Lithofacies consists of limestone beds of different thicknesses (20-40) and brown to dark black color due to the organic matter and is found in all parts of the Chia Gara Formation in both sections. The lower part of the Formation contain phacoid structure (PHL) and the upper part contains ammonite fossils (AL) (Fig. 9). Ammonite fossils indicates that it was deposited within the outer shelf enviroment (Rikhtegarzadeh et al., 2016).

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**Fig. 6.** (a) Radiolarian lime mudstone Submicrofacies; (b) Calcispheres lime mudstone Submicrofacies; (c) Radiolarian lime Wackestone Submicrofacies; (d) Calcispheres Wackestone Submicrofacies; (e) Sponge lime Wackestone Submicrofacies; (f) Radiolarian and Calcispheres lime Packstone Submicrofacies. Scale 5X.
• **Shale lithofacies (S)**

These lithofacies are widespread within the successive rocks of the Chia Gara Formation, and it alternates with limestone beds with different thicknesses of brown-dark brown and black colors due to the presence of organic matter. This lithofacies in the upper part contains ammonite fossils (Fig.8). According to (Armstrong and Brasier, 2005), the evidence for these lithofacies indicates that it was deposited within the outer shelf into the deep sea because it needs a low-energy environment.

![Fig.7](image-url) **Fig.7.** Microfacies  (a)The blue arrow indicates to Blocky Cement and the red arrow indicates to Dissolution process; (b)Granular Cement; (c)Drusy Cement; (d) Fibrous Cement; (e) Neomorphism process; (f) Silicification process; (g) Aphantopic Fabric dolomite; (h) Floating rhomb fabric dolomite. Scale10X.
Fig. 8. Microfacies (a) Physical Compaction process; (b) Hummocky Stylolite; (c) Irregular Stylolite; (d) Peak Low Amplitude; (e) Parallel Stylolite. (f) Peak High Amplitude. (g) micrite groundmass. (h) microspar groundmass. Scale 10X

3.4. Systematic Paleontology

Order Ammonoidea Zittel, 1884
Suborder Ammonitina Hyatt, 1889
Superfamily Haplocerataceae Zittel, 1884
Family Haploceratidae Zittel (1884) emended Callomon 1981
Haploceras sp. (Fig. 9a)
Superfamily Perisphintaceae Steinmann, 1890
Family Olcostephanidae Haug, 1910
Genus Groebericeras Leanza, 1945
Groebericeras rocardi Pomel, 1889 (Fig. 9b)
Genus Proniceras Burckhardt, 1919
Proniceras jimulcense Imaly, 1939 (Fig. 9c)
Genus Spiticeras Djanelidze, 1922
Spiticeras sp. (Fig. 9d)
Family Neocomitidae Salfeld, 1921
Genus Argentiniceras Spath 1924
Argentiniceras sp. (Fig. 9e)
Genus Berriasella Uhlig, 1905
Berriasella Jacobi Mazenot, 1939 (Fig. 9f)
Genus Pseudargentiniceras Spath, 1925
Pseudargentiniceras sp. (Fig. 9g)
4. Discussion

4.1. Age Determination of Chia Gara Formation

The formation is one of the ammonite-rich successions. This fossils were nicely preserved in sedimentary successions of the limestone and marly limestone beds. Its occurs at the upper part of the Formation, in the upper surface of the beds, there are only rare traces of ammonites, where a fauna dominated by Berriasella Jacobi appears, Chia Gara Formation in its type section distinguished by ammonite assemblage has equivalent in Tethyan sites. The biozone recently determined is identified in the upper part of the Chia Gara Formation in northern Iraq. It includes an incomplete record and it is characterized by the presence of Berriasella Jacobi, in the Tethys Realm, Berriasella Jacobi is considered an index fossil for the lowermost Berriasian (Reboult et al., 2014), and in South America (Salazar, 2012) and the taxon is here assigned to the lower Berriasian, based on its well established Tethyan range. (Figs. 10 and 11)
Fig. 10. Paleogeography of Early Cretaceous (Sharland et al., 2001).

Fig. 11. Early Cretaceous ammonites compared with the studied section (Gradstein et al., 2012).
4.2. Depositional Environment of the Chia Gara Formation

The microfacies analysis and skeletal fossils are used in the current study to identify the depositional environment of the Chia Gara Formation. This is achieved through the study of sedimentological, biological evidence and microfacies analysis, it was found that the environment of formation in the lower part is shallow and towards the deeping in the middle part and then shallowing in the upper part, that is, it starts from the upper Bathyal range in the lower part due to the presence of the phcoid structure and the Calcispheres, that hang down the slope area and into middle Bathyal environment in the middle part of the Formation according to presence radiolarian and silica sponge, and then it becomes shallower towards the upper part (outer shelf) due to the presence of ammonite lithofacies (AL), Which is similar to the researcher's environment (Sherwani and Edilbi, 2019), by comparing the current study microfacies with the standard facies zone (FZ) of the Wilson Model (modified by Schlager, 2002), indicating a Rimmed Carbonate Platform (Flugel, 2010), that displays dominant Standard Microfacies (SMF 1,3) which include to the Facies Belt Zone (1B, 2 and 3), Toe of slope and deep sea (Fig.12).

![Fig.12. Depositional environment model of Chia Gara Formation](image)

5. Conclusions

- The Chia Gara Formation's petrographic investigation revealed homogeneous petrography consist in the limestones in all studied areas. The matrix is mostly formed of micrite and microspar, and different diagenetic processes have influenced the limestones of the Chia Gara Formation, including cementation, recrystallization, silicification, dolomitization, dissolution, and compaction.
- The petrographic study revealed a group of skeletal grain, namely: radiolarian, ammonites, calcispheres, and sponges.
- The detailed facies analysis demonstrates that the rocks succession consists mainly of three microfacies. The main microfacies include lime mudstone, wackestone and packstone. In addition to limestones and shales lithofacies.
- The study identified seven species of Ammonites funa, these are *Haploceras sp.*, *Groeberticeras rocardi*, *Proniceras jimulcense*, *Spiticeras sp.*, *Argentiniceras sp.*, *Berriasella Jacobi* and *Pseudoargentiniceras sp.*
One biozone is the Berriasella Jacobi which leads to the conclusion that the section is early Cretaceous in age (lower Berriasian).

6-The overall characteristics of these facies indicating that the Formation was deposited in three different environments; (1) outer shelf environment at the lower part, (2) upper bathyal in the middle part, and (2) middle are bathyal in the upper part.

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