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BIOSTRATIGRAPHY AND CHRONOSTRATIGRAPHY OF LATE JURASSIC – EARLY CRETACEOUS IN SELECTED AREAS IN KURDISTAN REGION, NORTHERN IRAQ

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ABSTRACT

The biostratigraphy and chronostratigraphy of Late Jurassic – Early Cretaceous (Tithonian – Aptian) successions at three outcrops in the Kurdistan Region, northern and northeastern Iraq (Amadia, Gara, and Barsarin sections) are studied depending on ammonite, planktic, and benthic foraminiferal contents. The studied formations: Chia Gara, Sarmord, and Qamchuqa, are recorded in all studied localities, while Garagu and Balambo formations are exposed at some studied localities. Age determination of the Chia Gara Formation relied on the ammonite fauna. The ammonites investigated are the major assemblage fauna of the Durangites Zone, which corresponds to the Late Tithonian. The detailed planktic foraminiferal investigation in Balambo Formation permits the recognition of five well-defined zones, these are *Favusella hoterivica* Interval Zone, *Hedbergella sigali* Interval Zone, *Globigerinelloides ferreolensis* Interval Zone, *Globigerinelloides blowi* Interval Zone, and *Globigerinelloides algeriana* Taxon Range Zone (part), which reveal a Late Valanginian to Late Aptian age.

The stratigraphic distribution of the benthic foraminifera shows three zones, these are *Everticyclammina kelleri* Assemblage Zone, *Pseudocyclammina lituus* Assemblage Zone, and *Palorbitolina lenticularis* Taxon Range Zone, the 1st and 2nd zones were recognized in the Sarmord Formation at Amadia section, which extends in age from late Valanginian to Hauterivian. While the 3rd zone is recorded from Qamchuqa Formation at the Gara section representing the Early Aptian age.

INTRODUCTION

The Late Jurassic – Early Cretaceous successions in the north and northeastern Iraq (High Folded and Balambo – Tanjero zones) comprise five formations; Chia Gara, Garagu, Sarmord, Qamchuqa, and Balambo, which represent a part of the Late Tithonian – Early Turonian Megasequence (AP8).

According to Jassim and Buday (2006), the AP8 Megasequence was deposited in a large intra-shelf basin contemporaneous with a new stage of ocean floor spreading in the southern Neo-Tethys. The thickness of this megasequence varies within regions of Iraq, as it is thicker within the Foothill Zone and Tigris subzone of the Mesopotamian Zone, reaching (1200 m) near Baghdad and more than 500 m in Sinjar northwest of Iraq. However, this megasequence

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does not exist in a part of Mosul city as a result of the erosion processes (Jassim and Buday, 2006a).

The Late Tithonian – Early Turonian megasequence (AP8) includes two main groups, which are; the Upper Tithonian – Aptian Thamama group and the Albian – Lower Turonian Wasi'a group. The Thamama group covers all regions of Iraq except the area of the Rutba-Jazira Zone, where it is missing as a result of truncation or non-deposition.

This study deals with three outcrops in northern and northeastern Iraq (Amadia, Gara, and Barsarin sections). The studied Formations are recorded in all studied localities, while Garagu and Balambo Formations are exposed to some localities.

GEOLOGICAL SETTING

The study area covers two main structural zones within the northern and northeastern parts of Iraq; the High-Folded and the Imbricated (Balambo – Tanjero subzone) Zones. The first zone represents in this study by two structures, which are; the Maten and Gara anticlines in the north of the Duhok area, while the second zone represents by the Zozik anticline near Rawanduz town (Figure 1).

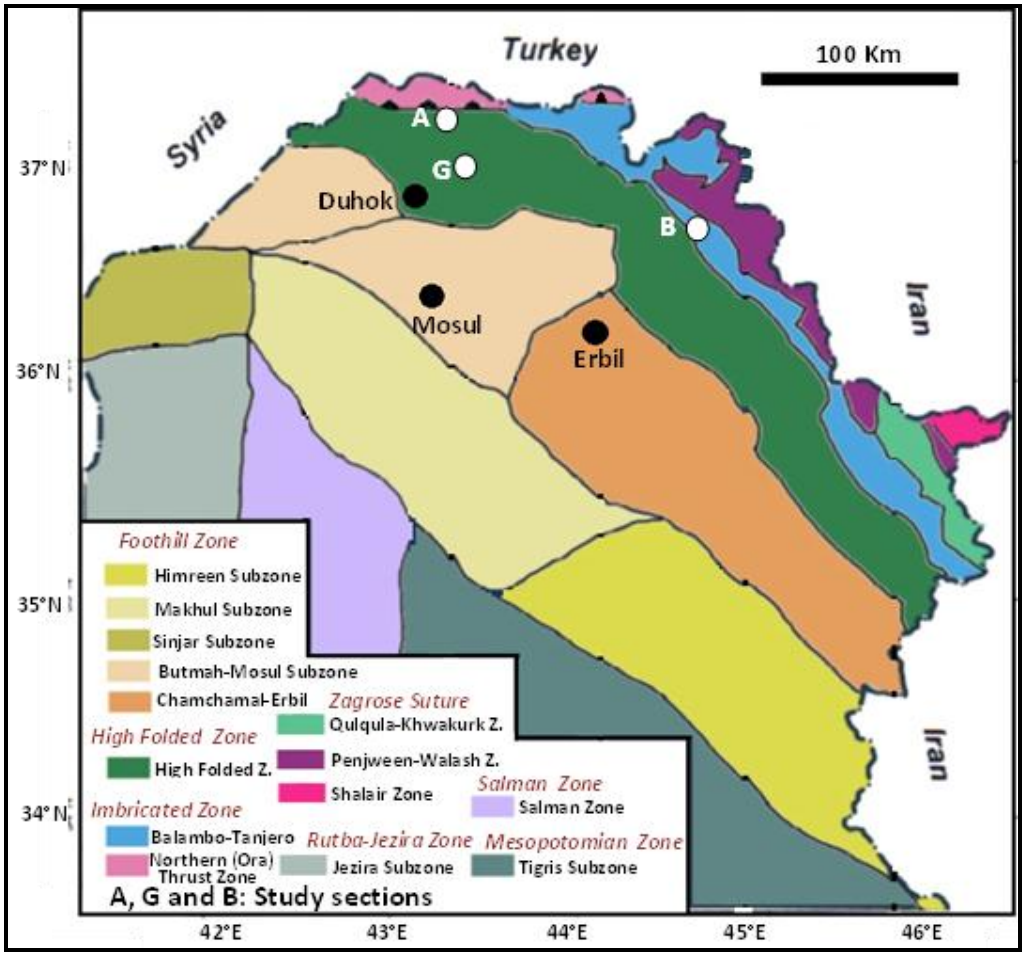

Figure 1: Location and tectonic map of the study area, modified after (Jassim and Buday, 2006).

In the Late Tithonian age, great paleogeographic changes happened in the north and east of the Arabian plate, which are not expounded via preceding models of plate tectonics in the

area (Jassim and Buday, 2006). This age represents a geodynamic reversal of the tectonic behavior of the Arabian plate edge from extension to compression, which began in the Late Jurassic and continued during the Cretaceous (Numan, 2000), and this was confirmed by Brew *et al.* (1999), who mentioned that there is a great case of reorganization in the tectonic behavior that occurred within the boundaries of the Arabian plate. As the spread of the new ocean floor of Tethys ended and the peripheral edge began to erode as a result of the process of erosion under the Iranian and Turkish plates. There was a volcanic flow in the northern edges of the Arabian plate extending from the eastern Mediterranean to Amman, and the opening appeared at the ocean floor within the continental crust in the north of the Arabian plate, leading to the separation of small blocks from the Arabian plate and the opening of a narrow ocean called southern New Tethys. This activity was accompanied by deposits of widespread radiolarian chert in southeastern Turkey (Karadut Complex) and northeastern Iraq (Qulqula Group). The opening of this narrow ocean has been associated with a major tectonic event, the breakup of Gondwana, including the opening of the eastern Mediterranean (Jassim and Buday, 2006).

MATERIALS AND METHODOLOGY

The biostratigraphic and chronostratigraphic frameworks for the studied formations were based on ammonites fossils, Planktonic and benthonic foraminiferal zonation. To achieve these work goals, three outcrops have been selected and utilized to identify sediment composition and fossils content. More than 336 rock samples from the studied sections were collected. The present study is based on the assessment of more than 250 thin sections, generated for microfacies and foraminiferal analyses at Mosul University's Department of Earth Sciences workshop.

LITHOSTRATIGRAPHY

The Late Tithonian – Early Aptian stratigraphic column in High Folded and Balambo – Tanjero zones in Iraq is represented by the succession comprised of Chia Gara, Garagu, Sarmord, Qamchuqa, and Balambo formations. The generalized stratigraphic successions of the studied sections consist of the following lithostratigraphic units in ascending order:

- **Chia Gara Formation**

Wetzel in 1950, described the Chia Gara Formation (M. Tithonian – Berriasian) for the first time in the Chia Gara anticline, south of Amadia town in northern Iraq's High Folded Zone. The thickness of the formation is about 232 m in its type locality (Bellen *et al*., 1959). The thickness of the formation in the studied sections is about 90 m in Amadia, 40 m in Gara, and 87 m in Barsarin. It is composed of alternation thin beds of pale to dark brown shale and white-yellowish limestone. Moreover, the upper part of the formation is distinguished by ammonite shells in Amadia and Barsarin sections. The lower boundary in all sections is sharp between the tough dolostone of the Barsarin Formation (Late Kimmeridgian) and the thin-bedded limestone of the Chia Gara Formation, without any indication of unconformable evidence. While the upper boundary in all sections is unconformable with the overlying Sarmord Formation in Amadia and Barsarin sections and Garagu Formation in the Gara section.

- **Garagu Formation**

The Garagu Formation (Valanginian-Hauterivian) was first described by Wetzel in 1950 in the core of the Chia Gara anticline, about 600 meters. north of Garagu village in the High Folded Zone of northern Iraq, with 92 m thick (Bellen *et al*., 1959). The formation was recorded in the current study in the Gara section only with a total thickness of about 34 m and

composed of an alternation of pale brown and pale gray limestone, dolostone, and arenaceous limestone with a basic conglomerate at the bottom of the formation. The lower boundary is unconformable with Chia Gara Formation due to the basal conglomerate at the bottom of the Garagu Formation. Whereas, the upper boundary is gradational with the overlying Balambo Formations.

- **Sarmord Formation**

The Sarmord Formation was described for the first time by Wetzel in 1959 from the Surdash anticline, Sulaimaniyah District, northeastern Iraq (Bellen *et al*., 1959). The type section is comprised of two different areas; the upper 182 m of the formation are exposed in the Qamchuqa Gorge section. The lower 273 m are described from the section in the course of the stream, which flows northwards through Sargelu village. The formation was recorded in the current study with different thicknesses, ranging from 68 m in Amadia, 60 m in Gara, and 32 m in Zozik. Lithologically, it comprises of pale-yellow conglomerate interspersed with pale gray marl rocks, pale-yellow limestone intervened by thin beds of gray marl, pale brown dolomite beds, dolostone, and pale-yellow marl. The lower contact is unconformable with the Chia Gara Formation in Amadia and Barsarin sections, while it is sharp with Balambo Formation in the Gara section. On the other hand, the upper contact is sharp with Qamchuqa Formation in Amadia and Gara sections and with Balambo Formation in the Barsarin section.

- **Qamchuqa Formation**

The type section of the Qamchuqa Formation was described from Qamchuqa Gorge (northwestern Sulaymaniyah city) in the High Folded Zone, northeastern Iraq by Wetzel in 1959, with a total thickness of about 799 m (Bellen *et al*., 1959). In the present study, the formation is recognized with different thicknesses, ranging between 10 m in Gara to 32 m in Amadia, while it's recorded in the Barsarin section as overlapping beds with a Balambo Formation in a total thickness of about 40 m. The Qamchuqa Formation consists of thick-bedded pale brown to pale gray massive limestone and dolomitic limestone. The lower contact is conformable with Sarmord Formation, while the upper contact is unconformable with Aqra Formation.

- **Balambo Formation**

This formation was described for the first time in its type section via Wetzel, in 1959, which is located in the Sirwan Valley near the city of Halabja in northeastern Iraq (Bellen *et al*., 1959). Its total thickness was about 762 m. In the current study, the formation is recorded in the Gara (115 m) and Barsarin (136 m) sections only. The Balambo Formation consists of an alternation of thin-bedded pale brownish limestone, marly limestone, and pale bluish marl. The lower boundary is gradational with Garagu Formation in the Gara section, while it is recognized by the sharp contact with Sarmord Formation in the Barsarin section. The upper boundary is sharp with Sarmord Formation in the Gara section and gradational with the Qamchuqa Formation in the Barsarin section.

BIOSTRATIGRAPHY

The formations under study were characterized by the diversity of their fossil content. Despite their small numbers, the Chia Gara Formation is characterized by its content of ammonite fossils and radiolaria, Garagu Formation contains only pelecypod bioclasts debris and some benthic foraminifera. While Sarmord and Qamchuqa formations are characterized by abundant benthic foraminifera, rare green algae, and gastropods. The presence of the planktic foraminifera was exist only in the Balambo Formation, in addition to the Radiolaria. Because of the importance of determining the ages of the formations under study and to give

biostratigraphic zonation and accurate Chronostratigraphy, this research included a taxonomic study for ammonite within the Chia Gara Formation, and the benthic foraminifera in Sarmord and Qamchuqa formations, which resulted in describe three benthic foraminiferal biozones within these formations. In addition to identifying all the planktic foraminifera that exist in Balambo Formation and diagnosing five- planktonic foraminiferal zones in this formation.

AGE DETERMINATION OF AMMONITE

The study revealed six species from five genera and three families (Figure 2). Two of them had previously been described, *Berriasella privasensis* and *Parodontoceras calistoides*, while four are still classified as unknown. *Parodontoceras* sp., *Spiticeras* (*Kilianiceras*) sp., *Substeueroceras* sp., and *Haploceras* sp. are among them.

The ammonites analyzed are the major assemblage fauna of the Durangites Zone, which was previously documented in Iraq by Howarth (1992) and Leanza (1996) and corresponds to the Late Tithonian age. As a result, all of the biostratigraphic evidence of the studied ammonite indicated that the upper part of the Chia Gara Formation in the Amadia area represents the Late Tithonian age, whereas the lower part of the formation in the studied section had previously been registered as Middle Tithonian age based on previous research at the type section (Bellen *et al*., 1959).

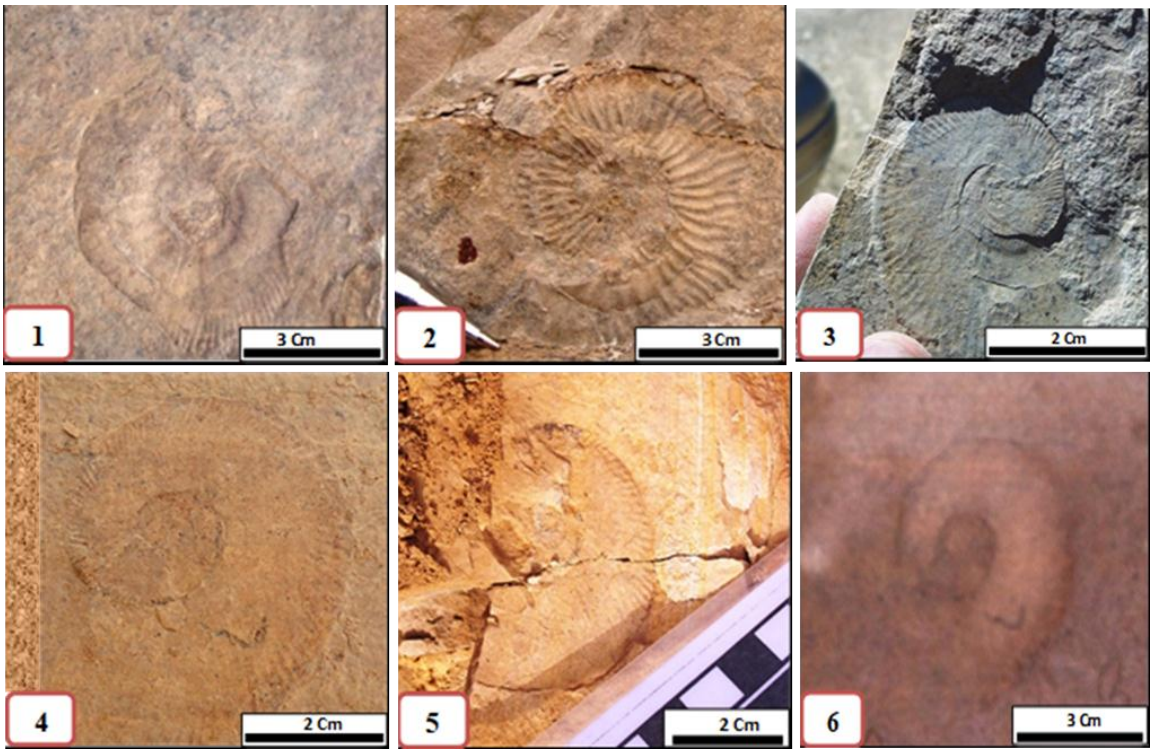

Figure 2: Associated faunas that were recorded in the current study, **1)** *Berriasella privasensis*, **2)** *Parodontoceras calistoides*, **3)** *Parodontoceras* sp., **4)** *Spiticeras* (*Kilianiceras*) sp., **5)** *Substeueroceras* sp., and **6)** *Haploceras* sp.

- **Planktonic Foraminifera Biozones**

Based on the planktonic foraminifera assemblages (Figure 3), the Balambo Formation was subdivided in the present study into five biozones. The first, second, and part of the third biozones were recorded in the Gara section (Figure 4), while all the biozones were recorded in the Barsarin section (Figure 5). These biozones are correlated with their equivalent standard

biozones in other regions of the world (Figure 6). Furthermore, the absolute age has been determined based on the geological time scale recorded by Ogg *et al*. (2016).

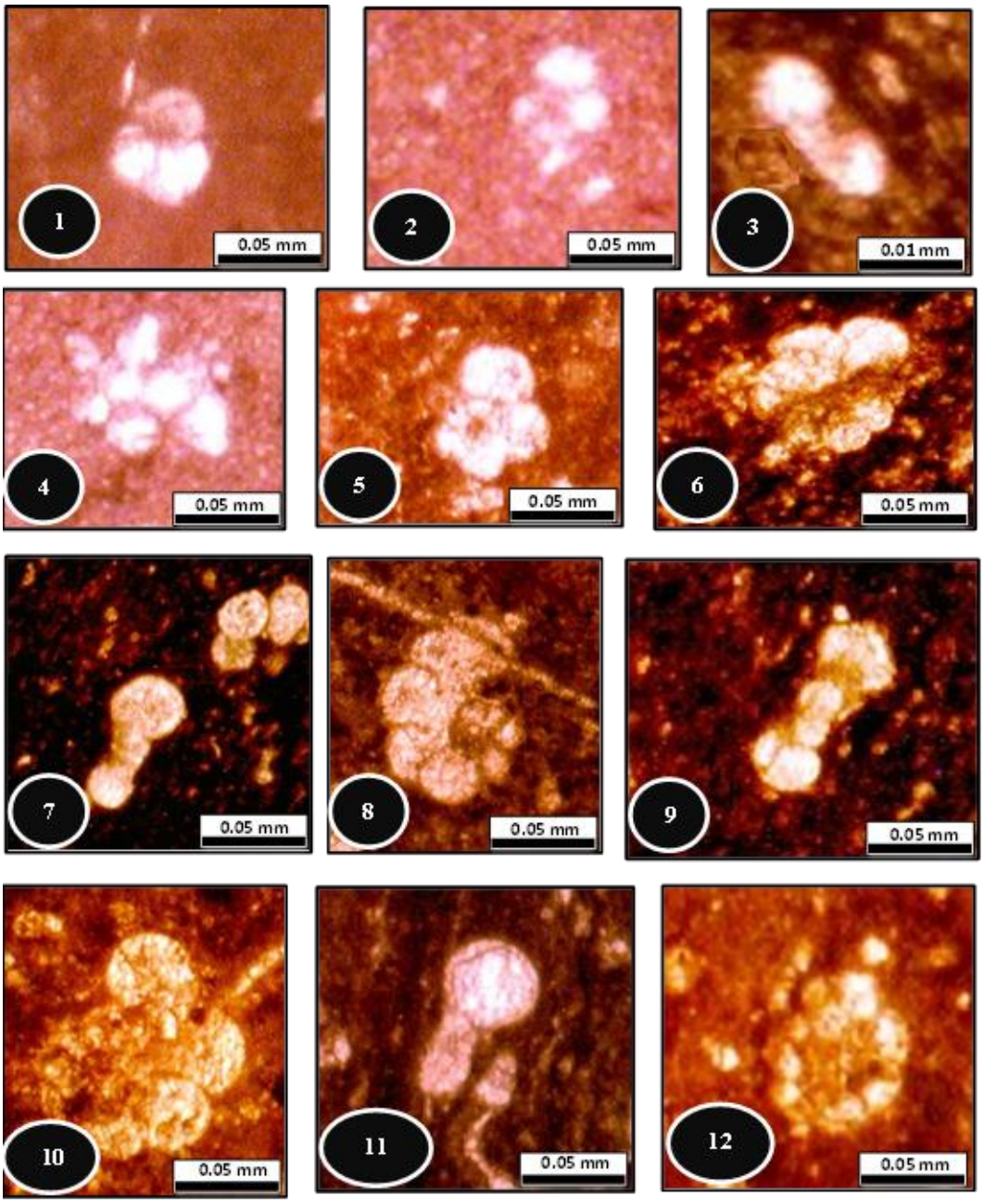

Figure 3: Planktonic foraminiferas that were recorded in the current study, **1)** *Favusella hoterivica*, **2)** *Hedbergella sigali*, **3)** *Hedbergella acculta*, **4)** *Hedbergella bizonae*, **5)** *Hedbergella delrioensis*, **6)** *Hedbergella planispira*, **7)** *Globigerinelloides algeriana*, **8)** *Globigerinelloides algeriana*, **9)** *Globigerinelloides ferreolensis*, **10)** *Globigerinelloides ferreolensis*, **11)** *Globigerinelloides blowi*, **12)** *Hedbergella trocoidea*.

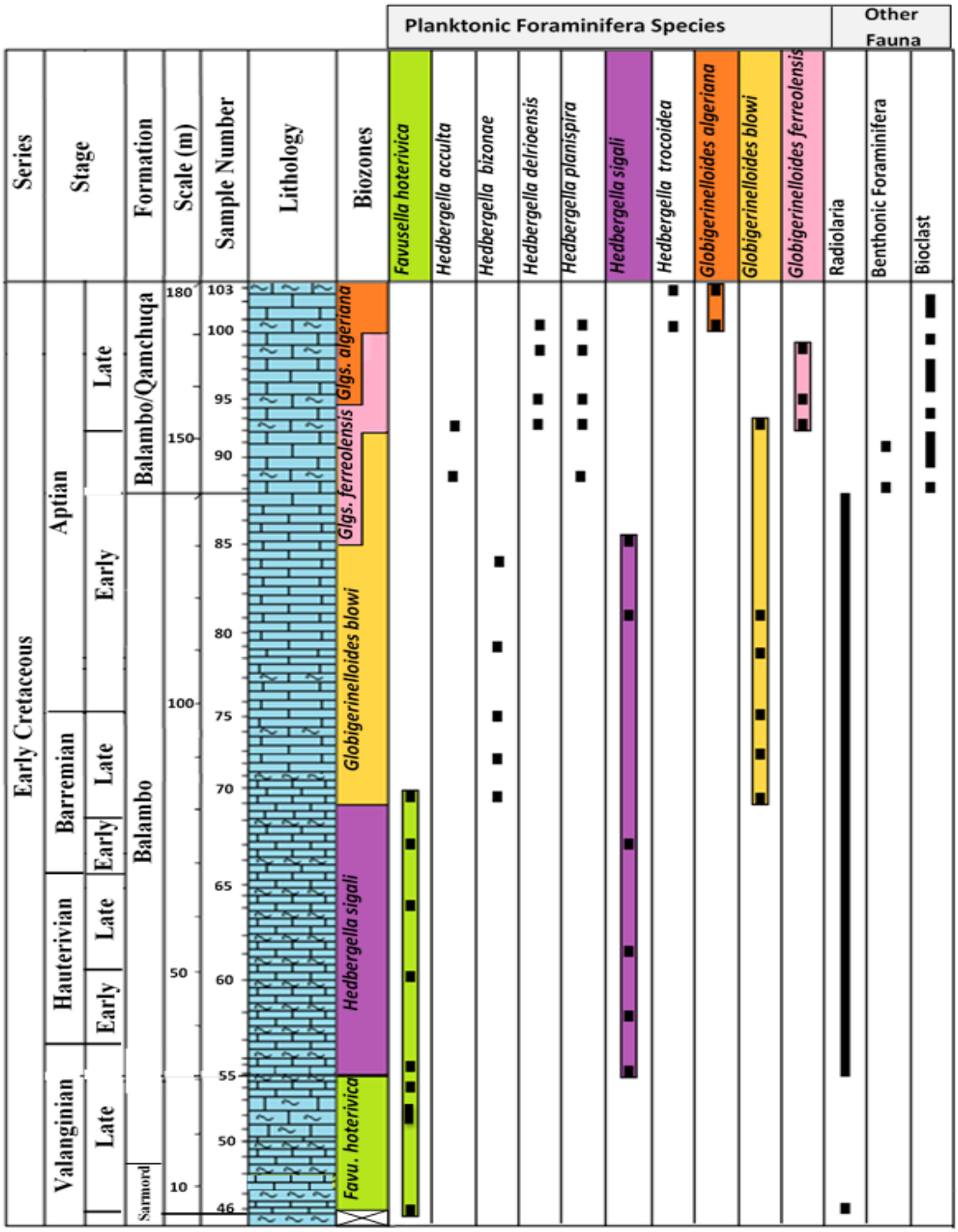

Figure 4: Stratigraphic column of Balambo Formation showing planktonic foraminifera ranges and its biostratigraphic zones in the Barsarin section.

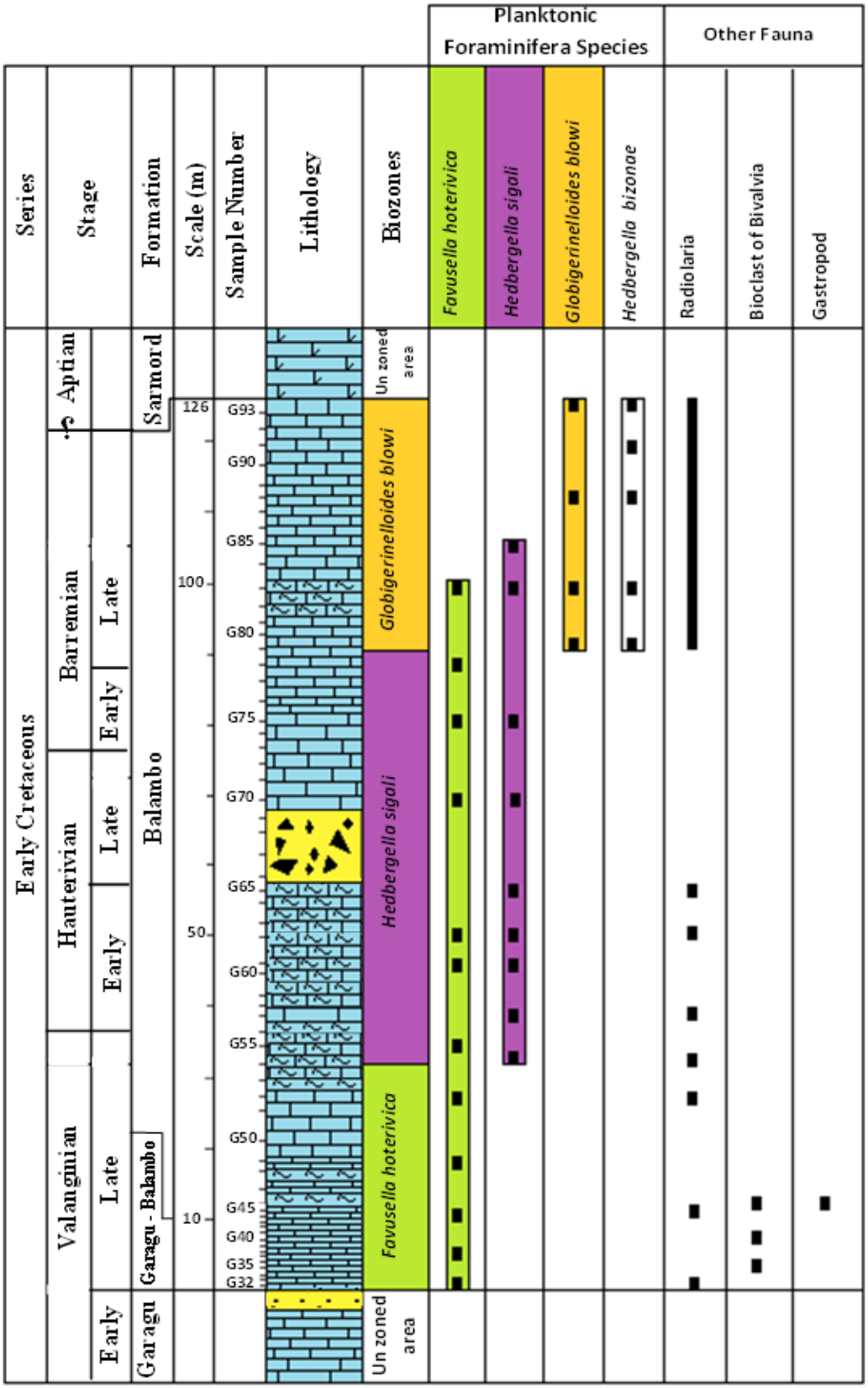

Figure 5: Stratigraphic column of Balambo Formation showing planktonic foraminifera ranges and its biostratigraphic zones in the Gara section.

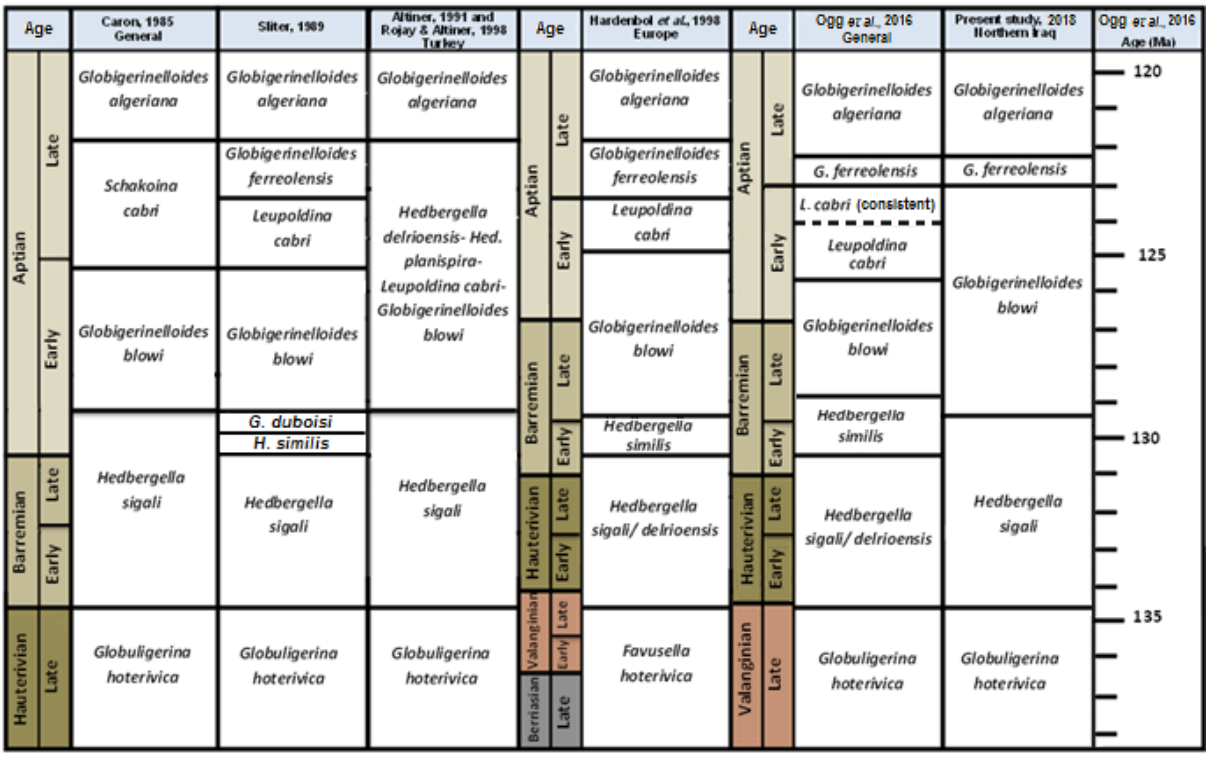

Figure 6: Planktonic foraminifera biostratigraphy correlation of the Balambo Formation with other zonal schemes.

– ***Favusella hoterivica* Interval Zone:**

- **Definition:** Van Hinte (1972) defines the current zone as dating from the Late Hauterivian. It indicates the stratigraphic range of the indicator species *Favusella hoterivica* (Subbotina), which appeared before *Hedbergella sigali* Moullade.
- **Age:** Late Valanginian.
- **Boundaries:** The first occurrence of *Favusella hoterivica* (Subbotina), marks the lower border of this zone, whereas its upper boundary is placed at the first appearance of the species *Hedbergella sigali* Moullade.
- **Thickness:** 32 m in the Gara section and 26 m in the Barsarin section.
- **Correlation and Age Determination:** The current zone corresponds to the *Globuligerina hoterivica* zone of the Late Hauterivian age described by Caron (1985), Sliter (1989), Altiner (1991), and Rojay and Altiner (1998) in Turkey. While it is correlative to the Hardenbol *et al*. (1998) *Favusella hoterivica* zone of the Late Berriasian-Late Valanginian age. Furthermore, it corresponds to the Late Valanginian *Globuligerina hoterivica* zone described by Ogg *et al*. (2016).

– ***Hedbergella sigali* Interval Zone:**

- **Definition:** Moullade (1966) described the current zone for the first time, which extends from the Barremian to the Early Aptian. It depicts the stratigraphic range of the index species, *Hedbergella sigali* Moullade, from its earliest occurrence to the first appearance of *Globigerinelloides blowi* (Bolli).
- **Age:** Latest Valanginian – early Late Barremian.

- **Boundaries:** The first occurrence of the index species *Hedbergella sigali* Moullade marks the lower limit of this zone, while the first appearance of the species *Globigerinelloides blowi* marks the higher boundary (Bolli).
- **Thickness:** 58 m in the Gara section and 50 m in the Barsarin section.
- **Correlation and Age Determination:** This zone corresponds to the *Hedbergella sigali* zone of Caron (1985), the *Hedbergella sigali*, *Hedbergella similis*, and *Globigerinelloides duboisi* zones of Sliter (1989), all of which are of Early Barremian – Early Aptian age. It is also comparable to the *Hedbergella sigali* zone of Altiner (1991) and Rojay and Altiner (1998) of the same age. While it is correlative with the *Hedbergella sigali/ delrioensis* and *Hedbergella similis* zones of Hardenbol *et al*. (1998) and the *Hedbergella sigali/ delrioensis* and lower portion of *Hedbergella similis* zones of Ogg *et al*. (2016), it is attributed to the Later Valanginian – Early late Barremian age.

– ***Globigerinelloides blowi* Interval Zone:**

- **Definition:** This zone was initially identified by Moullade (1974) from the Early Aptian, representing the interval between the first appearance of *Globigerinelloides blowi* (Bolli) to the first occurrence of *Globigerinelloides ferreolensis* (Moullade).
- **Age:** Early Late Barremian-Latest Early Aptian.
- **Boundaries:** The first occurrence of *Globigerinelloides blowi* (Bolli) determines the lower limit of this zone, whereas the first appearance of *Globigerinelloides ferreolensis* determines the upper boundary (Moullade).
- **Thickness:** 32 m in the Gara section, and 71 m in the Barsarin section.
- **Correlation and Age Determination:** This zone is related to the *Globigerinelloides blowi* and lower part of *Schakoina cabri* zones of Caron (1985), the *Globigerinelloides blowi* and *Leupoldina cabri* zones of Sliter (1989), and the lower-middle part of Altiner's (1991) and Rojay and Altiner's (1998) *Hedbergella delrioensis-Hed. Planispira-Leupoldina cabri-Globiger* in the Early Late Barremian–Early Aptian age. Furthermore, it is correlated to the *Globigerinelloides blowi* and *Leupoldina cabrizones* of Hardenbol *et al*. (1998) and the top portion of *Hedbergella similis*, as well as the *Globigerinelloides blowi* and *Leupoldina cabrizones* of Ogg *et al*. (2016).

– ***Globigerinelloides ferreolensis* Interval Zone:**

- **Definition:** The current zone represents the *Globigerinelloides ferreolensis* Interval zone (Moullade). Which appears before Globigerinelloides algeriana Cushman and Ten Dam.
- **Age:** Late Aptian.
- **Boundaries:** The first appearance of *Globigerinelloides ferreolensis* (Moullade), represents the lower boundary of this zone, while the upper boundary is marked by the last appearance of *Globigerinelloides ferreolensis* (Moullade), which coincides with the first appearance of *Globigerinelloides algeriana* Cushman and Ten Dam.
- **Correlation and Age Determination:** This zone is correlated with the upper part of the *Schakoina cabri* zone of Caron (1985), *Globigerinelloides ferreolensis* zone of Sliter (1989), and upper part of *Hedbergella delrioensis-Hed. Planispira-Leupoldina cabri-Globigerinelloides blowi* zone of Altiner (1991) and Rojay and Altiner (1998) of Late Aptian age. Besides, it is also equivalent to the *Globigerinelloides ferreolensis* zone of Hardenbol *et al*. (1998) and Ogg *et al*., (2016), which is assigned to the Late Aptian age.

– ***Globigerinelloides algeriana* Taxon range Zone. (part):**

- **Definition:** The present zone is representing the total range of *Globigerinelloides algeriana* Cushman and Ten Dam.
- **Age:** Late Aptian.
- **Boundaries:** The first appearance of *G. algeriana* Cushman and Ten Dam, represent the lower boundary of this zone, while the upper limit is assigned by the last occurrence of the nominate taxon. It is noteworthy, the upper boundary of this zone is not represented in the present study.
- **Thickness:** 9 m.
- **Correlation and Age Determination:** Theis zone corresponds to the Late Aptian Globigerinelloides algeriana zone of Caron (1985), Sliter (1989), Altiner (1991), Rojay and Altiner (1998), Hardenbol *et al*. (1998), and Ogg *et al*. (2016).

▪ **Benthonic Foraminifera Biozones**

Based on the benthic foraminifera assemblages (Figure 7), three biozones were diagnosed, and two of them were recognized in Sarmord Formation (*E. kelleri* Assemblage and *P. lituus Assemblage* zones) at Amadia section (Figure 8) and the third biozone (*P. lenticularis* Taxon Range Zone) was distinguished in the Qamchuqa Formation at the Gara section (Figure 9). The identified benthonic foraminiferal biozones were correlated with their equivalent standard biozones in other regions of the world (Figure 10).

– ***Everticyclammina kelleri* Assemblage Zone:**

- **Definition:** Assemblage Zone of the index species *E. kelleri* (Henson) associated with other species of benthonic foraminifera (*E greigi* (Henson), *E.* sp. *Lenticulina* sp., and *Cuneolina* sp.), in addition to some gastropods.
- and echinoderms.
- **Age:** Late Valanginian.
- **Boundaries:** This Zone's bottom limit is characterized by the first appearance of the index species *Everticyclammina kelleri* (Henson) in association with other species. while the upper limit is set by the extinction of these species.
- **Thickness:** 14 m. within Sarmord Formation in the Amadia section.
- **Correlation and age determination:** This zone correlated with the *Everticyclammina kelleri* zone of Chatton and Hart (1960) in Iraq and the lower part of *Pseudocyclammina lituus* of Sampo (1969) in Iran, whereas it is corresponding to the *Lituola kelleri* zone of British Petroleum and Idemitsu (1990) and the *Cyclammina gregi* zone of Al-Eisa (1997) in Iraq in Late Valanginian.

– ***Pseudocyclammina lituus* Assemblage Zone:**

- **Definition:** This zone is the assemblage zone of the index species *Pseudocyclammina lituus* Yokoyama, which is associated with other benthonic foraminifera species (*Pseudocyclammina* sp. and *Lenticulina* sp.) and certain gastropods.
- **Age:** Early–Late Hauterivian.
- **Boundaries:** The bottom limit of this zone is characterized by the initial appearance of the index species *Pseudocyclammina lituus* Yokoyama, along with several associated species. whereas its upper limit is set by the extinction of these species.
- **Thickness:** 41 m. within Sarmord Formation in the Amadia section.

- **Correlation and age determination:** This zone is similar in Iraq to the *Pseudocyclammina lituus* zone of Chatton and Hart (1960) and the middle-upper part of *Pseudocyclammina lituus* of Sampo (1969) in Iran of Late Hauterivian age. Whereas, it is correlated with the lower-middle part of the *Choffatella decipiens* zone of British Petroleum and Idemitsu (1990) and the *Pseudocyclammina lituus* zone of Al-Eisa (1997) of the Early – Late Hauterivian age.

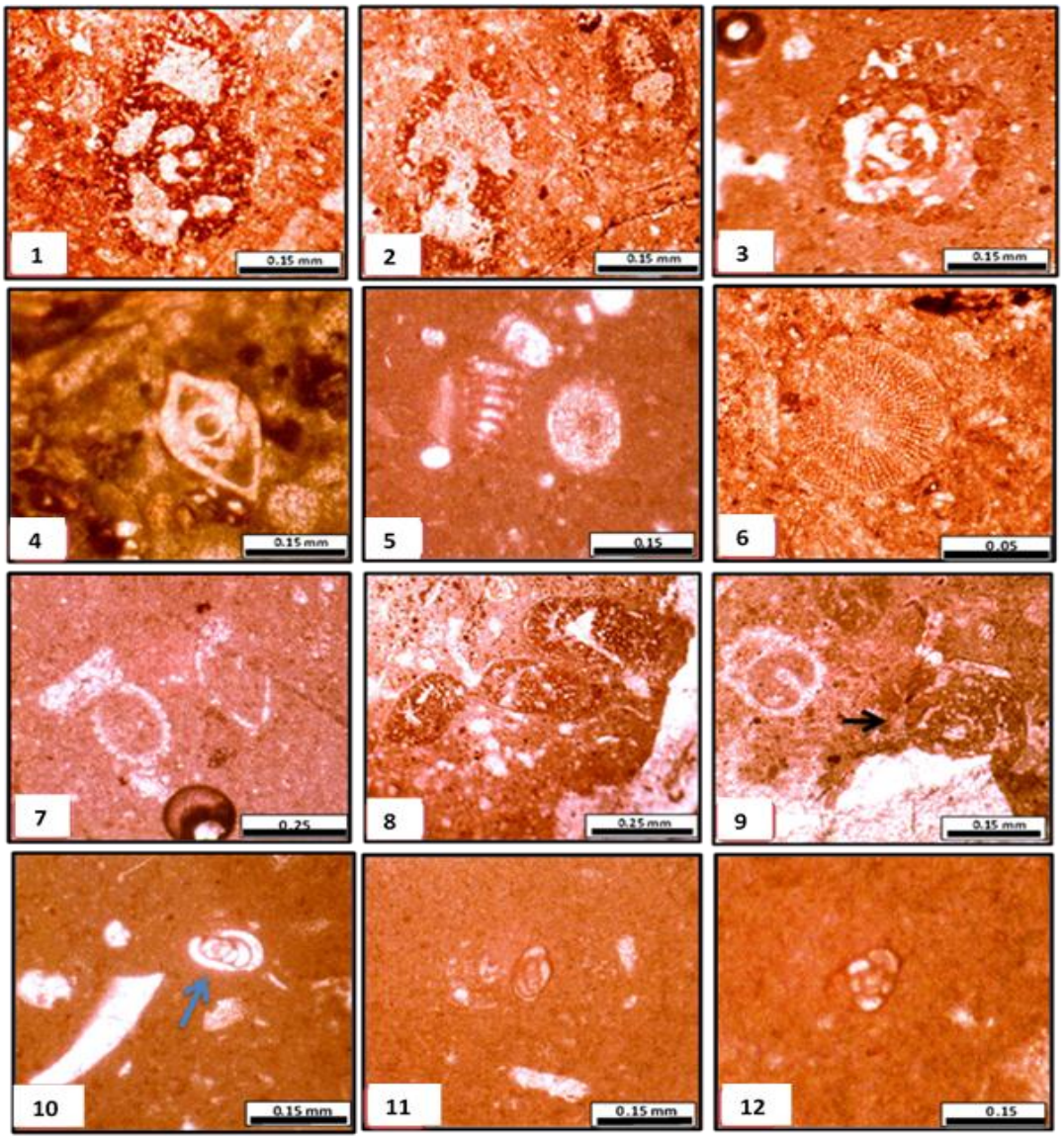

Figure 7: Benthonic Foraminiferas with some other faunas that were recorded within the biozones in the current study. **1)** *Everticyclammina kelleri*, **2)** *Everticyclammina greigi*, **3)** *Everticyclammina* sp., **4)** *Lenticulina* sp., **5)** *Cuneolina* sp., **6)** Cross section in a spine of echinoderm, **7)** Green algae, **8)** *Pseudocyclammina lituus*, 1890, **9)** *Pseudocyclammina* sp., **10)** *Istriloculina eliptica*, **11)** *Istriloculina* sp., and **12)** *Scythiloculina* sp.

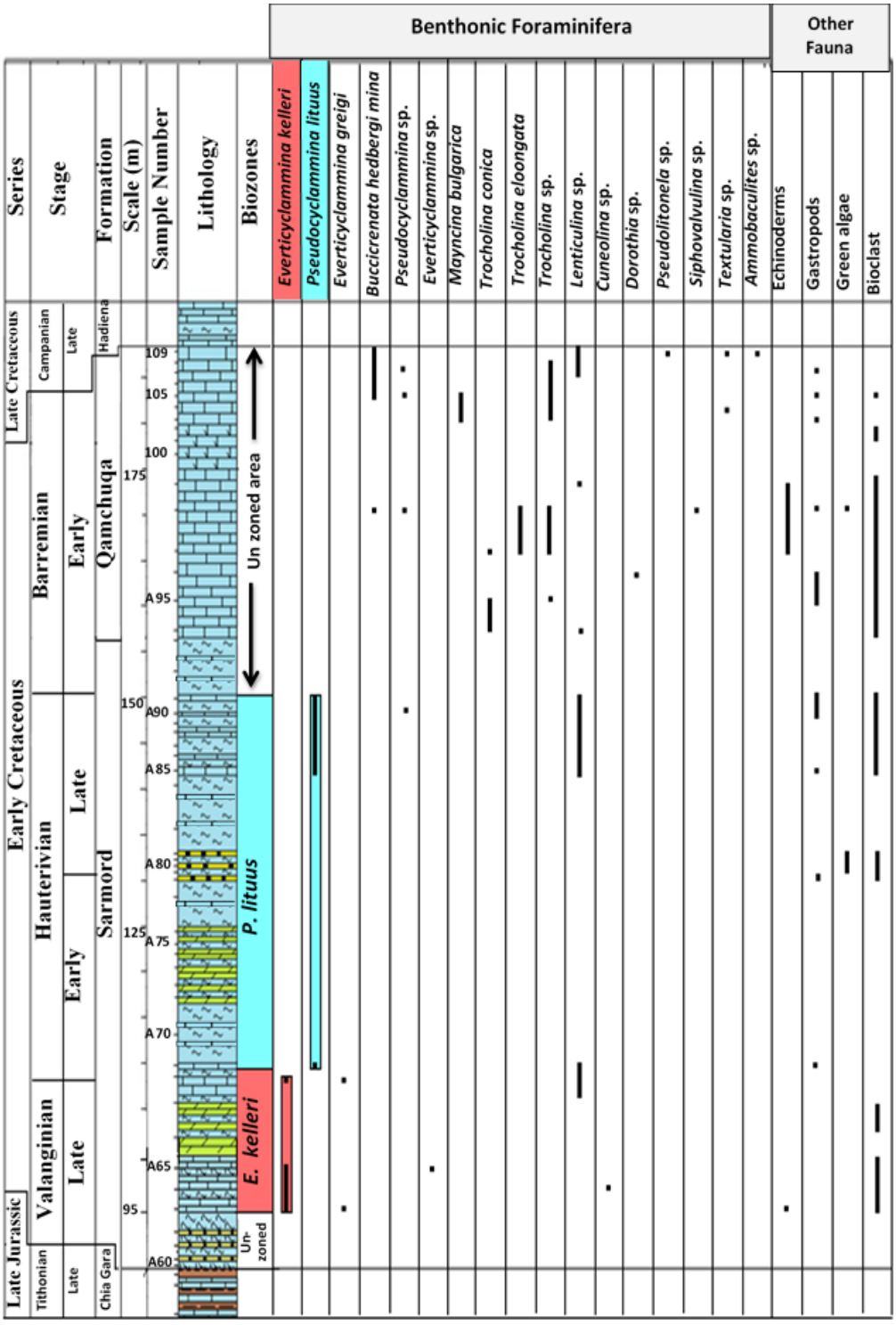

Figure 8: Stratigraphic column of Sarmord and Qamchuqa formations showing benthonic foraminifera ranges and its biostratigraphic zonation in the Amadia section.

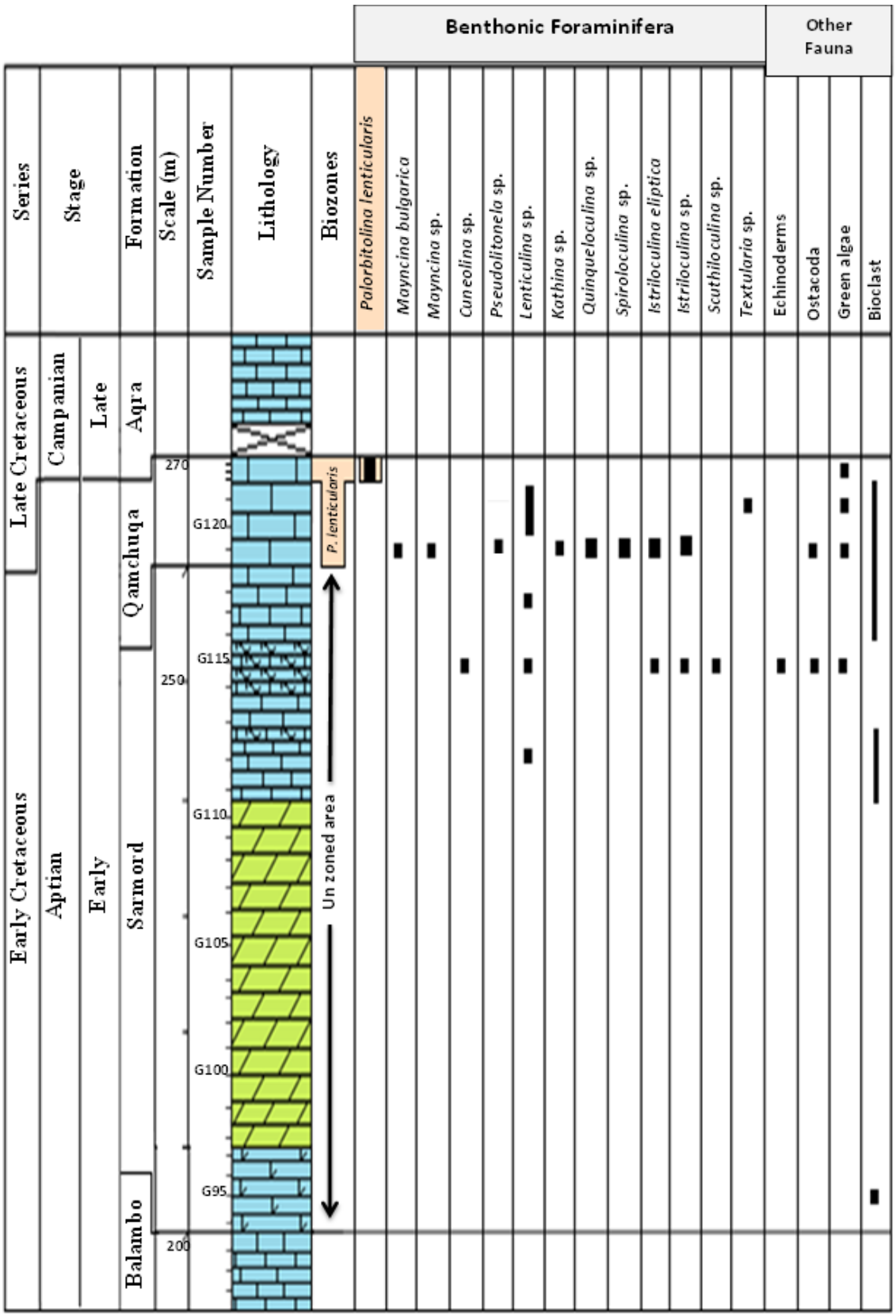

Figure 9: Stratigraphic column of Sarmord and Qamchuqa formations showing benthonic foraminifera ranges and its biostratigraphic zonation in the Gara section.

Stage		Chatton & Hart, 1960, Iraq	Sampo, 1969 SW Iran	B. P. & Idemitsu 1990, Iraq	Al- Eisa, 1997 Iraq	Present Study
Aptian	Late	*Orbitolina discoidea*	*Choffatella decipiens*	*Orbitolina*	*Choffatella decipiens/ Salpingoporella dinerica*	*Un zoned area*
	Early	*Orbitolina discoidea-Choffatella decipiens*		*Palorbitolina lenticularis*	*Choffatella decipiens/ Palorbitolina lenticularis*	*Palorbitolina lenticularis*
Barremian	Late		*Dictyoconus arabicus*			*Un zoned area*
	Early	*Choffatella decipiens*		*Choffatella decipiens*	*Choffatella decipiens*	
Hauterivian	Late	*Pseudocyclammina lituus*	*Pseudocyclammina lituus*		*Pseudocyclammina lituus*	*Pseudocyclammina lituus*
	Early					
Valanginian	Late	*Pseudocyclammina kelleri*		*Lituola kelleri*	*Cyclammina gregi*	*Pseudocyclammina kelleri*

Figure 10: Correlation chart of Benthonic foraminifera of Sarmord and Qamchuqa formations zones with other zonal schemes.

- ***Palorbitolina lenticularis* Taxon Range Zone (Part).**
  - **Definition:** This zone represents the Taxon Range Zone of the index species *Palorbitolina lenticularis* (Blumenbach). It is expected that the specific thickness of this biozone in the current study represents the middle-upper parts of the total range of this biozone.
  - **Age:** Early Aptian.
  - **Boundaries:** the lower boundary of this biozone was set at the first appearance of *Palorbitolina lenticularis* (Blumenbach), noting that the upper boundary of this biozone was not distinguished in this study.
  - **Thickness:** This biozone represents the highest portion of the Qamchuqa Formation in the Gara section only. The thickness of this range is (1.5) meters.
  - **Correlation and age determination:** The present biozone is equivalent to both the upper part of the *Orbitolina discoidea-Choffatella decipiens* zone, of Chatton and Hart (1960), and the lower part of the *Choffatella decipiens* zone (Sampo, 1969) in Early Aptian age. Whereas it is correlated to the middle part of *Palorbitolina lenticularis* of British Petroleum and Idemitsu (1990), and the upper part of the *Palorbitolina Choffatella decipiens-lenticularis* of Al-Essa (1997) in the Early Aptian age.

CHRONOSTRATIGRAPHY

- **Middle-Late Tithonian**

The specific age of the Chia Gara Formation according to (Bellen *et al*., 1959) is the Middle Tithonian – Berriasian, and by comparing the fauna diagnosed in the current study at Amadia and Barsarin sections with the type section, it was noted that these successions correspond to the units (n-I). for (Bellen *et al*., 1959), which represents the Middle – Late Tithonian age. The formation in the current study was characterized by the prevalence of

Radiolaria, which reached its climax in the middle of the formation. While the upper part of the formation was represented by the presence of ammonites, which represented the main crowds of the Durangites biozone that had previously been recorded within the Chia Gara Formation at the Late Tithonian age by Howarth, (1992) and Leanza, (1996). Furthermore, Bellen *et al*. (1959) have mentioned that the boundary between the Tithonian and the Berriasian is represented by the unit (h), which was not diagnosed in the current study. Accordingly, the age of the Chia Gara Formation in the current study represents the middle-Late Tithonian (Figure 11).

- **Berriasian–Valanginian**

In general, the Berriasian–Valanginian age is not distinguished in all sections in this study, except the late Valanginian which is recorded within the lower part of the Sarmord Formation at Amadia section only by the distinguishing the *Everticyclammina kelleri* zone. Al-Essa (1997) considered the biozone indicative of the late Valanginian is *Cyclammina gregi*, while, in the current study the *Cyclammina gregi* species was recorded in the current study under the genus *Everticyclammina* as crowds associated with the species *E. kelleri.*

The absence of the age of Berriasian and Early Valanginian in the current study is consistent with what was indicated by Bellen *et al*., (1959), which considered that sedimentation of Berriasian and Valanginian in northern Iraq is a subject of controversy and undecided in most of the exposed sections, as it is in the regions of Rania, Delmar, and Sirwan, most or all of the Berriasian period is missing. While, in the regions of Aura and Galki, which lie north and west of the Chia Gara type section. The upper part of the Chia Gara Formation is tectonically destroyed (there was a period of erosion and interruption in sedimentation), which led to its removal or the deposition of the Garagu Formation in its place. Also, he added that the areas located to the east and southeast of the typical section lack the early Valanginian age.

As for the Gara and Barsarin sections, the scenario is slightly different, as the age specified for the Garagu Formation by Bellen *et al*. (1959) is Valanginian-Hauterivian and for Sarmord Formation is Valanginian-Aptian. Since the late Valanginian period was determined within the lower parts of the Balambo Formation in these two sections by *Favusella hoterivica* and the lower part of the *Hedbergella sigali* biozones, the proposed age of the Garagu Formation in this study is the early Valanginian. Whereas, in the Barsarin section, the Sarmord Formation, which is located below the Balambo Formation represented the early Valanginian period.

- **Hauterivian**

This period was represented by the dominance of index fossils *Pseudocyclammina lituus*, which became one of the important features of the foraminifera during the Hauterivian (Al-Essa, 1997). This species was recorded in the current study as an index species for the *Pseudocyclammina lituus* assemblage zone in the upper part of the Sarmord Formation at Amadia section representing Hauterivian age. This corresponds to the studies of Chatton and Hart, (1960) and Al-Essa, (1997), which considered that this zone is indicative of the Hauterivian age.

As for the Gara and Barsarin sections, the Hauterivian age is represented by the continuity of *Hedbergella sigali* biozone, which represented the middle part of the Balambo Formation in the current study.

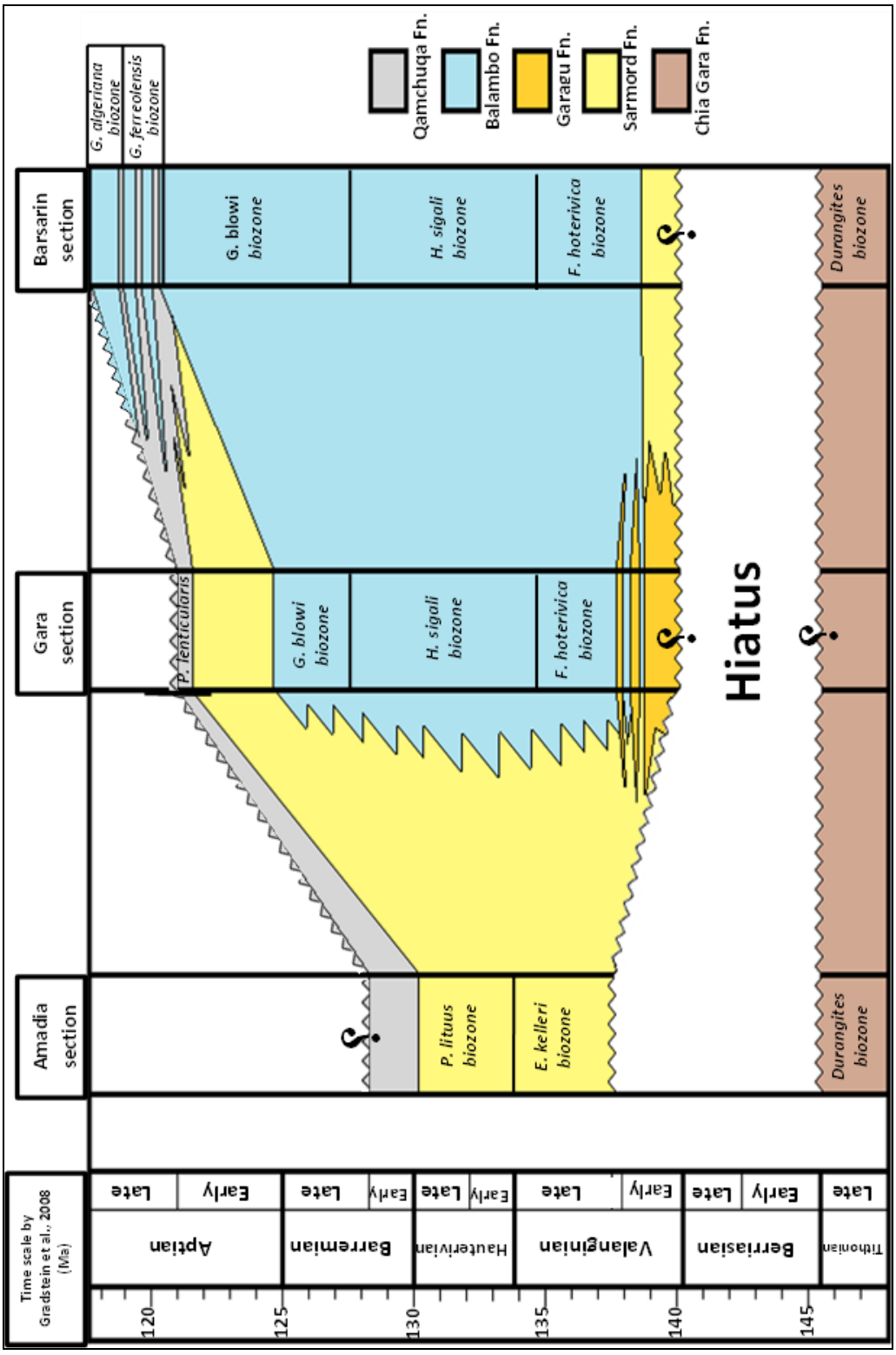

Figure 11: Chronostratigraphic Correlation of the studied Formations in the current study.

- **Barremian**

This age was recorded in the three sections. In the Amadia section, the Qamchuqa Formation was represented by the early Barremian age only, due to the presence of the species *Buccicrenata hedbergi* (Maync), which indicate the Early Barremian age. The

succession of this section has witnessed interruptions in sedimentation and erosion that led to the removal of the remainder of the Early Cretaceous and part of the beginning of the Late Cretaceous. Besides, this is field-documented by a hardground bed, which represents the last bed of the Qamchuqa Formation exposed within the aforementioned section, as it is directly followed by the Hadina Formation of the late Campanian age (Al-Rashidi, 2013).

As for the Gara and Barsarin sections, the Barremian age is represented by the upper part of the *Hedbergella sigali* biozone and the lower part of the *Globigerinelloides blowi* biozone within the middle part of the Balambo Formation.

- **Aptian**

This age was recorded in the Gara and Barsarin sections, while they were not recorded within the Amadia section, due to the unconformity within that previously mentioned section. The upper part of the Gara section of the Early Aptian age was represented only within the upper part of the Balambo, Sarmord, and Qamchuqa formations. The continuity of the *Globigerinelloides blowi* biozone was recorded within the upper part of the Balambo Formation. In addition to the *Palorbitolina lenticularis* biozone at the top of the Qamchuqa Formation, which reflects the Aptian age, and represented the end of the Gara succession in the current study. The lack of the Late Aptian period within the Gara section is due to the reasons for erosion and the cessation of sedimentation that lasted from the top of the Early Aptian to the Late Campanian. Where the Aqra Formation unconformably overlies Qamchuqa Formation, and the boundary between the two formations was not observed because of its coverage with recent sediments. As for the Barsarin section, it represented the early Aptian and a part of the late Aptian, by recording the continuation of the *Globigerinelloides blowi* biozone, in addition to the *Globigerinelloides ferreolensis* and part of the *Globigerinelloides algeriana* biozones.

CONCLUSION

- The study of the ammonite's fauna from the upper part of the Chia Gara Formation in the current study included the identification of six species belonging to five genera. The ammonites investigated are found as an assemblage of fauna in the Durangites Zone, indicating a Late Tithonian age for the upper part of the Chia Gara Formation.
- The planktonic foraminiferal biozones are extending from Late Valanginian to the Late Aptian age. The 1st, 2nd, and part of 3rd biozones were recognized in the Gara section, while the five biozones were recorded in the Barsarin section. accordingly, the age of the Balambo Formation in the Gara section extends from late Valanginian to late Barremian and late Valanginian to late Aptian in the Barsarin section.
- The stratigraphic distribution of the benthonic foraminifera shows three biozones,
- the 1st and 2nd were determined in the Sarmord Formation at Amadia section, which extend in age from late Valanginian to Hauterivian. While the 3rd biozone was recorded from Qamchuqa Formation at the Gara section in the Early Aptian age.
- The study identified a chronostratigraphic unconformity of Berriasian and Early Valanginian in the Amadia section, which lasted about 7.5 million years, while in the Gara and Barsarin sections, the loss of the Berriasian was recorded only about 5.5 million years. It follows from this, that this age witnessed the first stages of folding during the Cretaceous in Iraq and that the reason for this difference in the age loss is due to the difference in the depth of these areas within the sedimentary basin before exposure, as well as their geographical location and distance from the edge of the plate that affected the intensity of folding within each region.

- The current study showed that during the Berriasian age, that followed the unconformity, the delay in sedimentation was diagnosed in the Amadia section to the Late Valanginian section, compared to the Gara and Barsarin sections, in which the sedimentation started during the early Valanginian. This is because the Amadia region did not witness any deposition of deep marine facies, in addition to the low thickness of the shallow limestone successions formed in that region. This indicates that the Amadia region behaved as an elevated area than the other study areas, which led to a delay in the progress of water and its flooding to the Amadia area.

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