IRAQI BULLETIN OF GEOLOGY AND MINING (IBGM)
IRAQ GEOLOGICAL SURVEY (GEOSURV-IRAQ)

Vol.19, No.1, 2023 ***p 17 – 28***

BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE ANAH FORMATION IN KURDISTAN REGION, IRAQ

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Received: 08/ 09/ 2022, Accepted: 12/ 12/ 2022
Keywords: Biostratigraphy; paleoecology; Anah Formation; Kurdistan Region; Iraq

ABSTRACT

In the current study, biostratigraphy and paleoecology of the Anah Formation have been investigated. The study area is located in the Sulaimanyah Governorate, Kurdistan Region, Northeast Iraq where the Darzila section has been sampled. Twenty-five species of larger foraminifera and skeletal fragments of coral, echinoid spine, pelecypods, and gastropods are described in seven samples collected from the Darzila section. Based on the distribution of the larger-benthic foraminifera and other skeletal grains, two assemblage biozones of the Late Oligocene – Early Miocene age have been recognized. According to the paleoecological parameters, such as temperature, nutrients, depth, and salinity in the study area, the Anah Formation has deposited the euphotic zone, abundant imperforate foraminifera are present, sub-tropical waters under oligotrophic to mesotrophic middle ramp environment with normal to a higher salinity inner ramp setting and at water depths that ranged from 40 m to 80 m, and a temperature about 18 – 25 ºC.

INTRODUCTION

The studied area is located within Sulaimaniyah Governorate, Ashdagh mountain, Sangaw area at the two plunges of Ashdagh and Khwellen anticline. Darzila section is located at the SW plunge of the Ashdagh anticline. Darzila section is located at 35º 08' 36.4" N latitude and longitude E: 45° 17' 22", about 15 Km South-East of Sangaw town (Figure 1).

The Anah Formation was studied for the first time by Bellen (1956), from the type locality, which is located 15 Km east of Nahiyah village, Anah town, at the coordinates 43° 37' 00" E, 34° 58' 00" N (Bellen *et al*., 1959). It is exposed in Qara Chough Dagh and along the Iraqi – Iranian international borders in north Iraq, and exposed in the Butmah East anticline (Sissakian and Al-Jubori, 2011). According to the I.P.C. (1963), the formation is not encountered in all the oil wells drilled in the Butmah anticline. The lower and the upper boundary are conformable and unconformable with the Azkand and Euphrates formations, respectively (Bellen *et al*., 1959). In the final report on the regional geological survey of Iraq, Jassim and Karim (1984) and Jassim *et al*. (1984), mentioned that the Anah Formation was rich in fossils and deposited in a shallow water environment.

The objectives of this study are to reconstruct a coherent biostratigraphic framework for the carbonate deposits of the Anah Formation in the studied area based on available biozonation schemes and to give the paleoecological study of the Anah Formation.

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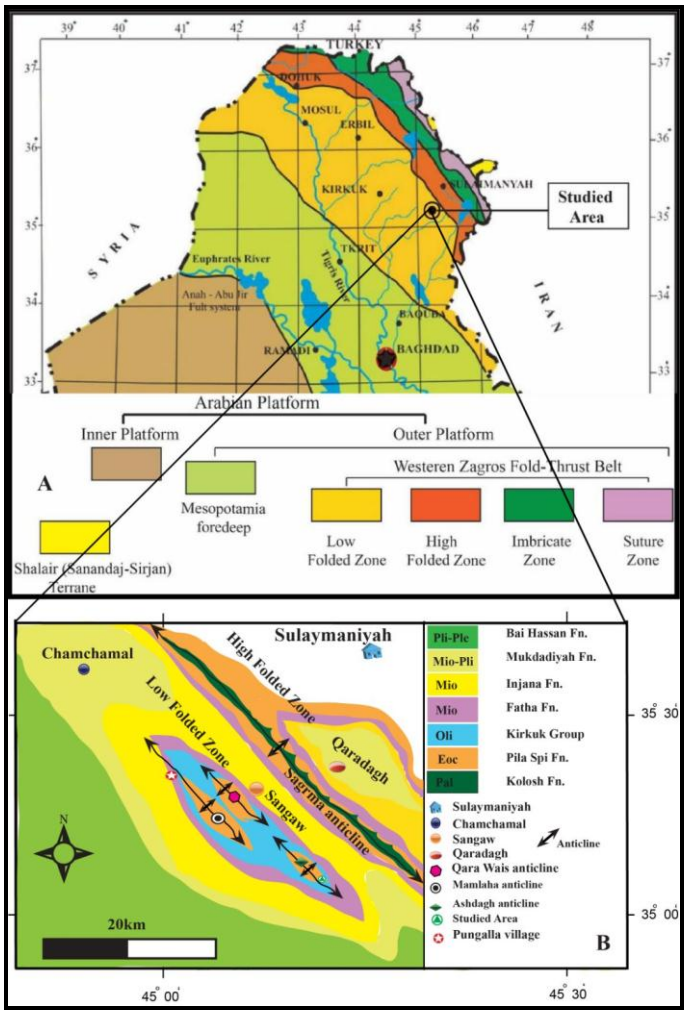

Figure 1: Location map of the studied area; **A)** a tectonic map of Iraq after (Fouad, 2015) and **B)** a geological map of the studied area.

PREVIOUS WORK

Oligocene – Miocene formations studied by different authors in Iraq (Muhammad, 1983; Abid, 1997; 2011; 2015; 2022a, and 2022b; Ghafor and Muhammed, 2005; Ghafor and Ahmad, 2019, and 2021; Muhammed and Ghafor, 2008). Youkhana and Hradecky (1977) studied the Anah Formation around the Bamu anticline. Behnam (1979) studied the stratigraphy and paleontology of the Anah Formation. Buday (1980) confirmed the presence of nine formations in the Kirkuk Group succession. The biostratigraphy of the Anah Formation has been studied in the Kirkuk and Bai Hassan areas by Muhammad (1983). Jassim and Karim (1984) described and studied Anah Formation. Al-Hashimi and Amer (1985) described the petrographic texture and paleontological character of the Anah Formation in the Anah area, where the Late Oligocene age of the Anah Formation is recorded (Fouad *et al*., 1986), and the Late Oligocene – Early Miocene age was reported by Abid and Sayyab (1989). However, Al-Twaijri (2000) studied Anah Formation and gives Late Chattian time. At the Wadi Banat Al-Hassan, Western Iraq, the biostratigraphy of the Euphrates and Anah formations were studied (Al-Sayyab and Al-Hamdani, 1990). Abid (1997) and Al-Ghreri (2007) clarified that the Anah Formation is within the Late Oligocene – Early Miocene age. Ghafor and Muhammed (2005) studied the evolutionary aspects of *Lepidocyclina* (*Nephrolepidina*) from Baba and Azkand formations in the Kirkuk area. The Anah Formation

was reviewed by Sissakian and Mohammed (2007) in the Western Desert. The biometric analysis of Miogypsinidae and their Taxonomic Significance from Oligocene – Miocene was analyzed by Muhammed and Ghafor (2008) in the Kirkuk area, Iraq. The Oligocene – Miocene boundary in northern Iraq was revised by Al-Banna (2008). Microfacies and biostratigraphy of the Baba Formation were explained by Ghafor (2011) in the Bai-Hassan well-25, Kirkuk area. The evolutionary aspects of *Lepidocyclina* (*Nephrolepidina*) from the Baba Formation (late Oligocene) in Bai-Hassan well-25, Kirkuk area, Northeast Iraq have been studied by Ghafor (2015). Ghafor and Ahmad (2019) studied the biostratigraphy and paleoecology of the Anah Formation in the Sangaw area, Northeastern Iraq, and in 2021 studied the stratigraphy of the Oligocene – Early Miocene successions, Sangawarea, Kurdistan Region, NE-Iraq. Ghafor (2022b) studied the Oligocene – Miocene Qarah Chaugh – Dagh section from the viewpoint of biostratigraphy and microfacies. Ghafor (2022a), studied the systematic, microbiostratigraphy and paleoecology of the Bajwan Formation (Late Oligocene) in the Kirkuk Well-160, northeastern Iraq.

MATERIAL AND METHODS

To achieve the aim of this study, the Darzila section was measured, described, and sampled for paleontological and paleoecological studies (Figure 2). Thin sections were made and a polarized microscope was used to identify different types of microfossils. (Seyrafian and Mojikhalifeh 2005; Laursen *et al*., 2009; Sirel *et al*., 2013; Gedik, 2014; Serra-Kiel *et al*., 2016; and Roozpeykar Moghaddam, 2016), were used for identifications of the benthic foraminifera and the paleoecological studies were done by using the studied (e.g., Geel, 2000; Romero *et al*., 2002; Brandano *et al*., 2009; and Flügel, 2010).

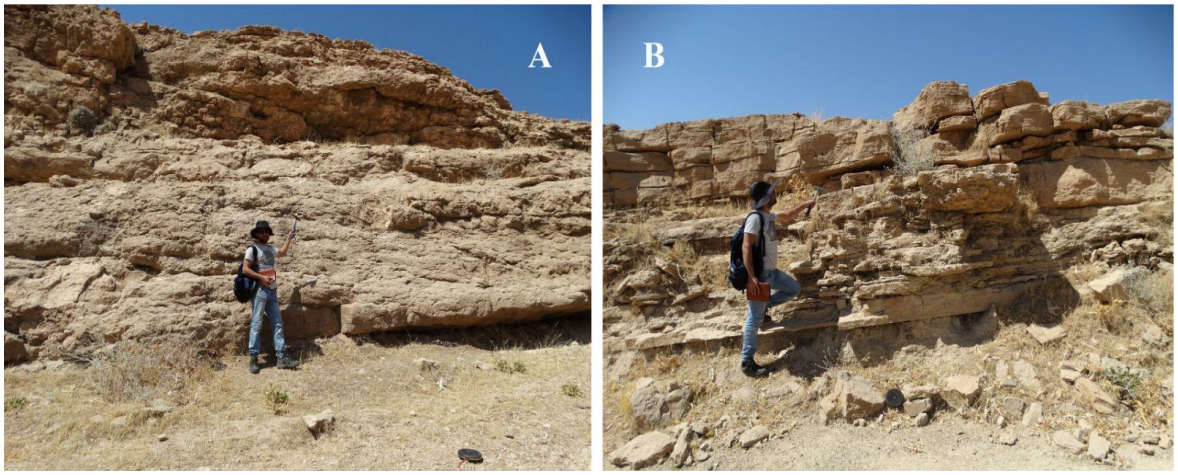

Figure 2: Field photographs showing the studied section of **A)** Anah Formation and **B)** Jeribe Formation.

- **Geological Setting**

Ashdagh Anticline is located between the southwest of Sulaimani city and southeast of Kirkuk city, 30 Km SW of Chamchamal town, and 13 Km NE of Sangaw town. Tectonically, the study area is located within the Low Folded Zone. The studied section is situated on the southwestern limb of the Mamlaha anticline, which is part of three anticlines (Ashdagh, Mamlaha, and Qara Wais). The Mamlaha anticline is smaller than the other two anticlines, and its limbs have gentle slopes and trends NW – SE like other anticlines in the area. The Ashdagh anticline is located southeast of the Mamlaha anticline and the Qara Wais anticline

is located northeast of the Mamlaha anticline (Figure 3). The studied section is comprised of limestone beds that are white thickly bedded highly jointed and fractured coralline limestone. The lower contact is with the thin to intermediate-red algal limestone of the Bajwan Formation and the upper contact is with the milky thick bedded highly jointed fossiliferous limestone of the Euphrates Formation. The thickness of the Anah Formation in the studied section is about 7 m (Figure 4).

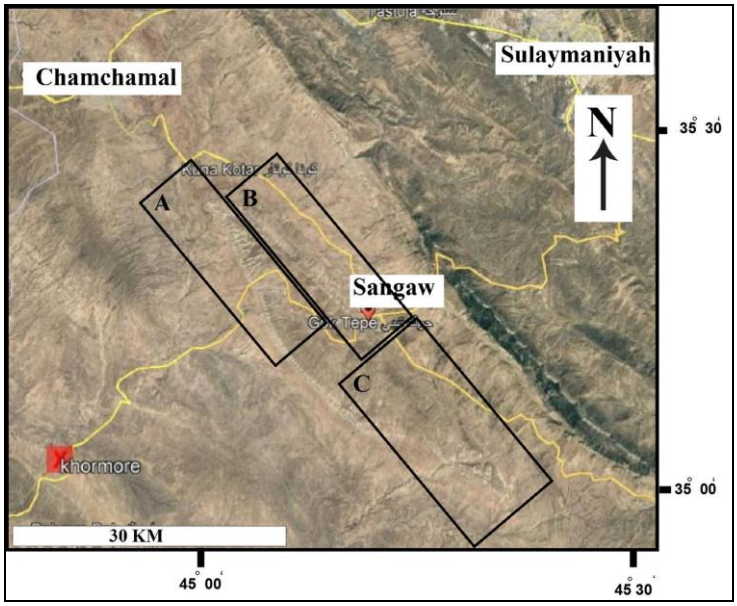

Figure 3: Satellite map of the study area taken from Google Earth (2019) Showing: **A)** Mamlaha anticline, **B)** Qara Wais anticline, **C)** Ashdagh anticline.

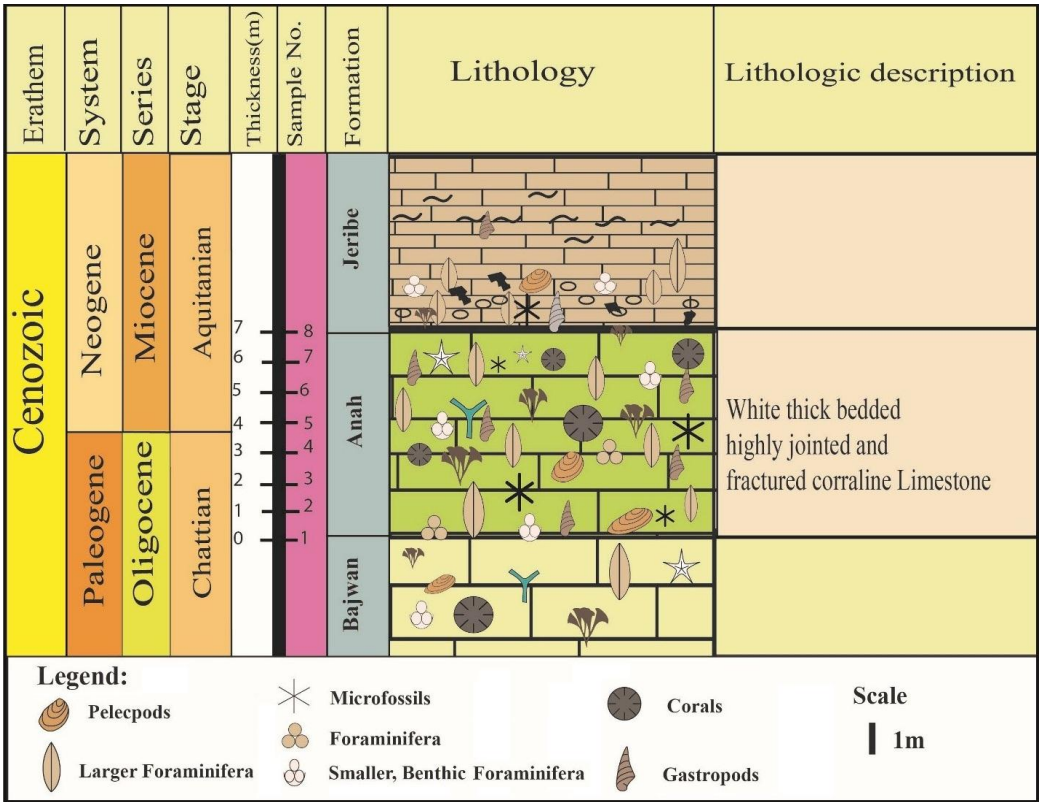

Figure 4: Lithostratigraphic column of the studied section, Ashdagh anticline, Sangaw area.

RESULTS AND DISCUSSION

- **Biostratigraphy**

Forty species from the Late Oligocene – Early Miocene foraminiferal assemblages and skeletal-fragments of brachiopod layer grain, coral, pelecypods-bivalves, and gastropods were analyzed to establish the biostratigraphic framework of the Anah Formation (Figures 5, 6, and 7). From base to top, two biozones were recognized (Figure 8). Two assemblage zones are recognized in this study:

***Meandrospina anahensis-Austrotrillina asmariensis* Interval Zone**.

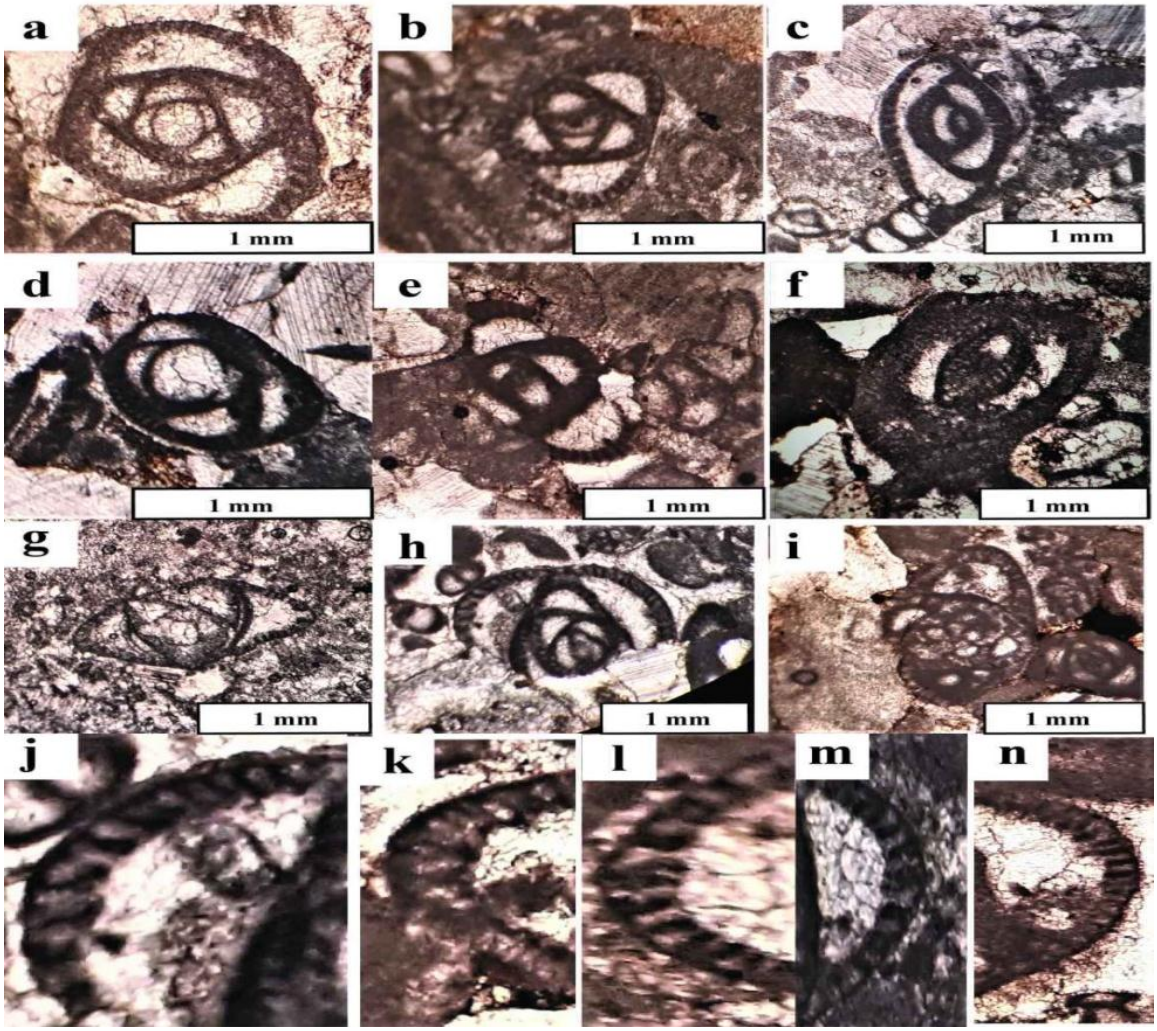

Figure 5: Larger Benthonic Foraminifera from the Anah Formation, Darzila section. Where **a, b, l** and **m)** *Austrotrillina striata* (Todd and Post, 1954), equatorial section, a, b, l, and m equatorial section, c- subequatorial section, sample no. (7); **c, d, e, f, g, h, j,** and **n)** *Austrotrillina asmariensis* (Adams, 1968), subequatorial section, e, f, and n equatorial section, sample no. (7). **I** and **k)** *Austrotrillina howchini* (Schlumberger, 1893), equatorial section, sample no. (7).

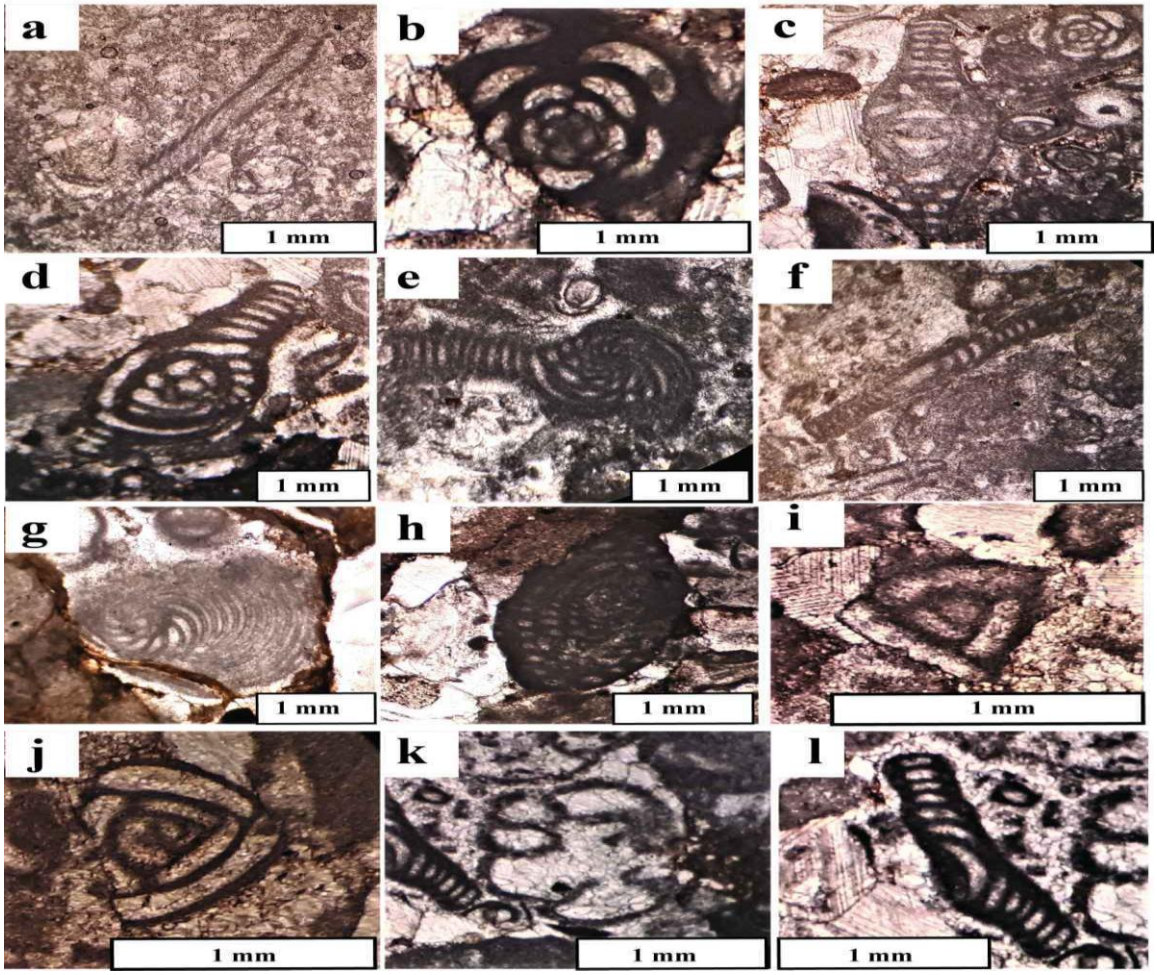

Figure 6: Larger Benthonic Foraminifera (LBF) from the Anah Formation, Darzila section. **a)** *Meandropsina anahensis* (Henson, 1950), axial section, sample no. (25). **b)** *Quinqueloculina* sp., equatorial section, sample no. (6). **c)** *Archaias hensoni* (Smout and Eames, 1958), sample no. (7). **h)** *Peneroplis thomasi* (Henson, 1950), d-subaxial section, e-oblique equatorial section, sample no. (6). **d, e, f, g** and **l)** *Peneroplis evolutus* (Henson, 1950), f- axial section, g-equatorial section, sample no. (5). **I** and **j)** *Triloculina trigonula* (Lamarck, 1804), equatorial section, sample no. (7). and **k)** *Valvulina* sp., sample no. (5).

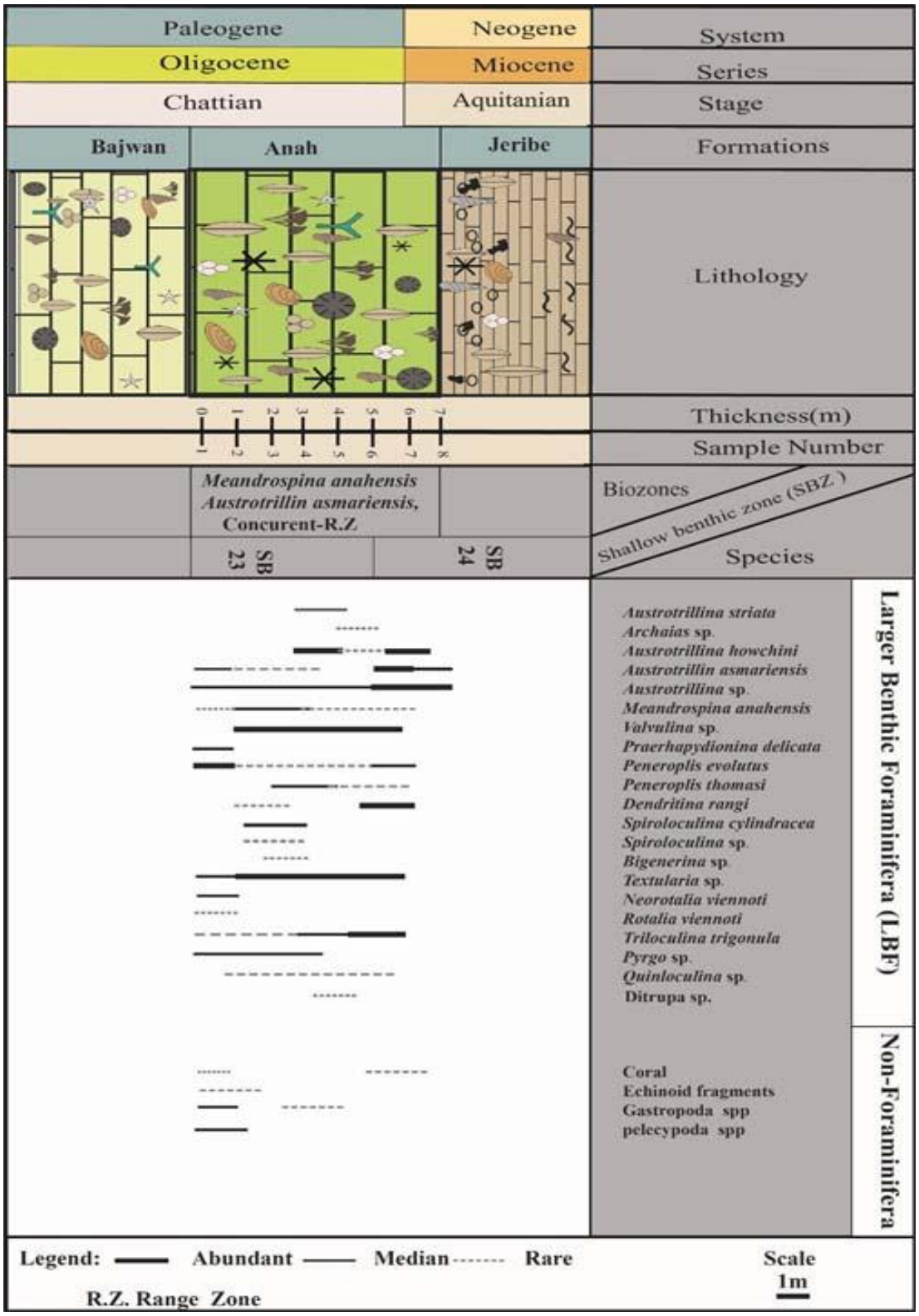

Figure 7: Biostratigraphic column of the Anah Formation in the studied section.

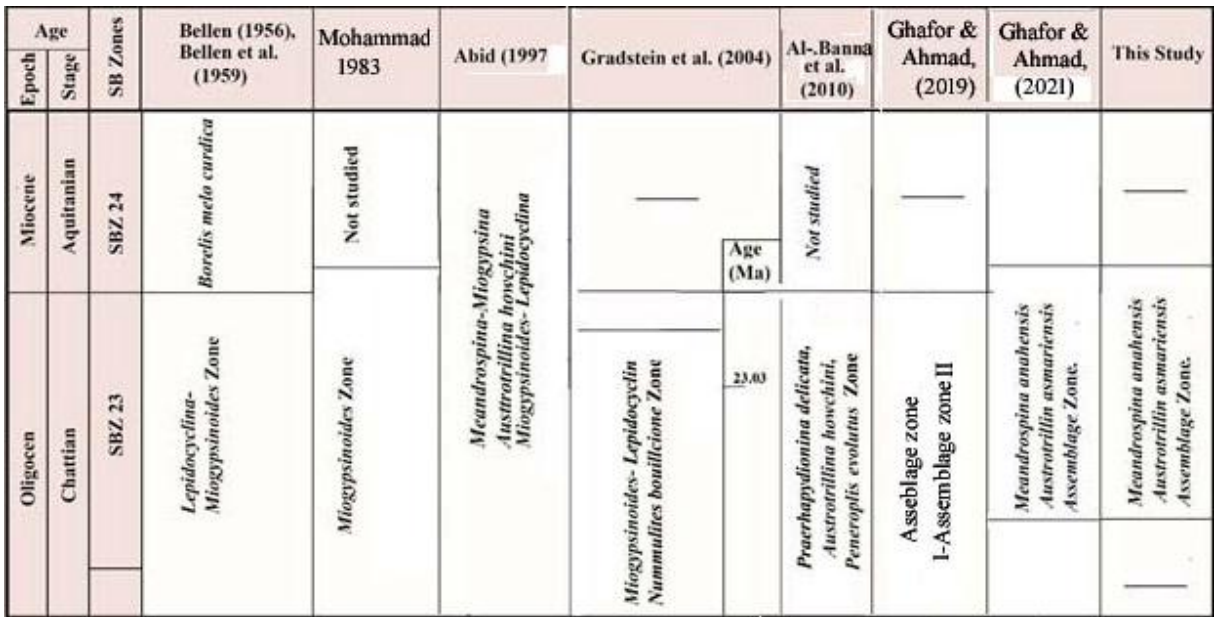

Figure 8: Correlation chart showing the biostratigraphic zones of this study with the other studies inside Iraq.

– **Definition:** Biostratigraphic interval of this zone is characterized by the Concurrent Range of the nominate taxa (*Meandrospina anahensis* Henson, and *Austrotrillina asmariensis* Adams).

– **Remarks:** This zone consists of a 7 m thick reef/ back reef Anah Formation from samples 1 – 7, which starts with the First Appearance Datum (FAD) of *Meandrospina anahensis* Henson, in the sample number 1, and ends by the Last Appearance Datum (LAD) of *Austrotrillina asmariensis*, in the sample number 7. The most diagnostic species include: (*Austrotrillina howchini, Austrotrillina asmariensis, Austrotrillina* sp., *Bigenerina* sp., *Dendritina rangi, Meandrospina anahensis, Pyrgo* sp., *Ditrupa* sp., *Peneroplis evolutus, Peneroplis thomasi, Quinqueloculina* sp., *Triloculina trigonula, Textularia* sp., and *Valvulina* sp.), and includes some non-foraminifera species like coral, echinoid spine, pelecypods, and gastropods.

– **Correlation:** This assemblage is correlated with the biozone *Lepidocyclina-Miogypsinoides,* zone of Bellen (1956) and Bellen *et al*. (1959), and it is correlated to the *Miogypsinoides* zone of (Muhammad, 1983), it is correlated with the *Meandrospina-Miogypsina-Austrotrillina howchini-Miogypsinoides-Lepidcyclina* zone of (Abid, 1997), also corresponding with biozone *Miogypsinoides-Lepidocyclina-Nummulites bouilli* zone of (Gradstein *et al*., 2004), it is correlated with the Assemblage zone I and Assemblage zone II of (Ghafor and Ahmad, 2019), and equivalents to the biozone *Meandrospina anahensis-Austrotrillina asmariensis* of (Ghafor and Ahmad, 2021) in the Pungalla section, Northeastern Iraq (Figure 8).

– **Age:** Late Chattian – Early Aquitanian (Oligocene – Miocene).

- **Paleoecological Interpretation**

In this study, the paleoecological elements (temperature, salinity, nutrients, and water depth), are used for paleoecological interpretation. The authors Hallock and Glenn (1986); Pedley (1998); Geel (2000); Pomar (2001); Romero *et al*. (2002); Beavington-Penney and

Racey (2004); Pomar *et al*. (2004); Pomar and Hallock (2008); Brandano *et al*. (2009); Van Buchem *et al*. (2010); Flügel (2010); Pomar *et al*. (2012); and Taheri *et al*. (2017), interpreted the paleoecological elements of Late Oligocene – Early Miocene carbonate platforms. *Austortrillina*, coralline and imperforate foraminifera (*Peneroplis* and *Dendritina*), and skeletal grains consisting of gastropod, and bivalve fragments are the most significant and dominant biogenic components in the Late Rupelian – Early Chattian succession at the studied area. Anah Formation could be interpreted as follows, according to the paleoecological conditions during Late Oligocene – Early Miocene time. According to Bosence (1983); Hottinger (1997); Beavington-Penney and Racey (2004), most of the imperforate foraminifera in the studied area thrived in oligophotic to mesophotic mid-ramp environments mostly at water depths that ranged from 40 m to 80 m. Wilson and Vecsei (2005) clarified that larger benthic foraminifera lives in tropical and subtropical water environments and restrict to temperatures of 14 °C to 25 °C. Some imperforate foraminifera, such as *Dendritina*, *Peneroplis*, and miliolids are restricted to tropical environments (BouDagher-Fadel and Wilson 2000; Brandano *et al.*, 2009). The association of *Dendritina* with coral indicates temperatures between 18 and 25°C in a tropical environment (Wilson and Vecsei, 2005). *Operculina*, *Neorotalia*, *Archaias*, miliolids, *Amphistegina*, *Dendritina Austrotrilina*, mollusks, bryozoans, and coral have low energy, normal salinity, euphotic-mesophotic zone in inner ramp (Roozpeykar and Moghaddam, 2015). Occurrence of coralline, imperforate foraminifera (*Peneroplis*, *Dendritina*, and *Austrotrillina*), miliolids, and mollusca in the studied section have normal to higher seawater salinity in the inner ramp setting (Flügel, 2010; Allahkarampour Dill *et al*., 2012; and Taheri *et al*., 2017) (Table 1).

Table 1: Vertical distribution of faunal composition, paleoecological elements, salinity, nutrient, and depth estimation of the Anah Formation in the studied section.

Age	Fossils abundance	Temperature	Depth (m)	Nutrients	Sea water Salinity
Chattian-Aquitanian	Larger Benthic Foraminifera (LBF) *Operculina, Heterostegina, Spiroclypeus, Amphistegina, Neorotalia, Archaias, Austrotrillina, Peneroplis* and *Dendritina* Coralline, with mollusca, coral, and miliolids.	18 – 25 °C	40 – 80	Oligotrophic-Mesotrophic	Normal marine to slightly saline

CONCLUSIONS

This study has the following conclusions:

- The Anah Formation in the Darzila section is characterized by different microfossils of larger foraminifera, and skeletal fragments of coralline red algae and brachiopods layer grain, coral, pelecypods-bivalves, gastropods, and bryozoan shells.
- The Anah Formation is subdivided into two assemblage biozones that extend in age from Late Chattian to Early Aquitanian.
- The Anah Formation in the studied section was deposited at a temperature of ranges between 18 °C and 25 °C, normal-higher salinity, having 40 m to 80 m water depth, with oligotrophic – mesotrophic nutrient conditions.

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