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BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE ANAH FORMATION (UPPER OLIGOCENE) IN THE SANGAW AREA, SULAIMANIA GOVERNORATE, KURDISTAN REGION, NE IRAQ

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ABSTRACT

Biostratigraphy and paleoecology of the Anah Formation are investigated for the first time in the Sangaw area, Sulaimania Governorate, Northeastern Iraq. Forty species of larger foraminifera and skeletal fragments of brachiopod, coral, pelycepods (bivalves), gastropods, bryozoan and algae shell, are described in seven samples collected from one section near the Pungala village. Based on the distribution of the larger benthic foraminifera and other skeletal grains, two assemblage biozones of Upper Oligocene (Chattian) age have been recognized. During the Chattian, the carbonate deposits of the Anah Formation in the studied section are mostly composed of coralline red algae and large flat benthic foraminifera. The biotic associations identified in this study suggest that the carbonate sedimentation of the Anah Formation thrived in tropical to subtropical waters under oligotrophic to mesotrophic middle ramp environment with normal seawater salinity to a higher salinity inner ramp setting and at water depths that ranged from 40 to 80 m.

الطباقية الأحيائيه والبيئة القديمة لتكوين عنة (اوليغوسين اعلى) في منطقة سنكاو، محافظة السليمانية، اقليم كردستان، شمال شرق العراق

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المستخلص

يتضمن البحث الحالي دراسة الطباقية الاحيائيه والبيئة القديمة لتكوين عنة لأول مرة في منطقة سنكاو، محافظة السليمانية في اقليم كردستان، شمال شرق العراق. أجريت هذه الدراسة على سبعة نماذج من الحجر الكلسي الغني بالمتحجرات جمعت من مقطع واحد قرب قرية بنكالا. تم تشخيص أربعين نوعا من الفورامنيفرا القاعية الكبيرة والمتحجرات الأخرى، وبالاعتماد على هذه الأنواع من الفورامنيفيرا والمتحجرات الاخرى، تم التعرف على نطاقين احيائين وعلى اساسهما جرى تحديد عمر التكوين في هذا المقطع بالاوليغوسين الأعلى (جاتين). تم استنباط البيئة القديمة من خلال دراسة التنوع الاحيائي لتكوين عنه حيث ان الدلائل تشير الى ان التكوين ترسب في مياه بحرية استوائية الى شبه استوائية ضمن بيئة منصة وسطية ذات ملوحة اعتيادية الى منصة داخلية ذات ملوحة اعلى وفي عمق تراوح مابين 40 – 80 م.

INTRODUCTION

The studied section is located near Pungala village (Mamlaha Anticline), at latitude N: 35° 19' 35" and longitude E: 45° 02' 57" The area is about 30 Km southwest of Cham Chamal town and about 12 Km northwest of Sangaw town, within the Sulaimania

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Governorate (Fig.1). The studied area is characterized by a mountainous terrain; where the mountain ranges trend NW – SE, separated by narrow or wide valleys.

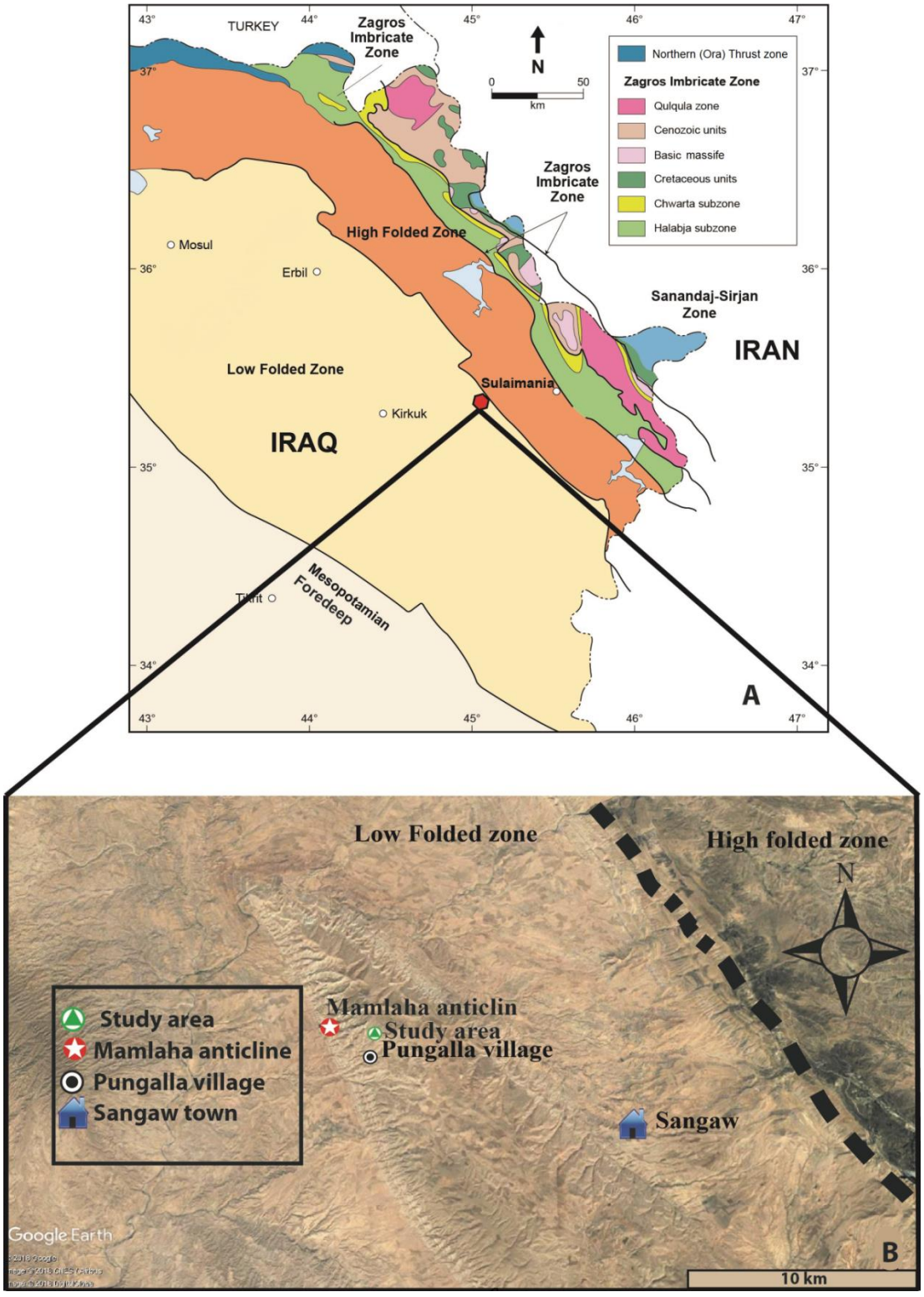

Fig.1: Location map of the studied area. **A)** Tectonic map of Iraq after Al-Kadhimi *et al*. (1996). **B)** Satellite map of the study area taken from Google Earth (2018)

The Anah Formation was introduced by Bellen (1956), the type locality lies 15 Km east of Nahiyah village, west of Anah town, along the Euphrates River and defined by the coordinates: 43° 37' 25" E, 34° 58' 00" N (Bellen *et al*., 1959). In northern Iraq, the Anah Formation is exposed in Qara Chough and along the Iraqi – Iranian international borders in Shaloradar and Bawgaru anticlines, and as traces along the Bezniyan anticline. According to Al-Banna (1997) in Sissakian and Al-Jubori (2011), the Anah Formation is exposed in the Butmah East anticline. During the regional geological mapping, carried out by Taufiq and Domas (1977) in the Butmah anticline, the base of the Fatha Formation was not found (not exposed); therefore, the formation is not encountered in all the oil wells drilled in the Butmah anticline (I.P.C., 1963). The lower contact is gradational and conformable with the Azkand Formation (Upper Oligocene), whereas, the upper contact with the Euphrates Formation (Miocene) is unconformable (Bellen *et al*., 1959). The main objective of this paper is to study the biostratigraphy and paleoecology of the Anah Formation in a selected section in NE Iraq, studied for the first time, to determine the age and depositional environment.

- **Previous Work**

- Bellen (1956) described the stratigraphy as the "Main Limestone" of the Kirkuk, Bai Hassan and Qara Chauq Dagh structures in Northern Iraq. He reported the following fossils in the type area: algae, anthozoa, bryozoa, echinoidea, mollusca and abundant foraminifera, *Archaias* sp., *Austrotrillina howchini* (Schlumberger), *Borelis pygmaea* Hanzawa, *Heterostegina* cf. *assilinoides Blanckenhorn*, *Miogypsinoides complanata* (Schlumberger), *Rotalia viennoti* Greig. Numerous undetermined miliolids.
- Ctyroky and Karim (1971) studied the stratigraphy and paleontology of the Oligocene and Miocene strata near Anah town, in the Euphrates valley, and defined the *Miogypsinoides complanata* in the Anah Formation as being of Late Oligocene age.
- Ditmar and the Iraqi – Soviet team (1971) revised Bellen's classification based on three cycles and divided the Oligocene sedimentary cycle into two sub-cycles. The Lower Cycle comprises the Sheikh Alas, Shurau, Palani and Tarjil formations, and the Upper Cycle consists of the Anah, Azkand, Baba, Bajawan and Ibrahim formations.
- Youkhana and Hradecky (1977) recorded the existence of some Oligocene formations (Shurau, Baba, Bajawan, Azkand and Anah formations) around the Bamu anticline. The thickness of the Oligocene sequence in the recorded area is about 82 m.
- Behnam (1979) studied the stratigraphy and paleontology of the Oligocene – Miocene strata in the Khanaqin area (East Iraq) and described, for the first time from exposed rocks in the area, six Oligocene formations (Shurau formation from the Lower Oligocene, Tarjil, Baba and Bajawan formations from the Middle Oligocene, and Anah and Azkand formations from the Upper Oligocene).
- Buday (1980) confirmed the presence of nine formations in the Kirkuk Group succession.
- Muhammad (1983) studied the biostratigraphy of the formations in the Kirkuk Group in the Kirkuk and Bai Hassan areas.
- Al-Hashimi and Amer (1985) studied the petrographic texture, paleontological character, fossil zonation, facies types and depositional environments of the Oligocene formations as part of their work on the Tertiary microfacies of Iraqi formations.
- Said in Fouad *et al*. (1986) claimed the age of Upper Oligocene for the Anah Formation in the succession cropping out in the Anah area.
- Abid and Sayyab (1989) restudied of the sortidae foraminifera of the Anah Formation and reported an Upper Oligocene – Lower Miocene age.
- Lawa *et al*. (2000) indicated that an Oligocene sequence may be present near the boundary between the High and Low Folded Zones of Iraq.

- Al-Twaijri (2000) suggested that the Anah Formation to be developed during Late Chattian time in a successive superposition.
- Al-Sayyab and Al-Hamdani (1990) studied the biostratigraphy of the Euphrates and Anah formations at Wadi Banat Al-Hassan (W Iraq).
- Abid (1997) and Al-Ghreri (2007) considered the Anah, Azkand and Ibrahim formations to be within the Upper Oligocene – Lower Miocene age.
- Al-Banna (2004), focused on the microfacies analysis of the Oligocene formations in Butmah and Rafan areas Northwest Iraq.
- Sissakian and Mohammed (2007) reviewed stratigraphy of the Iraqi Western Desert that involves the Anah Formation.
- Kharajiany (2008) described the sedimentary facies of the Oligocene rock units at Ashdagh Mountain in Sangaw area, north of Iraq and reported the Anah Formation as of Upper Oligocene age. Al-Banna (2008), studied the Oligocene – Miocene boundary in northern Iraq and revised the previously assigned upper sub-cycle of the Upper Oligocene age (Chattian), suggested by Bellen *et al*. (1959), into an Lower Miocene age (Early Aquitanian).
- Khanaqa *et al*. (2009) studied the lithostratigraphy of a Late Oligocene – Miocene succession in south of Sulaimania city, NE Iraq.
- Al-Banna *et al*. (2010) studied the Oligocene stratigraphy in the Sinjar Basin, northwestern Iraq.
- Karim (2010) modified the time-expanded stratigraphic column of NE Iraq during the Cretaceous and Tertiary times.
- Ghafur (2012) studied the sedimentology and reservoir characteristics of the Oligocene – Early Miocene carbonates (Kirkuk Group) in southern Kurdistan Region.
- Karim *et al*. (2012) studied facies analysis of the Oligocene succession in Sharwaldir anticline, NE of Kalar town, NE Iraq.
- Karim *et al*. (2014) studied the stratigraphy of the Oligocene – Lower Miocene Formations in the Sinjar area, NW Iraq.
- Kharajiany (2014) studied the occurrence of Lower and Middle Miocene rocks (Euphrates, Dhiban and Jerebe formations) in the Ashdagh Mountain, Sangaw area, Sulaimania vicinity, NE Iraq.
- Kharajiany *et al*. (2014) studied the Oligocene and Miocene rock units in Mamlaha anticline, Chamchamal town, Sulaimania Governorate.
- Ghafor and Karim (2014) studied the biostratigraphy of the Oligocene succession in the High Folded Zone, Sulaimania Governorate.
- Al-Qayim *et al*. (2015), studied microfacis and sequence stratigraphy of the Oligocene – Miocene sequence at Golan Mountian.
- Lawa and Ghafur (2015) studied sequence stratigraphy and biostratigraphy of the prolific Late Eocene, Oligocene and Early Miocene carbonates from the Zagros Fold-Thrust Belt in the Kurdistan Region.

SAMPLES AND METHODS

This study is based on seven samples collected from 7 m thick outcrop section of the Anah Formation in the Mamlaha anticline, near Pungala village (Fig.2). The samples are collected on the basis of lithology change and type of fossil content. The lithology of the sequence is described based on field observations. Most of the samples contain well preserved and abundant benthic foraminifera, coral, algae and other skeletal grains of microfossils. The laboratory work included preparation of two thin sections for each sample. The thin sections were examined using polarized microscope to identify different types of microfossils. A

digital camera was used to photo the microfossils in thin sections. The first part of this paper is assigned to biostratigraphic analysis of the Anah Formation, based on benthic foraminifera described by Laursen *et al*. (2009) study. The second part is focused on paleoecological interpretations, such as salinity, nutrients, and depth, based on the studies of many workers (e.g., Geel, 2000; Romero *et al*., 2002; Brandano *et al*., 2009 and Flügel, 2010).

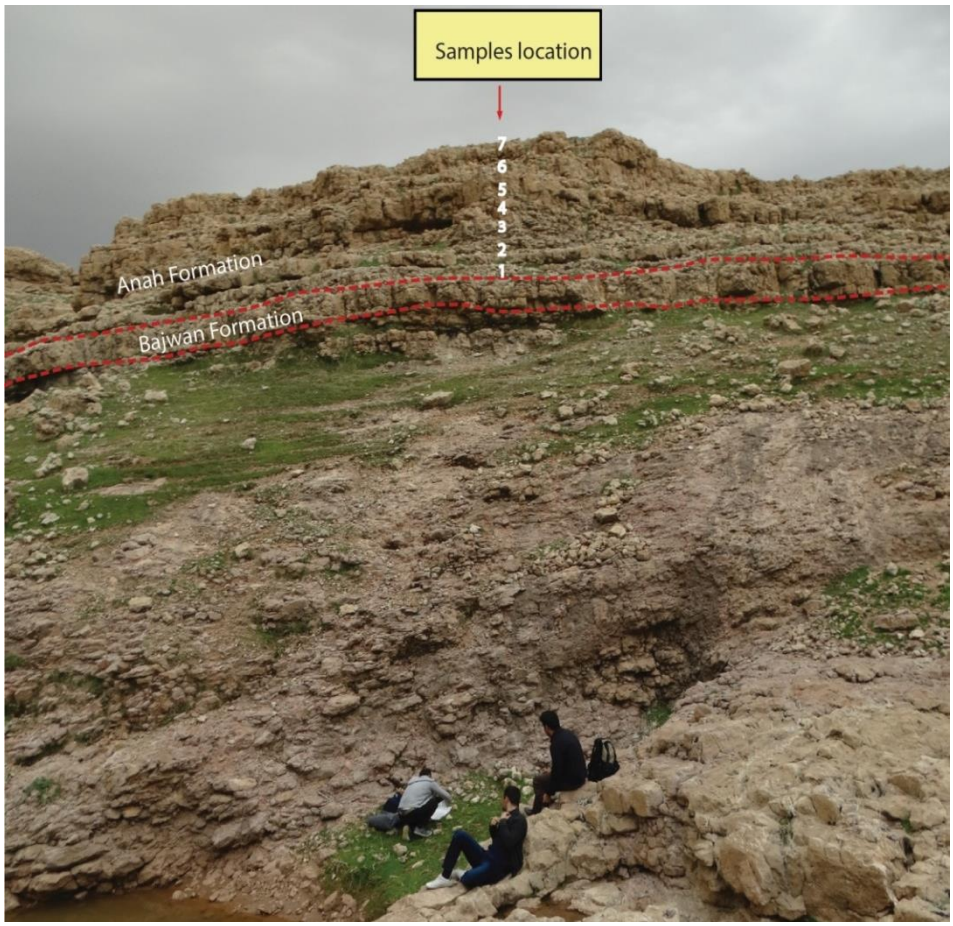

Fig.2: Sampling location showing the Anah Formation and its lower contact with the Bajwan Formation at the Pungala village, Sulaimania Governorate

GEOLOGICAL SETTING AND LITHOSTRATIGRAPHY

Mamlaha anticline locates between southwest of Sulaimani city and the southeast of Kirkuk city, 30 Km SW Chamchamal town, and 13 Km NE 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 enechelon 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 Mamlaha anticline and Qara Wais anticline is located northeast of the Mamlaha anticline (Fig.3). The studied section is comprised of limestone beds with white thickly bedded highly jointed and fractured coralline limestone. The lower contact is with 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 (Fig.4).

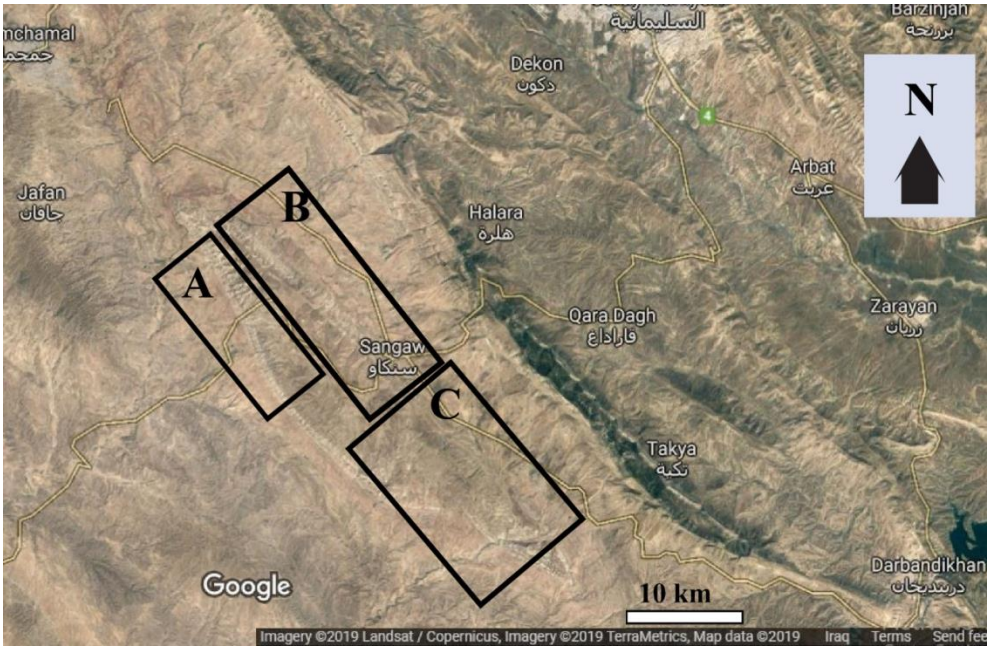

Fig.3: Satellite map of the study area taken from Google Earth (2019) Showing. **A)** Mamlaha anticline, **B)** Qara Wais anticline, **C)** Ashdagh anticline

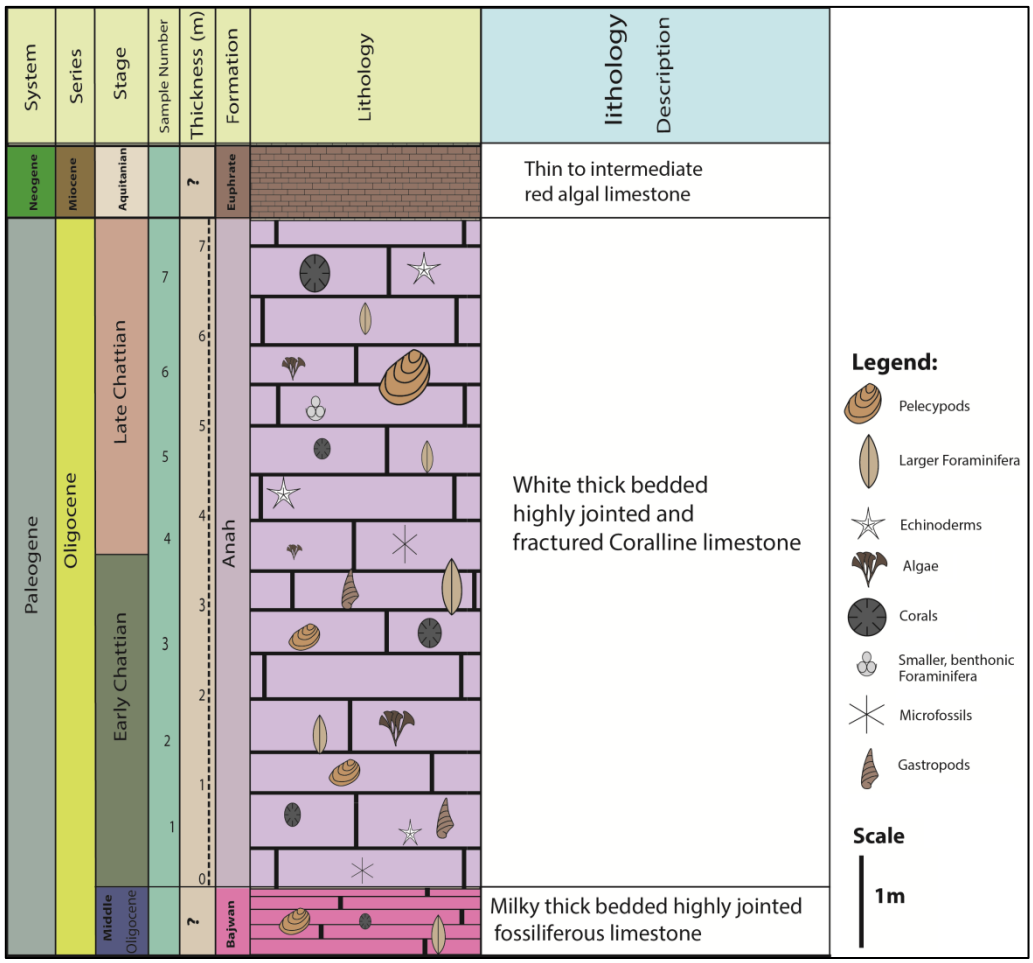

Fig.4: Lithostratigraphic column of the studied section

RESULTS AND DISCUSSION

- **Biostratigraphy**

Forty species from the Late Oligocene foraminiferal assemblages and skeletal fragments of brachiopod layer grain, coral, pelecypods-bivalves, gastropoda shell, bryozoan shell and algae are recognized and analyzed to establish the biostratigraphic framework of the Anah Formation in the studied section (Fig.5). Two assemblage zones are recognized in this study:

– **Assemblage Zone I:** The thickness of this zone is 3 m, recorded from the lower part of the studied section. The most diagnostic species identified include*: Austrollina howchini; Quinquloculina* sp. *Austtrotrillin apaucialveolata*; *Austrotrillina* sp.; *Valvulina,* sp.; *Amphistegina lessonii*; *Peneroplis thomasi*; *-Peneroplis evolutus*; *Textularia* sp.; *Triloculina* sp.; *Triloculina trigonula; Triloculina tricarinata*; *Operculina complanata*; *Operculina* sp.; *Nummulites vascus*; *Nummulites* cf. *bouillei*; *Austrotrillina brunni*.; *Austrotrillina* sp.; *Spiroclypeus blankenhorni*; *Spiroloculina cylindracea*; *Peneroplis* cf. *farsensis; Elphidium* sp.; *Neorotalia viennoti*; *Dendritina rangi*, with other different fossils such as braciopoda layer grain-large brachiopod grain, coral, pelecypods, gastropoda, echinodermata, bryozoan and algae (Figs.6 – 8). This assemblage is correlated with the *Lepidocyclina – Operculina – Ditrupa* Assemblage Zone of Laursen *et al*. (2009) and Van Buchem *et al*. (2010), and to the SBZ 22 of Cahuzac and Poignant (1997) and to the Assemblage Zone 1 of Taheri *et al*. (2017). Based on Laursen *et al*. (2009) this Assemblage Zone is attributed to the Rupelian-Chattian age. However, Ehrenberg *et al*. (2007), believes that the presence of *Spiroclypeus blanckenhorni* indicates Early Chattian age, so the age of this part of the sequence should be limited to Lower Chattian.

– **Assemblage Zone II:** The thickness of this zone is 4m, recorded from the upper part of the studied section. The most diagnostic species include (Figs.6 – 8). *Archaias kirkukensis*; *Risananeiza pustulosa*; *Archaias asmaricus*; *Archaias hensonis*, *Archaias* sp.; *Austrollina howchini*; *Quinloculina* sp.; *Peneroplis thomasi*; *Peneroplis evolutus*; *Triloculina* sp.; *Triloculina trigonula*; *Triloculina tricarinata*; *Archaias operculiniformis*; *Austtrotrillin apaucialveolata*; *Austrotrillina* sp.; *Meandropsina anahensis*; *Meandropsina* sp.; *Valvulina* sp.; *Amphistegina lesson*; *Textularia* sp.; *Triloculina* sp.; *Triloculina trigonula*; *Triloculina tricainata*, *Operculina complanata*; *Operculina* sp.; *Austrotrillina brunni*; *Pyrgo* sp., *Risananeiza crassaparies* with other different fossils such as braciopoda layer grain-large brachiopod grain, coral, pelecypod shells, gastropoda shells, echinodermata, bryozoan shell and algae (Figs.6 – 8). The microfauna from this biozone correspond to the *Archaias asmricus – Archaias hensoni – Miogypsinoides complanatus* Assemblage Zone of Laursen *et al*. (2009) and Van Buchem *et al*. (2010), and to the Assemblage Zone 2 of Taheri *et al*. (2017), and indicate Chattian age. The presence of *Risananeiza crassaparies* indicates Late Chattian age, based on Benedetti and Briguglio (2012) and consequently the age of this zone should be limited to Upper Chattian.

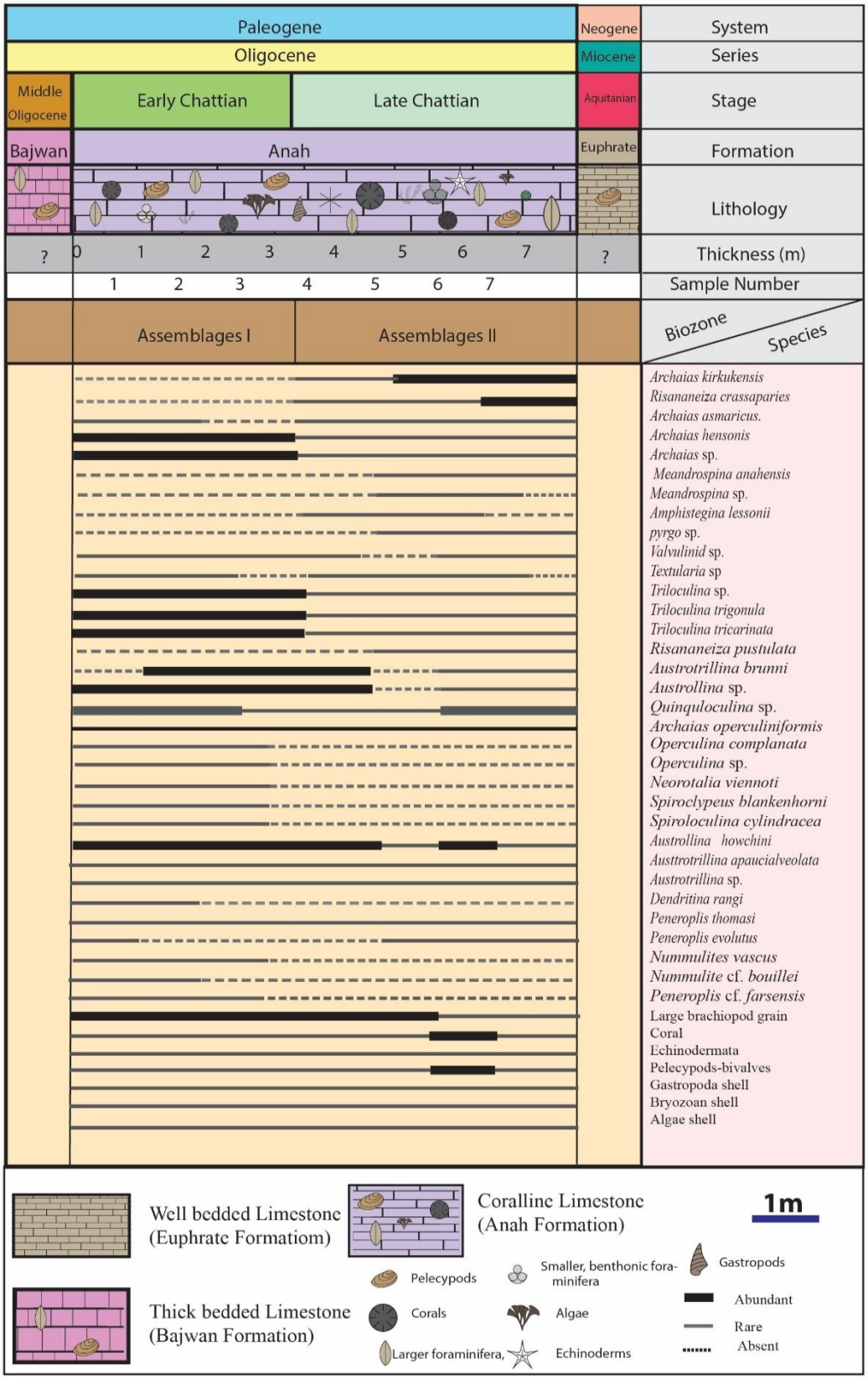

Fig.5: Biostratigraphic column of the Anah Formation in the studied section

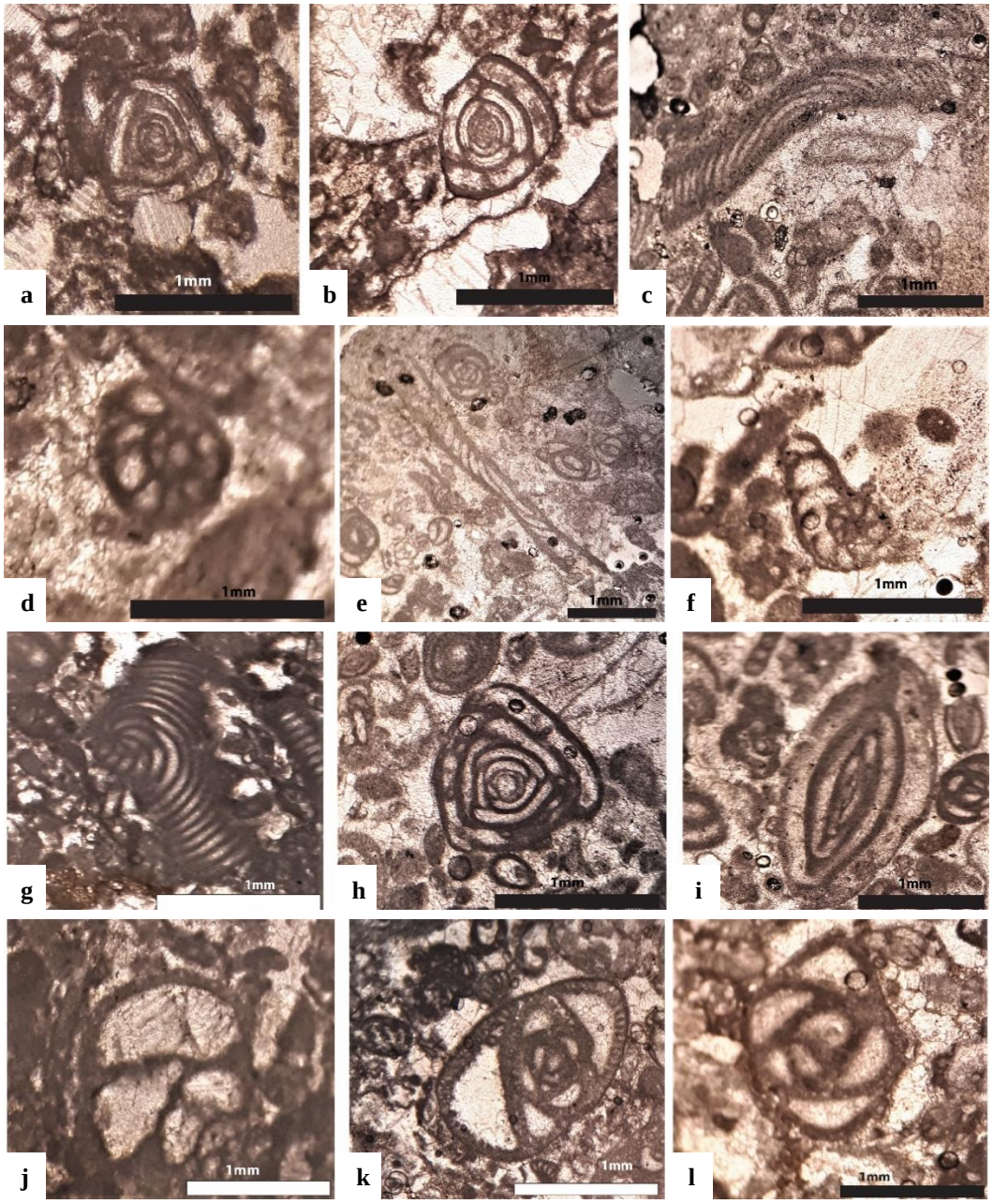

Fig.6: **a)** *Triloculina tricarinata* (d'Orbigny, 1826), sample no. 2; **b)** *Triloculina trigonula.* (Lamarck, 1804), sample no.2; **c)** *Archaias kirkukensis* (Henson, 1950 in Hayward *et al*., 2018), sample no.3; **d)** *Elphidium* sp. sample no.3; **e)** *Meandropsina anahensis* (Henson, 1950 in Hayward *et al*., 2018), sample no.3; **f)** *Spiroloculina* cf. *cylindracea* (Henson, 1950 in Hayward *et al*., 2018), sample no.3; **g)** *Archaias hensoni* (Smout and Eames, 1958), transverse section, sample no.5; **h)** *Triloculina* sp. sample no.2; **i)** *Nummulites* cf. *bouille*, sample no.3; **j)** *Valvulinid* sp., sample no.4; **k)** *Austrotrillina brunni* Marie, transverse section, sample no.4; **l)** *Austrotrillina* sp. sample no.4

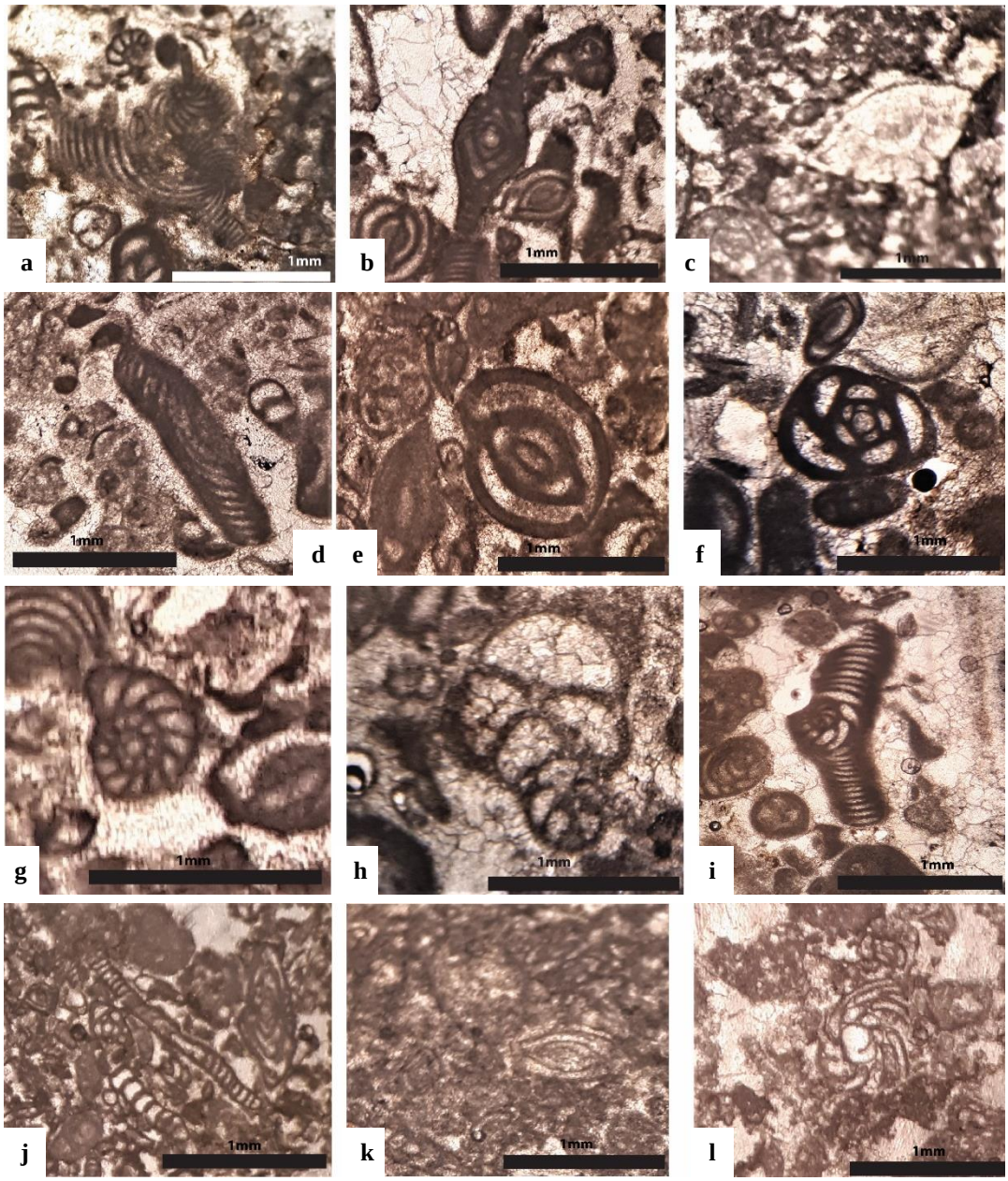

Fig.7: **a)** *Archaias hensoni* (Smout and Eames, 1958), oblique sections, sample no.1; **b)** *Archaias hensoni* (Smout and Eames, 1958), axial section, sample no. 1; **c)** *Neorotalia viennoti* (Greig, 1935), axial section, sample no.1; **d)** *Peneroplis evolutus* (Henson, 1950; in Hayward *et al*., 2018), sample no.1; **e)** *Pyrgo* sp., sample no.1; **f)** *Quinquelocualin* sp., equatorial section, sample no.1; **g)** *Risananeiza pustulosa* (Boukhary and Abdelraouf, 2008) sample no. 1; **h)** *Textularia* sp. sample no.1; **i)** *Archaias hensoni* (Smout and Eames, 1958), transverse section, sample no.2; **j)** *Archias asmaricus* (Smout and Eames, 1958), sample no.2; **k)** *Nummulites vascus* (Joy and Leymerie, 1848 in Hayward *et al*., 2018), axial section, sample no.2; **l)** *Heterostegina* sp., sample no.2

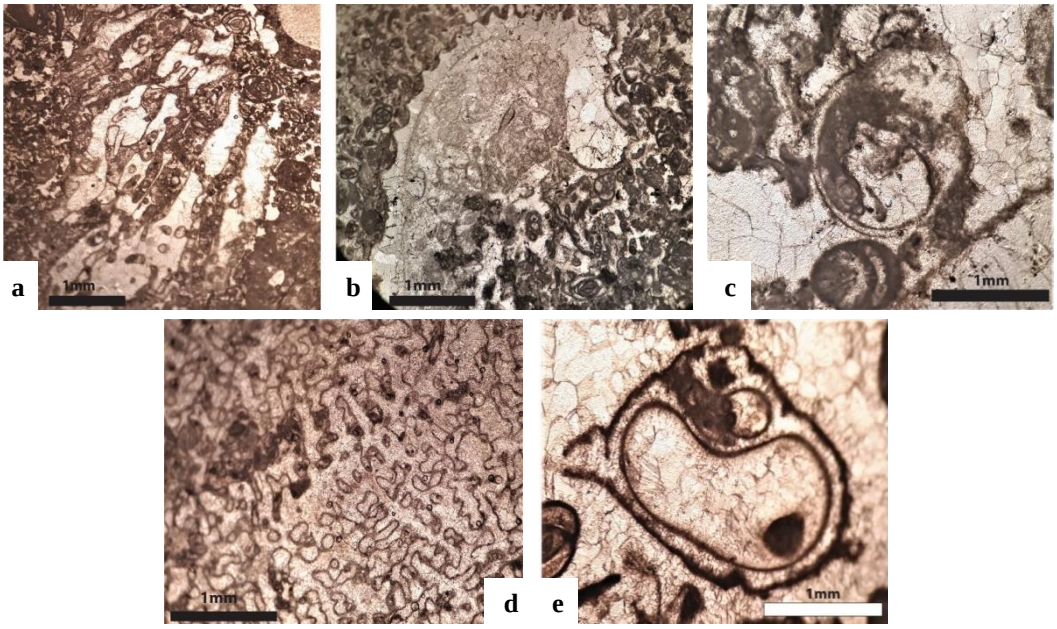

Fig.8: **a)** Bryozoan colonies, the zooecia wall structure has a fibrous microstructure, filled with sparry calcite cement, sample no.1; **b)** Brachiopod fragment has a fibrous crenulated shell. the fragments have been preserved, but the surrounding skeletal grains have been replaced with spary calcite, sample no.1; **c)** Gastropoda shell, the gastropod has a geometric shape and the outer shell of the gastropod has been replaced with fine calcite cement, sample no.1; **d)** Coral, sample no.6; **e)** Pelecypoda (bivalves), the bivalves have micritized rims and the inner portion has been replaced with sparry calcite, sample no.3

- **Paleoecological Interpretation**

In this study the most significant paleoecological elements investigated are salinity, nutrients, and water depth. Paleoecological interpretation of the Oligocene carbonate platforms has been attempted by different authors (e.g., 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}. In the Chattian succession of the studied section the most significant and dominant biogenic components are large, flat and perforate benthic foraminifera (*Operculina, Heterostegina, Spiroclypeus, Amphistegina*), coralline red algae and imperforate foraminifera (*Archaias, Peneroplis, Dendritina*). Other skeletal grains consist of, gastropod, bryozoan and bivalve fragments. Accordingly, the paleoecological conditions of the Anah Formation during the Chattian time could be interpreted as follows: Nummulitids and red algae thrived in oligophotic to mesophoticmid-ramp environments mostly at water depths that ranged from 40 to 80 m (Bosence, 1983; Hottinger, 1997; Beavington-Penney and Racey, 2004). Occurrence of large perforate benthic foraminifera (*Heterostegina, Neorotalia, Amphistegina*), coralline red algae, imperforate foraminifera (*Archaias, Peneroplis, Dendritina, Austrotrillina*), miliolids and molluscs (bivalves and gastropods) in the section indicate normal to higher sea water salinity in inner ramp setting (Flügel, 2010; Allahkarampour Dill *et al*., 2012), (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	Fossil Components	Seawater Salinity	Nutrients	Depth (m)
Chattian	Coralline red algae and large benthic foraminifera *Opeerculina*, *Heterostegina*, *Spiroclypeus*, *Amphistegina*, *Neorotalia*, *Archaias*, *Austrotrillina*, *Peneroplis* and *Dendritina*, with mollusca, coral, and miliolids,	Normal marine to slightly saline	Oligo-Mesotrophic	40 – 80

CONCLUSIONS

- The Anah Formation in the studied section at the Sangaw area is characterized by different microfossils of larger foraminifera, and skeletal fragments of coralline red algae and brachiopoda layer grain, coral, pelecypods-bivalves, gastropods and bryozoan shells.
- The Anah Formation is subdivided in this work into two assemblage biozones, that extend in age from Early to Late Chattian.
- The paleoecological study shows that the Anah Formation in the studied section was deposited under normal to higher seawater salinity, with water depth that ranged from 40 to 80 m, and under oligotrophic to mesotrophic nutrient conditions.

REFERENCES

Abid, A.A., 1997. Biostratigraphy and Microfacies of the Late Oligocene – Middle Miocene formations Center and North Iraq. Ph.D. Thesis, College of Science, University of Baghdad. 285pp.

Abid, A.A. and Sayyab, A.S., 1989. Restudy of the sortidae (foraminifera) of the Anah Formation (Late Oligocene – Early Miocene). Bulletin of Iraqi Natural History Museum, Vol.2, p. 15 – 57.

Al-Banna, N.Y., 1997. Sedimentology and stratigraphical study of the Lower – Middle Miocene, west Mosul. Unpub. Ph.D. Thesis, Mosul University, 177pp (In Arabic).

Al-Banna, N.Y., 2004. Microfacies analysis of Oligocene formations in Butmah and Rafan areas Northwest Iraq. Iraqi Jour. of Earth Sci., Vol.4, No.1, p. 8 – 21.

Al-Banna, N.Y., 2008. Stratigraphic Note: Oligocene/ Miocene boundary in northern Iraq, GeoArabia, Vol.13, No.2, Gulf Petro Link, Bahrain.

Al-Banna, N.Y., Al-Mutwali M.M. and Ismail, N.R., 2010. Oligocene stratigraphy in the Sinjar Basin, northwestern Iraq. GeoArabia, Vol.15, No.4, p. 17 – 44.

Al-Hashimi, H.A.J. and Amer, R.M., 1985. Tertiary microfacies of Iraq. D.G. geol. Surv. Min. Invest. Puli., Baghdad, 56pp, 17figs., 159pls. (S.O.M.), p. 1 – 216.

AL-Ghreri, M.F., 2007. Biostratigraphic Succession of the Formations of Euphrates Valley between Hit and Al-Qaim in Iraq. Ph.D. Thesis, College of Science, University of Baghdad, 121pp.

Al-Kadhimi, J.M.A., Sissakian, V.K., Fattah, A.S. and Deikran, D.B., 1996. Tectonic Map of Iraq, scale 1: 1000 000, 2nd edit., Iraq Geological Survey, Baghdad.

Allahkarampour Dill, M., Seyrafian, A. and Vaziri Moghaddam, H., 2012. Palaeoecology of the Oligocene-Miocene Asmari Formation in the Dill Anticline (Zagros Basin, Iran): NeuesJahrbuchfür Geologie und Paläontologie – Abhandlungen, Vol.263, No.2, p. 167 – 184.

Al-Qayim, B., Fattah, a. and Kharajiany, S., 2015. Microfacis and sequence stratigraphy of the Oligocene – Miocene sequence at Golan Mountian, Kurdistan, Iraq. Carbonates and Evaporites, Vol.31, No.3, p. 259 – 276.

Al-Sayyab, A.S. and Al-Hamdani, A.T., 1990. Biostratigraphy of the Anah and Euphates Formations at Wadi Banat Al-Hassan (W Iraq). Bulletin of the Iraq Natural History Museum. Vol.8, No.3, p. 61 – 83, Publisher: Baghdad University. Available at: https://www.iasj.net/iasj?func=article&aId=73738 access on January 2018.

Al-Twaijri, F.S.S., 2000. Sequence Stragraphic Analysis of the Oligocene Succession in Western Iraq. M.Sc. Thesis, University of Baghdad, 166pp.

Behnam, H.A., 1979. Stratigraphy and paleontology of Khanaqin area NE Iraq. GEOSURV, int. rep. no. 903.

Bellen, R.C. Van., 1956. The stratigraphy of the main Limestone of Kirkuk, Bai Hassan and Qarah Chaugh Dagh structures in Northern Iraq. JournnaI of the Institute of Petroleum, Vol.42, p. 233 – 263.

Bellen, R.C., Van Dunnington, H.V., Wetzel, R. and Morton, D., 1959. Lexique Stratigraphic International. Asie, Fasc. 10a, Iraq, Paris, 333pp.

Beavington-Penney, S.J. and Racey, A., 2004. Ecology of extant nummulitids and other larger benthic foraminifera: applications in palaeoenvironmental analysis: Earth-Science Reviews, Vol.67, No. (3 – 4), p. 219 – 265.

Benedetti, A. and Briguglio, A., 2012. Risananeiza crassaparies n. sp. from the upper Chattian of Porto Badisco (Southern Apulia, Italy), Bollettino della Societa Paleontologica Italiana, Vol.51, No.3, p. 166 – 176, DOI: 10.4435/BSPI.2012.19

Brandano, M., Frezza, V., Tomassetti, L. and Cuffaro, M., 2009. Heterozoan carbonates in oligotrophic tropical waters, The Attard member of the lower coralline limestone formation (Upper Oligocene, Malta): Palaeogeography, Palaeoclimatology, Palaeoecology, Vol.274, No. (1 – 2), p. 54 – 63.

Bosence, D., 1983. Coralline algae from the Miocene of Malta: Palaeontology, Vol.26, p. 147 – 173.

Boukhary, M.; Kuss, J.; Abdelraouf, M. 2008. Chattian larger foraminifera from Risan Aneiza, northern Sinai, Egypt, and implications for Tethyan paleogeography. Stratigraphy. Vol.5, p. 179 – 192.

Buday, T., 1980. The Regional Geology of Iraq. Vol.1. Stratigraphy and Paleogeography. In: I.I., Kassab and S.Z., Jassim (Eds.). GEOSURV, 445pp.

Cahuzac, B. and Poignant, A., 1997. Essai de biozonation de l'Oligo-Miocene dans les bassins européens a l'aide des grands foraminifères néritiques: Bulletin de la Societé Géologique de France, Vol.168, No.2, p. 155 – 169.

Ctyroky, P. and Karim, S.A., 1971. Stratigraphy and Paleontology of the Oligocene and Miocene strata near Anah, Euphrates Valley. NIMCO Report No. CZ 140, SOM. Library, Baghdad.

Ditmar, V. and Iraqi-Soviet team, 1971. Geological Conditions and Hydrocarbon Prospects of the Republic of Iraq-Northern and Central Parts. Iraq National Oil Company Library, Baghdad (unpublished).

Orbigny d', A.D., 1826. Tableau méthodique de la classe des Céphalopodes. Annales des Sciences Naturelles. Vol.7, 96 – 169, p. 245 – 314.

Ehrenberg, S.N., McArthur, J.M., Pickard, N.A.H., Laursen, G.V., Monibi, S., Mossadegh, Z.K., Svana, T.A., Aqrawi, A.A.M. and Thirlwall, M.F., 2007. Srontium isotope stratigraphy of the Asmari Formation (Oligocene – Lower Miocene), Sowthwestern Iran. Journal of Petroleum Geology, Vol.30, p. 107 – 128.

Flügel, E., 2010. Microfacies of Carbonate Rocks, Analysis, Interpretation and Application, 2nd edit. Springer-Verlag,Berlin Hiedelberg, 984pp.

Fouad, S.F., Al-Marsoumi, A.M., Said, F.S., Hassan, F.A. and Nanno, H.O., 1986. Detailed geological survey of Anah area. GEOSURV, int. rep. no. 1527.

Geel, T., 2000. Recognition of stratigraphic sequences in carbonate platform and slope deposits: empirical models based on microfacies analysis of Palaeogene deposits in southeastern Spain: Palaeogeography, Palaeoclimatology, Palaeoecology, Vol.155, No. (3 – 4), p. 211 – 238.

Ghafur, A.A., 2012. Sedementology and reservior characteristics of the Oligocene – Miocene carbonates (Kirkuk Group) of Southern Kurdistan, Ph.D. Thesis, School of Earth and Ocean Sciences Cardiff University.

Ghafor, I.M. and Karim, K.H., 2014. Biostratigraphy of oligocene succession in the High Folded Zone, Sulaimani, Kurdistan region, Northeastern Iraq, Arab J. Geosci, Vol.7, No.9, p. 3599 – 3610.

Hallock, P. and Glenn, E.C., 1986. Large foraminifera: a tool for paleoenvironmental analysis of Cenozoic carbonate depositional facies: Palaios, Vol.1, No.1, p. 55 – 64.

Hayward, B.W., Le Coze, F. and Gross, O., 2018. World Foraminifera Database. *Nummulites vascus* Joly and Leymerie, 1848 †. Accessed at: http://www.marinespecies.org/foraminifera/aphia.php?p=taxdetails&id=926258 on 2019-05-30.

Hayward, B.W., Le Coze, F. and Gross, O., 2018. World Foraminifera Database. *Archaias kirkukensis* Henson, 1950 †. Accessed at: http://www.marinespecies.org/foraminifera/aphia.php?p=taxdetails&id=908141 on 2019-05-30.

Hottinger, L., 1997. Shallow benthic foraminiferal assemblages as signals for depth of their deposition and their limitations: Bulletin de la Societé Géologique de France, Vol.168, No.4, p. 491 – 505.

I.P.C., 1963. Geological and Production Data. GEOSURV, int. rep. no. 130.

Karim, K.H., 2010. Modification of the time-expanded stratigraphic column of North East Iraq during Cretaceous and Tertiary. Published In: Petroleum Geology of Iraq. First Symposium, 21 – 22 april, Baghdad, Abstract book Vol.1, No.1, 4pp.

Karim K.H., Khanaqa, P.A., Ismail K.M. and Sissakian, V.K., 2012. Facies analysis of the Oligocene succession in Sharwaldir anticline, NE of the Kalar Town, NE Iraq. Iraqi Bull. Geol. Min., Vol.8, No.2, p. 1 – 19.

Karim, S.A., Sissakian, V.K., and. Al-Kubays, K.N., 2014. Stratigraphy of the Oligocene – Early Miocene exposed formations in Sinjar area, NW Iraq. Iraqi Bull. Geol. Min., Vol.10, No.3, p. 1 – 28.

Kharajiany, S.O.A., 2008. Sedimentary facies of Oligocene rock units in Ashdagh mountain-Sangaw district-Kurdistan region, NE Iraq. Unpublished thesis, College of Science, University of Sulaimani.

Kharajiany, S.O.A., 2014. The Occurrence of Early and Middle Miocene Rocks (Euphrates, Dhiban and Jeribe formations) In Ashdagh Mountain, Sangaw Area, Sulaimanyah Vicinity, NE Iraq. Iraqi Bull. Geol. Min., Vol.10, No.1, p. 21 – 39.

Kharajiany, S.O.A., Qader, F.M. and Hakkari, S.h., 2014. Oligocene and Miocene Rock Beds in Mamlaha anticline, Chamchamal town, Sulaimani city – Kurdistan region/ Iraq. Jour. Zankoy Sulaimani, Part 1, Vol.16, DOI: 10.17656/jzs.10295.

Kareem, K.H., Sissakian, V.K., Karim, S.A. and Khanqa, P.A., 2009. Lithostratigraphic Study of a Late Oligocene – Early Miocene Succession, South of Sulaimaniyah, NE Iraq. Iraqi Bull. Geol. Min., Vol.5 No.2 p. 41 – 57.

Lamarck, J.B. de., 1804. Suite des mémoires sur les fossiles des environs de Paris. Annales du Muséum d'Histoire Naturelle. Vol.9, p. 236 – 240. available online at http://www.biodiversitylibrary.org/page/3497726#page/276/

Laursen, G., Monibi, S., Allan, T., Pickard, N., Hosseiney, A., Vincent, B., Hamon, Y., van-Buchem, V., Moallemi, A. and Druillion, G., 2009. The Asmari Formation Revisited, Changed Stratigraphic Allocation and New Biozonation: First International Petroleum Conference and Exhibition, Shiraz, Vol.1, No.5.

Lawa, F.A.A., Ali, S.S. and Kareem, K.H., 2000. Geological and hydro geological survey of Sulaimania and Kirkuk area. Part one. Crosssections. FAO. UN agency Baghdad, Iraq. 220pp, 20 maps.

Lawa, F.A. and Ghafur, A., 2015. Sequence stratigraphy and biostratigraphy of the prolific late Eocene, Oligocene and early Miocene carbonates from Zagros fold-thrust belt in Kurdistan region. Arabian Journal of Geosciences, Vol.8, No.10, p. 8143 – 8174.

Muhammed, Q.A., 1983. Biostratigraphy of Kirkuk Group in Kirkuk and Bai-Hassan areas. M.Sc. Thesis. University of Baghdad. Baghdad, Iraq.

Pedley, M., 1998. A review of sediment distributions and processes in Oligo – Miocene ramps of southern Italy and Malta (Mediterranean divide): Geological Society, London, Special Publications, Vol.149, No.1, p. 163 – 179.

Pomar, L., 2001. Ecological control of sedimentary accommodation: evolution from a carbonate ramp to rimmed shelf, Upper Miocene, Balearic Islands: Palaeogeography, Palaeoclimatology, Palaeoecology, Vol.175, No.1, p. 249 – 272.

Pomar, L. and Hallock, P., 2008. Carbonate factories: A conundrum in sedimentary geology: EarthScience Reviews, Vol.87, No.3, p. 134 – 169.

Pomar, L., Brandano, M. and Westphal, H., 2004. Environmental factors influencing skeletal grain sediment associations: a critical review of Miocene examples from the western Mediterranean: Sedimentology, Vol.51, p. 627 – 651.

Pomar, L., Bassant, P., Brandano, M., Ruchonnet, C. and Janson, X., 2012. Impact of carbonate producing biota on platform architecture: Insights from Miocene examples of the Mediterranean region: Earth-Science Reviews, Vol.113, No. (3 – 4), p. 186 – 211.

Romero, J., Caus, E. and Rosell, J., 2002. A model for the palaeoenvironmental distribution of larger foraminifera based on late Middle Eocene deposits on the margin of the South Pyrenean basin (NE Spain): Palaeogeography, Palaeoclimatology, Palaeoecology, Vol.179, No. (1 – 2), p. 43 – 56.

Sissakian, V.K. and Mohammed, B.S., 2007. Geology of Iraqi Western Desert: Stratigraphy. Iraqi Bull. Geol. Mining. Special Issue No.1, p. 51 – 124.

Sissakian, V.K. and Al-Jubori, B.M., 2011. Stratigraphy of the Low Folded Zone. geology of the Low Folded Zone. Iraqi Bull. Geol. Min., Special Issue, No.5, p. 63 – 132.

Smout, A.H. and Eames, F.E., 1958 .The genus Archaias (Foraminifera) and its stratigraphical distribution: Palaeontology, Vol.1, p. 207 – 225.

Taheri, M.R., Mogaddam H.V., Taheri, A. and, Ghabeishavi, A., 2017. Biostratigraphy and paleoecology of the Oligo – Miocene Asmari Formation in the Izeh zone (Zagros Basin, SW Iran. Boletín de la Sociedad Geológica Mexicana, Vol.69, No.1, p. 59 – 85.

Taufiq, J.M. and Domas, J., 1977. Report on the regional geological mapping of Duhok – Ain Zala Area. GEOSURV, int. rep. no. 837.

Van Buchem, F.S.P., Allan, T.L., Laursen, G.V., Lotfpour, M., Moallemi, A., Monibi, S., Motiei, H., Pickard, N.A.H., Tahmasbi, A.R., Vedrenne, V. and Vincent, B., 2010. Regional stratigraphic architecture and reservoir types of the Oligo-Miocene deposits in the Dezful Embayment (Asmari and Pabdeh Formations) SW Iran: Geological Society, London, Special Publications, Vol.329, p. 219 – 263.

Youkhanna, R.Y., and Hradecky, P., 1977. Report on Regional Geological Mapping of Khanaqin – Maidan Area (Part I). Geological Survey Department, State Organization of Geological Survey and Mineral Investigation.

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