LITHOSTRATIGRAPHIC STUDY OF A LATE OLIGOCENE – EARLY MIOCENE SUCCESSION, SOUTH OF SULAIMANIYAH, NE IRAQ

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ABSTRACT

Late Oligocene – Early Miocene rocks are not previously known in the High Folded Zone, especially in northeast Iraq; neither in outcrops nor in subsurface sections. In most areas, the exposures of the Pila Spi Formation (Middle – Late Eocene) are overlain usually by the exposures of the Fat'ha Formation (Middle Miocene).

Recent field observations and lithostratigraphic study, of an area near Basara Gorge, south of Sulaimaniyah, Northeast Iraq, revealed the presence of a succession (20 – 25 m thick) between the Pila Spi and Fat'ha formations. This succession has unconformable contact with the underlying Pila Spi Formation, marked by the presence of (6 – 8) m thick, sedimentary breccias and conglomerate indicating the presence of rocks of different ages. The succession consists of two main parts; the lower part consists of breccia, conglomerate, and red sandstone and claystone, whereas the upper part consists of fossiliferous limestone interbedded with green marl.

Micropaleontological studies, of samples collected from the studied succession, proved the presence of Late Oligocene – Early Miocene rocks between the Pila Spi Formation (Middle – Late Eocene) and Fat'ha Formation (Middle Miocene), with indication of mixing environments (basinal/ shelf). The lithological diversity indicates the presence of a break in sedimentation, indicated by breccia and conglomerate over the Pila Spi Formation. Moreover, the cyclic repetition of green marl with limestone indicates oscillation of the sea level during deposition of the studied succession.

This is the first time to recognize rocks with such age and mixed environments from the areas of the High Folded Zone in Sulaimaniyah Governorate, Northeast Iraq.

دراسة الطباقية الصخارية لتتابع الأوليغوسين المتأخر – المايوسين المبكر، جنوب السليمانية، شمال شرق العراق

پولا آزاد خانقة، ساهرة عبد الكريم محمد، فاروجان خاجيك سيساكيان و كمال حاجي كريم

المستخلص

ان تكشفات الأوليغوسين المتأخر – المايوسين المبكر غير معروفة سابقاً في المناطق الواقعة ضمن نطاق الطيات العالية، وخاصة في شمال شرق العراق. في غالبية هذه المناطق تعلو تكشفات تكوين البيلاسبي (الإيوسين الأوسط – المتأخر) تكشفات تكوين الفتحة (المايوسين الأوسط) بشكل عدم توافقي.

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أظهرت المشاهدات الحقلية الجديدة والدراسات الطباقية الصخارية في مضيق باسارة، جنوب السليمانية، شمال شرق العراق، وجود تتابع صخاري، سمكه (20 – 25) متر بين التكوينين المذكورين في أعلاه مع دلائل واضحة لوجود عدم توافق في الحد الاسفل مع تكوين البيلاسبي، متمثلة بطبقة من البريشيا والمدملكات سمكها يتراوح من (6 – 8) متر، مشيراً الى وجود صخور من أعمار مختلفة عن عمر التكوينين المذكورين.

ان صخور هذا التتابع هي بريشيا ومدملكات قاعدية وصخور كلسية تحتوي على المستحثات تتخللها طبقات من الطفل الأخضر وصخور رملية وطينية حمراء. أظهرت دراسة المتحجرات الدقيقة والصخارية للنماذج الملتقطة، من هذا التتابع، بان هذه الصخور تعود لعصري الأوليغوسين المتأخر– المايوسين المبكر وتقع بين صخور تكويني البيلاسبي (الإيوسين الأوسط – المتأخر) والفتحة (المايوسين الأوسط)، ويدل أيضاً على اختلاط بيئتين ترسيبيتين (القاعية/ الساحلية). وان البريشيا والمدملكات تدلان على وجود انقطاع في الترسيب وان تتابع الصخور الكلسية والطفل الأخضر يدل على تذبذب مستوى البحر خلال ترسيب هذه الصخور.

هذه هي المرة الأولى التي يثبت فيها وجود صخور عائدة للعمر المذكور وببيئتين مختلفتين مختلطتين معاً، في مناطق الطيات العالية في شمال شرق العراق.

INTRODUCTION

The studied area is within Sulaimaniyah Governorate, Northeast Iraq. It is located along a gorge, called Basara, which transects the Qara Dagh Mountain (anticline) (Fig.1). Two sections were sampled and measured; they are called here Basara and Khewata sections. The former (about 25 m thick) is located in the outlet of the Basara gorge, across the southwestern limb of Qara Dagh anticline (within the Foothills Zone) at latitude N: 35° 26' 39.43" and longitude E: 45° 09' 17.65". The latter (about 20 m thick) is located on the paved road between Sulaimaniyah city and Deleeza village; southeast of Khewata village, along the southwestern limb of Kalawe Anticline (within the High Folded Zone) at latitude N: 35° 28' 51.40" and longitude E: 45° 11' 44.09".

The aim of this study is to indicate the age and environment of the exposed rocks, between the Pila Spi and Fat'ha formations and to study the depositional environment as related to the tectonic history.

To achieve the aim of this study, two sections were measured, described and sampled; six samples were collected for paleontological and petrographical studies, to determine the age of the studied rocks and their depositional environments. To confirm the achieved results; both sections were resampled; further ten samples were collected and studied, both paleontologically and petrographically.

PREVIOUS WORK

The Late Oligocene and Early Miocene formations were first described by Bellen *et al.* (1959), as Anah, Ibrahin and Azkand (Late Oligocene), and Serakagni and Euphrates (Early Miocene). They described the type locality of each formation and stated that:

- Anah Formation is of Late Oligocene age; composed of grey, recrystallized, detrital and coralline limestone, with index species *Miogypsinoides compulanata* SCHLUMBERGER.
- Ibrahim Formation is of Late Oligocene age; composed of globigirinal, marly limestone with pyrite, occasionally glauconitic, showing slight dolomitization.
- Azkand Formation is of Late Oligocene age; composed of massive, dolomitic and recrystallized limestone, with index species *Miogypsinoides compulanata* and *Heterostegina* cf. *assilinoides.*
- Serakagni Formation is of Early Miocene age; composed of globigirinal chalky limestone and limestone, with index species *Globoquadrina dehiscens* and *Globigerinoides* sp.
- Euphrates Formation is of Early Miocene age; composed of shelly, chalky, well bedded and recrystallized limestone, with index species *Miogypsina* sp.

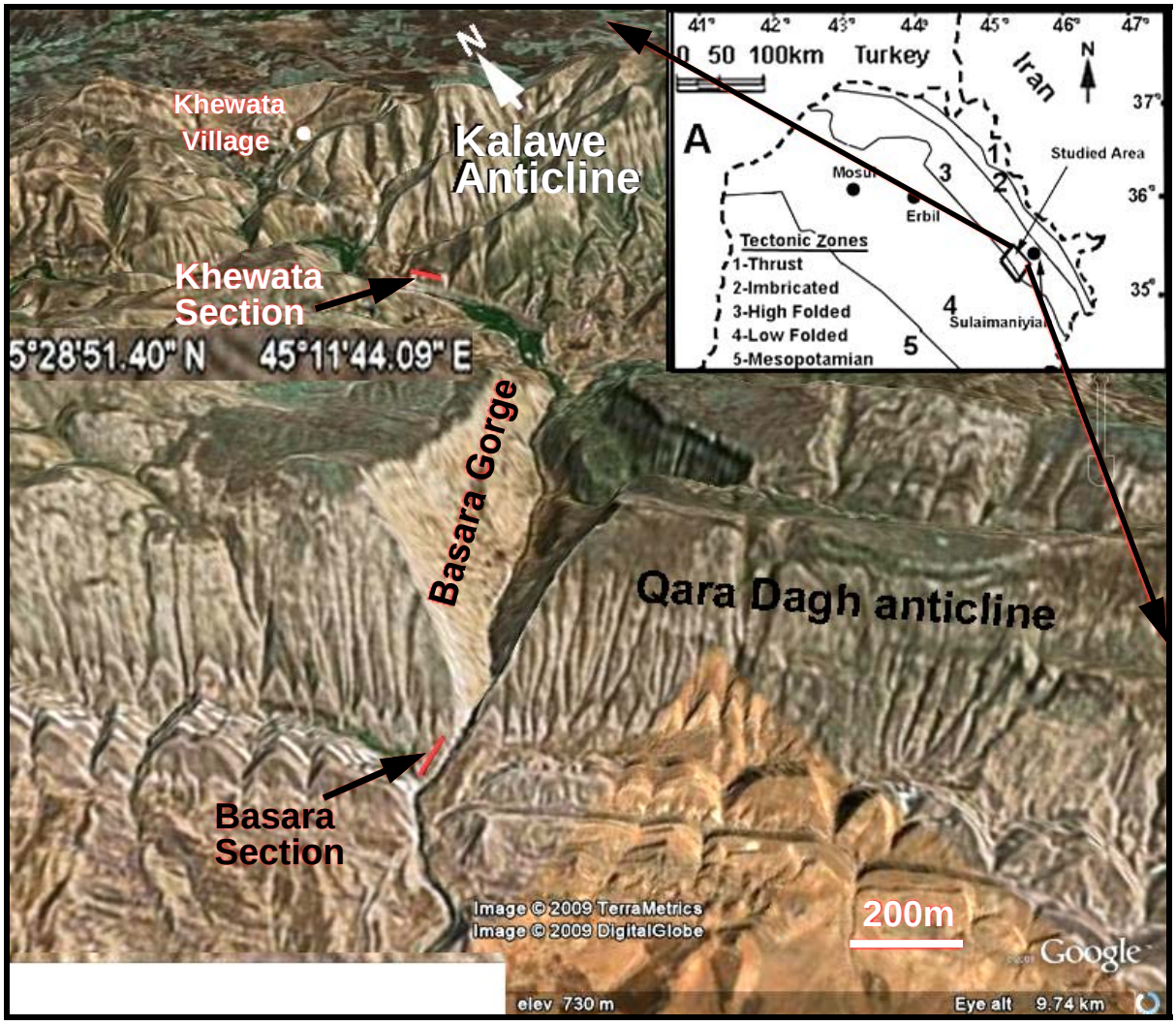

Fig.1: Google Earth satellite image shows the location of the studied two sections

The age of the aforementioned formations is confirmed by many authors; among them are Bellen *et al*. (1959); Ditmar *et al*. (1971); Buday (1980); Jassim *et al*. (1984) and Jassim and Buday in Jassim and Goff (2006).

According to previous studies, the geographic distribution of the aforementioned Oligocene – Miocene formations were limited either to the northeastern or southwestern limits of the Oligocene and Miocene seas. The northeastern limits were defined; in the northeastern parts of Iraq, till Qara Dagh, Baski Zanur Dagh, Aj Dagh (Bellen *et al*., 1959 and Ditmar *et al*., 1971 in Buday, 1980). The proposed line of the mentioned limits runs south of the studied Basara Section, about (12 – 15) Km; within the present day Foothills Zone (Al-Kadhimy *et al*., 1996).

The Late Oligocene and Early Miocene rocks were not recognized, previously, in areas of the High Folded Zone in Northeast Iraq, between Pila Spi and Fat'ha formations (Bellen *et al*., 1959; Ditmar *et al.,* 1971; Buday, 1980; Jassim *et al*., 1986 and 1990; Sissakian, 2000; Buday and Jassim in Jassim and Goff, 2006 and Ma'ala, 2007). Baba Shekh (2006), however, found two conglomerate beds and fossiliferous limestone between the Pila Spi and Fat'ha

formations. He mentioned the possibility of the presence of Oligocene rocks in Sangaw area (about 12 Km southeast of the studied area). Moreover, Ameen (2009) referred to the presence of Oligocene rocks in different parts of Kurdistan, but not in areas of the High Folded Zone. Kharajiany (2008) studied fossiliferous limestones and recognized Baba, Sheikh Alas, Bajwan, Shurau and Anah formations along both limbs of the Aj Dagh anticline, southeast of Sangaw town, in the Foothill Zone; 12 Km south of the studied Basara Section.

The main reason for not recognizing Oligocene – Miocene rocks, in the aforementioned areas, is due to lack of systematic geological mapping there. The presently available geological maps were prepared from interpretation of aerial photographs (Ibrahim, 1984); from which it is almost impossible to recognize the studied succession, due to similarity of image properties with the overlying and underlying rocks, besides its minor thickness, which does not exceed 25 m.

It is worth mentioning that the studied succession is very clearly visible in the field and can be followed from Koi Sanjaq (about 100 Km west of the studied sections) along Haibat Sultan Mountain towards east; passing in Darbandi Bazian gorge, Basara Gorge and continues farther eastwards to Darbandi Khan region and probably extends eastwards inside Iran.

GEOLOGICAL SETTING

The studied area is located within the High Folded Zone (Al-Kadhimi *et al*., 1996; Jassim and Buday in Jassim and Goff, 2006 and Fouad, 2009). The zone is characterized by the presence of long and narrow anticlines, among them are Qara Dagh and Kalawe Anticlines (Figs.1 and 2), with NW – SE trend, the former is about 110 Km long, with almost symmetrical limbs. The Pila Spi Formation (Middle – Late Eocene) is the oldest exposed formation within the anticline, in the study area, while the youngest one is the Bai Hassan Formation; south of the studied Basara Section; in Singaw area (Sissakian, 2000 and Ma'ala, 2007).

Previously, all existing geological maps show that the Pila Spi Formation is overlain unconformably by Fat'ha Formation, in areas of the Foothills Zone. This is the situation along the southwestern limbs of all anticlines along the boundary between the High Folded and Foothills Zones. Along the northeastern limbs of the same anticlines, however, no younger formation than the Pila Spi Formation is recorded (Ibrahim, 1984; Sissakian, 2000 and Ma'ala, 2007) (Fig.2). Recently, however, Ameen (2009) revealed the presence of Oligocene rocks between Pila Spi and Fat'ha formations, only in some areas of the Foothills Zone. This was also mentioned by Bellen *et al*. (1959) and Ditmar *et al.* (1971), from Darbandi Sagirma and Sangaw areas that are about 12 Km southeast of the studied Basara Section.

METHOD OF WORK

During recent field trips, by the authors in the studied area, an unidentified succession was recognized between the Pila Spi and Fat'ha formations, along the southwestern limbs of Qara Dagh and Kalawe anticlines. According to its stratigraphic position and depending on the previous works, this succession was suspected to be of Oligocene and/ or Miocene age.

Two sections (Figs.3 and 4) were measured, described and sampled, along the southwestern limbs of Qara Dagh and Kalawe anticlines, near to the outlet and inlet of the Basara gorge. A total of sixteen samples were collected and studied from both sections for paleontological and petrographical studies. The samples were thin sectioned and studied in the Geological Laboratories of the S.C. of Geological Survey and Mining, Baghdad.

- **Field Description**

Both sections were described and measured in the field (Figs.5 and 6). The succession consists of well bedded fossiliferous coarse and medium grained detrital limestone, with intercalation of sandy marl or red claystone (Figs.5 and 6); three packages could be recognized with thickness of about (9.5 – 10) m. The lower part of the succession, which is underlain by the Pila Spi Formation consists of breccia and conglomerate, with thin horizon (30 cm) of detrital limestone (at the top), with reddish brown claystone and sandstone; occasionally pebbly; with thickness of (9 – 13) m. The succession is separated by reddish brown coarse grained sandstone bed from the overlying Fat'ha Formation.

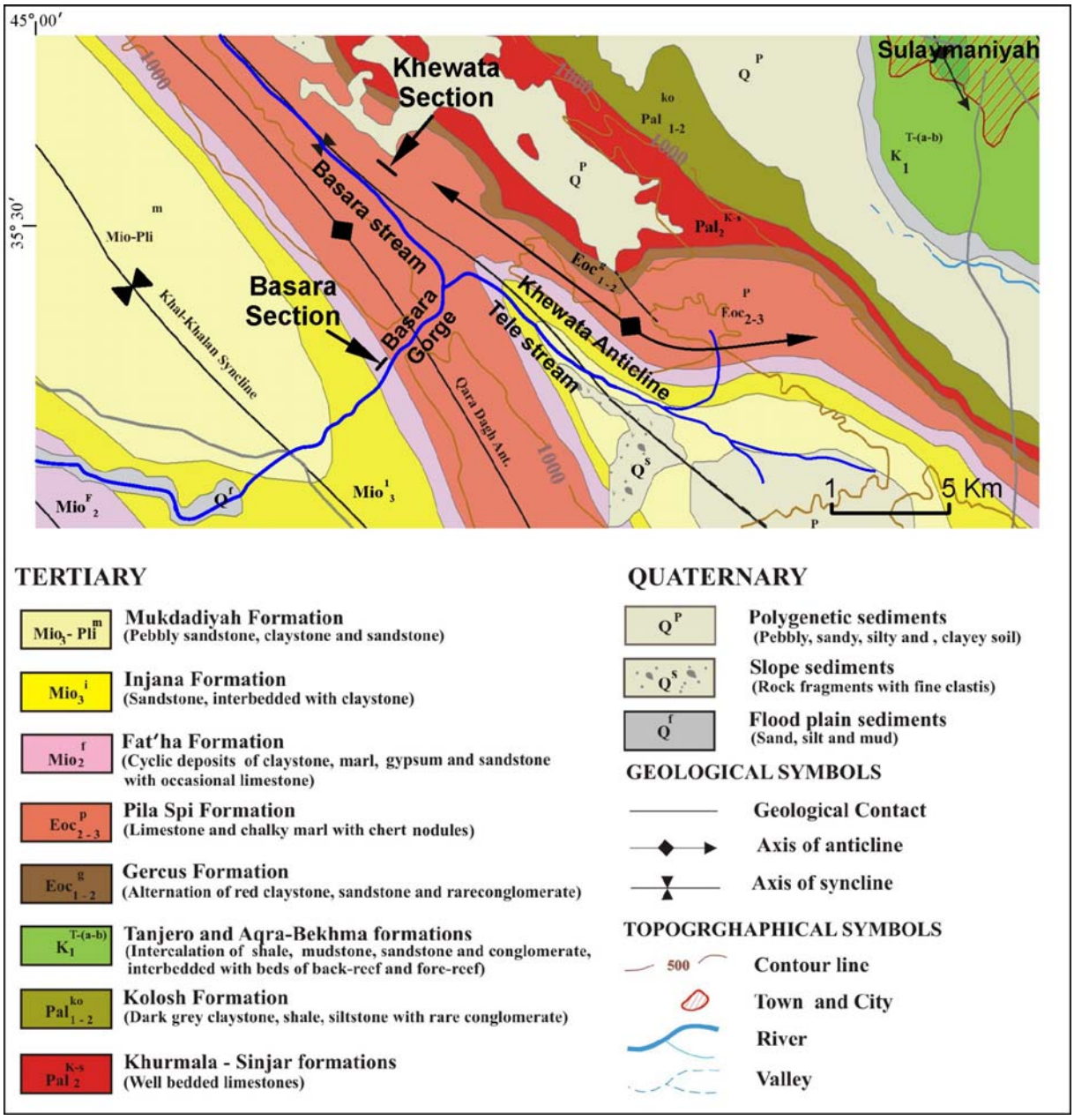

Fig.2: Geological map of the studied area (after Ma'ala, 2007)

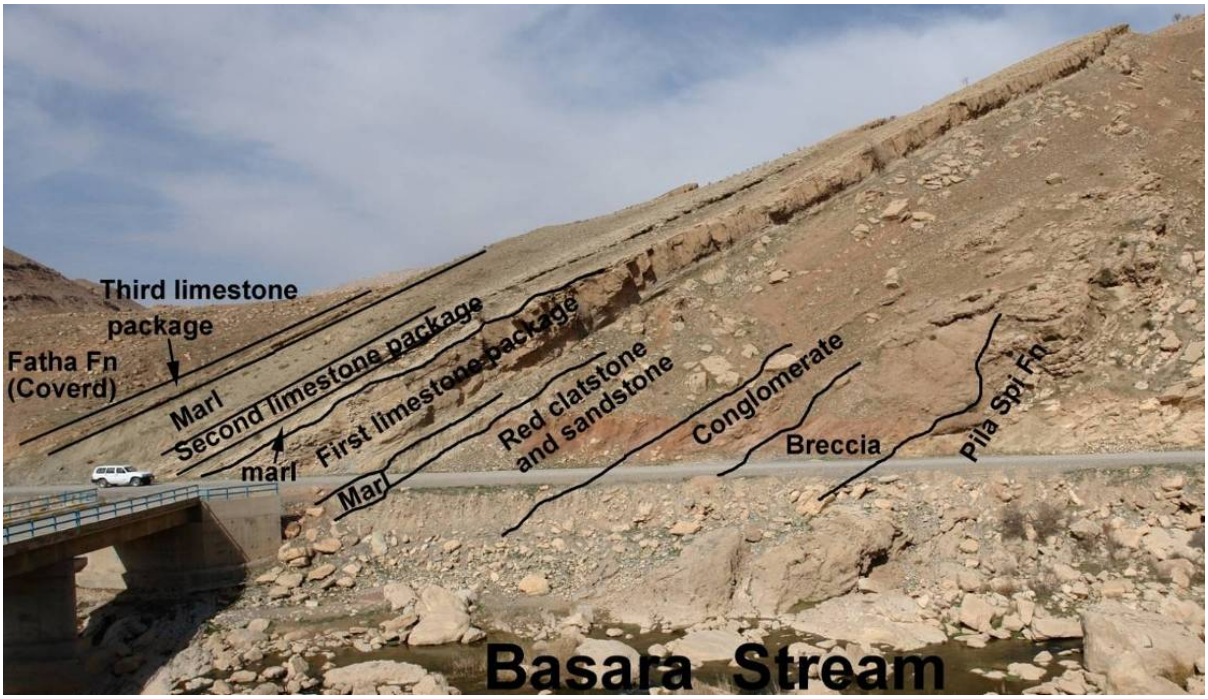

Fig.3: Basara Section, along the southwestern limb of Qara Dagh Anticline

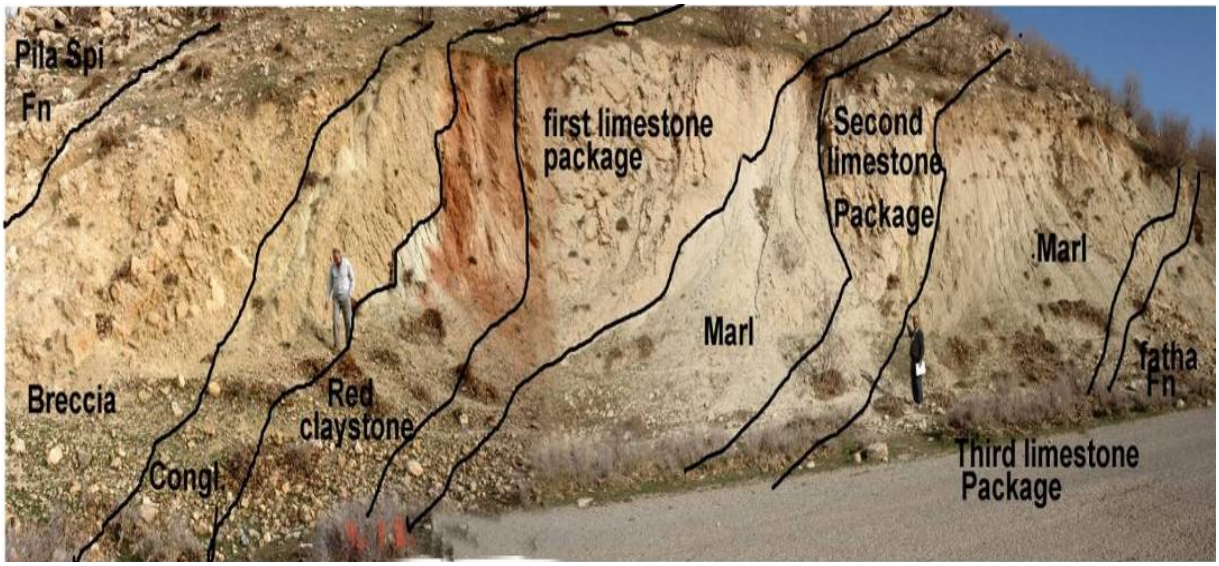

Fig.4: Khewata Section, along the southwestern limb of Kalawe Anticline

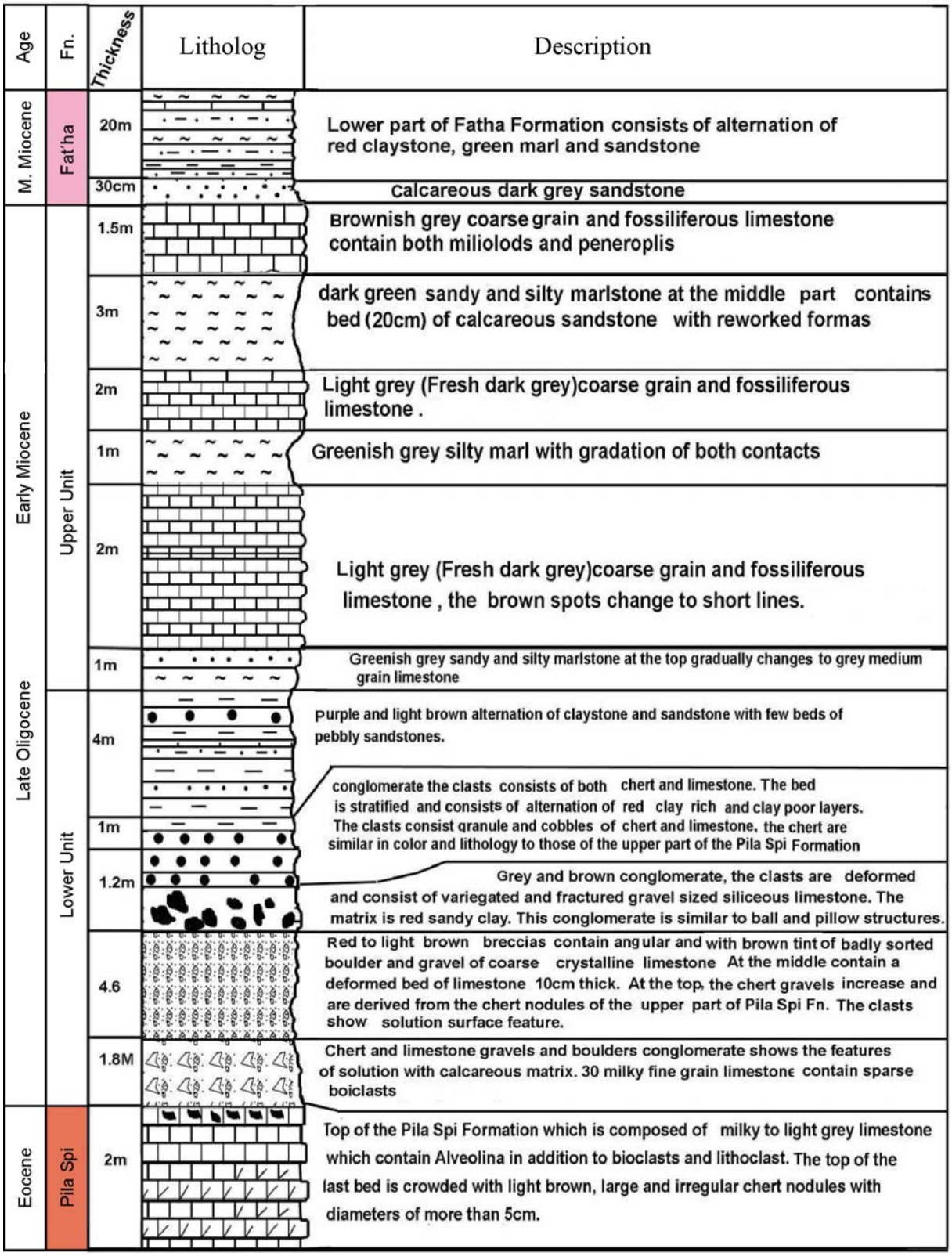

Fig.5: Lithological description of Basara Section
(**not to scale**)

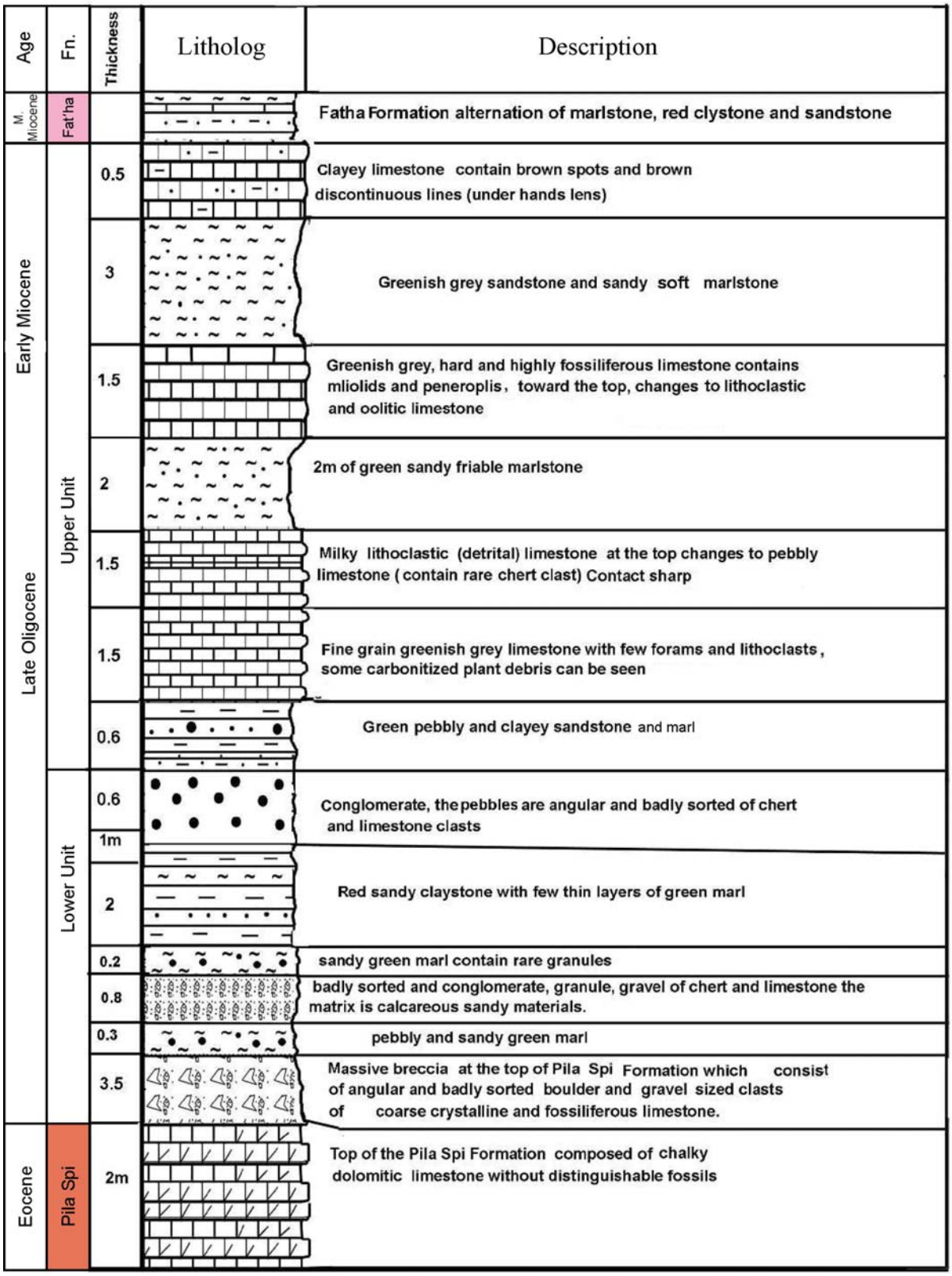

Fig.6: Lithological description of Khewata Section
(**not to scale**)

▪ **Paleontological Study**

Thin sections were prepared from the collected limestone samples and were studied, using binocular microscope to identify the fauna present in the samples, which represent three packages, occasionally several thin sections were prepared from the same sample. The identified fauna in the studied samples are:

– Basara Samples

Globigerina ciperoensis*, ***Glob. angulisuturalis****, ***Globorotalia* cf. *mayeri****, ***Glt. siakensis****, *Sprolina* sp, *Quinqueloculina* sp., *Peneroplis* sp. *Peneroplis farsensis*, *Peneroplis thomasi*, *Chiloguembellina* sp., *Spiroloculaina* sp., *Glob. praebulloids*, *Praerhapydionina* sp. ***Austrotrillina howchin****, *Amphistegina* sp., *Triloculina* sp., *Pyrgo* sp., *Vaginulina* sp., *Nodosaria* sp. *Elphidium* sp., ***Globigerinoides* sp.****, ***Globoquadrina dehiscens****, *Ammonia beccarii*, *Operculina* sp. *Heterostegina* sp., *Globigerina* sp., *Triloculina* sp. corals and rotalia. ***Globigerinoides primordius****, *Globorotalia. scitula,* ***Miogypsina* sp.****, *Spirolina* sp., *Bolivina* sp., *Amphistegina* sp., Textularia, traces of Miogypsinoides, Bryzoa, ostarcods, algae, gastropods and shell fragments.

– Khewata Samples

Triloculina sp., *Quinqueloculina* sp., *Peneroplis thomasi*, *Peneroplis farsensis*, ***Austrotrillina* sp.***, *Rotalia viennoti*, *Elphidium* sp., *Globigerina* sp., *Archaias* sp., *Globorotalia* sp., *Pyrgo* sp., *Operculina* sp., *Bolivina* sp., ***Globigerina ampliapertura****, ***Hetrostegina* sp***, ***Miogypsinoids complanatus****, *Amphistegina* sp., *Spiroloculina* sp., *Spirolina* sp., ***Globorotalia archeomenardi*****, *Ammonia beccarii*, ***Globoquadrina dehiscencs*****, *Operculina* sp., ***Globigerinoides triloculinoides*****, *Bolivina* sp., *Ammonia beccarii, Elphidium* sp., *Miogypsina* sp. and abundant miliolids, ostracod and bryzoa,

Note:

Fossils marked by (*) and (**) indicate Late Oligocene and Early Miocene age, respectively (Figs.7 and 8)

The first two packages could be of Late Oligocene age, as suggested from the presence of *Globigerina ciperoensis*, *Glob. angulisuturalis*, *Globorotalia* cf. *mayeri*, *Glt. siakensis* and *Austrotrillina howchin.* The last limestone package may represent the Early Miocene sequence as indicated from the presence of *Globigerinoides* sp., *Globoquadrina dehiscens*, *Globigerinoides primordius,* and *Miogypsina* sp.

▪ **Lithological and Petrological Description**

The studied samples are limestones; they are mainly grey and light brown in color, tough to very tough, few of them are fossiliferous. Petrologically, the rocks are mainly biomicrosparite; some of them are compacted, others are pelbio-oosparite and oncoidal oopelbio-sparite. The ground-mass consists mainly of micrite, microsparite and sparry calcite that was originally formed from recrystallization of micrite. The recognized diagenetic processes are recrystallization, inversion, compaction, dissolution, cementation and very rarely silicification and reduced porosity.

From reviewing the lithological constituents of the studied succession (Figs. 3 and 4), it could be divided into two units: **Lower Unit** (8.5 – 13.5 m) consists of breccia and conglomerate, indicating lowermost part of the Late Oligocene sequence, as indicated from the recognized index fossils of Late Oligocene above this unit. The remaining part of the succession, the **Upper Unit** (carbonate unit, about 10 m), includes three limestone packages with shallowing upward indications; from marl to limestone.

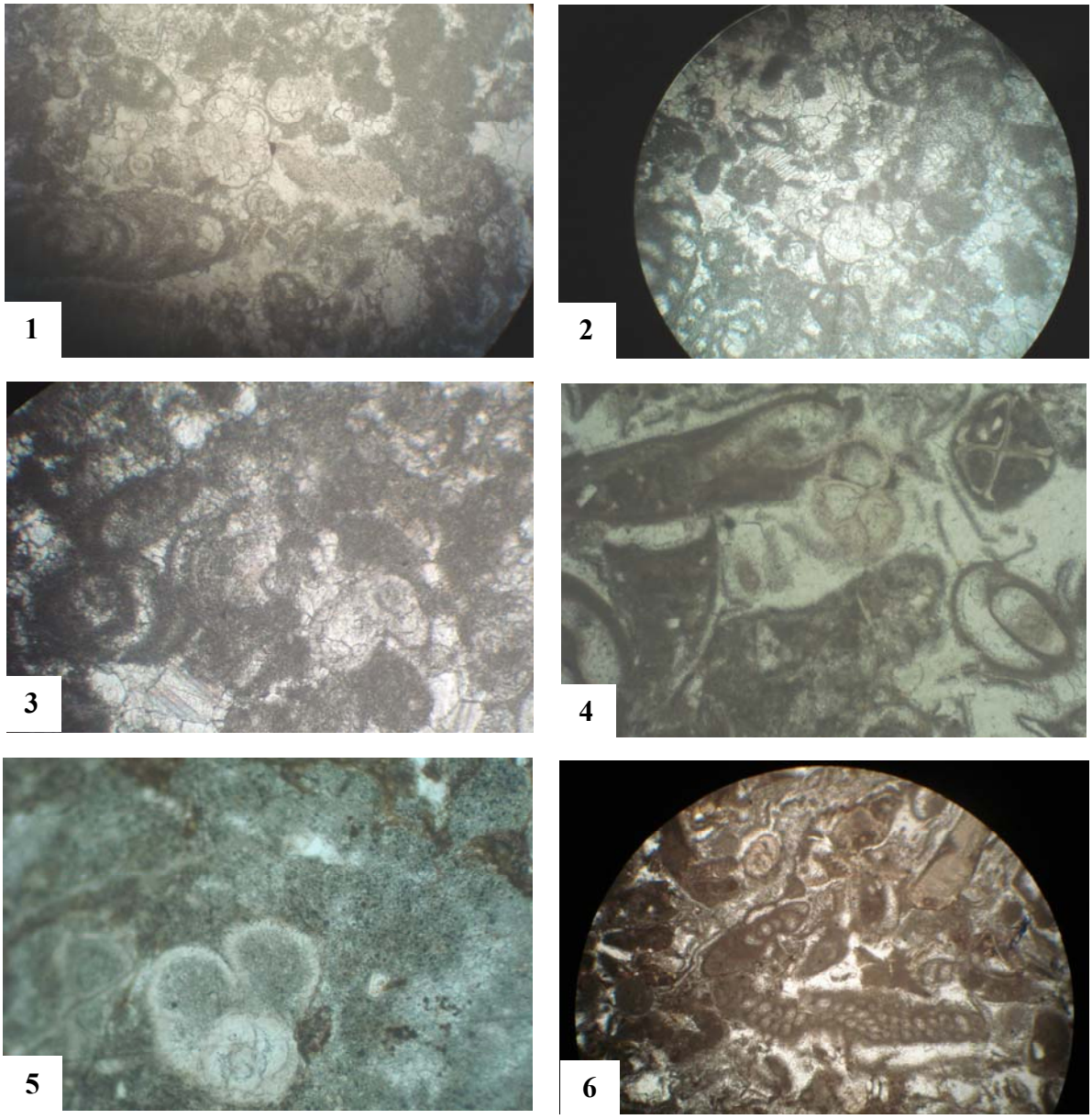

Fig. 7: Index fossils of Late Oligocene

1, 2 and 3) *Globugerina ciperocnsis* BOLLI (X 75)
4) *Globugerina praebulloides* BLOW (X 75)
5) *Globorotalia siakensis* (LEROY) (X 75)
6) *Miogybsinoids complinatus* (X 35)

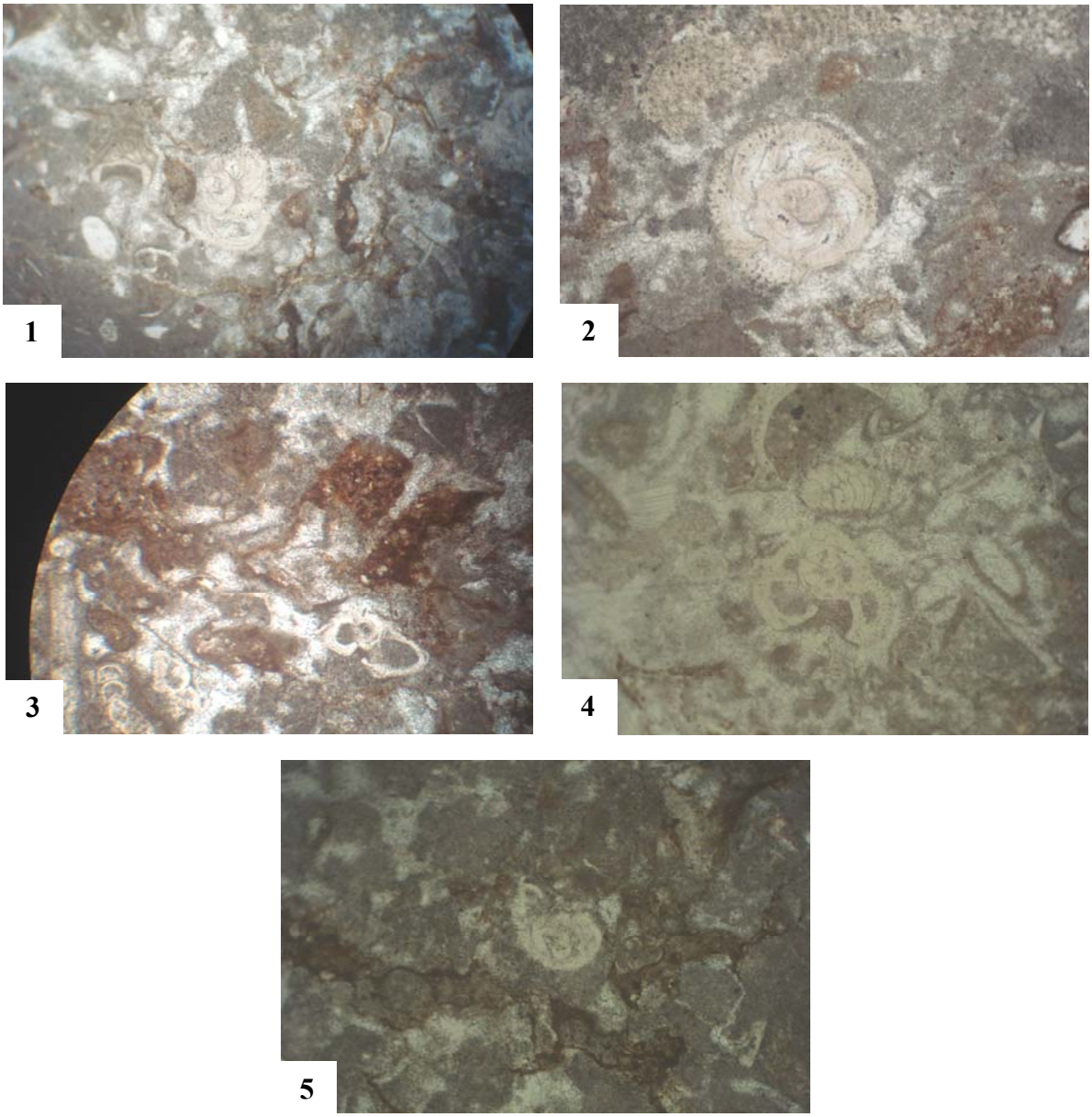

Fig.8: Index fossils of Early Miocene

1 and **2)** *Globprotalia scitula* (X 35)
3) *Globigerinoides* sp. (X 35)
4) *Globigerinoides primordius* Blow and BANNER (X 35)
5) *Globorotalia archeomenardi* BOLLI (X 75**)**

BIOSTRATIGRAPHY

The biozonation of the Late Oligocene – Early Miocene rocks of the studied sections is based on the planktonic and benthonic foraminifera; biostratigraphic data provided by earlier authors for the marine Late Oligocene – Early Miocene (Chattian – Aquitanian) sediments of Iraq (Karim, 1978 and Jassim *et al*., 1984) and is compared with more regional schemes; in Iran; it is correlated with the Asmari Formation (Vaziri-Moghaddam *et al*., 2005; Laursen *et al.,* 2006; and Mousavi and Momeni, 2009) and in Egypt (Kuss and Boukhary, 2008).

Among the identified planktonic foraminifera, of Chattian age, are: *Globigerina ciperoensis*, *Gl. angulisturalis*, *Chiloguembelina* sp. and rare *Gl. ampliapertuna*. As well as *Miogypsinoides complanatus* (Laursen *et al*., 2006), which is an index fossil for the Asmari Formation; it is also identified within the studied samples (Fig.7).

The biozonation concept proposed by Blow (1969) and Postuma (1971) for basinal Late Oligocene – Early Miocene sediments was adopted. In Iraq, the same planktonic zonation was found by Karim (1978) and Jassim *et al*. (1984).

The following identified benthonic fauna, in this study, indicate Late Oligocene (Chattian) age: *Miogypsinoids complanta*, *Peneroplis thomasi*, *Archias* sp., *Austrotrillina howchini* and *Praerhapidionina* sp. These fauna are compared with the Late Oligocene (Chattian) of the Zagros Range (Adams and Bourgeois, 1967); in the Middle East (Sharland *et al*., 2001), in Iran (Laursen *et al*., 2006) and in West Iran (Vaziri-Mghaddam *et al*., 2005).

The Early Miocene (Aquitanian) identified planktonic foraminifera that belong to Zone N4 are: *Globigerinoides primordius* and *Globorotalia pseudokugler.* In Sinjar area, West Iraq, the same planktonic zone was found in Serakagni Formation by Karim (1978) and Jassim *et al*. (1984). The following identified benthonic fauna, in this study, indicate Early Miocene (Aquitanian) age: *Ammonia beccari, Peneroplis farsensis* and *Miogypsina* sp. These fauna are compared with the fauna of Early Miocene in Iraq (Jassim *et al*., 1984) and in Iran (Vaziri-Moghaddam *et al*., 2005) and were found to be well correlatable.

The absence of indication for unconformable contact between the Late Oligocene and Early Miocene rocks in the succession, as it is the case in many parts of Iraq, could be explained to the assumption of Sharland *et al.* (2001), concerning the continuous deposition of the Asmari Formation in Iran, which is also recognized by Mohanar (2006) and Mousavi and Momeni (2009); they claimed four thick shallowing-upward sequences (3rd order cycles). No major hiatus were recognized between them. Therefore, the contacts are interpreted as SB2 sequence boundary types. In the studied sections, three shallowing-upward cycles could be observed, represented by marl and limestone, the third one being of Early Miocene age.

DEPOSITONAL ENVIRONMENT

The studied Late Oligocene – Early Miocene (Chattian – Aquitanian) sequence indicates two mixed environments; basinal (planktonic) and inner shelf (miliolids – peneroplis). This is interpreted as deposition in a ramp type shelf without a barrier separating the platform from the open sea. Mixed environments also could be resulted from rapid processes of transgression and regression, or oscillation of the sea level; especially in the case of the studied area, which is located near the shore-line of the Late Oligocene – Early Miocene Sea. Such mixed environments were found in Asmari Formation in which five mixed depositional environments were recognized (Mousavi and Momeni, 2009).

The turbulent condition observed in the studied samples is attributed to the effect of active waves marine environment, which is indicated by the presence of oolitic – pelletic horizons (Reineck and Singh, 1975). This phenomenon also proves that the studied area is near to the shore line of the Late Oligocene – Early Miocene sea.

The reduced thicknesses of the three limestone packages (about 10 m), especially the last one, could be attributed to the location of the studied area within the basin, which is located in the northeastern margin of the plate. Such reduced thickness is explained due to very low rate of subsidence during deposition (Jassim and Buday in Jassim and Goff, 2006).

SEQUENCE STRATIGRAPHY

Sharland *et al.* (2001) mentioned that the Asmari Formation in Iran is of Oligocene – Early Miocene age and it is deposited on both sides of the Zagros foredeep. Progressive, punctuated inversion of the fold belt during Oligocene and Miocene resulted in a number of MFS (Maximum Flooding Surface) within the fringing reefal Asmari/ Taqa/ Kirkuk carbonate successions. The MFS is associated with Aquitanian microfossils (*Miogypsinoides-Archaias* Biozone). In the studied samples, *Globorotalia archeomenard*, and *Globoquadrina dehiscencs* are index fossils of Aquitanian and could be well correlated with MFS of Sharland *et al.* (2001). Moreover, Sharland *et al.* (2001) mentioned the Ng10 (Neogene; early Miocene, Aquitanian) MFS is also expressed at the northern end of the plate, where, following a period of emergence and erosion, it is marked by return to relatively open marine conditions in the Serakagni and Euphrates formations (Bellen *et al*., 1959; Jones and Racey, 1994). The Ng10 MFS is most clearly expressed at the northern end of the plate and within the foredeep basins along the northern plate margin. Because the study area is located within a basin along the northern plate margin, therefore the same situation could be supposed.

The Ng10 GSS (Genetic Stratigraphic Sequence) is interpreted as a 3rd order succession within the overlying MFS driven by subsidence and eustacy. On the northeast side of the foredeep, the Ng10 early Oligocene HST (High Stand) shelf (Shurau, Shiekh Alas formations) and slope to basin floor sediments (Palani Formation) are located as a lowstand wedge (LSW) in front of the earlier Eocene slope facies. This Ng10 shelf was probably not very extensive in a dip direction, but interpretation is complicated by subsequent major erosion of these lagoonal sediments during the Middle Oligocene and earliest Miocene. In the northeast plate areas, to the northeast of the foredeep, the Anah and Bajwan formations (platform) and Azkand and Baba formations (slope) facies represent HST sediments deposited on the basin margin, passing into basinal facies of the Tarjil Formation, and perhaps uppermost Ibrahim Formation (van Bellen *et al*., 1959 and Goff *et al*., 1994). The Tarjil, Azkand and Anah formations are then overlain by the Ng10 MFS at the base of the Serakagni and Euphrates formation. In the studied area, it is clear that the same situation almost is present, except the absence of the Early and Middle Oligocene formations. This could be attributed to the position of the area in the basin, which is in the northeastern side of the plate. Therefore, they were either eroded or not deposited. Moreover, the presence of the Early Miocene (Aquitanian) in very thin thickness was also observed in Asmari Formation in Iran by Laursen *et al*. (2006); they proved that the sequence stratigraphy also shows evidence for condensation/ non-deposition in the Aquitanian interval. The presence of the Asmari Formation in Iraq is claimed by Mousavi and Momeni (2009).

DISCUSSION

The Oligocene – Early Miocene rocks are neither known in exposures nor in subsurface sections in the north and northeast of the High Folded Zone in Northeast Iraq. The common succession is that the Pila Spi Formation (Middle – Late Eocene) is overlain by Fat'ha Formation (Middle Miocene) and the whole Oligocene and Early Miocene rocks are previously reported as missing. This is attributed to the closure of the Neo-Tethys by the end of Eocene, due to continental collision, in the northeastern margin of the Arabian Plate with Central Iranian microplate of the Eurasian continent. Consequently, the area remained near

the sea level, without deposition (Jassim and Buday in Jassim and Goff, 2006). Moreover, Jassim and Buday in Jassim and Goff (2006) mentioned the presence of a ridge that formed as an obstacle preventing the deposition of Oligocene – Miocene sediments; the location of the supposed ridge follows the line that forms the present days boundary between the High Folded and Foothills Zones (Al-Kadhimi *et al*., 1996 and Fouad, 2009). This assumption was also mentioned by Buday (1980) and Buday and Jassim (1987).

The authors are in full accordance with previous workers, concerning the non-deposition of Oligocene rocks between Late Eocene and Middle Miocene, in the areas involved, due to the presence of the aforementioned ridge. However, they postulate that the north and northeastern limits (the supposed ridge) of the Oligocene and Miocene seas were more northeastwards for about (10 – 15) Km from the limits supposed by previous authors. This is confirmed by the presence of the Late Oligocene – Early Miocene rocks in the study area that most probably belong to Anah/ Ibrahim and Serakagni/ Euphrates formations. Moreover, the aforementioned formations, along the southwestern limb of Kalawe anticline (inside the High Folded Zone) is also overlain by Fat'ha Formation (Middle Miocene) (Fig.9), which means that the limits of the Middle Miocene sea also does not coincide with that motioned by previous authors and as shown in all available geological maps.

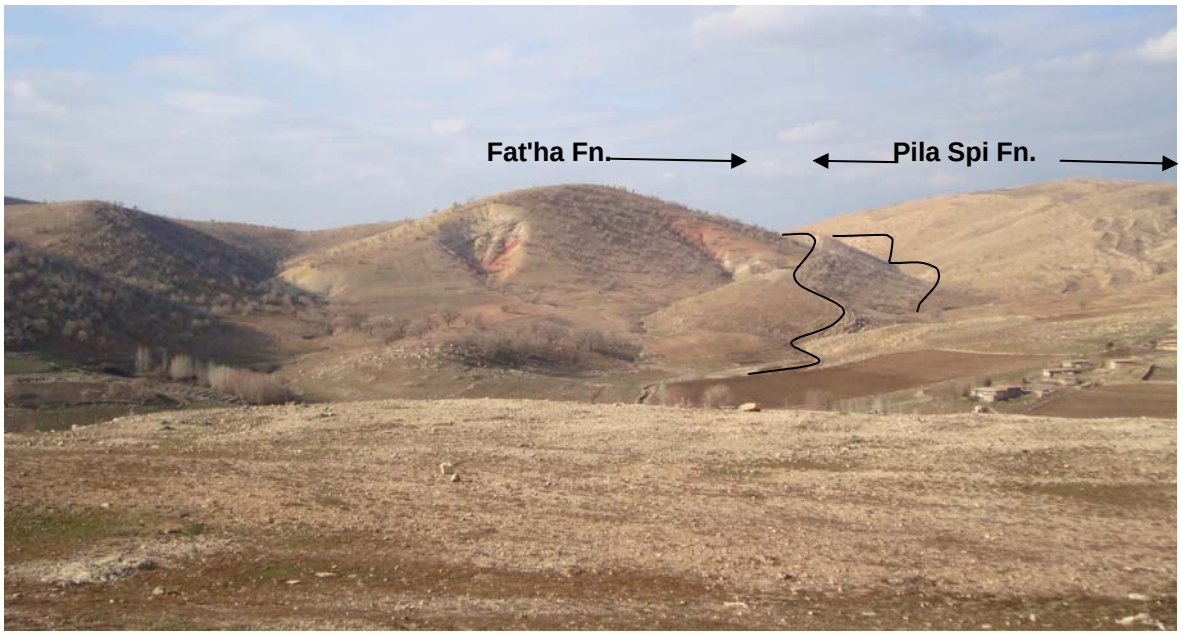

Fig.9: Late Oligocene – Early Miocene Succession between Pila Spi and Fat'ha formations in Kalawe anticline, south of Sulaimaniyah city

The presence of rocks of basinal and shelf environments together (possibly represented by Anah/ Ibrahim and Serakagni/ Euphrates formations) is known from different areas, in the world (Bock, 1982 and Chin *et al*., 2007, respectively). This could be attributed to the subsequent oscillation of sea level due to tectonic activities, which are known in the study area, because it is located in the northeastern margin of the Arabian Plate (Jassim and Buday in Jassim and Goff, 2006).

The tectonic activities could be confirmed by recognition of some compacted fossils in the studied samples, relatively thick breccia and conglomerate (8.5 – 13.5 m) in the base of the Early Oligocene rocks, as compared to the total thickness of the succession (20 – 25 m) and

the presence of cyclic deposition in the upper part of the succession; three packages of limestone alternated with green marl. Moreover, such mixing environments are common in basins with gentle slopes without barrier island and active marine conditions, which is the same case in the studied area, because it represents the marginal area of the sea, as indicated by the presence of breccia and conglomerate (8.5 – 13.5 m thick) overlain by carbonate rocks and marl, in the studied succession, besides the reduced thickness of the succession.

It is worth to mention that most of the Late Oligocene – Early Miocene lithostratigraphic units of the studied area were based on those established by Bellen *et al*. (1959). Lithologically, these rocks are restricted to biomicrite, biomicrosparite with some biosparite, pelbio – oosparite and oncoidal oopelbiosparite, which also indicate near shore sediments, with active wave area within the depositional basin.

The correlation of the two studied sections reveals a good coincidence between the main rock types of the succession. Moreover, the succession in the lower part, contains more clastics than in the type localities of the Oligocene formations, this could be attributed to the location of the studied area, as being in the shoreline of the depositional basin, this was also recognized by Bellen *et al*. (1959), but in the Foothill Zone, only; because they did not recognize the studied succession within the areas referred to the High Folded Zone. The presence of cyclic deposition, as indicated by the alternation of green marl and limestone, indicates the oscillation of the sea level and the area being close to the shore line of the basin, which was affected by tectonic movements during Savian Orogeny in the end of Eocene that caused to the closure of the Neo-Tethys. Moreover, Jassim and Buday in Jassim and Goff (2006) mentioned that the rate of the subsidence during Oligocene – Early Miocene was relatively slow; this could be an indication of the reduced thicknesses of the studied sequence in the studied area.

CONCLUSIONS

The followings could be concluded from the present study:

- The exposed rocks between Pila Spi and Fat'ha formations, in the studied area, south of Sulaimaniyah city are of Late Oligocene (Chatian) – Early Miocene (Aquitanian) age.
- Part of the recognized succession is well correlated, age wise and lithologically, with the Asmary Formation of southwestern Iran.
- The identified fauna in the collected samples indicate most probably Anah/ Ibrahim and Serakagni/ Euphrates formations, or might be a new Late Oligocene – Early Miocene lithostratigraphic unit; equivalent to Asmari Formation.
- The lower contact of the studied succession is unconformable. It is clearly indicated by the presence of breccia, whereas the upper contact is most probably conformable, indicted by the presence of reddish brown clastics, bellow the Fat'ha Formation, and as it is the case in the whole Iraqi territory.
- The contact between Late Oligocen and Eraly Miocene is most probably conformable, as indicted from the absence of any indication for a hiatus and it is confirmed by sequence stratigraphy.
- The sequence stratigraphy shows evidence for condensation/ non-deposition in the Aquitanian interval.
- The north and northeastern limits of the Late Oligocene and Early Miocene Sea were more northwards, as compared to those supposed by previous authors.
- The youngest exposed rocks, in the study area are Middle Miocene age of Fat'ha Formation, underlain by Early Miocene succession and Late Oligocene succession, and not Middle – Late Eocene rocks of Pila Spi Formation, as mentioned previously, by previous authors.

- The authors highly recommend to perform detailed sampling for the studied sections and other exposed near surrounding sections, starting from Koi Sanjaq to Iraqi – Iranian borders, southeast wards; from the studied area; for detailed faunal identification, biostratigraphical zonation and petrological identification. The results of such studies will be more persuadable to the achieved results in this study.

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