Microfacies, Sequence Stratigraphy and Cooling Events of The Oligocene (Palani and Tarjil Formations) at Sinjar Area, Northwestern Iraq

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ABSTRACT

Lithological study of Oligocene carbonate exposure near Sinjar City northwestern Iraq indicates its affiliation to Palani and Tarjil Formations. One microfacies characterizes the condensed section of Palani Formation (Early Oligocene), attributed to outer shelf environment. Three microfacies were distinguished throughout Tarjil Formation, their depositional environments ranging from middle shelf to middle bathyal zones.

Sequence stratigraphic analysis delineated five sequences, four of them are of 3rd order and one of 4th order. Two cooling events are inferred during the Middle Oligocene, corresponding to global cooling and sea-level fluctuations.

السحنات الدقيقة و الطباقية التتابعية وظواهر البرودة خلال الاوليجوسين (تكويني بلاني وتارجيل) في منطقة سنجار، شمال غرب العراق

الملخص

اظهرت الدراسة الصخرية عائدية ترسبات الاوليجوسين الى تكويني بلاني وتارجيل في المقطع السطحي قرب مدينة سنجار شمال غرب العراق. تمثلت ترسبات تكوين بلاني بسحنة دقيقة واحدة اعتبرت مقطعا مضغوطا (condensed section) لفترة الاوليجوسين المبكر وهي تشير الى ترسبات الرصيف الخارجي. اما تكوين تارجيل فقد ضم ثلاث سحنات دقيقة امتدت بيئاتها الترسيبية من الرصيف الاوسط حتى الباثيال الاوسط. اظهرتحليل الطباقية التتابعية وجود خمسة تتابعات، اربعة من المرتبة الثالثة وواحدة من المرتبة الرابعة. تم تمييز فترتي برودة خلال الاوليجوسين الاوسط ضمن المدى الزمني (33.0-31.5) مليون سنة و (30.5-29.5) مليون سنة، والتي اظهرت توافقا مع المناخ العالمي في هذه الازمنة.

INTRODUCTION

The studied surface section of Oligocene rocks located near Sinjar City northwest Iraq (Fig.1), is represented by Palani and Tarjil Formations. According to Al-Hashimi and Amer (1985) Palani Formation is known in the low folded and mesopotamian zones, including typical basinal facies rich in planktic foraminifera, which may be condensed and reduced to few meters in northwestern Iraq. Tarjil Formation occupies mostly the same areas of the former Palani Formation.

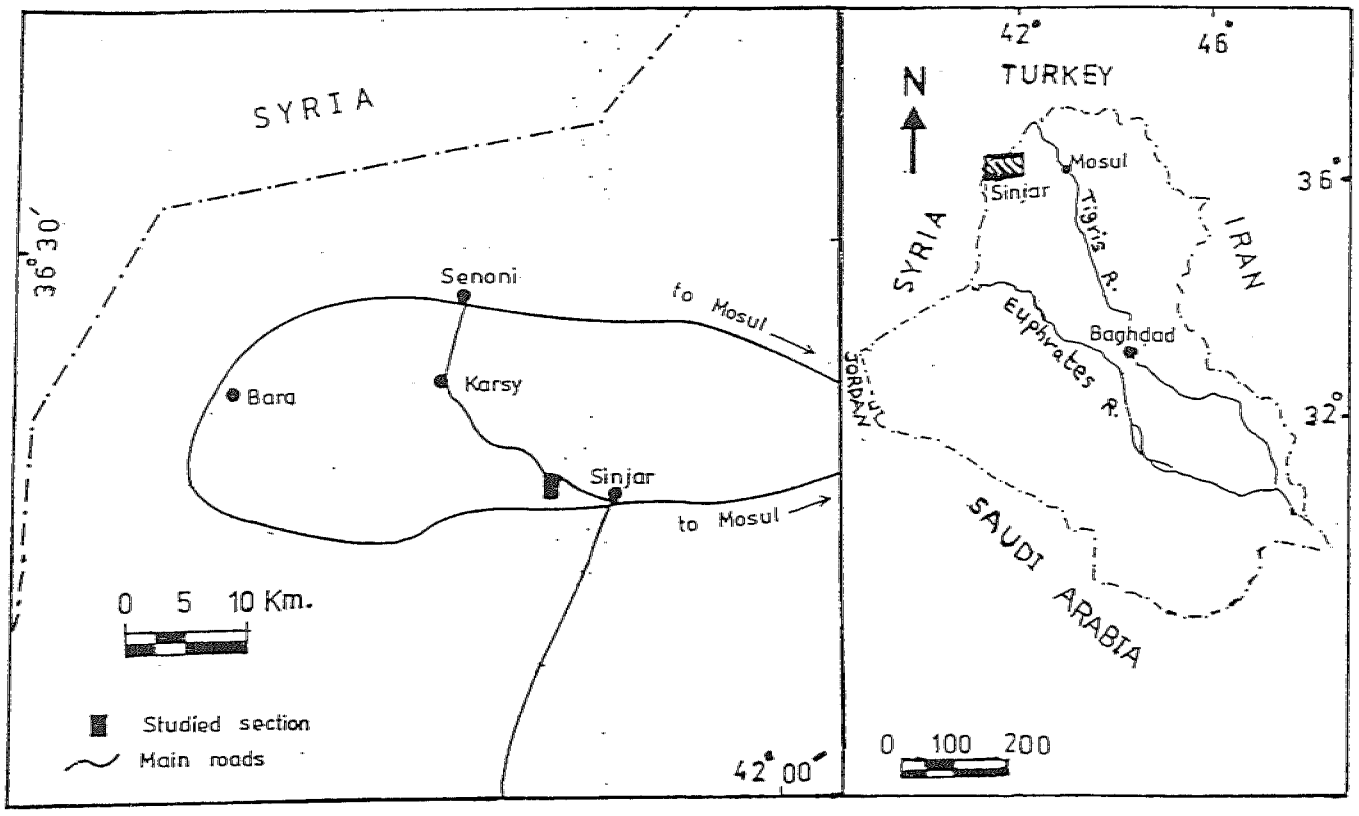

Fig.1:Location map

Previous stratigraphic studies (Bellen et al., 1959; Buday, 1980 and Al-Hashimi & Amer, 1985) indicated that Oligocene rocks are comprised of three cycles. Recently (Al-Eisa, 1992; Al-Banna, 1997) considered that the Oligocene rocks are consists of only two cycles. The first cycle includes Palani, Sheikh Alas and Shurau Formations, whereas the second cycle embraces Tarjil, Baba and Bajwan Formations.

The present study is based on 28 samples collected from surface section of 201m thick. Based on foraminiferal assemblages and sedimentary line of evidences, microfacies were recognized and used in the analysis of sequence stratigraphy.

MICROFACIES DESCRIPTION

Four microfacies constituting the Palani and Tarjil Formations are described, their biotic content provide a good information about paleoecology and oscillations of sea-level, which are reflected by the alternation of these microfacies indicating a relatively deep environment (upper bathyal) to middle shelf environments.

Palani Formation:

This formation is represented by 4m thick, greyish to pale brown, friable marly limestone bed, which is unconformably overlaying Jaddala Formation (Middle Eocene). The upper boundary is conformable with Tarjil Formation. One microfacies was recognized in Palani Formation.

Planktic foraminiferal packstone microfacies (Pa1):

This microfacies is allocated to greyish - pale brown soft marly limestone bed. The allochems percentage ranges between 80 - 90% and consists mainly of diverse Early Oligocene planktic foraminiferal species belonging to *Globigerina*, *Cassigerinella* and *Pseudohastigerina*, amounting to 85% of the total assemblage. Benthic foraminifera belonging to *Lenticulina*, *Cibicidoides* and *Gyrodina* exhibit rare occurrence. This microfacies is characterized by the presence of glauconite, enriched with easily dated planktic foraminifera and bioturbation (vertical and inclined burrows). Which collectively are an evidences of low accumulation rate and reflecting a condensed section deposited in outer shelf environment (Emray and Myers, 1996; Kitamura, 1998 and Pittet et al., 2000).

Tarjil Formation:

This formation is composed of 197m thick-yellowish brown to grey marly limestone beds alternating with thin marl beds. The upper boundary of Tarjil Formation is unconformable with the overlaying Ibrahim Formation (Early Miocene). Three microfacies have been recognized in Tarjil Formation.

Planktic foraminiferal packstone microfacies (T_1):

This microfacies is characteistically yellowish to pale brown limestone and marly limestone with thickness ranging between 4.5-27m. It contains 50-80% allochems with abundant planktic foraminifera belonging to the genera *Globigerina*, *Globorotalia*, *Catapsydrax* and *Globorotaloides*. Whose percentages are ranges from 60 to 85% of the total foraminifera (Plate 1, fig.1). Benthic foraminifera show low distribution represented by the genera *Cibicidoides*, *Uvigerina*, *Bulimina* and *Spiroplectamina*. These paleontological attributes indicate to upper - middle bathyal environment with water depth ranging between 200-700m (Miller et al., 1985, Gibson, 1989 and Berggren & Miller, 1989).

Planktic foraminiferal wackestone-mudstone microfacies (T_2):

This microfacies is represented by hard yellowish to pale brown limestone and marly limestone beds with thickness ranging between 15-65m. Allochems vary from 1 to 40% of the total content, where planktic foraminifera representing the main constituents of the allochems (Plate1, figs. 2 &3). The planktic foraminiferal assemblages at some

intervals show low diversity and consist primarly of small thin walled specimens. This trend corresponds to global paleoclimatic cooling conditions(Boltovskoy & Wright, 1976; Keller, 1985). Benthic foraminiferal attains less than 40% of total foraminifera and typified by the genera *Cibicidoides*, *Lenticulina*, *Bulimina*, *Textularia*, *Anomalinoides* and *Spiroplectamina*. These foraminiferal assemblages are indicative of outer shelf environment with depth ranging between 100-200 m (Funnell, 1967).

Benthic wackestone microfacies (T_3):

This microfacies describes massive pale brown marly limestone beds of 25 cm thick, representing the uppermost part of Tarjil Formation. The upper surface of this bed containing trace fossils (burrows and trails of Crawling), external molds of pelecypod shells and echinoid. This microfacies contains rare planktic and benthic foraminifera (*Cibicidoides*, *Lenticulina*) with echinoid spines (plate 1, fig. 4) which are set in a brown lime mud groundmass.

This microfacies is assigned to open shallow shelf (middle shelf) environment. The upper surface of this microfacies represents the unconformable surface with the overlaying deep marine deposits of Ibrahim Formation. Thus biostratigraphy and physical break in sedimentation are in harmony.

SEQUENCE STRATIGRAPHY

Sequence stratigraphy has become an elementary and popular tool for sedimentary basin analysis. This concept is used to identify genetically related strata and their bounding regional unconformities, or their correlative conformities. Haq et al. (1988) define sequence stratigraphy as that branch of stratigraphy which subdivides the rock record using a succession of depositional sequence composed of genetically related strata as regional and interregional correlative units.

The sequence is limited by two boundaries, their types related to the rate of relative sea-level fall. The sequence boundaries of the studied section are of type 2 where the shelf does not exposed due to relatively limited sea level fall, except the lower boundary of the section with Jaddala Formation which is of type 1 where the shelf was exposed due to the sea level fall.

The identification of depositional surfaces and sequence boundaries in the studied section is based on the premise that changes in relative sea level affect microfacies relationships in the sediments. The sequence interpretation and position of depositional surfaces given here is based on microfacies analysis and there tie to biostratigraphical and chronostratigraphic data given by Al-Mutwali and Al-Banna (in press) for the same section.

In the present study five sequences are recognized during Oligocene series (35-23.5 Ma) in Sinjar basin, four of 3rd order while the last one is of 4th order (Goldhammer et al., 1990) (Fig.2).

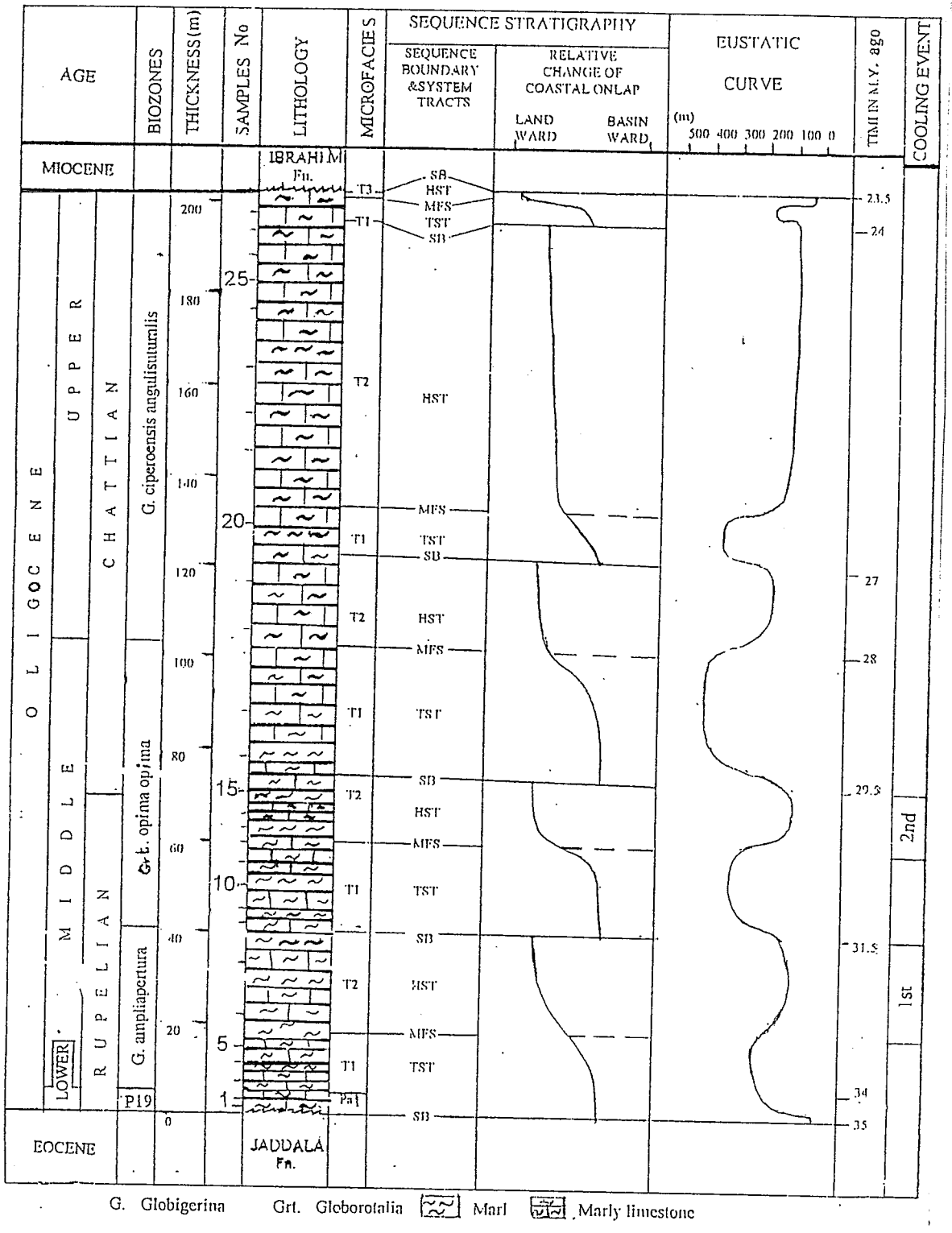

Fig.2:Lithostratigraphic paleontologic and sequence stratigraphic data of the Oligocene section at Sinjar area Paleontological zonation and their time duration after Al- Mutwali and Al-Banna (in press).

Sequence 1:

After a considerable hiatus (~9 My) ranging from Middle Eocene (Zone P11) to Early Oligocene (Zone P19), a rapid transgressive system of deposition succeeding the unconformity surface, represented by the deposition of greyish to pale brown marly limestone bed (microfacies Pa1), reflecting outer shelf environment. The presence of glauconite, burrows and abundant easily dated planktic foraminifera are indication of condensed section (Pittet et al., 2000).

The condensed section overlained by yellowish to pale brown marly limestone beds of Tarjil Formation which consists of planktic foraminiferal packstone microfacies (T_1), showing a dominance of planktic foraminifera with an average of 60-70% of the total assemblages, indicating upper bathyal – outer shelf environment. The two microfacies (Pa1 and T_1) represent the transgressive systems tract (TST).

The microfacies (T_1) followed by planktic foraminiferal wackestone-mudstone microfacies (T_2), in this interval the foraminiferal percentage is 5-15% of the total content and reflects the outer shelf environment (Funnell, 1967). The maximum flooding surface (MFS) can be recognized between microfacies T_1 and T_2 at 18m level, where microfacies (T_2) represents the highstand system tracks (HST) of the sequence.

The rare occurrence of small planktic foraminifera above the level (18 m) indicate cooling event during (33-31.5 Ma) (Boltovskoy & Wright, 1976; Keigwin & Keller, 1984). The lower sequence boundary is of type1, while the upper one is of type 2. The total thickness of the sequence is 37 m and its time duration about 3.5 My.

Sequence-2:

The sequence begins with surface boundary of type 2 followed by microfacies (T_1) which is represented the (TST) deposits that assigened to the upper bathyal environment. The microfacies (T_1) overlained by 15 m of marly limestone represented by microfacies (T_2), which characterized by rare occurrence of small size planktic foraminiferal species, reflecting the second cooling event at about 30.5-29.5 Ma. The maximum flooding surface (MFS) that separates (TST) from (HST) is at the level of 60m. This sequence is of 23m thick and spans about 2 My ended by sequence boundary of type 2.

Sequence-3:

This sequence is bounded by two surface boundaries of type 2. Its lower unit embraced microfacies (T_1) representing the (TST) of the sequence, which is gradationaly change to microfacies (T_2). The characteristic features of the microfacies (T_2) indicate outer shelf environment and representing the HST. The MFS seperating TST from HST is at the level of 103m. The total thickness of the sequence is 51m and spans about 2.5 My.

Sequence-4:

The lower hemicycle of the sequence revealing microfacies (T_1) which reflects TST and indicating deep marine environment. Microfacies (T_2) succeds microfacies (T_1) reflecting the (HST) of the sequence, the MFS clearly separates the TST from HST at the level of 133m. Total thickness is about 72m and their time duration 3 My ended by sequence boundary of type 2.

Sequence-5:

It begins with the deposition of microfacies (T_1) that indicates deep marine environment and reflecting TST. The upper 25cm of the sequence consist of microfacies (T_3), which indicate shallow marine environment and representing HST. The upper surface of this sequence is characterized by the presence of burrows, trails of crawling, molds of pelecypods and echinoid, which indicate the shallowing resulting in the surface unconformity represents by Oligocene-Miocene boundary. Total thickness of this sequence is 6m and time duration less than 1 My.

Relation of the sea level-change with cooling events

The recognation of global sea-level changes has allowed a better understanding of their effects on living biota especially foraminifera. In the studied section five sequences have been recognized, they are correlated with that proposed by Haq et al. (1988), showing a global response to paleoclimatic and sea level changes. The section started by a disconformity surface marks the contact between the Middle Eocene (Jaddala Formation) and the overlying Lower Oligocene (Palani Formation). Palani Formation including friable marly limestone bed of 4 m thick considered as condensed section, containing abundant well preserved easily separated planktic foraminifera of normal size. This fauna suggests warm conditions that prevailed during this interval (at about 35 Ma) following the Eocene-Oligocene boundary cool event (Keller, 1985; Boltovskoy and Boltovskoy, 1989; Al-Mutwali and Abawi, 2001).

During the deposition of Tarjil Formation (Middle-Late Oligocene) there were two sea-level drops through the Middle Oligocene at about 31.5 Ma and 29.5 Ma respectively, which represent the upper boundaries of sequences 1 and 2. These sea-level drops are indicated by the cyclicity between microfacies T1 and T2, where the oscillation of sea-level are evident and reflected by the alternation of these two microfacies.

The rare occurrence of small planktic foraminiferal species during the intervals of microfacies T_2 at about (33-31.5) Ma and (30.5-29.5) Ma, representing the upper hemicycles of sequences 1 and 2 suggests cool surface water temperatures prevailed during these intervals. This conclusion is similar to that reached by Keigwin and Keller (1984) in equatorial Pacific and Keller (1985) in Gulf of Mexico, where they related it to a world wide3 cooling events.

Faunal abundance data during Late Oligocene suggest a slightly warming conditions than the Middle Oligocene (Keller, 1985).

Loutit and Kennett (1981) stated that the time represented by each hiatus between the sedimentary cycles is dependant on the water depth during the time of deposition, the speed of sea-level change, in addition to the location and amount of erosion. The studied Oligocene section in Sinjar area has always remained submerged during all drops of sea-level, because the position of deposition is mainly middle-upper bathyal and outer shelf environments. In our opinion it represents the more complete Oligocene section in Sinjar basin (Al-Mutwali and Al-Banna, in press).

CONCLUSIONS

The Oligocene section (35-23.5 Ma) at Sinjar area reveals Palani and Tarjil Formations, in which Palani Formation represented by 4m thick condensed section of marly limestone bed, while Tarjil Formation consists of 197m thick marly limestone and

marl beds. Four microfacies were recognized within these formations and stretch from middle shelf to middle bathyal zone. Depending on the biostratigraphic and sedimentologic attributes five sequences were recognized, of which four sequences are of 3rd order and the last one is of 4th order. These sequences show good correlation with the global cycle chart of Haq et al. (1988). The Middle Oligocene sea-level drops represented by the upper boundary of sequence 1 and 2, happened after the cooling events during the intervals (33-31.5) Ma and (30.5-29.5) Ma.

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PLATE -1

fig.1: General view of planktic foraminiferal packstone microfacies (T1), Tarjil Formation Sample no. 4, X40.

fig.2: General view of planktic foraminiferal wackestone-mudstone microfacies (T2) with small sized planktic foraminifera, Tarjil Formation Sample no. 14, X40.

fig.3: General view of planktic foraminiferal wackestone-mudstone microfacies (T2) with abnormal sized planktic foraminifera (*Globigerina ciperoensis ciperoensis* Bolli), Tarjil Formation Sample no. 19, X40.

fig.4: General view of benthic wackestone microfacies (T3) with echinoid spine. Sample no. 28, X40.

PLATE -1