Sequence Development and Engineering Geological Survey of the Nfayil and Injana Formations in Abdulla Abo- Najam area Al-Qadissiya Governorate (Middle of Iraq)

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Abstract

Surface sections of the Nfayil Formation (Middle Miocene) and Injana Formation (Upper Miocene) are studied in Abdulla Abo-Najam area Al-QadissiyaGovernorate Middle of Iraq. The Nfayil Formation consists of marls interbedded with limestones and marly limestone while the Injana Formation consists of alternating sandstones, siltstones and claystone. The Nfayil Formation is deposited mainly within the restricted, shoal and shallow open marine conditions. While Injana Formation is deposited in meandering river.

Seven 4th order cycles can be recognized within the Nfayil- Injana succession in the study area. These cycles are asymmetrical and each represent period of sea level rise following episode of stillstand. A type two sequence boundary (SB-2) occurs between the Nfayil Formation and the Injana Formation. This succession is developed in an area of low subsidence, which reflects the major effect of eustacy as the main controlling factor in sequence development.

Engineering Geological Survey results showed that the uniaxial compressive strength of rocks in the study area ranges from the maximum value of 36 N/mm^2 in Nfayil Formation, to the minimum value of 8 N/mm^2 in Nfayil Formation, and the average is 22.865 N/mm^2 depending on the point load index (Is)., in the study area the uniaxial compressive strength is classified into very low to low uniaxial compressive strength.

Key words: Sequence Development, Engineering Geological Survey, Nfayil and Injana Formations.

الخلاصة

أجريت دراسة المقطع المنكشف لتكويني النفايل (المايوسين الأوسط) وانجانة (المايوسين الأعلى) في منطقة عبد الله أبو نجم في محافظة القادسية وسط العراق حيث تبين ان تكوين النفايل يتكون من تعاقب طبقات المارل مع الحجر الجيري والحجر الجيري المارلي بينما يتكون تكوين انجانة من تناوب الحجر الرملي والحجر الطيني والحجر الغريني. ان تكوين النفايل قد ترسب في البيئة البحرية المفتوحة الضحلة والبيئة الحصرة والبيئة الضحضاحية اما تكوين انجانة فقد ترسب في بيئة الأنهار الملتوية.

تم تشخيص سبع دورات ترسيبيه من الدرجة الرابعة في تتابع النفايل –انجانا في منطقة الدراسة. وهذه الدورات تكون غير متماثلة، وهي تمثل دورات متعاقبة من ارتفاع مستوى البحر وركوده. كما تم تمييز حد فاصل من الدرجة الثانية (SB-2) بين تكوين النفايل وتكوين انجانا .أن تتابع النفايل وانجانا في منطقة الدراسة قد تطور في منطقة تعكس تجلس واطئ وتأثير رئيسي لسطح البحر العالمي والذي يعتبر عامل رئيسي مسيطر في تطور التتابع.

اظهرت نتائج المسح الجيولوجي الهندسي بان قيم المقاومة الانضغاطية اللامحصورة والتي تم حسابها من قيم معامل حمل النقطة تراوحت بين N/mm^2 (8-36) لتكوين النفايل ,وصنفت قيم المقاومة الانضغاطية اللامحصورة لمنطقة الدراسة بانها واطئة الى وطئه جدا .

الكلمات المفتاحية: تطور التتابع، مسح جيولوجي هندسي، تكوينا النفايل وانجانا.

1-Introduction

This study deals with two different types of sedimentary rocks, which are clastics and carbonates, represented by the Nfayil Formation (Middle Miocene), and Injana Formation (Upper Miocene). The Miocene succession of western and southern Desert of Iraq is equivalent to Megasequence AP11 of Sharland, *et. al*, (2001) in (Aqrawi *et al*., 2010), It was affected by the closure of the of the Neo Tethys (Jassim and Goff, 2006) . In the Early Miocene to Early Middle Miocene where limited tectonic subsidence occurred in the Arabian plate (Aqrawi *et al*., 2010), and the Mesopotamian basin became narrow and shallower as the western part of Arabian plate was uplifted (Jassim and Goff, 2006).

Nfayil Formation is subdivided into two members: Lower carbonate Member composed of three cycles of limestone and marl intercalations and Upper clastic Member of sandstone and claystone with thin layers of limestone (Sissakian, 1999). Nfayil Formation is equivalent of Fatha Formation .The Fatha Formation was originally described by Bellen *et al.*, 1959), no type section was defined. It was named at first as the Lower Fars Formation. Al- Rawi, *et al.*, 1992 in (Aqrawi *et al*., 2010). The Injana Formation was first named as the Upper Fars Formation and renamed as Injana Formation by Al- Rawi 1992 in (Aqrawi *et al.*, 2010). This formation comprises varicolored marls and siltstones with beds of sandstone and grits. Occasional beds of fresh water lacustrine carbonates occurs.

2-Aim of the study

The main aims of the present study are depositional environment interpretation based on detailed petrographic study and facies analysis of selected section within the study area. This is one of the main requirements of sequence stratigraphic analysis in order to depict the Middle and Upper Miocene sequence development this succession is the first description, as well as assess the density and uniaxial compressive strength of rocks and classification of rocks.

3-Methodology and Study Area

This study deals with two formations. Detailed description and sample collection was carried on every noticeable change for the two studied formations, Nfayil and Injana.

The fieldwork included sampling of one composite sections (Figure.1) located at Abdulla Abo- Najam area Al-Qadissiya Governorate, (31° 35' 9.04″N) (44° 30' 8″ E). Detailed description was carried out as where every noticeable change. Selection of samples from this section was based on facies change, colour change, hardness of the beds and difference in other factors and evaluate of engineering properties of rock such as density and uniaxial compressive strength of rocks.

The Nfayil Formation consists of marls interbedded with limestones and marly limestone of up to 1 meters thick, (Figure. 2). The intercalated limestone beds varies in thickness from about 0.5-2 meters, they are yellowish to light grey in color and generally highly fossiliferous. The thickness of the Formation is about 18 meters. The lower contact with the Euphrates Formation is conformable and taken at the top of the limestone bed of Euphrates Formation and the base of green marl bed more than 1 meter thick of Nfayil Formation.

Fig.1: Location map of the study area

The Injana Formation consists of alternating reddish brown to grey sandstones, siltstones, and claystone. The sandstones of Injana Formation were classified according to (Pettijhon, 1975), this classification is based on texture that is weathering. The sandstones compos of grains only or contain more than 15% matrix. The lower contact with the Nfayil Formation is unconformable and taken at the top of the limestone bed of Nfayil Formation and the base of the brown claystone or sandstone bed of Injana Formation. The upper contact of Injana Formation is unconformable with overlong Quaternary deposited.

Detailed petrography and facies analysis for 46 samples taken as every noticeable change including different carbonate and clastic rocks.

Microscopic study on 38 thin sections is achieved, for the carbonates detailed microfacies study and identification of some fossils ware done. The clastic point counting technique was used to count 500 grains for each thin section. Biostratigraphy was employed in addition to depositional environmental interpretation, then lithofacies were related to system tracts and aspects of key surfaces were identified. Sequence stratigraphic subdivision is followed in order to integrate the 4th order cyclicity and sequence development.

4-Microfacies and Paleoenvironment of Nfayil Formation

The studied section consist of carbonates; detailed microfacies analysis was carried out taking into consideration the depositional texture and type of skeletal and nonskeletal grains to interpret the nature of environments. The standard microfacies of Wilson (1975) and their revision by (Flugel, 2004) were also considered**.** Th**e** Nfayil Formation is deposited mainly within the restricted, shoal and shallow open marine conditions.

A- Restricted marine environment. This environment was recognized by the following microfacies:

1-Lime Mudstone Microfacies. (MFA-1)

This facies contains marls, green to yellowish, with associated light grey, marly limestone. The Lime mudstone is generally homogeneous and without fossiliferous and is a pervasive in the upper parts of the studied section. This microfacies is unlaminated. It reflects deposition in quiet tidal ponds similar to SMF type -23 (Wilson, 1975) and (Flugel 2004).

2-Lithoclastic Sandy wackestones. (MFA-2)

This facies contains marls, green to yellowish with detrital quartz grains and benthic forams. Recrystallization is most affective in this facies.

B-Shallow Opens Marine Environment. It is characterized by:

1-Fossiliferous Packstone Microfacies. (MFB-1)

This facies composed of peloids with diversity of skeletal grains and forams such as: Gastropods, Pelecypods, Ostracods, Rotalia, and Miliolids, It may contain Authigenic quartz.

2-Fossiliferous Wackestone Microfacies. (MFB-2)

With Echinoderms, Rotallids algal fragments. Pelecypods, forams, Bioclasts, and peloids. These microfacies alternates with the previous one, it has close affinity to that microfacies, the main difference lies in the population of fauna being mostly low and with relatively high mud content. The population of fauna may be winnowed out material from the previous microfacies to more sheltered area at the inner platform towards the subtidal area, this microfacies is similar to SMF type –8, (Wilson, 1975).

3-Bioclastic Wackestone Microfacies. (MFB-3)

This facies is composed of an assemblage of skeletal fragments with or without the presence of few whole fossils with shells of Mollusks and Ostracods. Fragmentation of skeletal grains depends primarily on wave energy.

C-Shoal Environment.

The shoal environment is represented by **Peloidal Grainstone Microfacies (MFC)** and it consists mainly of abundant peloids, rare bioclasts, and intraclasts. The peloids are well sorted and rounded. The shoal environment is a belt of high tidal current and wave activity, which is located along the seaward margin of carbonate platform. Depths of deposition in this environment are less than 5-10 meters above wave-base. The peloids are well sorted and rounded. This facies is usually deposited within a high energy shoals and it is similar to SMF type -11, (Wilson, 1975).

5-Lithofacies and Paleoenvironment of Injana Formation

Facies analysis of the Injana Formation was carried out mainly on the bases of the grain size; and the subfacies are distinguished on a combination of lithology and sedimentary structures. Six lithofacies ware recognized according to their internal and external geometry, and their relationship in the Injana Formation, these facies can be integrated into four distinct facies associations; these are:

5-1- Reddish Brown to Grey Sandstone Lithofacies.

They are composed of the following lithofacies, in descending order of abundance:

a- Trough Cross-Bedding Sandstone Sublithofacie. (LFA)

The reddish brown to grey grain size is fine to coarse with thicknesses ranging from 1.5 to 2.8m.

b- Low Angle Cross-Bedding Sandstone Sublithofacie. (LFB)

Medium to coarse and may be pebbly with a light grey, grey with thicknesses ranging from 0.5 to 1.8m.

c- Horizontally laminated Sandstone Sublithofacie. (LFC). It consists of massive grey fine-grained sandstone.

Most sandstones in reddish brown to grey Sandstone Facies are subangular to subrounded, sorting generally increases towards the top ranging from moderately sorted at the bottom toward well sorted near the top. The composition of the sandstone indicates that the rock fragments which represents the major grains constituent 55-68% next is quartz. Fabric is typical of lithic arenite (Pettijhon, 1975). The sandstone is cemented by calcite cements, clays, and iron cement.

Coarse grained sandstone sublithofacies occurs as 1 to 3m thick individualistic channels to sheet-like sandstone bodies that are massive or trough and planar cross-bedded . Medium-grained sandstone sublithofacies varies from 0.5 to 1.5m in thickness. This sublithofacies composes as sandstone bodies with erosional or transitional base and a flat top. It represents multistoried sandstone bodies with high alternated sets of a large-scale trough, planar bedded. A finegrained sandstone sublithofacies presents interbedded siltstone and mudstone.

The reddish brown to grey sandstone are interpreted as river channel deposits stake on their dimensions. Channel lag deposits within a heavy loaded channel system. The coarse to medium with locally fine sandstone deposits with erosional bases and flat top form channel-like deposits. Fine-grained sandstone deposition occurs due to vertical increase on the top of channel sand bars during slightest flow conditions (Rust, 1975). Affluently large-scale trough and planar cross-bedded cossets in multistorey sandstone succession may be ascribed to lower current migration of sand dunes, sand waves, and transverse bars in shallow water stream channels. The fine grain sandstone and point bar elements are consistent with meandering- rivers (Miall, 1992).

5-2- Light Grey Siltstone Lithofacies.(LFD)

It is composed of well-sorted and medium grained, light grey siltstone and silty-very finegrained sandstone. Its generally represents as either individualistic beds or successive claystone in the top of the individual depositional units (Figure.2).

This lithofacies reflect deposition by shallow lakes and ponds in a flood plain environment. The parallel and cross-laminated siltstones were possible deposited on the upper part of sand bars and closely seamed with affluently channel and floodplain conditions during the intervals of decreased hydrodynamic energy and sediment discharge by vertical accretion or slow deposition (Walker and Cant, 1984). Thick and persistent siltstone is associated with floodplain succession, which is ascribed to deposition in extensive and long persistent overflow of stream.

5-3-Red-Brown Claystone Lithofacies. (LFE)

It is the most dominant in the Injana Formation. Individual bed ranges between 0.5, 3m thick mainly consists of massive to parallel laminated, and it consists alternated dark grey, reddish brown or light grey, silty sandstone. The upper and lower contacts of the lithofacies are sharp and gradational. It mainly overlies the sandstone and siltstone lithofacies.

The Parallel laminated claystone suggest that the sediments were deposited in floodplain environments with frequent variation of energy condition, thus resulting in grain-size variation vertically or laterally. Thin claystone at upper part of the channel sandstones cossets deposition from suspension during channel abandonment. The thick dark claystone associated with organic material suggests deposition by vertical accretion in back swamp or flood plain environments (Walker and Cant, 1984).

6-Sequence Development

Seven 4th order cycles can be recognized within the Nfayil- Injana succession in the study area (Fig.2). These include cycles **A, B, C, D,** and **E** of the Middle Miocene Nfayil, and cycles **F** and **G** of the Upper Miocene Injana Formation.

Cycle **A** consists of highstand systems tract (HST) represented by restricted marine facies restricted facies reflecting episodes of stillstand on the conformable surface with underlying Euphrates Formation(Lower Miocene). Cycles **B, C, D** and **E**. each cycle consists mainly of transgressive system tract (TST) represented by shallow open marine facies reflecting episodes of sea level rise overlying by restricted environment of highstand systems tract (HST) reflecting episodes of stillstand .These cycles are asymmetrical reflecting an imbalance between the relative sea level and carbonate production.

The Lowstand systems tract (LST) characterized by thick base level transfer cycles (BLTC) cycles represented by cycle F ,this cycle consist of flood plain and channel followed by highstand systems tract (HST) represented by flood plain facies and boundary below by type two sequence boundary(SB-2 (Fig. 2). While cycle **G** represent of transgressive flood plain facies, deposited during rising base level, followed by highstand facies of channel facies representing episodes of base level fall.

The succession in the study area was developed in an area of low subsidence, which reflects the major effect of eustacy as the main controlling factor in sequence development. The Nfayil carbonates were deposited on a slowly subsidence carbonate platform as a result of a major transgression where succession episodes of sea level rise and stillstand. The subsequent sea level fall exposed the low gradient platform and reflected the progradation of the fluvial Injana facies.

7- Engineering Geological Survey of the rock in the study area:-

7-1 Bulk density

Bulk density is the weight of rock to the total volume of the rock mass (Duggal, 2008). The bulk density give good information about the rock conditions from overburden pressure in situ, the bulk density has been calculated from cylindrical samples standard. The bulk density of rocks in the study area ranges from the maximum value of 2.55 gm/cm^3 in Nfayil Formation, to the minimum value of 2.02 gm/cm^3 in Nfayil Formation, and the average is 2.271 gm/cm^3, (Table-1).

7-2 Point load test

The point load test is used on small pieces of rock which either borehole core or irregular lumps. The test is derived from the Brazilian test in which a disc is compressed diametrally between two loading plates and the tensile stress at failure. The point load index (Is) was developed by (Franklin1971),Is is given by:-

$Is=P/D^2$ …….(1)

The point load index(Is) of rocks in the study area ranges from the maximum value of 1.5 N/mm^2 in Nfayil Formation , to the minimum value of 0.33 N/mm^2 in Nfayil formation , and the average is 0.952 N/mm^2,(Table-1).

The uniaxial compressive strength (qu) of rocks is calculated from point load test as in following equation:-

qu= 24* Is…….(2)

The uniaxial compressive strength of rocks in the study area ranges from the maximum value of 36 N/mm^2 in Nfayil Formation , to the minimum value of 8 N/mm^2 in Nfayil Formation , and the average is 22.865 N/mm^2, table-1, and the rock samples have been classified as very low uniaxial compressive strength to low uniaxial compressive strength according to(Bieniawski ,1975).

Table -1: Show the bulk density, point load index (Is), and uniaxial compressive strength of rocks in study area.

Sample No.	Formation	Rock type	Bulk density gm/cm^3	Is N/mm^2	qu= 24* Is N/mm^2
S1	Nfayil	Marl	2.12	0.5	12
S2	Nfayil	Limestone	2.52	1.5	36
S3	Nfayil	Marly limestone	2.25	1.054	25.3
S4	Nfayil	Marl	2.02	0.422	10.14
S5	Nfayil	Limestone	2.45	1.416	34
S6	Nfayil	Marl	2.02	0.541	13
S7	Nfayil	Limestone	2.55	1.416	34
S8	Nfayil	Limestone	2.32	1.291	31
S9	Nfayil	Marl	2.11	0.333	8
S10	Nfayil	Marly limestone	2.30	0.958	23
S11	Injana	Claystone	2.22	0.641	15.4
S12	Injana	Sandstone	2.37	1.291	31
S13	Injana	Siltstone	2.30	0.75	18
S14	Injana	Sandstone	2.34	1.375	33
S15	Injana	Claystone	2.13	0.708	17
S16	Injana	Sandstone	2.32	1.041	25
Average			2.271	0.952	22.865

Conclusions

1- The Nfayil Formation in the study area consists of marls interbedded with limestones and marly limestone. The lower contact with the Euphrates Formation is conformable and taken at the top of the limestone bed of Euphrates Formation and the base of green marl bed is more than 1 meter thick of Nfayil Formation. The Injana Formation consists of alternating reddish brown to grey sandstones, siltstones, and claystone. The lower contact with the Nfayil Formation is unconformable and occupied the top of the limestone bed of Nfayil Formation and the base of the brown claystone or sandstone bed of Injana Formation. The upper contact of Injana Formation is unconformable with overlong Quaternary deposited.

2- The Nfayil Formation is deposited mainly within the restricted, shoal and shallow open marine conditions. The Injana Formation is deposited in meandering river. Two main sub environments were identified; they are channel and flood plain.

3- Five 4th order cycles can be recognized within the Nfayil Formation in the study area. These cycles are asymmetrical reflecting an imbalance between the relative sea level and carbonate production, and two 4th order cycles can be recognized within the Injana succession. These cycles are asymmetrical and each represents a period of sea level rise following episode of stillstand. This succession was deposited on the unconformable surface with underlying Nfayil Formation. This surface is represented by type two sequence boundary (SB-2).

The Nfayil and Injana succession in the study area was developed in an area of low subsidence, which reflects the major effect of eustacy as the main controlling factor in sequence development. The Nfayil carbonates were deposited on a slowly subsidence carbonate platform as a result of a major transgression where succession episodes of sea level rise and stillstand. The subsequent sea level fall exposed the low gradient platform and reflected the progradation of the fluvial Injana facies where two 4th order cycles can be recognized as a result of relatively sea level fluctuation causing these base level transfer cycle.

4- The bulk density of rocks in the study area ranges from the maximum value of 2.55 gm/cm^3 in Nfayil Formation, to the minimum value of 2.02 gm/cm^3 in Nfayil Formation, and the average is 2.271 gm/cm^3. The point load index (Is) of rocks in the study area ranges from the maximum value of 1.5 N/mm^2 in Nfayil Formation, to the minimum value of 0.33 N/mm^2 in Nfayil Formation, and the average is 0.952 N/mm^2. The uniaxial compressive strength of rocks in the study area ranges from the maximum value of 36 N/mm^2 in Nfayil Formation, to the minimum value of (8) N/mm^2 in Nfayil Formation, and the average is 22.865 N/mm^2. Moreover, the rock samples have been classified very low uniaxial compressive strength to low uniaxial compressive strength according to (Bieniawski, 1975).

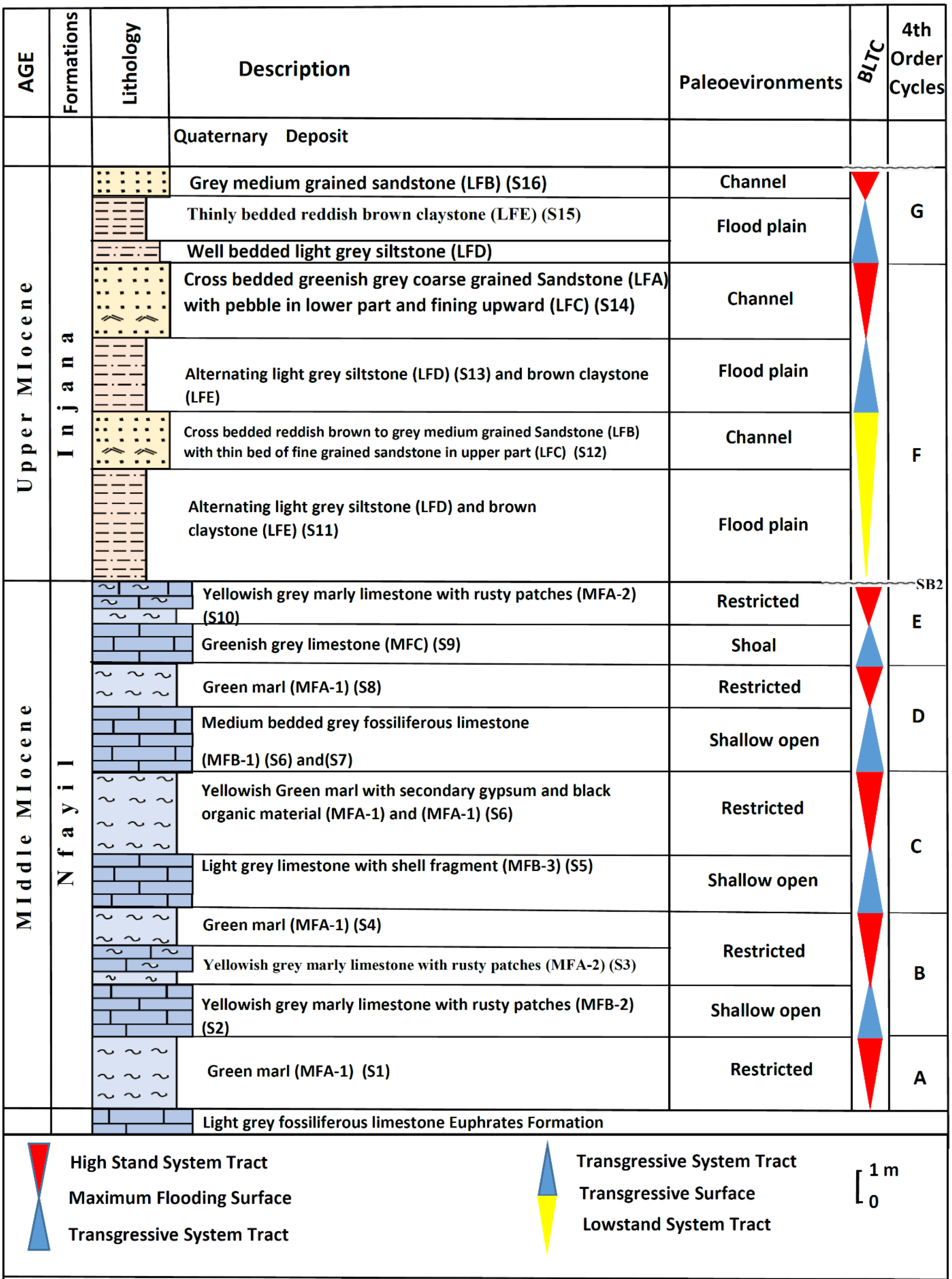

Fig. 2: Sequence stratigraphy subdivision of the Nfayil-Injana succession in the study area

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