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A Comparative Analysis and Environmental Interpretation of the First Cycle of Nfayil Formation in Two Distinct Southern Desert Locations, Iraq

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ABSTRACT: Nfayil Formation (Middle Miocene) is considered the equivalent of Fatha Formation; it is exposed in the western and southern Desert of Iraq with two members: a carbonate Lower Member that is composed of three cycles of limestone and marlstone intercalation and an Upper clastic Member of sandstone and claystone with thin layers of limestone. It extends from the western to the southern desert with a systematic succession of two or three cycles of lower members each one consisting of an interbedding of soft olive-green marl with medium tough shelly limestone rich with oyster shells. The upper member disappears in many localities due to erosion activity. From the field observation this succession was normally exposed in the southern Desert at the western parts of Al-Muthanna Governorate to the south of Dewaniyah Governorate, while in the eastern part of Al-Muthanna Governorate to the south of Al-Nasiriya Governorate, the beds showed a different lithology and fossil content. The olive-green marl turned to be rusty red with a higher content of fossils, the shelly limestone bed rich with oyster shells became red in colour, rusty and the oyster shells were substituted by pelecypods shells with the same concentration. A microfacies analysis study supported by chemical and X-ray analysis was carried out to predict the depositional environment and deposition circumstances in both sections. The thin section, chemical analysis and X-ray analysis were accomplished at the laboratories of the Iraq Geological Survey. Chemical analyses showed a high ratio of MgO oxide in Nasiriya section compare with Samawa section, that result was supported by X-ray analyses which refer to calcite mineral as the only mineral exists in Samawa beds while in Nasiriya minerals of dolomite, quartz, feldspar and clay minerals were appeared.

Environments extracted from thin section study showed more local fluctuations in sea level in Samawa section.

Key words: Middle Miocene, Nfayil Formation, pelecypods, Iraqi Desert

1. Introduction

Overall, the Nfayil Formation holds significance in the field of geology as it contributes to our understanding of past geological processes, environmental changes, and the geological history of southeastern Iraq during the specified timeframe. Nfayil Formation was exposed in several locations in Al-Muthanna Governorate as surface sections while the most abundance was as a subsurface section in drilled wells (fig. 1 and 2) [1]. It extends along the northern parts of the Southern Desert from west to east. In one location in the far east to the south of Al-Nasiriya and with a considerable area the first cycle of the lower member of the Formation showed a significant alteration in both, lithology and fossil content. Several samples were taken from this location to make a comparison study with the normal lithology a fossil content of Samawa Governorate section table No. (2,3).



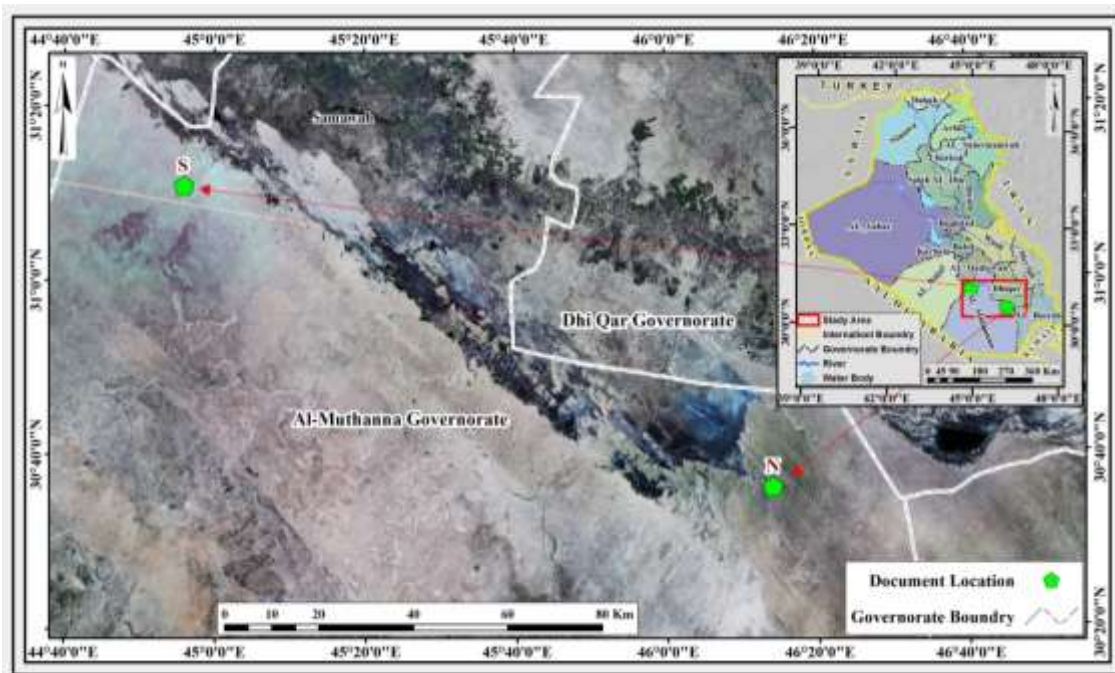


Figure 1: location map of the study area, green cycles represent the studied sections N:(Nasiriya), S:(Samawa).

Table 1: location coordinates of the study area.

Document	Northing	Easting	Long.	Lat.
N (Nasiriya)	3385970	618370	46.234752	30.600428
S (Samawa)	3449607	493587	44.932696	31.18049

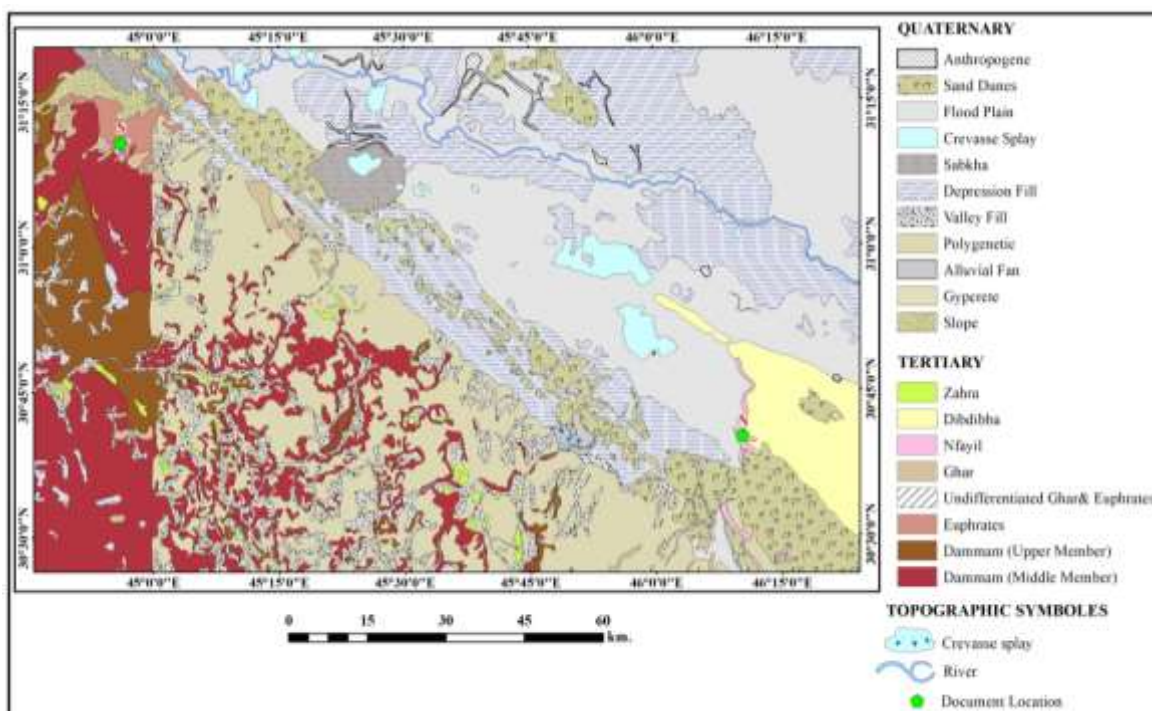


Figure 2: Geological map of the studied area, green cycles represent the studied sections

The Nfayil Formation has been extensively studied in Iraq, and several researchers have contributed to our understanding of its lithology, sedimentology, industrial, engineering and paleontology. Notable studies include:

The formation was officially announced by [1] [2] who stated that: In the western and southern Desert the equivalent of Fatha Formation, Nfayil Formation is exposed with two members: carbonate Lower Member composed of three cycles of limestone and marlstone intercalation and Upper clastic Member of sandstone and claystone with thin layers of limestone [3].

[4] studied the biostratigraphy and deposition environments of Hit- Kubaisa area from subsurface sections. She divided Miocene deposits into two cycles; Early Miocene transgressive cycle which is represented by Euphrates Formation and Middle Miocene regressive cycle which is represented by (Lower Fars) Fatha Formation. She stated that; the lithological and faunal characteristics indicate an open marine platform to near shore – shallow marine environments to the Miocene deposits.

[5] [6] accomplished a microfacies analysis and sequence stratigraphy of the Eocene – Miocene succession at Karbala- Najaf- Samawa area, he divided the Miocene succession into two formations; Euphrates Formation of Early Miocene age and Nfayil of Middle Miocene age. He referred to the occurrence of *Miogypsina* sp. in Nfayil Formation.

[7 and 8] carried out a detailed geological mapping of two stages in the south of Samawa area, he divided the Miocene deposits into two formations; Euphrates and Nfayil Formations, the later was divided into 3 cycles.

The primary objective of the study is to conduct a detailed analysis of the microfacies and geochemical composition within the Nfayil Formation. This analysis serves the purpose of deciphering the distinct depositional environments that shaped the formation. The comparative assessment between two separate sections of the formation is undertaken with the specific aim of discerning and delineating the variations existing between these sections. This comparative analysis sheds light on the nuanced differences in sedimentary characteristics, lithological composition, and geochemical signatures, allowing for a comprehensive understanding of the contrasting environments that influenced the formation's development in these distinct sections.

2. Geological Setting:

The Nfayil Formation is a geological unit within the western and southern Desert. It dates back to the Middle Miocene to epoch, approximately 15 million years ago. This period was characterized by significant geological and climatic changes globally [1]. Two members are divided the Nfayil Formation: carbonate Lower Member composed of three cycles of limestone and marlstone intercalation and Upper clastic Member of sandstone and claystone with thin layers of limestone [2]

2.1. Samawa Section:

Nfayil beds in Samawa city region appear with normal strata of interbedded marl and marly limestone beds. Geomorphologically the formation shows typical Mesas that related with Nfayil Formation occurrence in many localities [2] (plate 1. A). Two samples were taken and described as below:

Table 2: Field description of Samawa section (bottom to top)

Bed No.	Formation	Age	Rock's field name	colour	hardness	description
S1	Nfayil	Middle Miocene	marlstone	Greenish grey with pale brown	soft	Slope forming, fragmented, contain rusty and black materials, shiny surface due to recrystallization. High reaction with acid, Sharp contact. (Plate 1 B)
S2	Nfayil	Middle Miocene	Shelly limestone	Yellowish brown mottled with grey dark brown	Tough to very tough	Cliff forming, recrystallized, contains oyster shells with very high concentration, high reaction with acid. (plate1. C and D)



Plate1: A. Mesa of Nfayil Formation in Samawa region, B. Marlstone bed (No.1) in Samawa section, C. Shelly limestone bed (No.2) in Samawa section, D. oyster shells in the bed scattered around section

2.2. Nasiriya section:

In the eastern parts of Al- Muthanna governorate to the south of Nasiriya an exposure of first cycle of Nfayil Formation with different criteria of colour and fauna assemblage. the whole cycle appears with a significant rusty to brownish red colour with high concentration of

pelecypods shells scattered in the area due to erosion activity. Two samples were picked to be described and studied as below:

Table 3: Field description of Nasiriya section (bottom to top).

Bed No.	Formation	Age	Rock's field name	colour	hardness	description
N1	Nfayil	Middle Miocene	Clayey dolostone	Reddish brown to brown	soft	Slope forming, fragmented, few fossils appear, sand content, no reaction with HCl acid, sharp contact (plate2. A)
N2	Nfayil	Middle Miocene	Shelly dolostone	Rusty red	Medium tough	cap forming, very high assemblage of pelecypods shells floats on the bed texture, with a content of sand grains, no reaction with HCl acid, (plate 2 B and C)



Plate2: A. Clayey dolostone (bed No.1) in Nasiriya section. B. Pelecypoda shells float on the surface of Shelly dolostone (bed No.2 in Nasiriya section), C. Hand specimen of shelly dolostone bed

3. Methodology

Four samples were sent to the laboratories of Iraqi geological survey for each. chemical and X-ray analysis. Thin sections were prepared in the workshop of the Iraqi Geological Survey laboratories and classified according to [9] [10].

4. Microfacies analysis

In Samawa section two microfacies were recognized as the following:

1- Marlstone bed was classified as micritic mudstone (plate 2.A).

This microfacies is compatible with the SMF no. 23 in [11]. Which meets the facies zone No. 8,9 of [12]. According to these two facies zones the deposition environment of this bed ranges from an evaporative or brackish environment to a restricted environment.

2- Shelly limestone bed described as shelly wackestone with authigenic quartz and bioclast of gastropods (plate 2B).

Following the standard microfacies (SMF) of [12] and the facies zones (FZ) of [13] this microfacies is compatible with standard microfacies No. 12S and No.10, the inferred deposition environment according to the facies zone was restricted to the open marine environment.

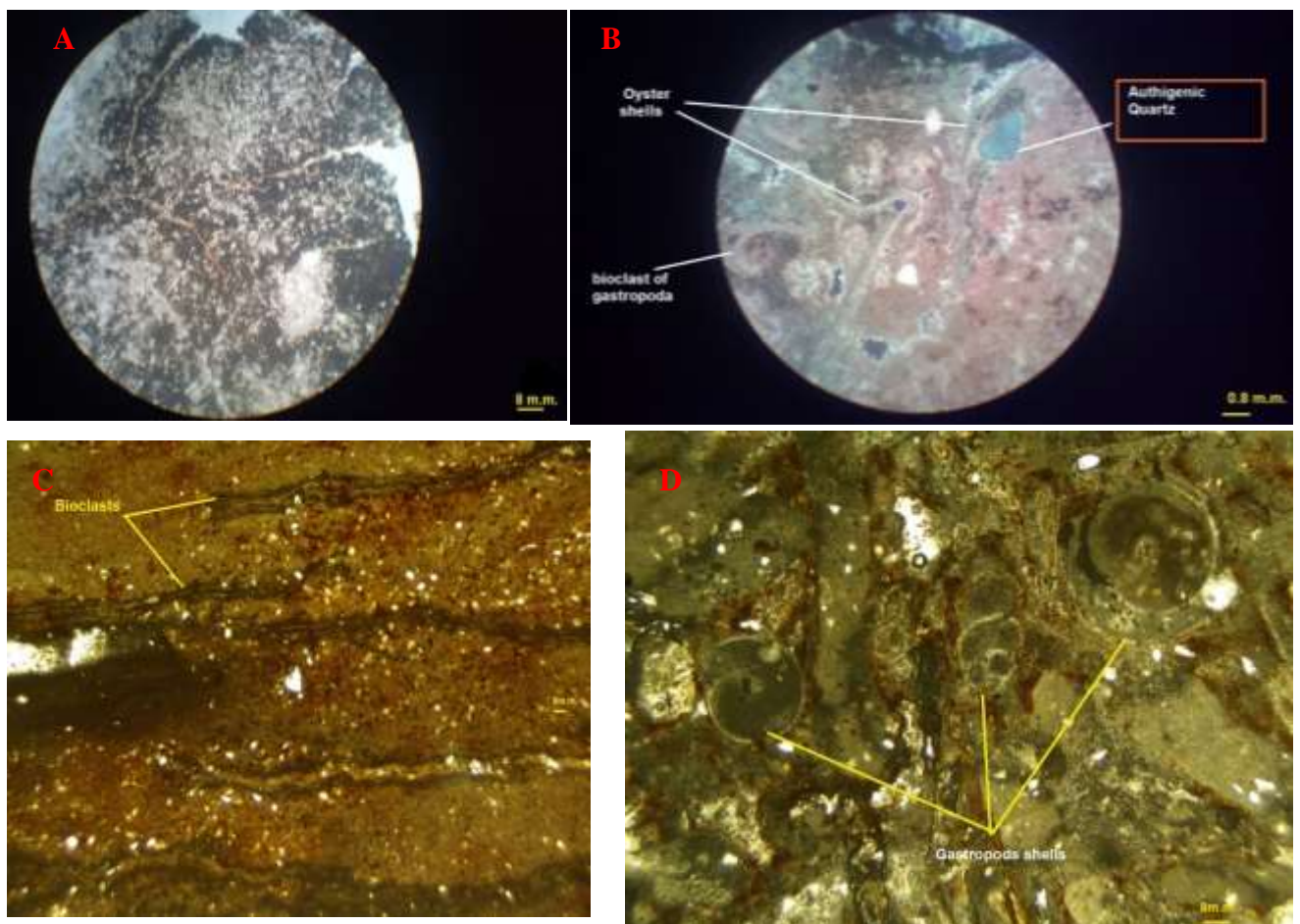


Plate 3- A. Micritic mudstone in Samawa section. B. clayey silty bioclastic dolomitic wackestone microfacies in Nasiriya section. C. clayey silty bioclastic dolomitic wackestone microfacies, D. bioclastic (Mollusca) dolomitic wackestone to packstone.

The microfacies observed in Nasiriya section were as below:

1-Clayey dolomite bed was classified as clayey silty bioclastic dolomitic wackestone (plate 2 C). Quartz and feldspar in silt size with ferruginous and clayey materials were observed. Bioclasts of shells mostly of pelecypods embedded in groundmass.

This microfacies is equivalent to SMF9 and SMF 10 which meet FZ7 of open marine environment in platform interior [11].

2-Shelly dolomite bed described as sandy bioclastic (Mollusca) dolomitic wacke to packstone. (Plate 2.D). Bioclasts of Mollusks (pelecypods and gastropods) embedded in sparry groundmass which contains clayey and ferruginous materials with quartz and feldspar grains of sand size. This microfacies is equivalent to SMF10 and open marine platform interior FZ7 in [11].

5. Chemical analysis

Chemical and X-ray analysis. Samawa section analysis results were as below:

Table 4: Chemical analysis of Samawa section.

Sample No.	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	SO ₃	Na ₂ O	K ₂ O	P ₂ O ₅	Cr p.p.m	Mn p.p.m
S1	14.98	1.63	3.47	40.61	1.56	0.41	0.69	0.77	0.38	59.00	210.00
S2	2.64	0.46	0.51	52.28	1.23	0.58	0.11	0.16	0.17	25.00	140.00

X-ray analysis results of Samawa section showed the majority of calcite minerals for all samples. The high ratio of calcium oxide for both beds in the chemical analysis was supported by X-ray analysis results which showed the appearance of only calcite mineral and the two beds are pure limestone. In the section of Nasiriya vicinity, the results of chemical and X-ray analyses were as shown in tables (5,6):

Table 5: Chemical analysis of Nasiriya section.

Sample No.	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	SO ₃	Na ₂ O	K ₂ O	P ₂ O ₅	Cr p.p.m	Mn p.p.m
N1	10.92	1.02	1.87	26.54	16.66	0.45	1.58	0.31	0.29	29.00	292.0
N2	18.70	1.74	3.94	19.75	15.28	0.50	2.06	0.71	0.39	59.00	346.0

X-ray analysis results was as below:

Table 6: x-ray analysis results for Nasiriya section

Sample No.	Description
N1	Dolomite, Halite, Quartz, Feldspar
N2	Dolomite, Halite, Quartz, Feldspar, palygorskite

The high ratio of magnesium oxide in chemical analysis was supported by the presence of dolomite as the main mineral in X-ray analysis.

That explains why the rocks had no reaction with acid in field.

The presence of halite reflexes a hypersaline condition environment, evaporate deposits are products of arid environments [11]. Halite can occur as a poikilitic cement in either carbonate or siliciclastic strata [14] [15].

while the content of feldspar and quartz refers to a clastic influx and continental attachment.

6. Discussion

The discussion for these results could focus on the sedimentary environments and the implications of the identified microfacies within the studied sections in Samawa and Nasiriya.

Sedimentary Environments:

The identified microfacies within the Samawa and Nasiriya sections exhibit distinctive characteristics that provide insights into the ancient depositional environments.

At Samawa Section, the presence of micritic mudstone suggests fluctuating or restricted marine conditions. Shelly limestone with authigenic quartz indicates a more stable, open marine environment conducive to the preservation of shelly fauna. While the Nasiriya Section has clayey dolomite and shelly dolomite beds, both signify an open marine environment within the platform interior, indicating a continuous or similar depositional setting [16](fig.3).

The presence of bioclasts, including pelecypods and gastropods, suggests a favorable environment for the thriving of diverse marine life. Both sections exhibit microfacies indicative of open marine environments, albeit with varying sediment compositions and specific characteristics. While the Differences between the two sections: The Samawa section includes indications of brackish to restricted environments, which might suggest local variations or changes in depositional conditions over time or space compared to the more consistently open marine environment in the Nasiriya section. The dominance of limestone and dolomite minerals supports the inference of a predominantly carbonate-based depositional environment, possibly within a marine setting due to the prevalence of calcite and dolomite. The presence of halite points toward arid conditions, indicative of evaporative deposits. This suggests periods of aridity or hypersaline conditions that influenced sediment deposition, possibly within an arid or semi-arid environment.

7. Conclusion:

The microfacies analysis in both sections reveals a predominantly open marine setting, with the Samawa section exhibiting some variations hinting at localized environmental fluctuations between an evaporative to brackish up to restricted marine environment with an open marine to restricted marine environment while in Nasiriya section the both beds were of open marine platform interior environment with continuous constant sea level deposition. These findings contribute to reconstructing the ancient depositional settings and understanding the evolution of sedimentary environments in the studied region. The mineralogical composition and the presence of specific minerals such as calcite, dolomite, and halite in the Samawa section offer valuable insights into the environmental conditions during deposition. The predominance of carbonate minerals suggests a marine influence, while the occurrence of halite indicates periods of aridity or hypersaline. These findings contribute to a more nuanced understanding of the ancient environmental conditions and sedimentary processes that shaped the formation of these rock beds in the Samawa section.

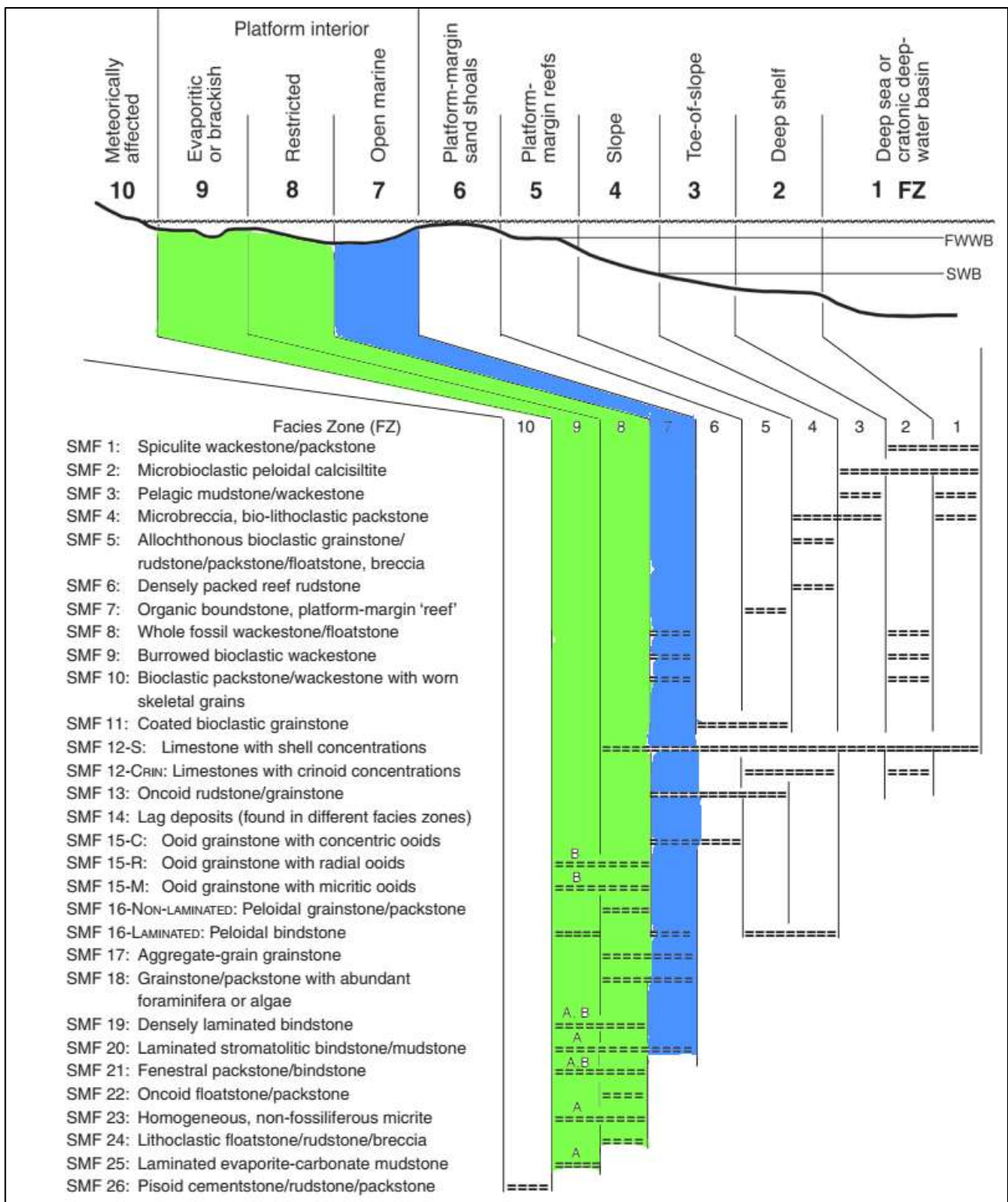


Figure 3. The suggested environments of studied area that projected on Flugel's model [11], green zone presents the Marlstone bed in Samawa section which classified as micritic mudstone is compatible with the SMF no. 23 in facies zone No. 8,9. Blue zone present the Shelly limestone bed described as shelly wackestone with authigenic quartz and bioclast of gastropods, also Clayey dolomite bed was classified as clayey silty bioclastic dolomitic

wackestone, finally Shelly dolomite bed described as sandy bioclastic (Mollusca) dolomitic wacke to packstone. All of these microfacies are located at SMF no. 9, 10 and 12 s that deposited at open marine [11].

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