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Postnikova O.V., Nilchi F.
Russian State University of Oil and Gas (National Research University) named after I.M. Gubkin, Moscow, Russia, olgapostnikova@yandex.ru

MICROFACIES AND SEDIMENTARY ENVIRONMENT OF ILAM AND LAFFAN FORMATIONS IN BANGESTAN MOUNTAIN, SOUTHWEST OF IRAN

Ilam (Cenomanian-Santonian) and Laffan (Coniacian) Formations are part of the Bangestan Group, which are located between Gurpi Formation on the top and Sarvak Formation on the bottom. The Ilam Formation is considered one of the main hydrocarbon reservoirs of the Bangestan Group in the Southwest of Iran. In this study, Ilam and Laffan Formations have been investigated in two sections of Tang-e Ban and Tang-e Abolfares areas. The purpose of this study is to identify and determine the microfacies and sedimentary environment of Ilam and Laffan Formations. The petrographic studies and facies analysis in the Tang-e Ban and Tang-e Abolfares sections led to the identification of 9 microfacies types that were deposited in lagoon, shoal, and open sea environments, which were located in the inner, middle, and outer-ramp setting. Due to the type of microfacies studied in both sections, the absence of large barrier reef, slump structures, calciturbidite, oncoids and pisoids, could consider that this sequence has been deposited in a homoclinal carbonate ramp environment.

Keywords: *Ilam Formation, Laffan Formation, Bangestan Group, microfacies type, sedimentary environment, carbonate ramp, Southwest of Iran.*

Introduction

One of the most common petroleum reservoir rocks in the world are carbonate rocks, which are often seen as limestone and dolomite. The most important oil and gas reserves of Iran, such as the Asmari (Late Oligocene - Chatian to Early Miocene - Aquitanian), Ilam (Cenomanian-Santonian) and Sarvak (Albian-Turonian) limestone Formations, which are located in the South and Southwest of Iran, are also accumulated in carbonate reservoirs. The ability to dissolve lime in water due to the phenomenon of diagenesis, as well as the brittleness of carbonate rocks and the creation of seams and cracks in them increases the porosity of these rocks and makes them suitable reservoirs for oil and gas storage.

The notion of Ilam limestone Formation was introduced for the first time by James G. and Wynd J. [James, Wynd, 1965] in Tang-e Grab area, in the Northwest of Kabir-Kouh anticline. This Formation at type section includes 190 meters of gray limestone with medium to thin layers along with shale interlayers and has a pelagic facies rich in Oligostegina and planktonic Foraminifera such as Globotruncana, whose is continuously located over the Gurpi Formation (Middle Campanian through Late Paleocene - Selandian) and is discontinuously located under the Sarvak Formation. The age of Ilam

Formation is Cenomanian-Santonian [James, Wynd, 1965], and it plays undergroundly the role of oil reservoir rock in the Khuzestan region and is located at the top of the Bangestan reservoir. Bolz H. in report “Reappraisal of the Biozonation of the Bangestan Group (Late Aptian - Early Campanian) of southwest Iran” (Report 1252. Tehran: RGU Iranian offshore company, 1977) notes the Laffan Formation with Coniacian age in Iran for the first time in the Persian Gulf. He believes that both Surgah and Laffan Formations could have been deposited in similar deep environments, but their sedimentary environments were different.

In Bangestan Mountain, in both sections under study, the Ilam Formation is gradually located top of the Laffan Formation and continuously under the Gurpi Formation (Fig. 1).

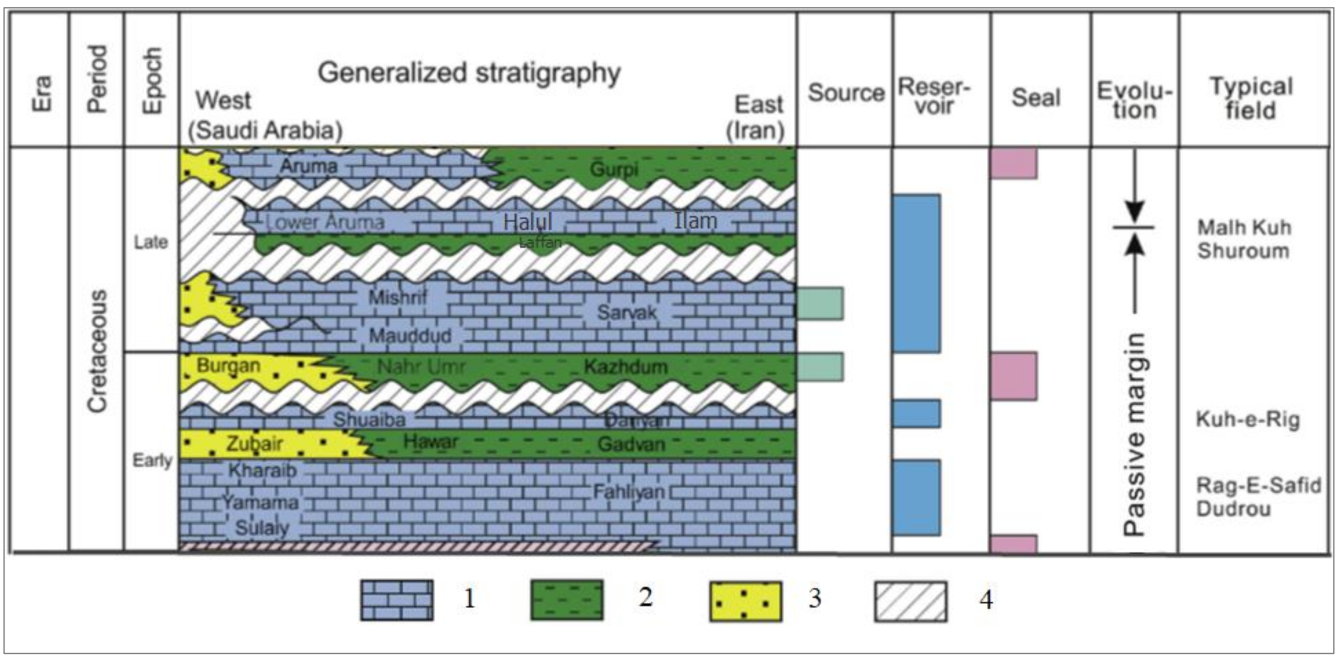

Fig. 1. Correlation chart of Cretaceous strata, Zagros Basin, Iran [James, Wynd, 1965]
1 - limestone, 2 - mudstone, 3 - clastic, 4 - erosion.

Khalili M. in report “The biostratigraphic synthesis of the Bangestan group in South West Iran” (Report 1219. Tehran: Offshore Oil Company of Iran, 1974) informed the freshwater and brackish water sediments of Laffan Formation in the areas of Bangestan Koranj and Khoviz Mountains, whose main characteristic is the widespread presence of Charophyta and Ostracoda fossils. The purpose of the present study is to investigate facies, identify microfacies and reconstruct the sedimentary environment of Ilam and Laffan Formations in Bangestan Mountain. Lithology of the Ilam and Laffan Formations in the studied sections is mainly limestone with interbedded shale.

Methods

Sampling was done in two sections of Ilam Formation (with a thickness of 59 meters in Tang-E Ban area and with a thickness of 67 meters in Tang-e Abolfares area) and Laffan Formation (with a thickness of 10 meters in Tang-E Ban and with a thickness of 5 meters in Tang-e Abolfares). The 168 thin sections were prepared from rock samples and finally studied with a polarizing microscope.

Have been used the method Flügel E. [Flügel, Munnecke, 2010] and standard Burchette T.P., Wright V.P. [Burchette, Wright, 1992] to determine and distinguish the microfacies and finally draw the model of the sedimentary environment (Fig. 2).

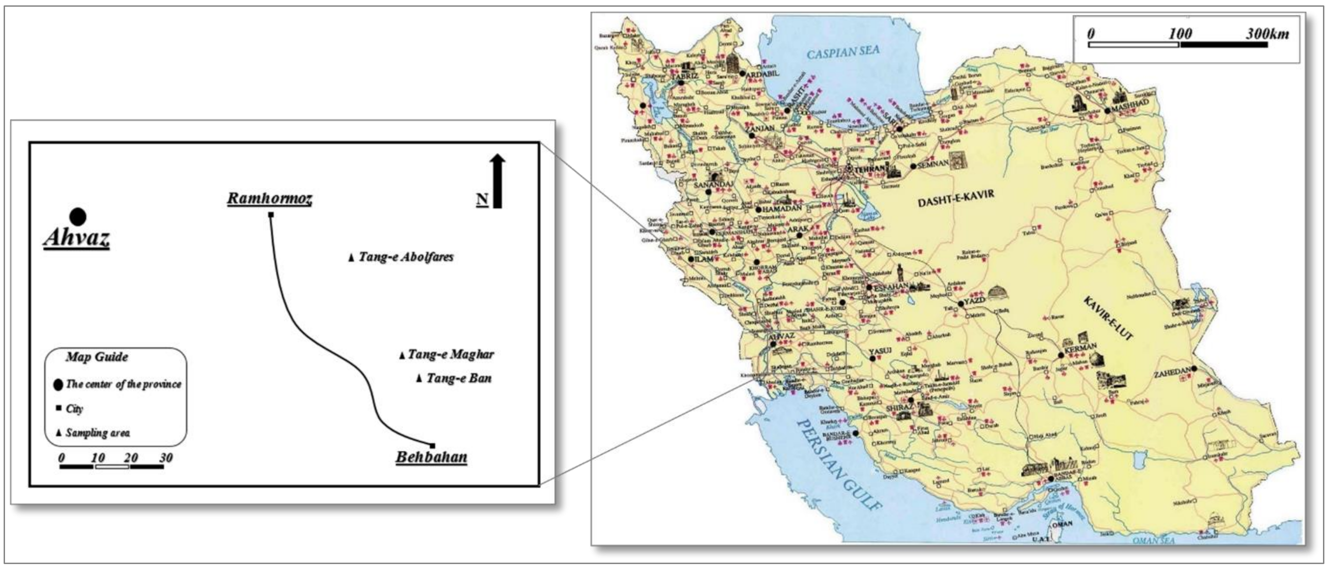

Fig. 2. The map of Iran (https://images.app.goo.gl/wyaDq5rW5CMmHokY7) and the geographical location of the studied area, which is on the southern edge of the Bangestan anticline in Khuzestan province

Microfacies analysis

Identification of microfacies and facies belts is one of the main parts of reservoir geology study in comprehensive reservoir studies [Ahr, 2008; Moore, Wade, 2013]. The microfacies description of the Ilam Formation has been carefully presented in some past studies in the Zagros basin [Adabi, Mehmandosti, 2008; Ghabeishavi, Vaziri-Moghaddam, Taheri, 2009; Mehrabi et al., 2013; Rahimpour-Bonab et al., 2013; Khodaei et al., 2021]. Based on the petrographic studies, analysis of microfacies and identification of the sedimentary environment of Ilam and Laffan Formations, in Tang-e Ban and Tang-e Abolfares sections, in line with the study of lithology, textural and diagenesis characteristics were investigated, which finally led to the identification of 9 microfacies that it is discussed below.

Laffan Formation

MF 9. Charophyta mudstone - wackestone

This microfacies is spread in the limestone and shale layers of both Tang-e Ban and Tang-e Abolfares sections. Among the important features of this microfacies can mention the existence relatively large amounts of Charophyta green algae and smaller amounts of Ostracoda in a mud-supported texture (Fig. 3 A, B).

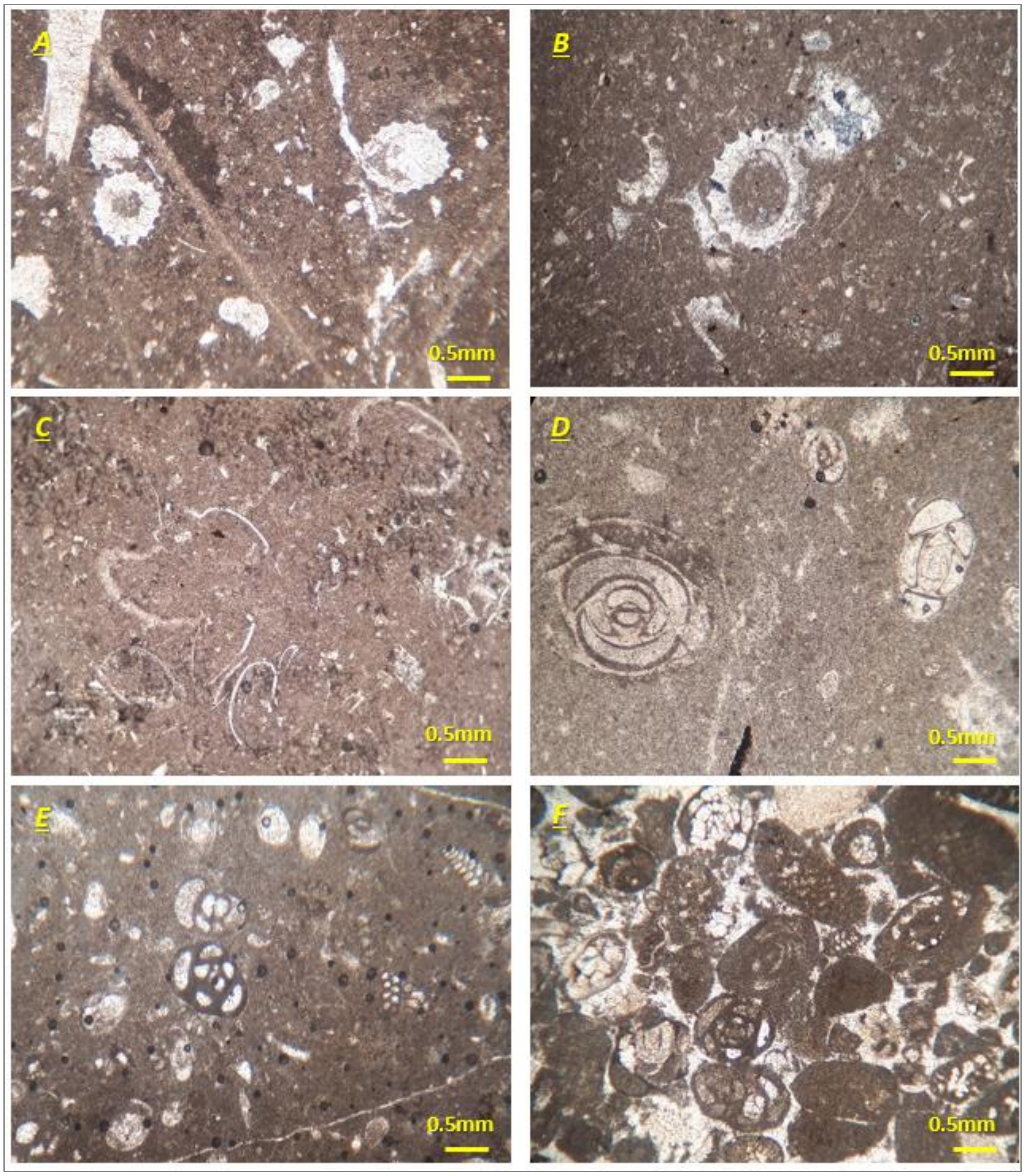

Fig. 3. Foto microfacies of Ilam and Laffan Formations

A, B - Charophyta mudstone - wackestone (MF 9), C - Ostracoda wackestone (MF 8), D, E - Miliolids wackestone (MF 7), F - Miliolids bioclast pack - grainstone (MF 6).

Interpretation

High amounts of monotypic Charophyta are interpreted as indicators of especially fresh to brackish and calcium-rich water and also the fossil forms of this group are found in shales and limestones [Racki, 1982]. In the Organyá Basin, a similar microfacies was reported from the lacustrine environment [Bernaus, Arnaud-Vanneau, Caus, 2003].

Based on Khalili M. (1974) studies that reported the freshwater and brackish water sediments of Laffan in the areas of Bangestan Mountains, whose main characteristic is the widespread presence of Charophyta and Ostracoda fossils, this microfacies is a good indicator of Laffan Formation in the study area.

MF 8. Ostracoda wackestone

This microfacies is spread in the limestone and shale layers of both Tang-e Ban and Tang-e Abolfares sections. Among the important features of this microfacies, can mention the existence relatively large amounts of Ostracoda in a mud-supported texture (Fig. 3 C).

Interpretation

High amounts of monotypic Ostracoda are interpreted as indicators of fresh, brackish; seawaters even exist in very salty environments, especially in shales and limestones. Except for high stress environments such as salty, very salty and sweet waters, these fossils are rarely the main producers of sediments [Scholle, Ulmer-Scholle, 2003]. The presence of Ostracoda and the absence of marine fauna is characteristic of shallow freshwater or saltwater environments.

Based on Khalili's M. (1974), this microfacies also is the indicator of Laffan Formation in the study area.

Ilam Formation

MF 7. Miliolids wackestone

This microfacies is spread in the limestone and shale layers of both Tang-e Ban and Tang-e Abolfares sections. Among the important features of this microfacies, can mention the existence benthic Foraminifera including miliolids in the wackestone texture. In some parts of this microfacies, fracture is also observed (Fig. 3 D, E).

Interpretation

Miliolids are benthic species of Foraminifera that are found with low diversity and high abundance in high or semi-saline environments [Scholle, Ulmer-Scholle, 2003]. In this microfacies, the low diversity of benthonic Foraminifera in the wackestone matrix and the relative abundance of oligotypic fauna of miliolids are interpreted as indicators of especially very shallow and limited environment with low to medium energy. This microfacies is the indicator of Ilam Formation in the study area.

MF 6. Miliolids bioclast pack - grainstone

This microfacies is spread in the limestone layers of Tang-e Ban section. Among the important features of this microfacies, can mention the existence high amounts of benthonic Foraminifera including miliolids in the grainstone texture (Fig. 3 F).

Interpretation

The structural characteristics of this microfacies indicate sedimentation in the environment behind the dam (leeward). Miliolids are benthic species of Foraminifera that are found with low diversity and high abundance in high or semi-saline environments [Scholle, Ulmer-Scholle, 2003]. This microfacies is similar to standard microfacies RMF 20 introduced by Flügel E. [Flugel, 2016] and belongs to the lagoonal environment in the inner ramp settings.

In this microfacies, the low diversity of benthonic Foraminifera in the grainstone background and the relative abundance of oligotypic fauna (such as miliolids) are characteristic of a shallow environment with medium to high energy. This microfacies is the indicator of Ilam Formation in the study area.

MF 5. Ooid bioclast packstone to grainstone

This microfacies consists of deformed ooids that have been affected by diagenesis, in the grainstone texture. Bioclasts are mostly unrecognizable due to diagenetic processes, but according to the remaining texture in their structure, they can be attributed to bryozoans and echinoids (Fig. 4 A).

Interpretation

Since the best environment for the formation of ooids is high-energy environments and also the presence of the grainstone texture indicates the formation of this microfacies in the shoal environment [Scholle, Ulmer-Scholle, 2003]. This microfacies is the indicator of Ilam Formation in the study area.

MF 4. Echinoid - bioclast grainstone

This microfacies is composed of a cement matrix with a relatively high amount of echinoids and bioclast fragments such as gastropoda, bryozoa and ooids. This microfacies is mainly occurs in massive limestones (Fig. 4 B).

Interpretation

This microfacies, like the MF 5 microfacies, indicates the deposition in high environmental energy conditions. Also, due to presence of the relatively high accumulation of echinoid fragments in the grainstone texture, can be attributed this microfacies to the front part of the shoal (seaward). This microfacies is the indicator of Ilam Formation in the study area.

MF 3. Planktonic Foraminifera wackstone

This microfacies is spread in the limestone and shale layers of both Tang-e Ban and Tang-e Abolfares sections. Among the important features of this microfacies, can mention the existence of planktonic Foraminifera in the wackestone texture (Fig. 4 C, D).

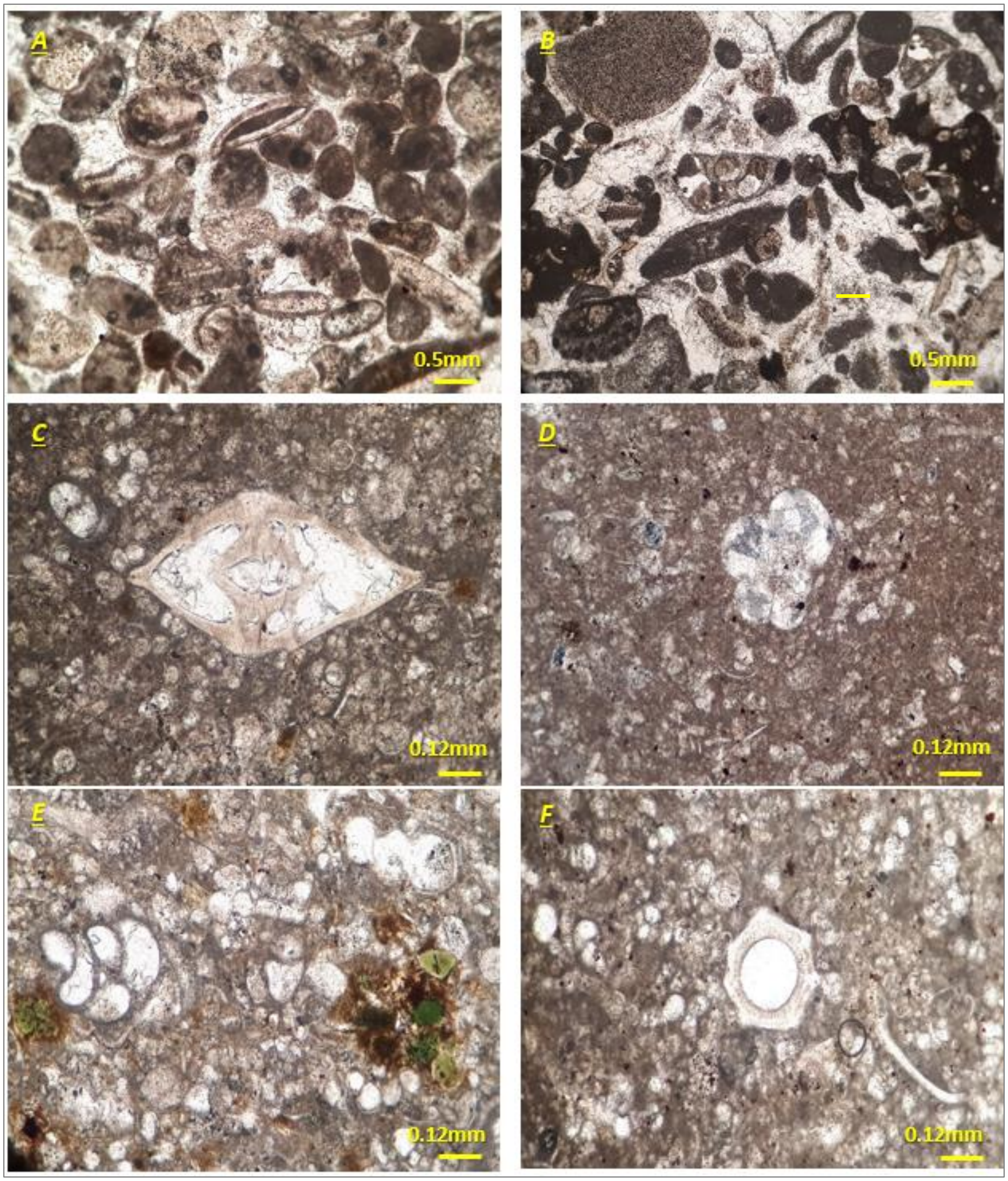

Fig. 4. Foto microfacies of Ilam Formation

A - Ooid bioclast packstone to grainstone (MF 5), B - Echinoid - bioclast grainstone (MF 4), C, D - Planktonic Foraminifera wackstone (MF 3), E - Planktonic Foraminifera packstone with glauconite (MF 2), F - Bioclast sponge spicules wackestone (MF1).

Interpretation

Foraminifera may be considered among the main elements forming rocks in open or limited platforms as well as in deeper deposits of the sea. In some cases, the abundance of Foraminifera reaches tens of thousands per cubic meter of sediment [Scholle, Ulmer-Scholle, 2003]. The general characteristics of this microfacies indicate the deposition of sediments in a low-energy environment of the open sea, which are characterized by abundant amounts of well-preserved planktonic Foraminifera and the absence of clastic fragments. The low level of dynamic energy indicates sedimentation below the normal wave line (SWB) [Wilson, 1975, Flügel, Munnecke, 2010]. This microfacies is the indicator of Ilam Formation in the study area.

MF 2. Planktonic Foraminifera packstone with glauconite

This microfacies is spread in the marly limestone layers of both Tang-e Ban and Tang-e Abolfares sections. Among the important features of this microfacies, can mention the existence planktonic Foraminifera (Oligostegina) in the packestone texture. Other components include small fragments of echinoids, and relatively high amounts of glauconites (Fig. 4).

Interpretation

Oligostegina planktonic Foraminifera and small amounts of clastic fragments are characteristic of a relatively deep environment with low energy and below the normal wave line (SWB) [Scholle, Ulmer-Scholle, 2003]. The abundance of planktonic Foraminifera and Oligostegina in a mud-supported texture indicates deposition in a low-energy, deep marine setting [Schulze, Kuss, Marzouk, 2005]. The presence of glauconite indicates a low level of sedimentation in a deep environment and less oxygenated or reducing conditions [Odin, Matter, 2003]. This microfacies is the indicator of Ilam Formation in the study area.

MF1. Bioclast sponge spicules wackestone

This microfacies is spread in the limestone layers of both Tang-e Ban and Tang-e Abolfares sections. Among the important features of this microfacies, can mention the existence planktonic Foraminifera (Oligostegina) and sponge needles in the wackestone texture (Fig. 4 F).

Interpretation

Planktonic Foraminifera and sponge needles are characteristic of a relatively deep environment (depths above 1000 meters). Large amounts of well-preserved plankontic Foraminifera are characteristic of sedimentation in the open marine, deep subtidal environments with low energy and below the normal wave line (SWB) [Scholle, Ulmer-Scholle 2003]. This microfacies is the indicator of Ilam Formation in the study area.

Sedimentary environment

The petrographic studies and facies analysis of the Ilam and Laffan Formations in the Tang-e Ban and Tang-e Abolfares sections led to the identification of 9 microfacies that were deposited in lagoon, shoal, and open to deep marine which were located in the inner, mid-ramp and outer-ramp. Due to the type of microfacies in both sections, the absence of large barrier reef, slump structures, calciturbidite, oncoids and pisoids, this sequence deposited in a homoclinal carbonate ramp environment. By comparing the known microfacies with the standards of Wilson [Wilson, 1975] and Flügel E. [Flügel, Munnecke, 2010] and studying the stratigraphic and tectonic status of the Ilam and Laffan Formations, the sedimentary environment model of this formations has been identified as a homoclinal carbonate ramp type, which has a relatively gentle slope. It is uniform and stretches from the coastline to the basin (Fig. 5).

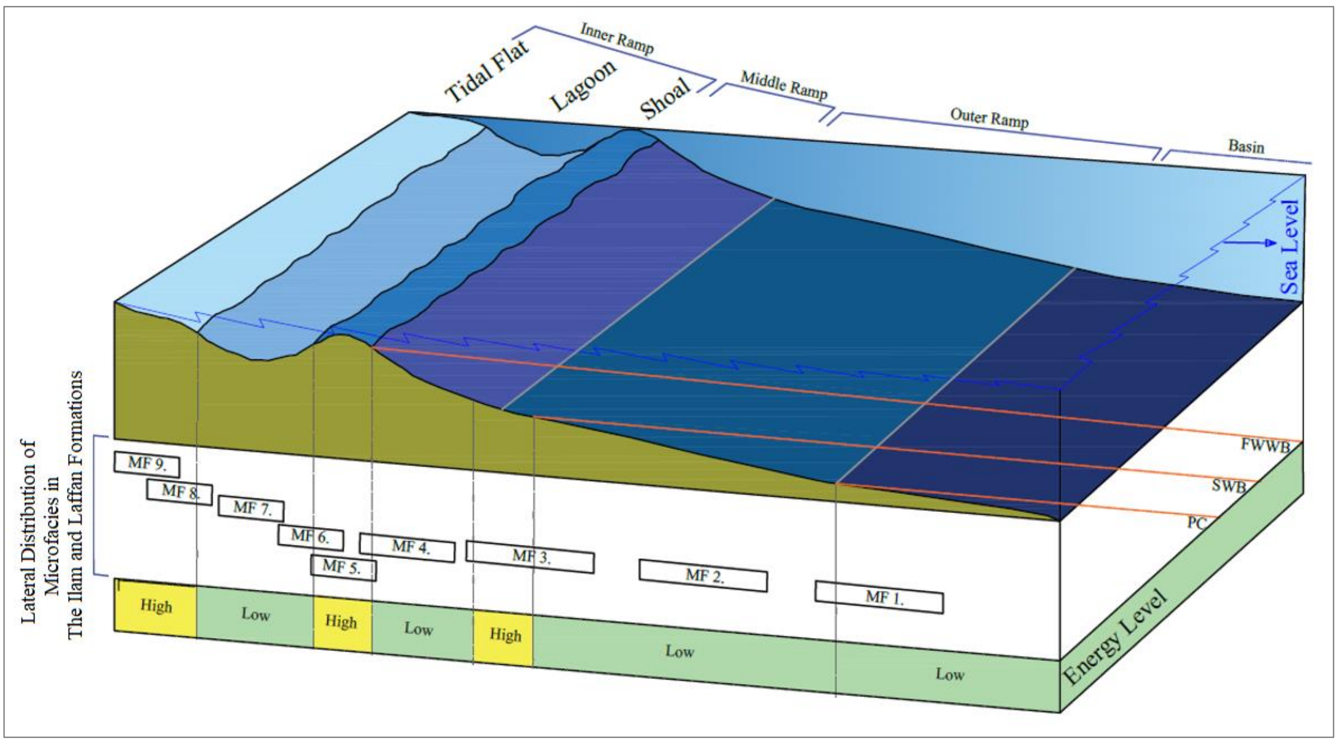

Fig. 5. The schematic model showing microfacial distribution of the Ilam and Laffan Formations in Tang-e Ban and Tang-e Abolfares (Bangestan Anticline, SW Iran)
(with additions and changes [Burchett, Wright, 1992, Flugel, 2016])

Conclusion

In the study area Ilam (Cenomanian-Santonian) and Laffan (Coniacian) Formations (part of the Bangestan Group) are located between Gurpi Formation (Middle Campanian through Late Paleocene) on the top and Sarvak Formation (Albian-Turonian) on the bottom. Lithology of the Ilam and Laffan

Formations in the studied sections is mainly limestone with interbedded shale.

The strata of Ilam and Laffan has been subdivided by author into 9 microfacies types (MF 9-1). These have been deposited in the lagoon, shoal, and open marine facies belts.

Laffan Formation: MF 9-8 belongs to fresh to brackish and calcium-rich water.

Ilam Formations: MF7 belongs to lagoon, MF 6-4 belongs to shoal and MF 3-1 belongs to shallow and deep open marine that were located in the inner, mid-ramp and outer-ramp.

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Постникова О.В., Нилчи Ф.
Российский государственный университет нефти и газа (национальный исследовательский университет) им. И.М. Губкина, Москва, Россия, olgapostnikova@yandex.ru

МИКРОФАЦИИ И ОБСТАНОВКА ОСАДКОНАКОПЛЕНИЯ СВИТ ИЛАМ И ЛАФАН БАНЖЕСТАНСКОЙ ГРУППЫ, ЮГО-ЗАПАД ИРАНА

Свиты илам (сеноман-сантон) и лаффан (коньяк) входят в состав банжестанской группы и располагаются между двумя свитами: гурпи - сверху, сарвак - снизу. Свита илам считается одним из основных коллекторов углеводородов в толщах банжестанской группы на юго-западе Ирана.

Свиты илам и лаффан исследованы на двух участках Танг-э Бан и Танг-э Аболфарес. Целью изучения является определение и идентификация микрофаций и обстановок осадконакопления этих свит. Петрографические исследования и фациальный анализ пород в разрезах Танг-э Бан и Танг-э Аболфарес позволили идентифицировать 9 микрофаций, отложившихся в условиях лагуны, мелководья и открытого моря, которые располагались во внутренней, средней и внешней частях карбонатного рампа. Благодаря отсутствию крупного барьерного рифа, оползневых структур, кальцитурбидитов, онкоидов и пизоидов, и выделенным типам микрофаций в обоих разрезах, можно предположить, что эти толщи откладывались на моноклинальном карбонатном склоне.

Ключевые слова: *свита илам, свита лаффан, группа банжестан, микрофации, обстановка осадконакопления, карбонатный рамп, юго-запад Ирана.*

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