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MICROFACIES ANALYSIS, DEPOSITIONAL ENVIRONMENT, AND DIAGENETIC PROCESSES OF THE KHANEH-ZU FORMATION IN THE EAST OF KOPET DAGH BASIN (NORTHEAST IRAN)

ANÁLISE DE MICROFACES, AMBIENTE DEPOSITÁRIO E PROCESSOS DIAGENÉTICOS DA FORMAÇÃO KHANEH-ZU NO LESTE DA BACIA DE KOPET DAGH (NOROESTE DO IRÃ)

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Resumo

A Formação Khaneh-Zu (Oxfordian-Kimmeridgian) é um reservatório de hidrocarbonetos na bacia de Kopet Dagh. Os principais objetivos desta pesquisa são investigar as microfaces, o ambiente deposicional e os processos diagenéticos dessa formação em duas seções de afloramentos na bacia de Kopet Dagh, no nordeste do Irã. Com base na observação de campo e petrografia, 9 microfaces foram identificadas. Essas microfaces foram depositadas em 4 linhas de fácies, incluindo: rampa interna, média, externa e bacia. O estudo conduzido mostrou evidências com base nas porcentagens de alochemas, mudança gradativa lateral e vertical de microfaces e falta de grandes recifes de barreira, de que a Formação Khaneh-Zu apresentou uma deposição em plataforma inclinada de carbonato. A pesquisa mostrou também que processos diagenéticos incluindo micritização, bioturbação, dissolução, cimentação, compactação química, dolomitização e fraturamento foram identificados na Formação Khaneh-Zu. Dolomitização, fraturamento e cimentação são os processos diagenéticos mais importantes nessa formação. O excesso de dolomitização causa a obstrução da porosidade inter-cristalina e, portanto não contribuem na qualidade do reservatório. A dissolução formou porosidade tipo vuggy isolada e, portanto, não tem efeitos positivos na permeabilidade. Ocorreram diferentes fases de fraturamento na Formação Khaneh-Zu, mas a maioria delas foi preenchida por diferentes tipos de cimentos de calcita. Assim, como um ponto de vista da caracterização do reservatório, o intervalo estudado mostra uma baixa qualidade do reservatório.

Palavras-Chave: Formação Khaneh-Zu; Bacia Kopet Dagh; Microfaces; Processos diagenéticos; Ambiente deposicional

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ABSTRACT
Khaneh-Zu Formation (Oxfordian- Kimmeridgian) is a hydrocarbon reservoir in Kopet Dagh basin. The main objectives of this research are investigation of microfacies, depositional environment, and diagenetic processes of this formation in two outcrop sections in Kopet Dagh basin in the north east of Iran. Based on field observation and petrography, 9 microfacies have been identified. These microfacies have been deposited in 4 facies belts including inner, mid ramp, outer ramp and basin. The evidences such as types and percentages of allochems, gradational lateral and vertical change of microfacies and lack of great barrier reefs it can be concluded that Khaneh-Zu Formation has been deposited in a carbonate ramp platform. Diagenetic processes including micritization, bioturbation, dissolution, cementation, chemical compaction, dolomitization and fracturing are identified in Khaneh-Zu Formation. Dolomitization, fracturing and cementation are the most important diagenetic processes in this formation. Over-dolomitization cause to occlude intercrystalline porosity and so has not positive effect on reservoir quality. Dissolution formed isolated vuggy type porosity and so has not positive effects on permeability. Different phase of fracturing occurred in the Khaneh-Zu Formation, but most of them filled by different types of calcite cements. So, as a point of view of reservoir characterization, the studied interval shows poor reservoir quality.
Keywords: Khaneh-Zu Formation; Kopet Dagh Basin; Microfacies; Diagenetic processes; Depositional environment

INTRODUCTION

Reservoir quality of carbonate rocks is mainly affected by microfacies and diagenetic processes (Lucia, 2007; Ahr, 2008; Moore and Wade, 2013). Therefore, it is essential to be aware of facies distribution and effect of diagenetic processes in order to identify heterogeneities. Carbonates of Khaneh-Zu Formation have been studied considering various aspects of facies changes, depositional environment, and diagenetic processes in different parts of Kopet Dagh (Afshar-Harb, 1979; Movahed, 1998; Kavoosi et al., 2009; Yazdi et al., 2019).

Khaneh-Zu Formation is somewhat heterogeneous at different scales due to extensive facies changes, effect of diagenetic processes horizontally and vertically and tabular communication in some areas with Chaman-Bid Formation. Diagenesis is the main controlling factor in many of hydrocarbon reservoirs, especially in Middle East. Diagenetic history of sediments is controlled by sea water level fluctuations (Sarg, 1988; Emery and Meyers, 1996; Sanjary and Hadavi, 2019). This formation is composed of porous zones and permeability as well as intra-reservoir non-porous horizons. Such heterogeneities and extensive changes made it essential to discuss factors affecting and controlling microfacies and diagenesis.

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This study was conducted to introduce microfacies, depositional environment, and effect of diagenetic processes on Khaneh-Zu Formation in Kopet Dagh Basin.

GEOLOGY AND STRATIGRAPHY

The studied sections are located in Kopet Dagh at north east of Iran (Figure 1). Kopet Dagh is a part of Alpine Himalayan System that was formed after the closure of the Paleo-Tethys. This area is the second hydrocarbon basin in Iran (Kavoosi et al., 2009; Poursoltani, and Hrati Sabzvar, 2019). In Kopet Dagh area, upper-middle Jurassic shale and Chaman-Bid Formation are the source rock in this sedimentary basin (Afshar-Harb, 1979). Carbonate rocks of Mozduran Formation is the main gas reservoir in this basin (Afshar-Harb, 1979).

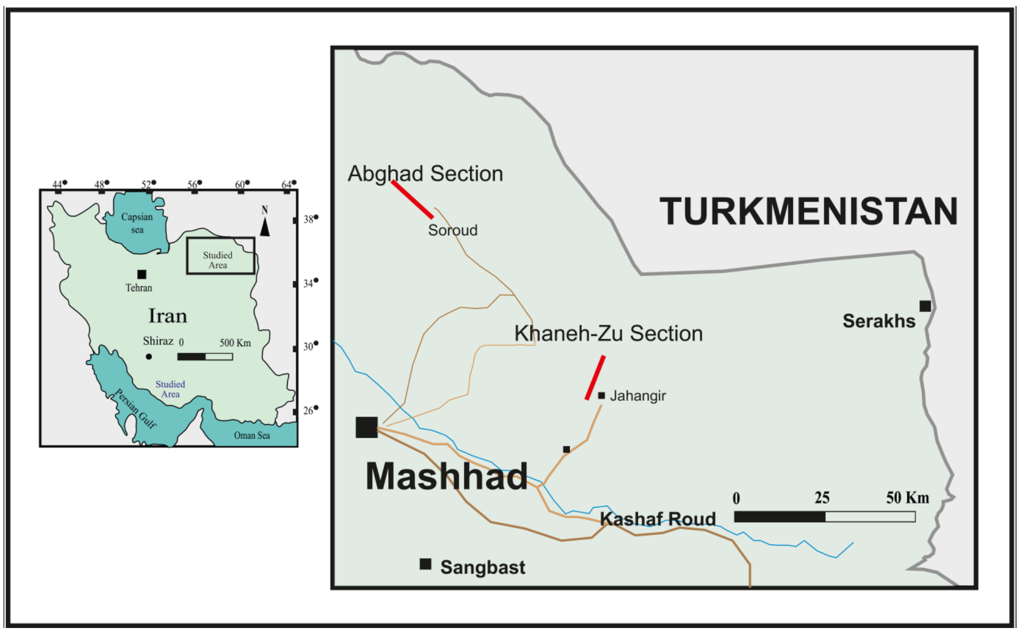

Figure 1: Geographic location map of studied area, outcrop sections and available pathways toward studied sections.
Source: Modified after Road atlas of Iran, Gitashenasi Jnstitue, (2005)

Upper Jurassic Khaneh-Zu Formation (Oxfordian- Kimmeridgian) (Afshar-Harb, 1994; Kalantari, 1979) consists of dolomite, dolomitic limestone, calcareous dolomite and alteration of limestone and shale. This formation is overlie at Mozduran 2 Formation and underline with Chaman-Bid Formation. This research presents stratigraphic studies to identify vertical and lateral facies changes and studying dolomitic intervals in different areas. Khaneh-Zu Formation consists of thick-carbonate layer and introduced by Afshar-Harb and Allahyari in 1971.

The name of this formation has been adopted from the small valley of Khaneh-Zu. Khaneh-Zu Formation has local distribution and with lateral change to Chaman-Bid Formation westwards (Afshar-Harb, 1994; Movahed, 1999). The thickness of this formation is about 271 meter. Due to rigid topography of Hezar-Masjed Mountains, lack of appropriate pathways, and severe fault system in the area this region has not been studied in details (Afshar-Harb, 1994).

Dolomite intervals are porous and are probable reservoir rock for hydrocarbon accumulation. The fossil content of this formation is thin-walled bivalves, radiolaria, sponge spicules and echinoderm (Afshar-Harb, 1994; Zoraghi et al., 2019; Mahari et al., 2019).

MATERIALS AND METHODS

This research is based on field studies of Khaneh-Zu Formation in two outcrop sections including Abghad (Figure 2) and Khaneh-Zu (Figure 3). During systematic sampling, 410 samples have been selected for thin section preparation. Thin sections were stained with alizarin red-s using Dickson's method (1966) for determination of calcite and dolomite. Different parameters such as lithology, type and percentage of allochem, texture, microfacies and diagenetic features were studied and interpreted in details. Carbonate rocks have been classified based on Dunham (1962) and Folk (1970) classification. Depositional environment was studied based on Wilson (1975) and Flügel (2010) standard models.

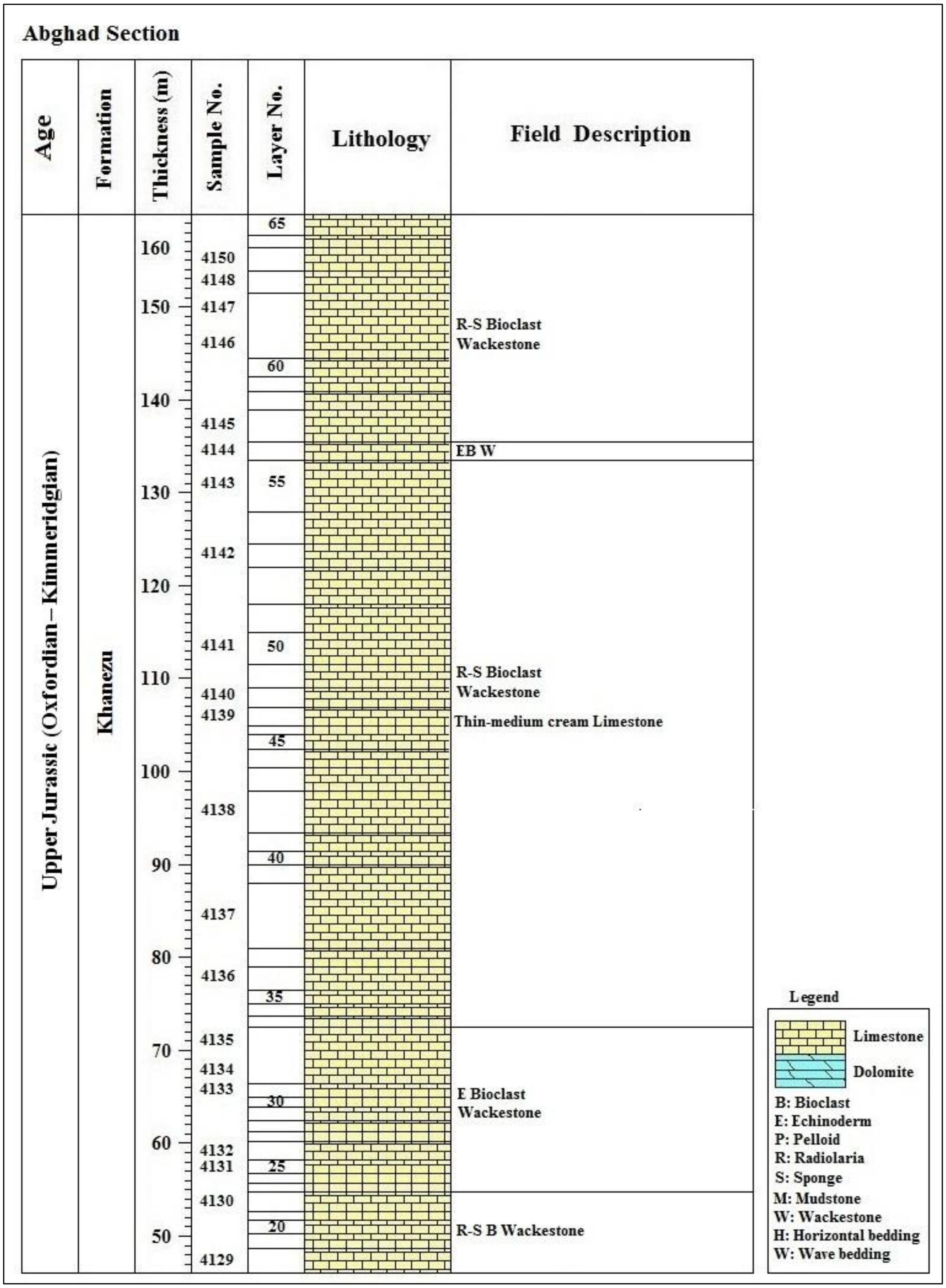

Figure 2: Stratigraphic section of Khaneh-Zu Formation in Abghad section
Source: Writers.

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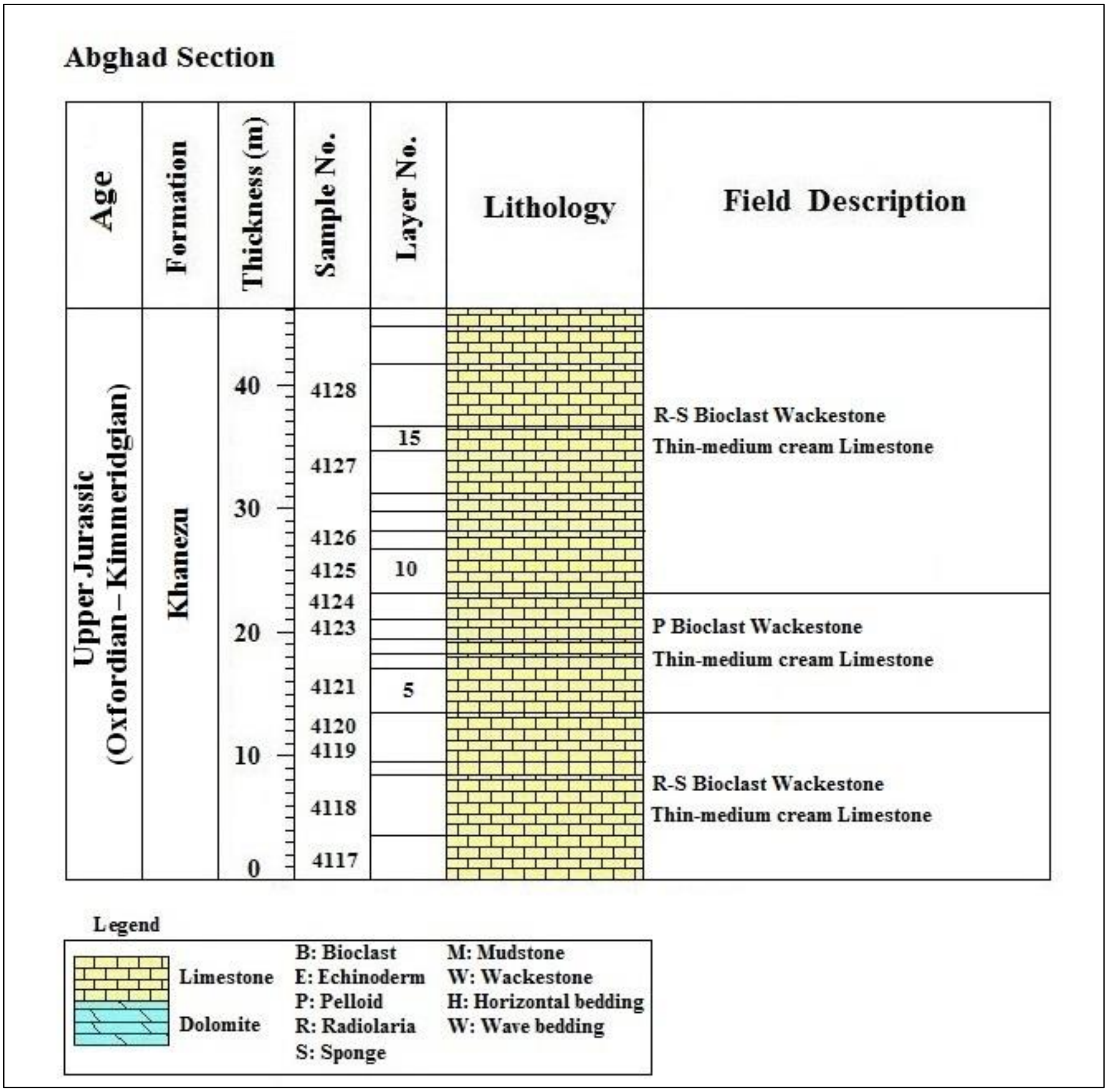
Figure 2: Contnd.



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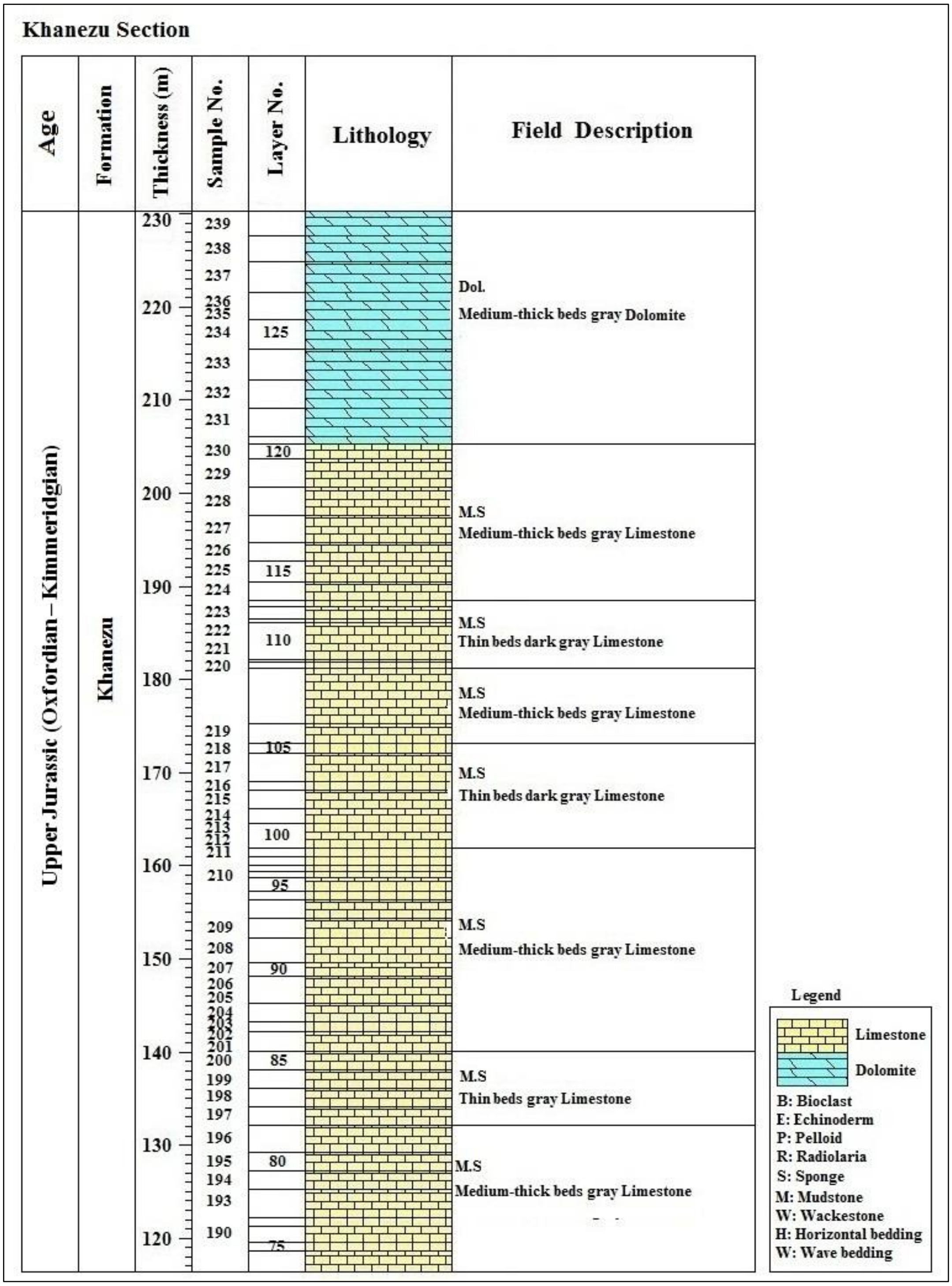

Figure 3: Stratigraphic section of Khaneh-Zu Formation in Khaneh-Zu type section
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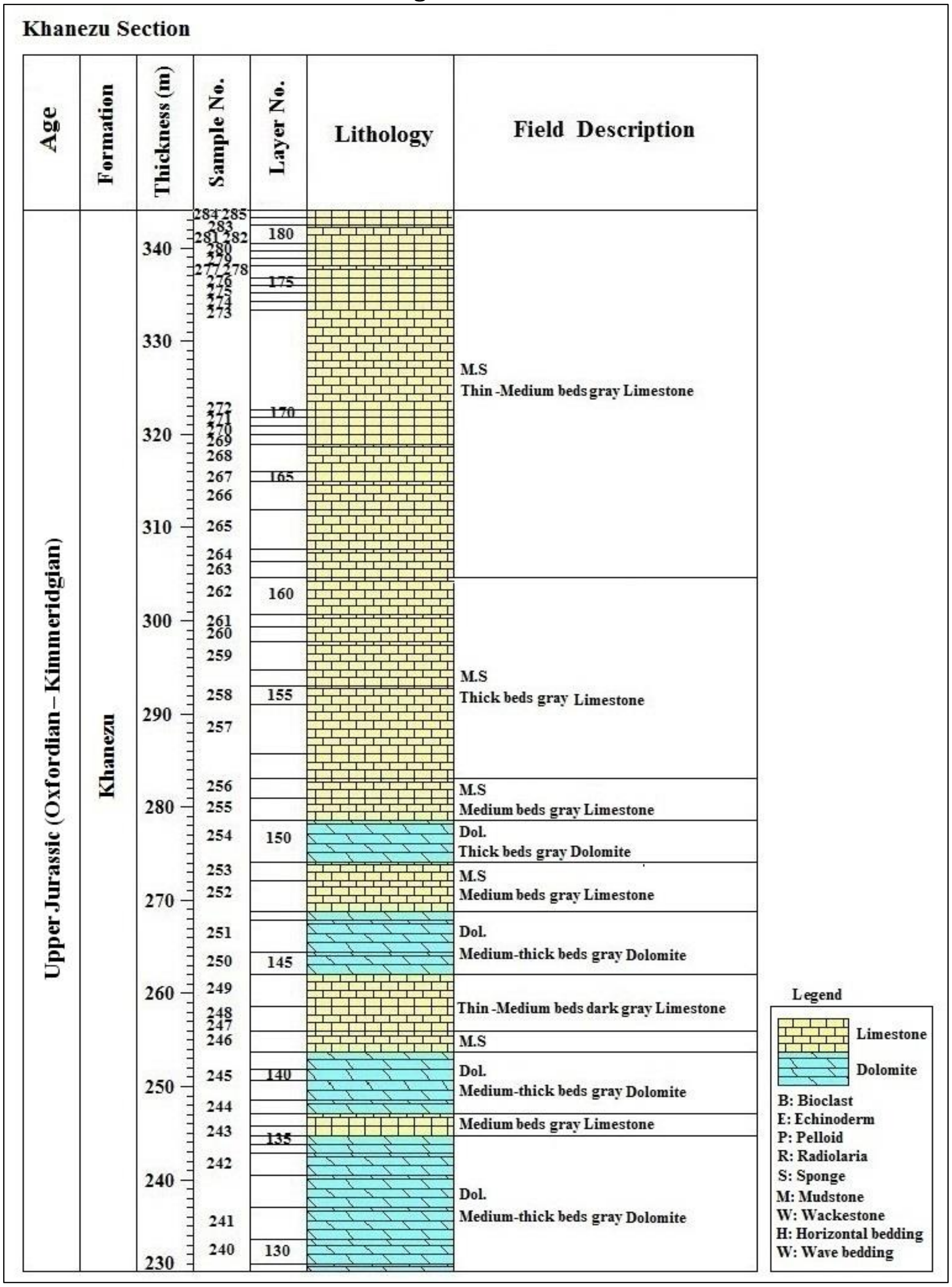

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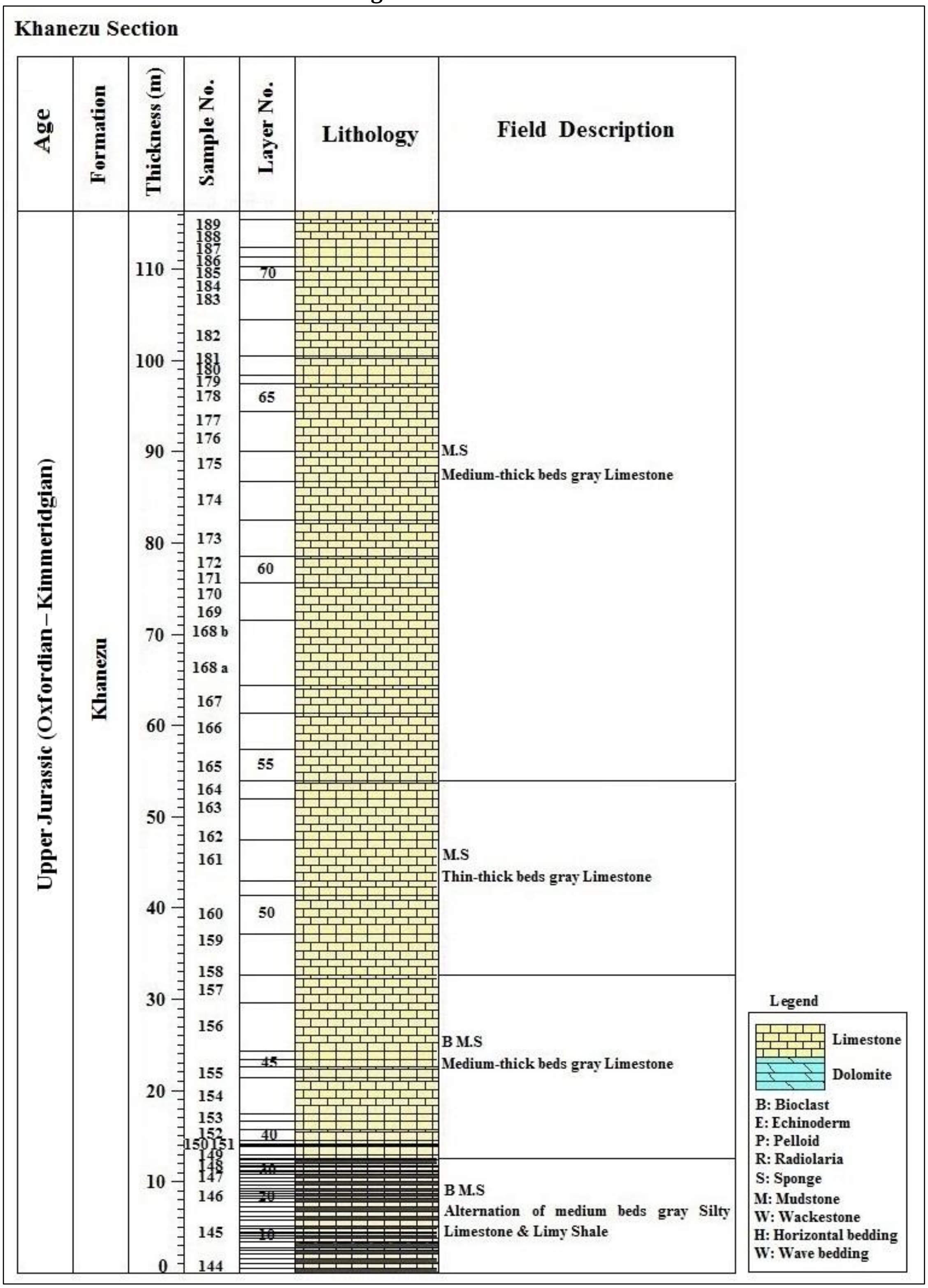

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MICROFACIES ANALYSIS AND DEPOSITIONAL ENVIRONMENT

According to the results obtained from petrography and combination of these data with field observation and comparing them to standard facies models (Wilson, 1975; Flügel, 2010), 9 microfacies were identified in the Khaneh-Zu Formation (Figure 4). The identified microfacies were placed in different facies belt including mid ramp, outer ramp and basin (Figure 5). Frequency of each facies belts have been illustrated in Figure 6. These microfacies have been briefly described in following part (Table 1).

Table 1: Identified microfacies and facies belts in Khaneh-Zu Formation

Number of facies	Microfacies	Allochems		Energy level	Facies Belts
		Skeletal	Non-skeletal		
1	Mudstone	-	-	Low	Basin
2	Fossiliferous mudstone	Shell debris	-	Low	Basin
3	Radiolaria sponge spicule wackestone	Sponge Spicule (r), Radiolaria (a)	Peloid (r)	Medium	Outer ramp
4	Peloid bioclast wackestone	Bivalve debris, pellet (a), Echinoid debris, benthic foraminifera (r)	Peloid (a)	Medium	Outer ramp
5	Bioclast wackestone	Benthic foraminifera, sponge spicule, Radiolaria, Shell debris, Echinoid	-	Medium	Outer ramp
6	Bioclast packstone	Sponge Spicule, thin-walled shell fragments (a)	-	Medium to high	Mid ramp
7	Bioclast Echinoid wackestone	Micro-Echinoid (a), benthic foraminifera	Peloid (r)	Medium	Mid ramp
8	Benthic foraminifera bioclast wackestone	Bivalves debris (r), benthic foraminifera (c), bioclasts (c)	-	Medium	Mid ramp
9	Bioclast peloid packstone	Bioclasts (c), benthic foraminifera (r)	Peloid	Medium to high	Mid ramp

Frequency percent: a: abundant (15-25%), c: common (10-15%), r: rare (2-9%)

Basin Facies Belt

- MF1- Mudstone: This facies with mudstone texture contains less than 2% skeletal debris. Based on Folk classification (Folk, 1974) this facies is called micrite. In some samples the clay content increased and the facies change to argillaceous mudstone. In this case the color of the sample grades to pale brown. This microfacies has been deposited in low energy condition in the deepest part of the depositional environment. The main diagenetic processes in this facie, are chemical compaction as microstylolite, Fe-staining, pyritization (as cubic form and framboidal), neomorphism (as alteration of micrite to microsprite). Dolomitization are also observed in the form of sucrosic fine crystals with xenotopic fabric.
- MF2- Fossiliferous Mudstone: This facie contains less than 10% bioclastic grains including sponge spicule, thin-walled shell fragments and echinoderm. Based on Folk classification (Folk, 1974) this facies is categorized as biomicrite. Pyrite in the form of cubic crystals is present in the matrix. Abundant low amplitude stylolites, microfractures and aggradational neomorphism are also observed in this microfacies.

Outer Ramp Facie Belt

- MF3- Radiolaria Sponge Spicule Wackestone: This facie shows wackestone texture and contains about 10-20% sponge spicule and *Radiolaria* sp.. There are abundant siliceous sponge spicule and radiolaria in deeper parts of the sections. Diagenetic processes of this facie are stylolites and abundant numerous solution seams. Microfractures filled by spary calcite cements. Framboidal pyrites are scattered in the matrix. In some samples the mold of sponge spicules filled by calcite cement. The dissolved silica may has been the origin for the formation of authigenic quartz.
- MF4- Peloid Bioclast Wackestone: The main skeletal allochems of this microfacies are sponge spicule (3%), echinoderm stem and spine (5-10%) and with lower amount benthic foraminifera (5-10%). Peloid is non-skeletal component (10-13%). Peloid are fine grained and varies from 20 to 40 micron in size. Based on Folk classification (Folk, 1974) this facies is called pelbiomicrite. Parallel stylolites and microfractures are present. Iron oxides stained the matrix and microfractures.

- MF5-Bioclast Wackestone: This facie with wackestone texture consists of various fossils including large thin-walled shell fragments (about 10%) and benthic foraminifera (2%). *Spirulina sp.* is the index benthic foraminifera in this facies. Sponge spicule and *Calcispherula* sp. are subordinate allochems. Based on the Folk classification (Folk, 1974) type of this facie is biomicrite. Chemical compaction in the form of parallel stylolites, solution seams and geopetal fabric are present in this microfacies.

Mid Ramp Facies Belt

- MF6- Bioclast packstone: Texture of this microfacies is packstone and in some parts grades to wackestone. This microfacies contains almost 20-30% long and thin-walled shell fragments that are associated with shallower parts of the basin. Besides that, sponge spicule with amount of about 5% is also present. Cubic pyrite can be observed in MF6. Burial and tectonic microfractures are filled with calcite cement. Low amplitude stylolites can be observed in different samples.
- MF 7- Bioclast Echinoid Wackestone: This facie with wackestone texture contains 5-15% echinoid stem and spine. Other subordinate bioclasts observed are including sponge spicule, *Calcispherula* sp. and large shell debris in Abghad section. Abundant low amplitude stylolites and solution seams are formed as a result of the effect of chemical compaction in this microfacies. Fe-staining and authigenic quartz can be observed in the matrix. Aggradational neomorphism occurred in the matrix and formed microsparite. Cross-cutting tectonic and burial fractures filled with spary calcite cement. This microfacies shows low porosity.
- MF 8- Benthic Foraminifera Bioclast Wackestone: This microfacies contains various benthic foraminifera with the amount of about 10-15% in surfaces sections of the Khaneh-Zu Formation. The main benthic foraminifera in this microfacies are *Spirulina* sp., *Textularia* sp. and Miliolids. Spicule sponges and rare planktonic foraminifera are subordinates. Low amplitude stylolite and Fe-staining are present in MF8. Microfractures are filled with calcite cements.

- MF 9- Bioclast Peloid Packstone: MF9 with packstone texture contains 10-30% peloid, benthic foraminifera (e.g. *Textularia* sp. and Miliolids) and shell debris. Bioturbation is common in this microfacies. Iron oxides (about 3%) can be observed as penetrated in the matrix and between the bioclastic grains. Long narrow microfractures resulted by burial and tectonic mechanism filled with calcite cement.

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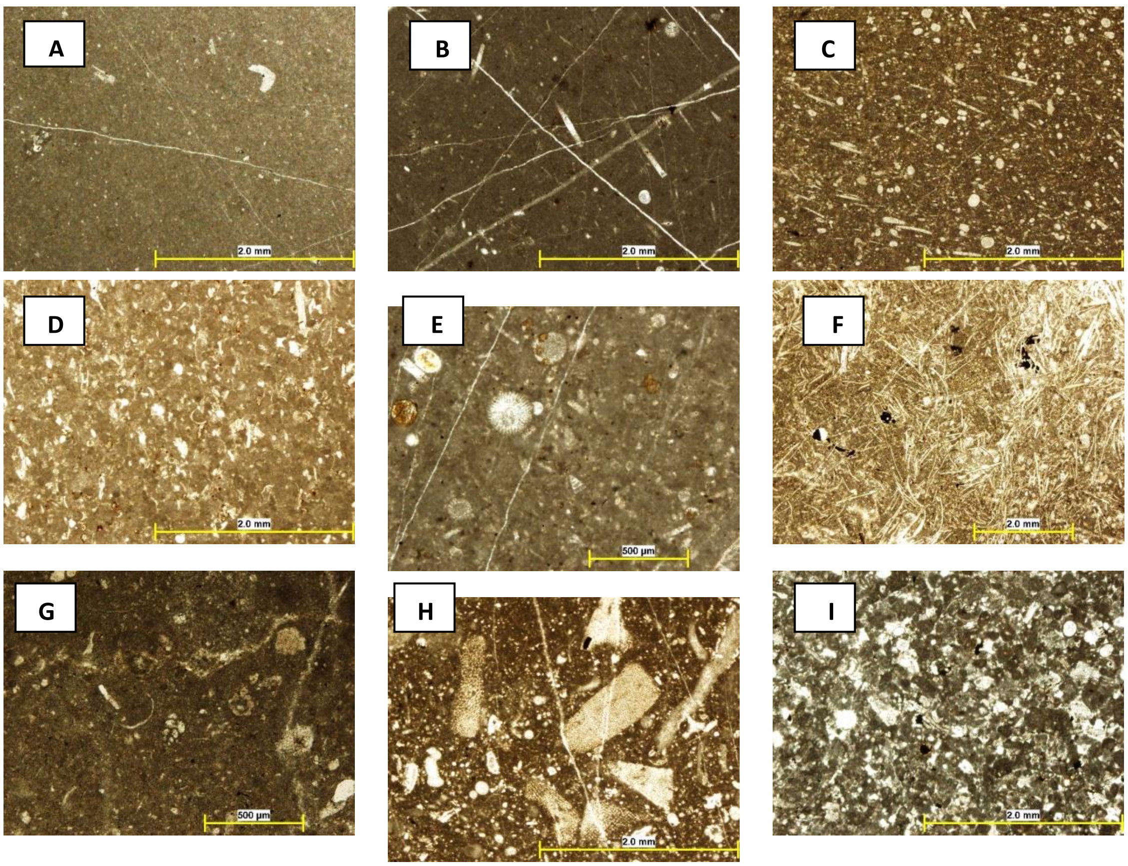

Figure 4: Microphotograph of identified microfacies of the Khaneh-Zu Formation in the studied sections. A- Mudstone, (MF1), PPL. B- Fossiliferous mudstone (MF2), PPL. C- Radiolaria sponge spicule wackestone (MF3), PPL. D- Bioclast packstone, (MF6), PPL. E- Bioclast wackestone (MF5), PPL. F- Peloid bioclast wackestone, (MF4), PPL. G. Bioclast echinoid wackestone, (MF7), PPL. H- Benthic foraminifera bioclast wackestone, (MF8), PPL. I. Bioclast peloid packstone (MF 9), PPL.
Source: (Writers)

DEPOSITIONAL ENVIRONMENT

Based on detailed field observation and petrographic analysis of thin sections, 9 microfacies have been identified in the studied interval of the Khaneh-Zu Formation. These microfacies have been deposited in terms of three facies belt including mid ramp, outer ramp and basin.

The evidences such as types and percentages of allochems, gradational lateral and vertical change of microfacies, lack of great barrier reefs and compare them to standard microfacies of Wilson (1975) and Flügel (2010) it can be concluded that Khaneh-Zu Formation has been deposited in a carbonate ramp platform (Figure 5).

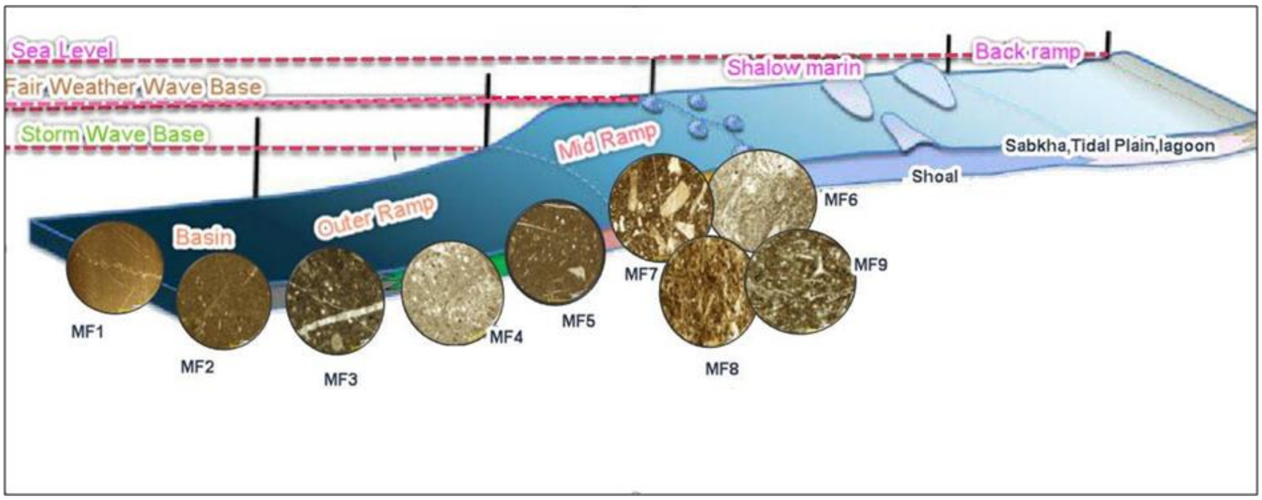

Figure 5: Schematic 2D diagram of depositional environment and their allochems distribution of Khaneh-Zu Formation in the studied sections.
Source: Writers.

By sea level progradation, on the siliciclastic Kashafroud Formation, shallow water ramp system was established and thick sequence of Khaneh-Zu Formation in terms of two cycles were deposited. The sea level fluctuation is relevant with

By retrograding the sea level, the second retrogradational cycles was formed (Movahed, 1998). Short term sea level fluctuation caused to form Khaneh-Zu Formation and then by transgratio n of the sea level the ChamanBid Formation simultaneously was deposited in the deeper parts of the platform and on the Khaneh-Zu Formation. The Khaneh-Zu Formation has local distribution and starts from north Mashhad extend to Ghuchan toward west. Then this

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formation wedge out and gradationally and laterally change to ChamanBid Formation (Movahed, 1998).

In the Kopet Dagh Basin the transition from Oxfordian to Kimmeridgian cause to the climate changed and also deposiotnal change. The channels formed in the Oxfordian filled during the Kimmeridgian (Kavoosi, 2009). The dominated platform during the deposition of Chaman bid formation is rimmed shelf while in the Kimmeridgian the platform change to ramp carbonate during the deposition of the Khaneh-Zu formation (Kavoosi, 2009). The lack of calciturbidites and redeposited sediments and also bioherms in the Kimmeridgian , and the dominant presence of packstone and to some extent grainstone in compare to reefal microfacies, cause to form ramp-like carbonate platform (Figure 6) (Kavoosi, 2009).

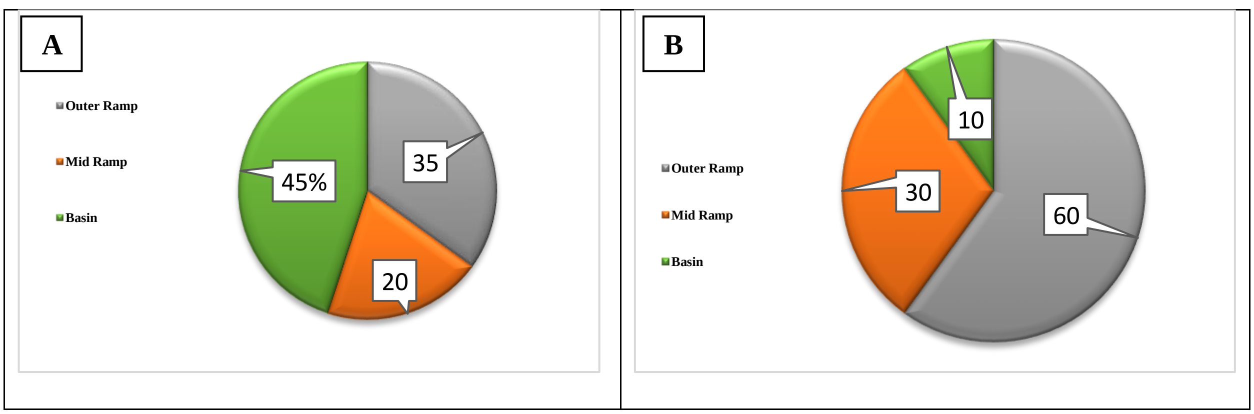

Figure 6: Pie diagram showing frequency of different distinct facies belt in the studied sections. A- Khaneh-Zu section. B- Abghad section. As these diagram illustrate, in Khaneh-Zu section the frequency of basin facies belt is higher than the others (outer and mid ramp), and in Abghad section the frequency of outer ramp facies belt is higher than the others.
Source: Writers.

In figure 6, frequency of facies belt in two outcrop sections have been showed. As these pie diagrams indicate, in Khaneh-Zu section the frequency of basin facies belt is higher than the other facies belt (outer and mid ramp); while in Abghad section the frequency of outer ramp facies belt is higher than the other. It can be concluded that Khaneh-Zu Formation is located in the deeper parts of the platform.

DIAGENETIC EVENTS

The results from petrographic studies and field observation show that the Khaneh-Zu Formation in the studied sections has been affected by different diagenetic processes varying from marine and burial stages. The main identified diagenetic features are micritization, bioturbation, cementation, dissolution, compaction, fracturing, and pyritization. These processes have been described herein (Figures 7, 8 and 9).

- Micritization: Micritization is the first diagenetic process that occurs simultaneously with sedimentation in phreatic marine environment (Longman, 1980). In this process, carbonate particles are replaced with hidden crystals (cryptocrystalline) of carbonate or micrite. This process is a primary diagenetic process and an index for shallow water marine environment (Tucker, 2001). Incomplete micritization creates micrite envelopes around grains (Bathurst, 1975) (Figure 7-A).
- Bioturbation: In studied interval, bioturbation rarely have led to change in primary structure of sediments (Burchette and Britton 1985; Flügel, 2010; Hollis, 2011) in the form of burrowing. This process has been observed in low-energy environments such as basin and sometimes in outer ramp (Hollis, 2011). Bioturbations have been replaced with calcite and cement so that its features can be observed in thin sections (Figure 7-B).
- Neomorphism: Neomorphism is observed as the recrystallization of micrite to microsparite in basin and outer ramp environment in Khaneh-Zu Formation. In studied samples, this process mostly affected on mud-supported facies which was deposited in low-energy condition (Figure 7-C).
- Cementation: The identified carbonate cements in Khaneh-Zu Formation are coarse spary calcite cement (Figure 7-D), drusy (Figure 7-E) and blocky cements (Figure 7-F). Coarse spary calcite cement partially filled some microfractures and interparticle porosity. This type of cement with fine unimodal crystals mostly observed in wackestone and packstone microfacies. This cement has partially reduced porosity in marine and burial environments (Hajikazemi et al., 2010). Drusy calcite cement is formed in meteoric environment (Tucker and Wright, 1990) filling some secondary porosities including vuggy and channel types. Blocky cement also filled some

microfractures, vuggy and channel pores and occurred in burial diagenetic environment. Drusy and blocky calcite cements exits in all of studied microfacies as the most important factors in decreasing porosity in Khaneh-Zu Formation. The most important parts of cementation occur in burial diagenetic environment due to dissolution of unstable minerals such as aragonite (Lucia, 2007).

- Dissolution: Khaneh-Zu Formation has been affected by dissolution process because of the nature of carbonated lithology and impact of burial diagenesis. This process has been frequent in all of Khaneh-Zu Formation with different distribution. The evidence of this process is observed as isolated and connected dissolution vugs (Figure 8-A). Some parts of the observed vugs have been partially filled by burial calcite cements.
- Fracturing: Fracturing is widespread in the studied interval (Figure 8B) and porosity due to fracturing is one of the most important types of porosity in studied interval. This porosity has been created by tectonic and burial processes parallel to layering or in different directions. This type of porosity can be seen in facies of all three groups. First-generation fractures have occurred in shallow burial conditions which cross-cut allochems and matrix and filled with equant and blocky calcite cement. Second-generation fractures are identified by cross-cutting stylolites and first-generation fractures. These fractures are filled by microcrystalline, blocky and drusy calcites cements; however some of them are still open (Figure 8-C). These fractures are identified as horizontal, vertical, filled and semi-filled, or with different amount of opening.
- Compaction: Mechanical compaction in the form of skeletal breakage of different fossils such as bivalves and fitted fabric has been observed in studied interval. Point, concavo-convex and penetrated contacts are present between the grains. Chemical compaction is characterized by the presence of solution seams (Figure 8-D) and stylolites (Figure 8-E) within the Khaneh-Zu Formation. The presence of these features indicates the entrance of facies into the realm of burial diagenesis. Stylolites are mainly low amplitude (Figure 8-F) and cross-cut grains, matrix and cements. Because of mud-dominated nature of most microfacies of the Khaneh-Zu Formation,

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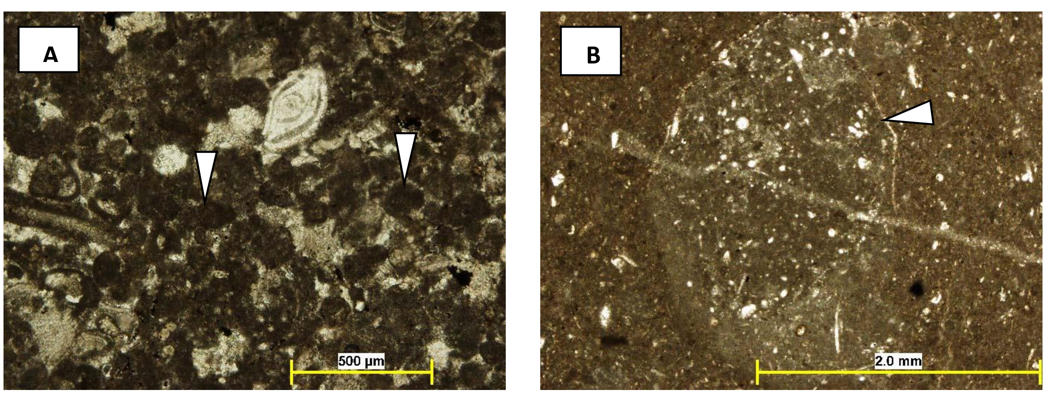
the products of chemical compaction are more frequent in the studied interval. Chemical compaction plays a vital role in reducing porosity and permeability.

- Dolomitization: Two phase of dolomitization have been identified in the studied samples of Khaneh-Zu Formation. Phase 1: dolomites are mostly subhedral to anhedral and rarely euhedral (Fiure 8-A). Size of the crystals varies from 30 to 75 micrometers. Dolomitization are mainly observed in mud-supported microfacies in compare with grain-dominated one. Dolomites are replacive with hypidiotopic to xenotopic texture. In general, dolomitization cab be observed in basin and outer ramp microfacies. Since dolomitization have been occurred around stylolites, it can be concluded that these types of dolomite formed by burial mechanism (Wanless, 1979; Lee and Friedman, 1987). Second phase of dolomite consists of coarse, anhedral crystals of dolomite with undulated extension. It is called saddle dolomite with planar-C texture and locally filled some pores (Figure 9-B).
- Pyritization: Pyrite is observed as sparse particles within the matrix (Figure 8-C), cubic, framboidal types and also replacement of skeletal grains (Figure 8-D). The presence of this mineral indicates the reduction condition for deposition of facies. It is mostly observed in open marine and outer ramp facies. Pyrites in cubic form are mainly occurred in burial diagenetic environment (Hajikazemi et el., 2010).



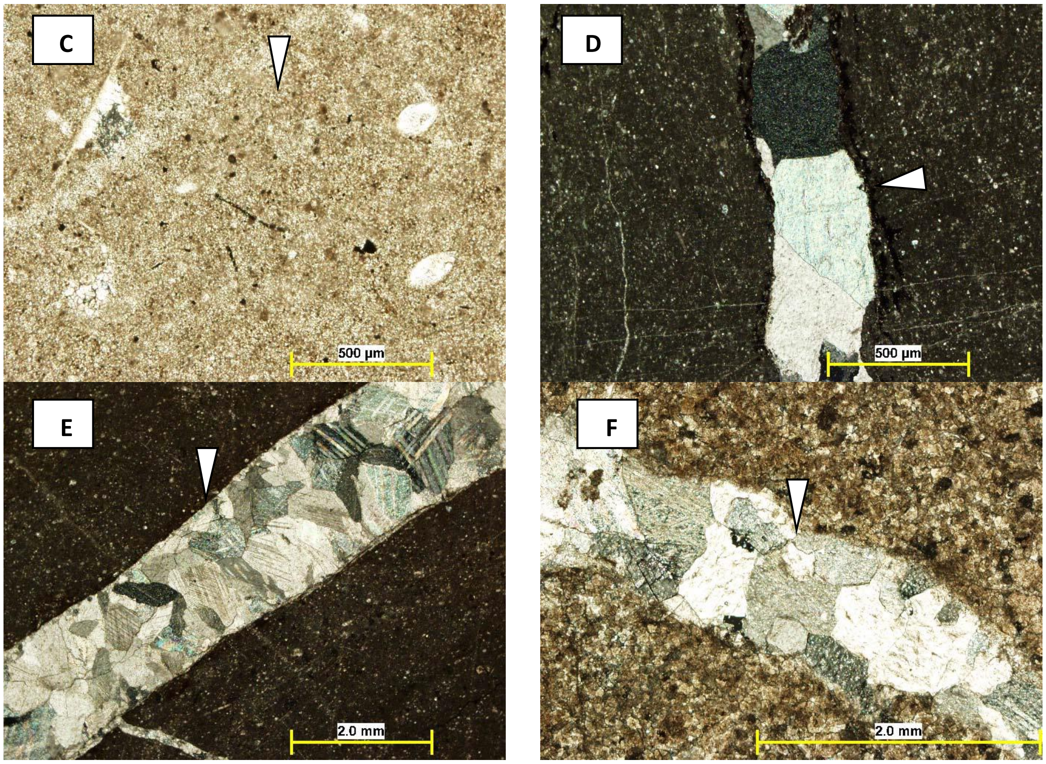
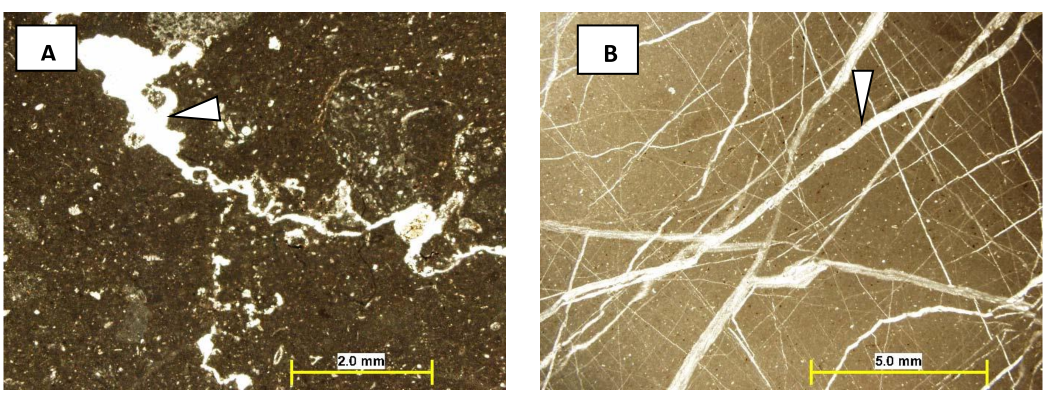


Figure 7: Identified diagenetic events in the Khaneh-Zu Formation, A- Micritization of skeletal debris, PPL. B- Bioturbation, PPL. C- Aggradational neomorphism in the matrix, XPL. D- Coarse spary calcite cement, XPL. E- Drusy calcite cement, XPL. F- Blocky calcite cement, XPL.



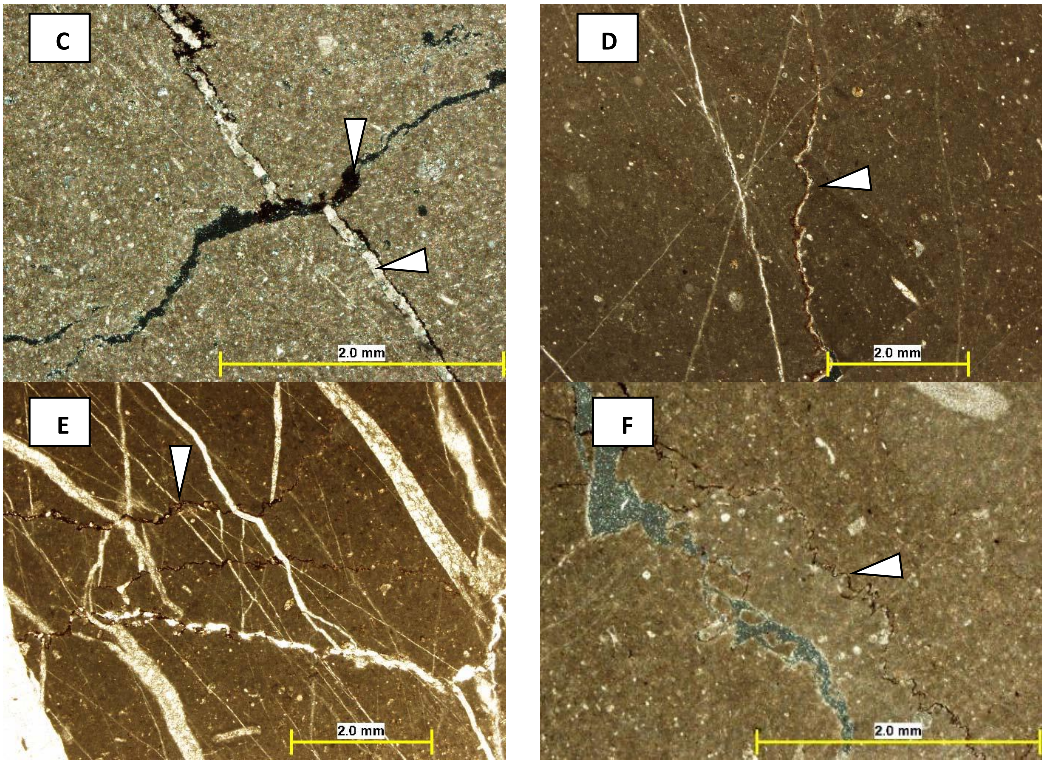
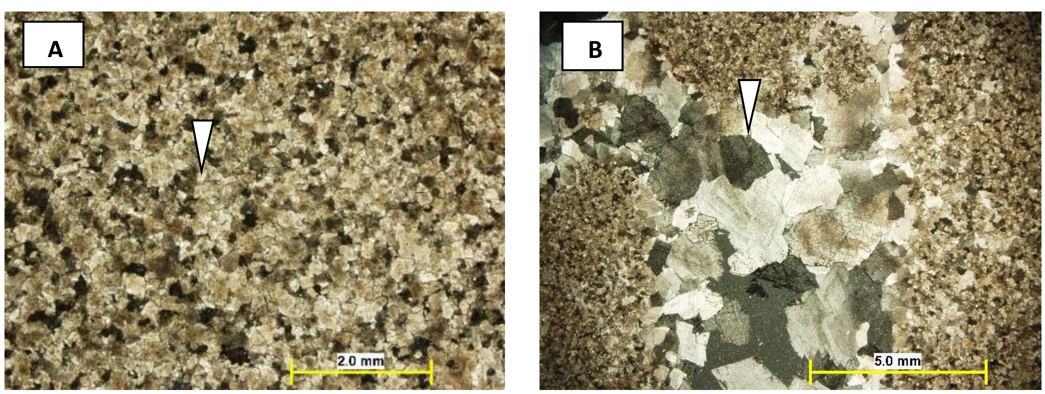


Figure 8*:* Identified diagenetic events in the Khaneh-Zu Formation, A- Dissolution along with open fracture, PPL. B- Abundant fractures filling by calcite cement, PPL. C- Two phase of fracturing, the first one filled by calcite and the second open fracture, XPL. D- Solution seam, PPL. E - Low amplitude stylolite and solution seams, PPL. F- Low amplitude stylolite, XPL.



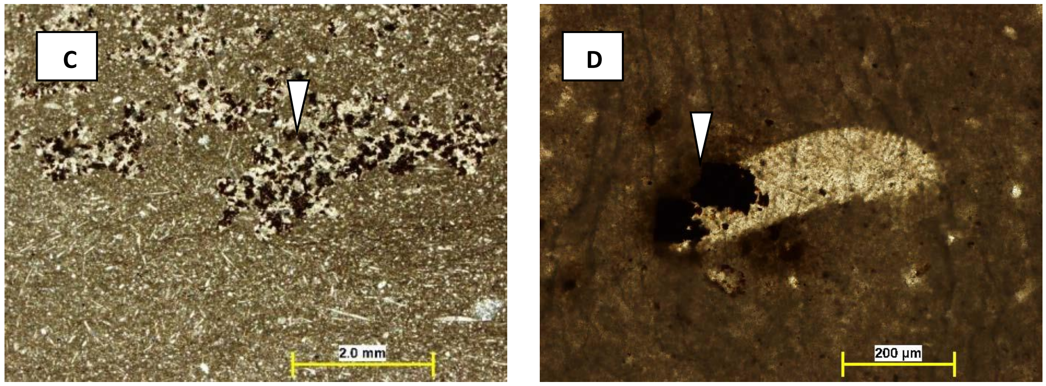


Figure 9: Identified diagenetic events in the Khaneh-Zu Formation, A- Dolomite crystals with subhedral to anhedral form and hypidiotopic to xenotopic texture, PPL. B- Saddle dolomite, XPL. C- Pyrite as scattered crystals in bioturbated features, XPL. D- Pyrite as replacement in echinoid debris, PPL.

- Paragenetic sequence: Paragenetic sequence of diagenetic processes indicates the relative time of effect of diagenetic processes in studied area. In Eogenetic stage, primary diagenetic processes include bioturbation and micritization that have been start immediately after sedimentation on the seafloor. In mesogenic stage, mechanical and chemical compaction processes, calcite cementation, first phase of fracturing, dissolution, and dolomitization have been occurred. Final diagenetic processes consist of erosion and uplifting due to tectonic processes leading to various fractures in carbonate sequences. Burial diagenetic processes in theses sequences lead to expansion of fractures, cracks, stylolites, and small separate pores in mud-supported facies. Order of identified diagenetic processes in studied sequence has been indicated based on the petrography (Table 2).

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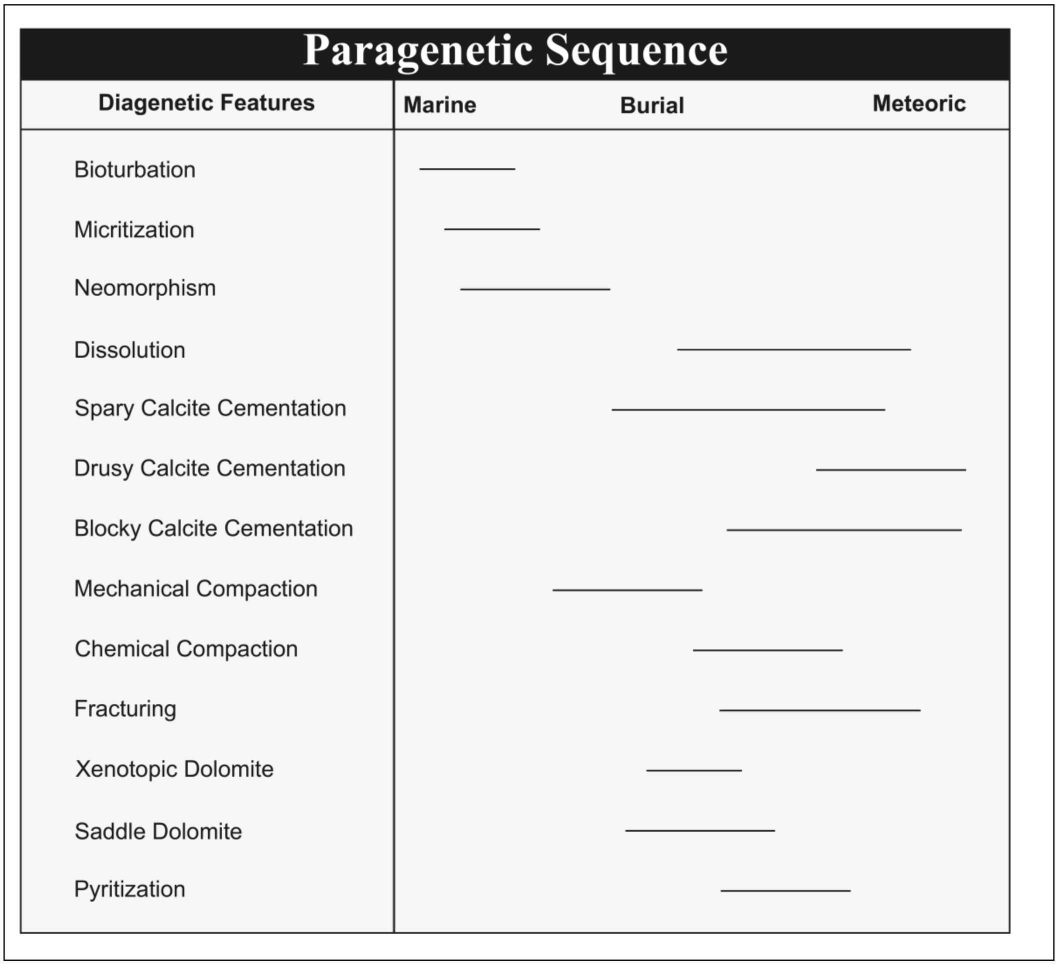

Table 2: Paragenetic sequence of the Khaneh-Zu Formation in studied sections.
Source: Writers.

CONCLUSION

Based on field studies integrated with petrographical investigation of thin sections of the Khaneh-Zu Formation in Kopet-Dagh Basin, 9 types of microfacies have been identified. These microfacies have been deposited in four facies belt related to inner, mid and outer ramp and basin.

Based on the lack of calciturbidites and great barrier reefs, a gentle carbonate ramp platform proposed for the Khaneh-Zu Formation.

Considering the tectonic transformations in the area and placement of sediment basin in present mode with northeastern-southwest trend, it is possible to consider carbonate ramp platform for Khaneh-Zu Formation in this area. According to unpublished seismic profiles, topography of sedimentary basin has been created by tectonic transformations at Upper Jurassic Time.

Different diagenetic processes affected on this formation which are micritization, bioturbation, cementation, dissolution, compaction, fracturing, and pyritization.

Among all, dissolution formed isolated vuggy porosity and so has not positive effects on permeability and reservoir quality increased reservoir quality. Cementation and compaction have negative effect on reservoir characteristics. So as a point of view of reservoir characterization, the studied interval shows poor reservoir quality.

REFERENCES

AFSHAR-HARB, A.; Geology of Kopet Dagh. In: Hushmandzadeh, A., (Ed.), **Treatise on the Geology of Iran, Geological Survey of Iran**, Tehran, 1994. 275 p. (In Persian)

AFSHAR-HARB, A.; **The Stratigraphy, Tectonics and Petroleum Geology of the Kopet Dagh Region, Northern Iran**, Unpublished Ph.D. Thesis, Imperial College of Science and Technology, London, 1979.

AHR, W.M.; **Geology of carbonate reservoirs**. John Wiley & Sons, Chichester, 2008. 296 p

AHR, W.M.; **Geology of carbonate reservoirs**. Wiley Pub, 2008a. 277p.

BATHURST, R.G.C.; **Carbonate Sediment and their Diagenesis**: Elsevier, North Holland, 1975. 658p.

BJORLYKKE, K..; **Petroleum Geoscience from Sedimentary Environments to Rock Physics**, 2010. 365 p.

BURCHETTE, T.P.; S.R. BRITTON.; Carbonate facies analysis in the exploration for hydrocarbons: a case study from the Cretaceous of the Middle East. In, P.J. Brenchley and B.P.J. Williams (Eds.), **Sedimentology**: Recent Developments and Applied Aspects, 1985. p. 311-338.

DEMBICKI, JR. Harry.; **Practical Petroleum Geochemistry for Exploration and Production**, 2017. 342p.

DICKSON, J. A. D.; **Carbonate identification and genesis as revealed by staining: Journal of Sedimentary Research**, 1966. v. 36, no. 2, p. 491-505.

DUNHAM, R.J.; Classification of carbonate rocks according to depositional texture. In: W. E. Ham (Ed.), **Classification of Carbonate Rocks**. AAPG Memoir, 1962. 1, 108-121.

EI- SOROGY, Abdolbaset. S.; GALMED, Mahmoud.; AL- KAHTANY, Khaled.; Al-ZAHRANI, Ali.; **Microfacies and Diagenesis of the middle Jurassic Dhruma Carbonates, Southwest Riyadh, Saudi Arabia**., Journal of African Earth Science, 2017. 130, 125-133.

EMERY, D.; MEYERS, K.J.; **Sequence Stratigraphy**. Blackwell, Oxford. Jordan, C.F., Connaly, T.C. & Vest, H.A. 1985. Middle Cretaceous carbonate of Mishrif Formation, Fateh Field, offshore Dubai, U.A.E. In: Roehl, P.O. & Choquette, P.W. (eds) Carbonate petroleum reservoirs. Springer-Verlag, New York, 1996. 426–442.

FLÜGEL, E.; **Microfacies of carbonate rocks**, Springer – Verlag, New York, 2010. 967p.

FOLK, R. L.; **Petrology of sedimentary Rocks**: Hemphill. Pub., Co., Austin, Texas, 1974. 182p.

HAJIKAZEMI, E.; AL-AASM, I. S.; CONIGLIO, M.; Subaerial exposure and meteoric diagenesis of the Cenomanian-Turonian Upper Sarvak Formation, southwestern Iran. In: Leturmy, P. & Robin, C. (Eds), **Tectonic and Stratigraphic Evolution of Zagros and Makran during the Mesozoic–Cenozoic**, Geological Society, London, Special Publications, 2010. 330, p. 253-272.

HOLLIS, C.; **Diagenetic controls on reservoir properties of carbonate successions within the Albian–Turonian of the Arabian Plate**. Petroleum Geoscience, 2011. v. 17, no. 3, p. 223-241.

KALANTARI, A.; **Iranian fossil, National Iranian Oil Company**, Lab., Public, 1981. no.9.

KAVOOSI, M. A.; LASEMI, Y.; SHERKATI, S.; MOUSSAVI-HARAMI, R.; **Facies analysis and depositional sequences of the Upper Jurassic Mozduran Formation, a carbonate reservoir in the Kopet Dagh Basin, NE Iran**, 2009. DOI: 10.1111/j.1747-5457.2009.00446.x.

LEE, Y.I.; FRIEDMAN, G.M.; **Deep – burial dolomitization in the lower Ordovician. Ellenburger**. Group Carbonates in west Texas and Southeastern New Mexico: Jour. Sed. Petrology, 1987. v.57, p.544-557.

LONGMAN, M.W.; **Carbonate diagenetic texture from nearshore diagenetic environment**, American Association of petroleum Geol. Bulletin, 1980. v.64. p.461-487.

LUCIA, F.J.; **Carbonate Reservoir Characterization**: an Integrated Approach. Springer, Berlin, New York, 2007. 336 p.

MAHARI, Rahim.; SHABANIAN, Rahim.; REIHANI, Farahnaz.; SHETABIFARD, Hamideh.; SADIGH JANBAHAN, Somaieh.; **Facies, sedimentary environments and sequence stratigraphy of Cretaceous deposits in the northwest of Azerbaijan**, Iran, Iranian Journal of Earth Sciences, 2019. Volume 11, Issue 2, Page 104-112.

MOORE, C. H.; WADE, W.J.; **Carbonate Reservoirs, Porosity and Diagenesis in a Sequence Stratigraphic Framework**, 2nd edn, Elsevier, Amsterdam, 2013. V. 67, 374p.

MOTIEI, H.; **Kopet Dagh Stratigraphy**, Treatise on the Geology of Iran, Geological Survey of Iran, 1993. 536p.

POURSOLTANI, M. R..; HRATI SABZVAR, M.; **Porosity evolution and diagenetic history of the upper Jurassic Mozduran Formation, eastern Kopet-Dagh Basin, NE Iran**, Iranian Journal of Earth Sciences, 2019. , Volume 11, Issue 2, Page 141-159.

SANJARY, S..; HADAVI, F.; NOTGHI MOGHADDAMM, M.; ALLAMEH, M.; **Calcareous nannofossils from chalky limestone intervals of the Abderaz formation in the Kopet Dagh range, NE Iran**, Iranian Journal of Earth Sciences, 2019. Volume 11, Issue 1, Page 47-55.

SARG, J. F.; **Carbonate sequence stratigraphy. In Sea Level Changes–An Integrated Approach** (C. K. Wilgus, B. S. Hastings, C. G. St. C. Kendall, H. W. Posamentier, C. A. Ross and J. C. Van Wagoner, Eds.), 1988. pp. 155–182. SEPM Special Publication 42.

SELLEY, R. C.; SONNENBERG, S. A.; **Element of Petroleum Geology**, 2014. 526p.

TUCKER, M.E.; **Sedimentary petrology**, Blackwell, Oxford, 2001. 3rd ed., Pp.262.

TUCKER, M.E.; WRIGHT, V.P.; **Carbonate Sedimentology**, Blackwell, 1990. Sci. Pub., p.482.

WANLESS, H.R.; **Limestone response to stress, pressure solution and dolomitization**, Jou. Sed. Petrol, 1979. 49: p. 437-442.

WILSON, J. L.; **Carbonate Facies in Geologic History**, Springer-Verlag, New York, 1975. 439p.

YAZDI, A.; ASHJA ARDALAN, A.; EMAMI, M. H.; DABIRI, R.; FOUDAZI, M.; **Magmatic interactions as recorded in plagioclase phenocrysts of quaternary volcanics in SE Bam (SE Iran)**, Iranian Journal of Earth Sciences, 2019. Volume 11, Issue 3, Page 215-225.

ZORAGHI, G. H.; SHABANI GORAJI, K.; NOURA, M. R..; RASHKI, A. R.; BUMBY, A., **Identification of sand dune sources in the east Sistan, Iran by using mineralogical and morphoscopic characterization of sediments**, Iranian Journal of Earth Sciences, 2019. Volume 11, Issue 3, Page 183-195.