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High Resolution Sequence Stratigraphy and Depositional Environment of Pabdeh Formation in Dashte – Arjan Area (Shiraz, Fars, Zagros, Iran)

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Abstract**—**Pabdeh shaly formation (Paleocene-Oligomiocene) has been expanded in Fars, Khozestan and Lorestan. The lower lithostratigraphic limit of this formation in Shiraz area is distinguished from Gurpi formation by purple shale. Its upper limit is gradational and conformable with Asmari formation. In order to study sequence stratigraphy and microfacies of Pabdeh formation in Shiraz area, one stratigraphic section have been chosen (Zanjiran section). Petrographic studies resulted in the identification of 9 pelagic and calciturbidite microfacies. The calciturbidite microfacies have been formed when the sea level was high, the rate of carbonate deposition was high and it slumped into the deep marine. Sequence stratigraphy studies show that Pabdeh formation in the studied zone consists of two depositional sequences (DS) that the lower contact is erosional (purple shale - type one, SBI or type two, SB2) and the upper contact is correlative conformity (type two, SB2).

Keywords**—**Pabdeh formation, Shiraz, Microfacies, Purple Shale, Zanjiran Section, Sequence Stratigraphy

I. Introduction

PABDEH formation as one of the oil source rocks in Zagros has drawn the attention of most geologists since a long time ago. In the type section, this formation with the thickness of more than 798m consists of shale and thin-bedded clay limestones. Its lower limit is distinguished from Gurpi formation by purple shale and the upper limit is gradational and conformable with Asmari formation. Pabdeh formation has been expanded in Fars, Khozestan and Lorestan [13].eas no detailed study has been done on sequence stratigraphy of Pabdeh formation in Shiraz area yet, the goal of this research is to do Petrographic and field study in the mentioned zone to identify sedimentary sequences, qualitative and quantitative study of calciturbidite and its relation with relative changes in sea level. Other objectives of this research are to study and identify microfacies and their changes in vertical and horizontal direction, identify sedimentary environments when the studied formation has been made, apply Walter law and do comparative studies on old and present sedimentary environments, identify sedimentary cycles and the pattern of their superposition to classify facies sets of tract systems, sequence boundary, and depositional sequence [8], [19] and [22].

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II. Methods and Materials

The method includes laboratory and field studies. After reviewing aerial maps of the studied zone and several field visits, two stratigraphic sections were chosen from outcrops of Pabdeh formation to be studied and 550 thin sections were provided. In order to find Petrographic features of the studied sections, microscope with polarized and normal light were applied.

With regard to carbonate samples (qualitative study of calciturbidite) after determining type and percentage of allochem and orthochem elements, the samples were studied with the purpose of proceeding nomenclature and exact identification of sedimentary environment. In nomenclature of carbonate microfacies Dunham method (1962) and in classifying facies and offering sedimentary model, Carrozi [6] and Flugel [9] methods were applied.

III. Geological setting

The Iranian plateau extends over a number of continental fragments welded together along suture zones of oceanic character. The fragments are delineated by major boundary faults, which appear to be inherited from older geological periods. Each fragment differs in its sedimentary sequence, nature and age of magmatism and metamorphism, and its structural character and intensity of deformation [3].

These fragments form the following provinces (Nabavi, 1976): 1-Folded Zagros, 2-High Zagros, 3-Esfandaghe-Marivan, 4-Makran, 5-Central Iran, 6-Lut Block, 7-Nehbandan-Khash, 8-Alborz- Azarbayejan, 9-Binalud, 10-Gorgan-Rasht, 11-Hezarmasjed-Kopedagh (Fig.1). The study area is located in the Zagros Basin, which was a continental margin attached to the eastern edge of Africa throughout the Phanerozoic. During the Permian, detachment of Iran plate (Compri sing Alborz, Central- east-Iran microcontinent and Sanandaj-Sirjan) from the Arabian plate caused the formation of Neotethis Ocean. Individual microcontinents were later detached from this assemblage and followed their northward path. The various fragments were sutured to Eurasia before and during Miocene time when Africa collided with Eurasia. The Alpidic-Himalayan Orogeny caused major deformation in all Iranian fragments and formed their present-day configuration [1],[16].

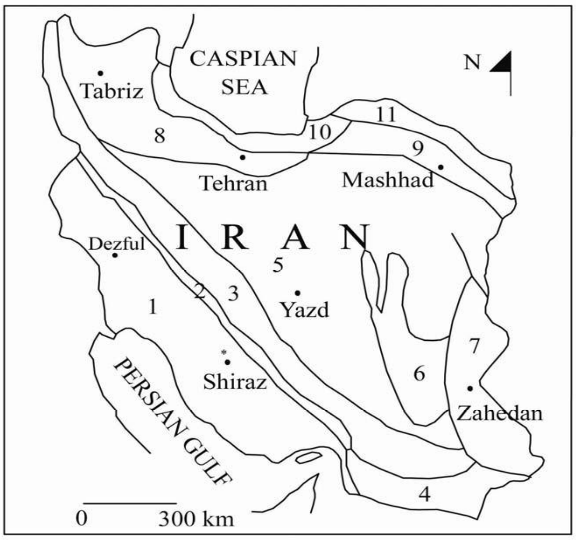

Fig. 1 Tectono-sedimentary provinces of Iran and the location of the study area. 1-Folded Zagros, 2-High Zagros, 3-Esfandaghe-Marivan, 4-Makran, 5-Central Iran,6-Lut Block,7-Nehbandan-Khash, 8-Alborz-Azarbayejan, 9-Binalud, 10-Gorgan-Rasht, 11- Hezarmasjed-Kopedagh; ✱ study area.

IV. Study Area

The study area is located in folded Zagros zone. In figure 2, geographic situation of the studied range has been characterized. The lithology of the studied section is as follows accordingly:

A Zanjiran Section:

This section is located 65km away from south east of Shiraz in Shiraz-Kavar road, Sefidar Mountain. The grid coordinates for the base of section is 52º8´52.5˝ eastern longitude and 29º4´4˝ northern latitude. Zanjiran section with the thickness of 420m includes blue and yellow shale and marl layers, thin to medium-bedded nomolite limestones and lime shale. The lower and upper limit of Pabdeh formation in Zanjiran section with Gurpi and Asmari formations are gradational (figure 5).

Fig. 2 Geographical situation of the studied section in Shiraz area: 1-Zanjiran section

V. Microfacies Description of Pabdeh Formation

After studying field and microscopic samples, it has been determined that the identified facies of Pabdeh formation have been all deposited in the see depth. They can be divided into two groups: pelagic and calciturbidite facies. Calciturbidites can be seen as interbedded in pelagic facies.

A. Pelagic Microfacies of Pabdeh Formation (Group A)

1- Mudstone/Gray Shale

Approximately this facies totally includes lime mud in dark gray to black. Mudstone/gray shale facies in the sequence of Pabdeh formation has relatively great thickness and expansion. It is mainly seen in alternation with globigerina bioclast mudstone, globrotalia and other facies of A group. Bioturbation is another feature of this facies. Mudstone/gray shale facies is seen in the ground in alteration with thin-bedded lime shale facies (figure 3B, 3N).

2- Globrotalia, Globigerina bioclast mudstone

In this facies less than 10% of skeletal allochem from globigerina and globrotalia family is floating in a micritic matrix. This facies has been deposited in a low order environment of open sea and its lithostratigraphic constitutes includes thin to medium-bedded gray to dark lime shale (figure 3A).

3- Globrotalia, Globigerina bioclast wackstone

About 35% of this facies is globrotalia, globigerina bioclast. The matrix of this facies is dark micrite and in some similar facies, a low percent (5%) of pellet is found. Fine cross lamination is another feature of the considered facies. In A3 facies a low percent of glauconitization in foraminifera's pores is seen. In lithostratigraphic view it has the exposure of thin to medium-bedded gray pelagic lime (figures 3C, 3N).

4- Glauconit Globigerina Bioclast Packstone

Over 50% of the sample mass of this facies consists of the species as globigerina and globrotalia in a micritic matrix. The mentioned facies includes 5-10% glauconitization in the pores of plankton microfossils. A4 facies has the exposure of thin to medium-bedded gray shale lime (figures 3D, 3E).

B. Calciturbidite Facies of Pabdeh Formation in the Studied Sections (Group B)

1- Nummulite Bioclast Wackstone

In this facies bioclasts from Nummulite and milliolide family are seen in a micritic matrix. Bioclasts oscillates from 30 to 50%. The size of skeletal grain of Nummulite also reaches to 1.5mm. In some similar samples, 10 to 25% of the facies has been dolomitized. There are also 5 to 10% of planktonic fossils in the sample such as *Globigerina* and *Globrotalia*. This facies has been deposited in the form of calciturbidite in the sea depth and interbedded in pelagic limes and shales. B1 facies has the exposure of medium to thick-bedded light-gray limestone. It is to be mentioned that the lower boundary of calciturbidite with shales is abrupt (figure 3K).

2- Globigerina, Discosyclina & Nummulites Packstone

This facies includes skeletal allochem from nummulite, discosyclina and allulinide family (which compromises 30 to 60%) as well as species from Globigerina family (10 to 15%) in a micritic matrix. The size of benthonic skeletal grains is variable between 0.5 to 2mm and being mixed with planktonic microfossils are the distinctive features of this facies. In lithostratigraphic view, B2 facies includes medium to thick-bedded limestone with abrupt lower boundary in alternation with light-gray shale (figures 3G, 3F).

3- Red Algae Bioclast Grainstone

In this facies about 35% of the skeletal allochem is red algae and milliulide family with average size of 0.5mm in a sparite matrix. In the considered facies intraclasts are also seen with density of about 10%. With regard to its lithostratigraphic features, the exposure of this facies is medium to thick-bedded limestone (figure 3L).

4- Intraclastic Bioclast Packstone

Over 50% of the sample mass of this facies consists of allochems as Nummulite and Milliolide family and a percent of planktonic fossil. In B4 facies one can find between 15 to 20% of the size of intraclasts more than 1mm and they are somehow pellet. Intraclasts which are highly rounded consist of fossil debris. The exposure of B4 in the ground is in the form of medium to thick-bedded calcarenite limestone (figure 3I).

5- Intraclastic Peloidal Bioclast Wackstone

In this facies you can see about 30% of pellet, 15% of intraclasts and 25% of skeletal allochem from milliulide family with debris of planktonic shell in a micritic matrix. In some similar samples rounded intraclasts with diameter of about 1mm including fossil debris are seen. The exposure of this facies in the ground is in the form of medium to thick-bedded limestone in alternation with pelagic facies of Pabdeh formation specially in Zanjiran section (figures 3H, 3J).

VI. Sedimentary Environment

Petrographic and field study of Pabdeh formation in the studied zone indicates that its sedimentary environment is related to deep sea environment and its facies include the facies group of shale, pelagic lime and calciturbidite (redeposited). The existence of planktonic bioclasts related to deep sea such as globigerina, Globrotalia and abundant micrite indicates the deposition of this group in deep sea environment. The studies [23], [10]and [4]. prove the case. The existence of glauconite in A1 to A4 facies (as authigenic and interbedded in foraminifera) is an indication of the deposition of this facies in the depth of open sea [9]. Existence of benthonic bioclasts such as milliolide and nummulite family in calciturbidite facies (B1 to B5) indicates deposition in a platform environment.

The indication that pelagic and turbidite facies are interbedded and the mixture of planktonic and benthonic grains in calciturbidites show the high rate of deposition, tempestite deposits, carbonate slumping from platform margin with steep slope and its deposition in the see depth [14]. The deep facies of Pabdeh formation are conformable with deep facies of Mozdooran and Chamanbid formations [2]. and facies away from Bahamas platform [5].(Fig.4).

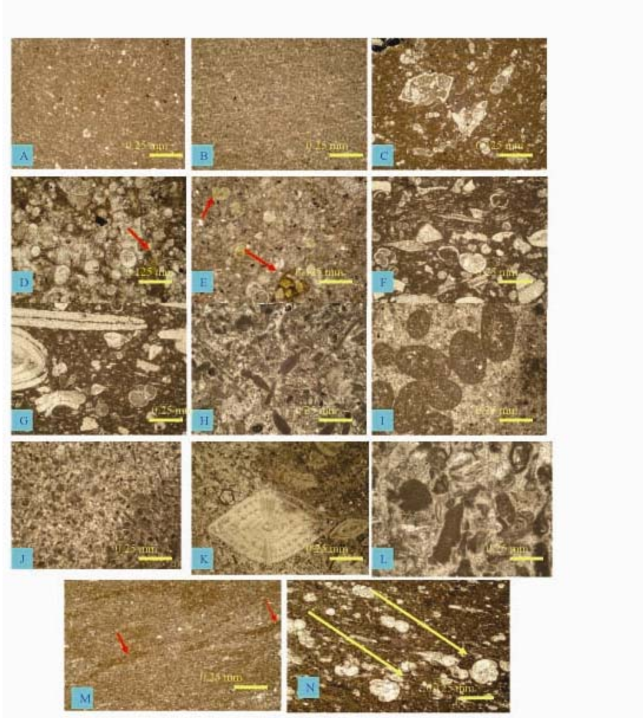

Fig. 3 microfacis of Pabdeh formation in study area. A&M: mudstone/gray shale(A1 facies). B: *Globrotalia-Globegerina* bioclast mudstone(A2 facies). C: Globrotalia-Globegerina bioclast wackestone(A3 facies). D&E: Glouconitic *Globegerina* bioclast packstone (A4 facies). K:*Nummulites* bioclast wackestone(B1 facies). F&G: Globegerina *Discosyclina Nummulites* packstone(B3 facies). L&H: Red algae bioclast grainstone(B3 facies). B4: Intraclastic bioclast packstone(B4 facies). J: Intraclastic peloiedal bioclast wackestone(B5 facies).

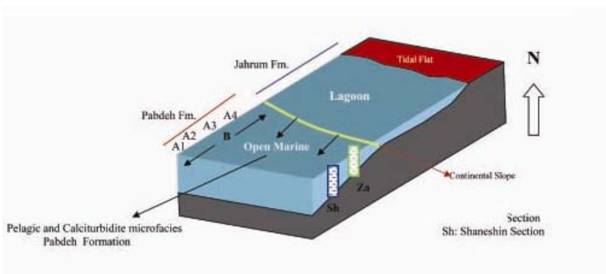

Fig. 4 sedimentary environment model of Pabdeh formation A:pelagic facies B:calciturbidite facies

VII. Sequence Stratigraphy

The study of vertical variations in the facies of Pabdeh formation in Zanjiran section has been resulted in the identification of two sedimentary sequences (the third class cycle). The thickness of the first sedimentary sequence (DS1) of Pabdeh formation has been 95m and its lower boundary of this section is identified by purple shale from Gurpi formation (SB2).

TST facies of the first sedimentary sequence with the thickness of 35m include mudstone as well as globrotalia, globigerina bioclast wackstone. Maximum flooding surface (MFS) of the sea is characterized by thin-bedded dark shale facies. In lithostratigraphic view, the outcrop of this facies includes alternation of gray and yellow shale and lime shale that as we go to the high, their thickness is decreased.

In the relative static state of sea level HST facies with the thickness of 60m includes alternation of pelagic facies and redeposited *Nummulite* limestones. The facies seen in this part includes Globigerina bioclast wackstone, *Alveolinide*, *Nummulite* bioclast packstone, *Globigerina Nummulite* bioclast wackstone, *Nummulite* bioclast packstone, *Globigerina Discosyclina*, algae bioclast grainstone, intraclast bioclast packstone and pellet intraclast bioclast wackstone which have been fallen on each other as cycles that as we go higher, their thickness become less.

The thickness of the second sedimentary sequence is 295m. Its lower limit is of second type (SB2) and its upper limit which is correlative conformity is ended below Asmari formation. Transgression surface begins with shale facies and its maximum flooding surface is distinguished by bioclast packstone facies with glauconitization in foraminiferal pores.

TST facies with the thickness of 85m consists of shale, globigerina bioclast mudstone, globigerina bioclast wackstone and globigerina bioclast packstone In lithographic view, this facies includes alternation of shale and lime shale exposure.

HST facies of the second sedimentary sequence (DS2) with the thickness of 210m consists of alternation of lime shale and redeposited limestones. Its microfacies include shale, *Globigerina* bioclast wackstone, milliolide *Nummulite* bioclast wackstone, intraclast and pellet bioclast wackstone and discosyclina and *Nummulite* bioclast packstone and in lithographic view, it includes alternation of medium to thick-bedded lime shale and redeposited shales exposure. This facies is ended under Asmari formation with a correlative conformity boundary.

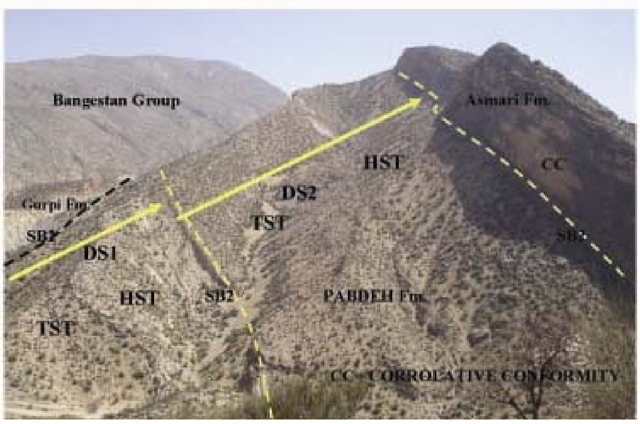

Fig. 5 DS1 and DS2 of Pabdeh formation in study area (Zanjiran section).

Identifying two sedimentary sequences of Pabdeh formation in Zanjiran section can be due to faults operation with active syndepositional tectonics of Zagros sedimentary basin [18].depositional faults operation causes different morphology in carbonate platform and the change in manner and type of deposition. The final result of this process can make different sequences in Pabdeh formation. The existence of benthonic bioclast as well as the mixture of benthonic environment and platform facies indicate the high rate of deposition which causes tempestite deposits, carbonate slumping from platform margin with steep slope and its deposition in the see depth [17]. (highstand shedding fig.5 and 6).

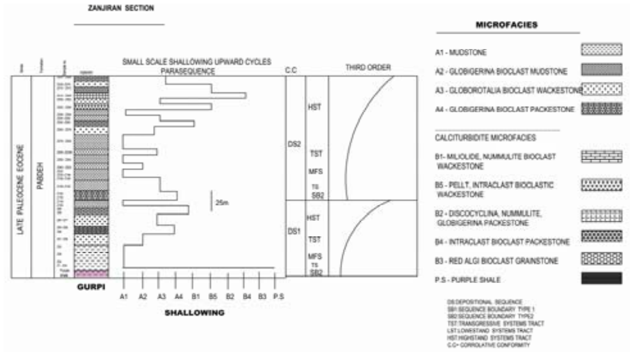

Fig. 6 Lithostratigraphical column and Sequense Stratigraphy of Pabdeh formation in Zanjiran section(Shiraz, Iran).

VIII. Conclusion

By field and laboratory studies on Pabdeh formation in the studied zone, the following conclusions have been reached:

1- The identified facies in Pabdeh formation merely belongs to sea depth including shale, globigerina bioclast mudstone, globigerina bioclast wackstone, globigerina bioclast packstone including glauconitic and calciturbidite facies. Calciturbidite facies have been formed when the seal level and the rate of carbonate deposition were high. Calciturbidite facies includes *Milliolide Nummulite* bioclast wackstone, *Nummulite Globigerina* bioclast wackstone, *Nummulite*, *Discosyclina* and *Globigerina* bioclast packsonte, algae bioclast grainstone and pellet intraclast bioclast wackstone including planktonic fossil debris.
2- Pabdeh formation consists two sedimentary sequence in Zanjiran section.
3- The lower limit of sedimentary sequence of Pabdeh formation with Gurpi formation is type 2 (SB2) on which there is a purple shale. The upper limit of this sequence is correlative conformity.
4- Pabdeh formation in the study area includes HST, TST facies consisting of parasequences which gets neritic as it goes to the top. TST facies merely includes alternation of mudstone and thin-bedded lime shale and HST facies includes lime shale, shale and redeposited limes.
5- Facies study of Pabdeh formation indicates that Pabdeh formation has been deposited in the deep basin neighboring carbonate platform of Jahrom formation.

6- The first sedimentary environment of carbonate microfacies lacking planktonic microfossils (including allochem elements such as nummulite, pellet and intraclast) is platform environment which is seen as interbedded with pelagic sediments due to slumping to sea depth (turbidite facies) and their secondary sedimentary environment is bathypelagic environment.
7- Syndepositional faults operation causes different morphology in sediment basin and finally making different sequences in Pabdeh formation.

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