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Factor Controlling Reservoir Properties and Flow Unit Determination in the Ilam Formation of Dezfol Embayment at Zagros Fold-Thrust Belt, Southwest of Iran

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Abstract

Dezfol embayment in the Southwest of Iran is located in the Zagros fold-thrust belt, which is one of the world's largest petroleum provinces. Ilam Formation (Santonian-Companian) is one of the reservoir formations in this area that has been less studied. This paper focused on reservoir properties in this formation using petrography and petrophysics data. According to the petrography studies Ilam Formation composed of limestone as dominant lithology. Detailed petrographic analyses, have led to identification of 10 micro-facies which are represented as a carbonate ramp depositional model. Also petrographic analyses are revealed that cementation, dissolution, compaction and dolomitization are most important digenetic processes. Detailed petrographic analyses and petrophysics data showed that due to mud-supported nature of more facies (inherited low reservoir potential from their depositional settings), diagenetic process plays an important role in increasing of reservoir quality. However cementation and dissolution had negative and positive effects on Ilam reservoir formation, respectively. Finally at the end for better correlation and to create a flow unit, according to the petrography data and using petrophysics log, this reservoir is divided into 5 units (flow unite) by using Geolog software and then they have been correlated across the field.

Keywords

Component, Diagenetic Process, Flow Unit, Petrophysic, Reservoir Characterization, Ilam, Formation, Dezfol Embayment

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1. Introduction

More than 65 percent of proven petroleum resources in the world and 34 percent of gas fields of the world are located in giant hydrocarbonic fields in the Middle East [1] [2]. Zagros is one of the most important fold belts and active tectonic in the Middle East that is suited in South-West of Iran, between the Arabian Plate and Center of Iran [1] [3] [4]. This area containing lucrative reservoir bodies and including enormous hydrocarbonic fields is famous as one of the richest oil belts in the world [1] [2]. Due to mud-supported nature of more facies which inherited low reservoir potential from their depositional settings, diagenetic process plays an important role in increasing of reservoir quality, but not always. However diagenetic processes have an important control on reservoir characteristic, in which even the quality of reservoirs can be investigated by studying of the diagenesis processes [5]-[10]. In fact, various diagenesis processes are able to influence on petrophysics features with different intensity on total and effective porosity, permeability, size of pore type and their distribution for example [2] [8] [11]-[13]. Therefore investigations of diagenesis processes are necessary for understanding reservoirs quality. The goal of this study is survey of effect of diagenetic presses on reservoir properties and also flow unites determination in the Ilam Formation of Dezfol embayment using petrography evidence and petrophysics data (such as [14] [15], and many others).

2. Geological Setting and Stratigraphy

The Zagros belt is extended along North-Northwest boundary of Arabian Plate, *i.e.* from Southeast of Turkey, Syria and Iraq to the Minab's fault in South of Iran [1] [2] [4] [16]. Dezfol embayment in Zagros sedimentary-structure zone is surrounded via tree structural phenomenon's, which are included Flexural Balarood zone in Northwest, flexural Kohestan zone in Northeast and a complicated fault zone named Qatar-Kazerun in East and Southeast (**Figure 1**). More than 45 fields are discovered inside Dezfol embayment [17].

The cretaceous deposits of Dezfol embayment such as Zagros embraced significant amount of hydrocarbonic
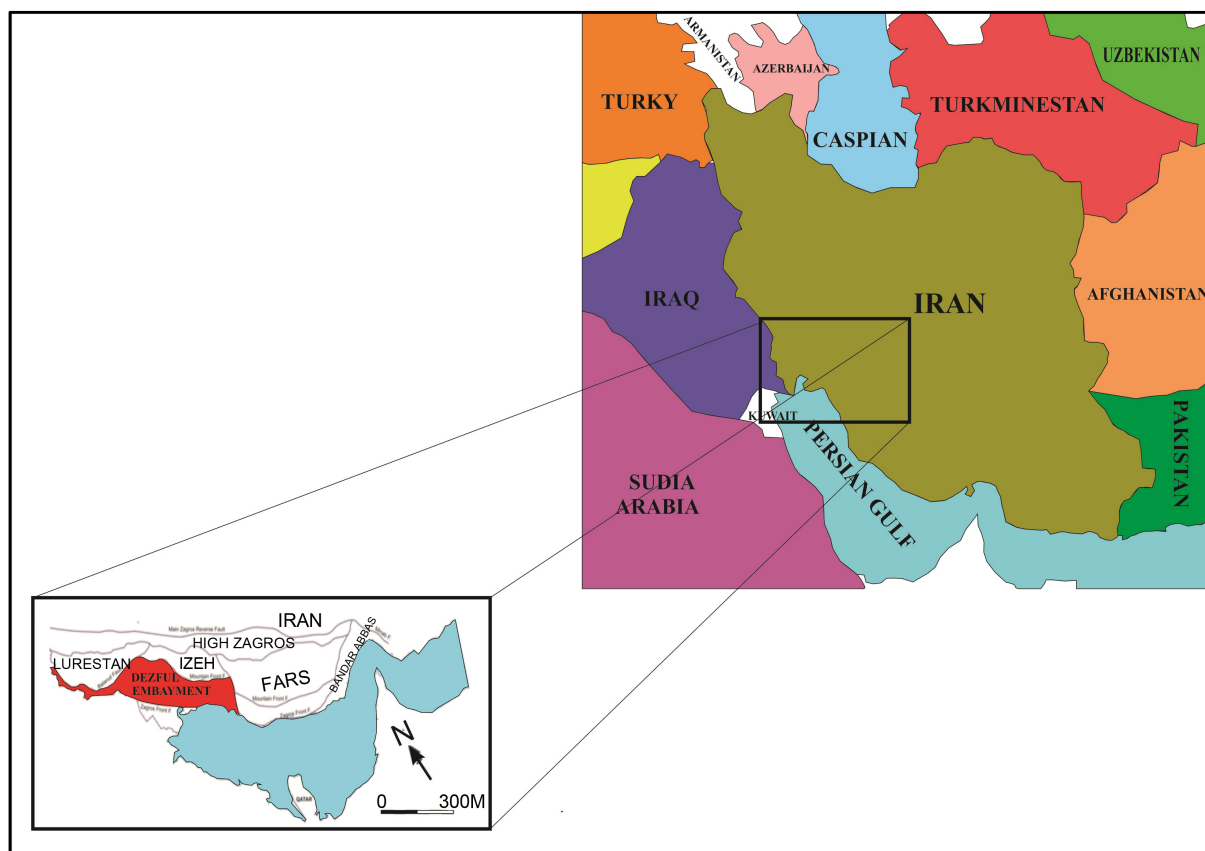
Figure 1. Approximate position of Dezfol embayment (updated from [14]).

reserves. [18]-[23] suggested the sedimentary carbonate ramps environment was extended over long time in this area. They also emphasized that the Arabian Plate, in that period of time, has tropical and subtropical climate. During the late Campanian and late Santonian, seawater had covered Zagros fields, and Ilam Formation was deposited. Then relative sea level rise continued and Gurpi Formation which have shale and marl lithology was deposited [24]. Wynd and Setudehnia (1975) believe that the boundary between two Formations of Ilam and Gurpi formed gradually and continues. Whereas Furst (1970) considered an erosional unconformity nature for mentioned boundary [24]. The stratigraphy position of this formation on the Arabian Plate and Dezfol embayment has been showed in (**Figure 2**).

3. Data and Method

In this research, 300 thin sections of cores and cutting from five wells in the studied field have been studied. Polarizing microscope is used to investigate petrography and diagenesis evidences and to describe facies. A modified Dunham (1962) [26] texture scheme was used. Flugel (2010) [27] method is applied for micro-facies determination and assortment, and finally method of Choquette and Pray (1970) [28] is used for classification and ordering of the facies. In order to recognition of depositional settings of facies associations and reconstruction of palaeoenvironmental condition, standard models of ancient and recent carbonate environments are used as analogues [27] [29] [30]. Detailed petrography analysis and well-logging data which are provided by Geolog professional software, this Formation is divided into five different zones of reservoir units. In term of reservoir quality. Determined reservoir unite are correlated among all five well and flow units have been determined across the studied field.

4. Facies and Depositional Environment

Detailed petrographic analyses, have led to identification of 10 Micro-facies types, which are grouped into six facies associations (**Table 1**). Depositional environments of facies range from the outer ramp to inner ramp settings. In order to recognition of depositional settings of facies associations and reconstruction of palaeoenvironmental condition, standard models of ancient and recent carbonate-evaporate environments are used as analogues [27] [29] [30] [31] (**Figure 3**).

5. Diagenetic Processes

The main diagenetic alterations and their controls on the reservoir properties of Ilam formation are elaborated in details and presented as follow and have been showed in **Figure 4**.
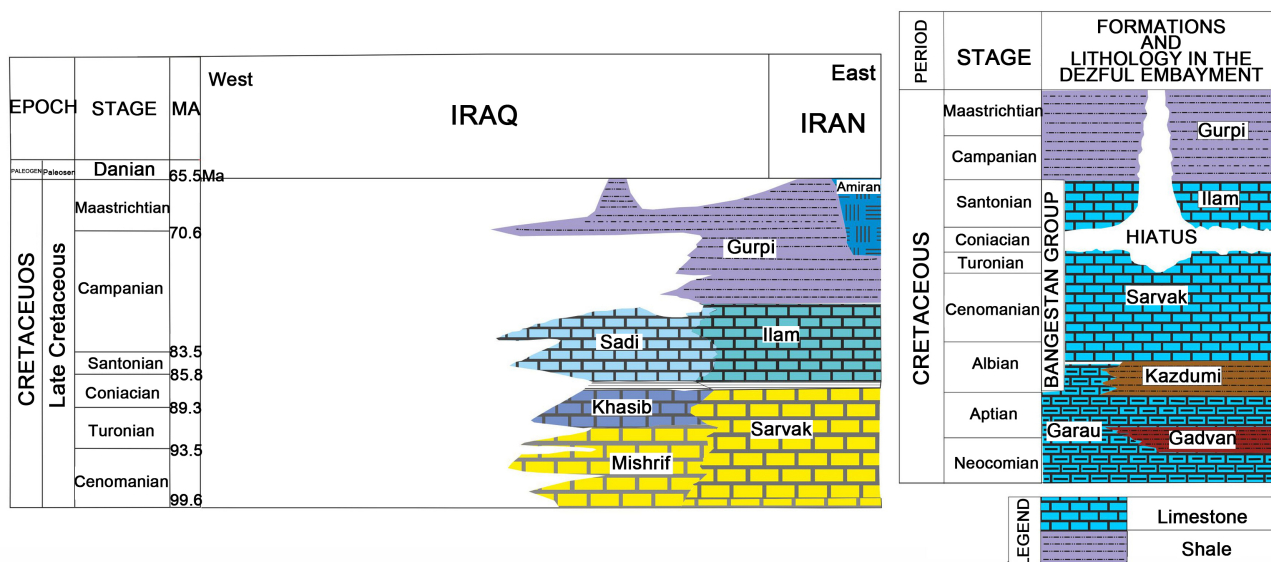

Figure 2. Ilam formation and its stratigraphy position at Arabian plate (modified from [1] [25]).

Table 1. Determined facies and depositional setting of Ilam formation of the studied field.

Facies number	Facies	Sedimentary environment
MF1	Miliolids Mudstone Wackestone	Lagon
MF2	Rudist Framenifral Wackeston-Packstone	Lagon
MF3	Bioclast Grainstone	Carbonate Shoal
MF4	Intraclast Bioclast Grainstone	Carbonate Shoal
MF5	Framenifra Intraclast Grainstone	Carbonate Shoal
MF6	Peloidal Packstone-Grainstone	Carbonate Shoal
MF7	Rudist Flotstone	Inner Ramp
MF8	Microbioclast Wackestone-Packstone	Inner Ramp
MF9	Ecinoid Oligosteginid Wackestone-Packstone	Outer Ramp
MF10	Sponge spicules oligosteginid Wackestone-Packstone	Outer Ramp
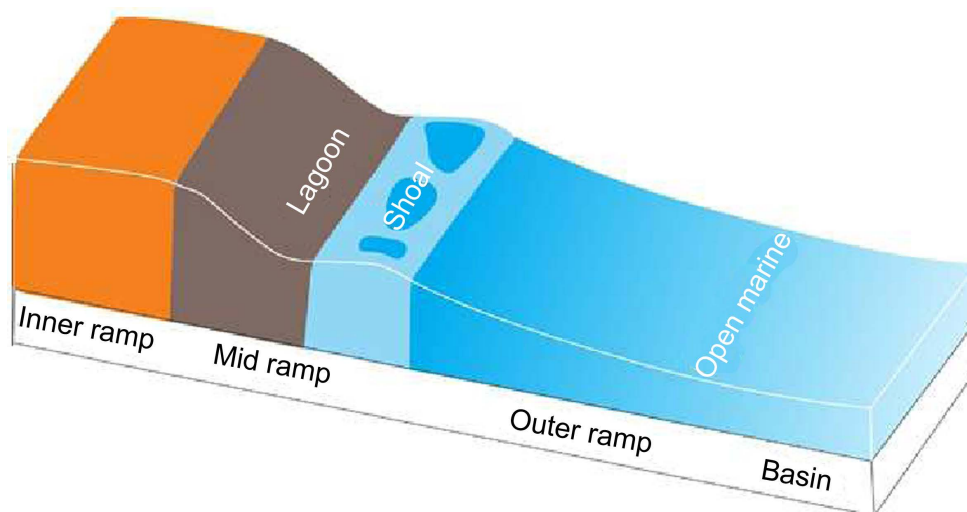
Figure 3. Conceptual depositional models of Ilam formation of the studied field.

5.1. Cementation

In the studied interval, early stage of marine cements is very rare, but the late stage diagenetic cements are frequent. Based on the time of formation, the following types of cement are recognized.

5.1.1. Isopachous Bladed Cement

This type of cement created in form of a thin and isopachous layer around the grains (**Figure 4(a)**). Existence of the layer of cement between the grain's boundaries indicates that these layers are generated on early stage of d genesis as first generation of cement, which mainly observed in the grainstone and packstone facies [27]. As a result of physical pressure, this type of cement prevents from the deformation and keeps the primary porosities [27] which meaning positive effect on reservoir quality. This cement is the index of sea water phreatic zone [27] [32] [33].

5.1.2. Equant Cement

Approximate homologous dimension is the remarkable common characteristics of this type of cement, which crystals are subhedral to anhedral form and boundary between each crystal is distinctly visible [27] [34] (**Figure 4(b)** and **Figure 4(c)**). This cement type is observed within grainstone facies with moldic porosity. Dissolution of unstable fragments created moldic porosity. The materials that are produced from dissoluted particle formed
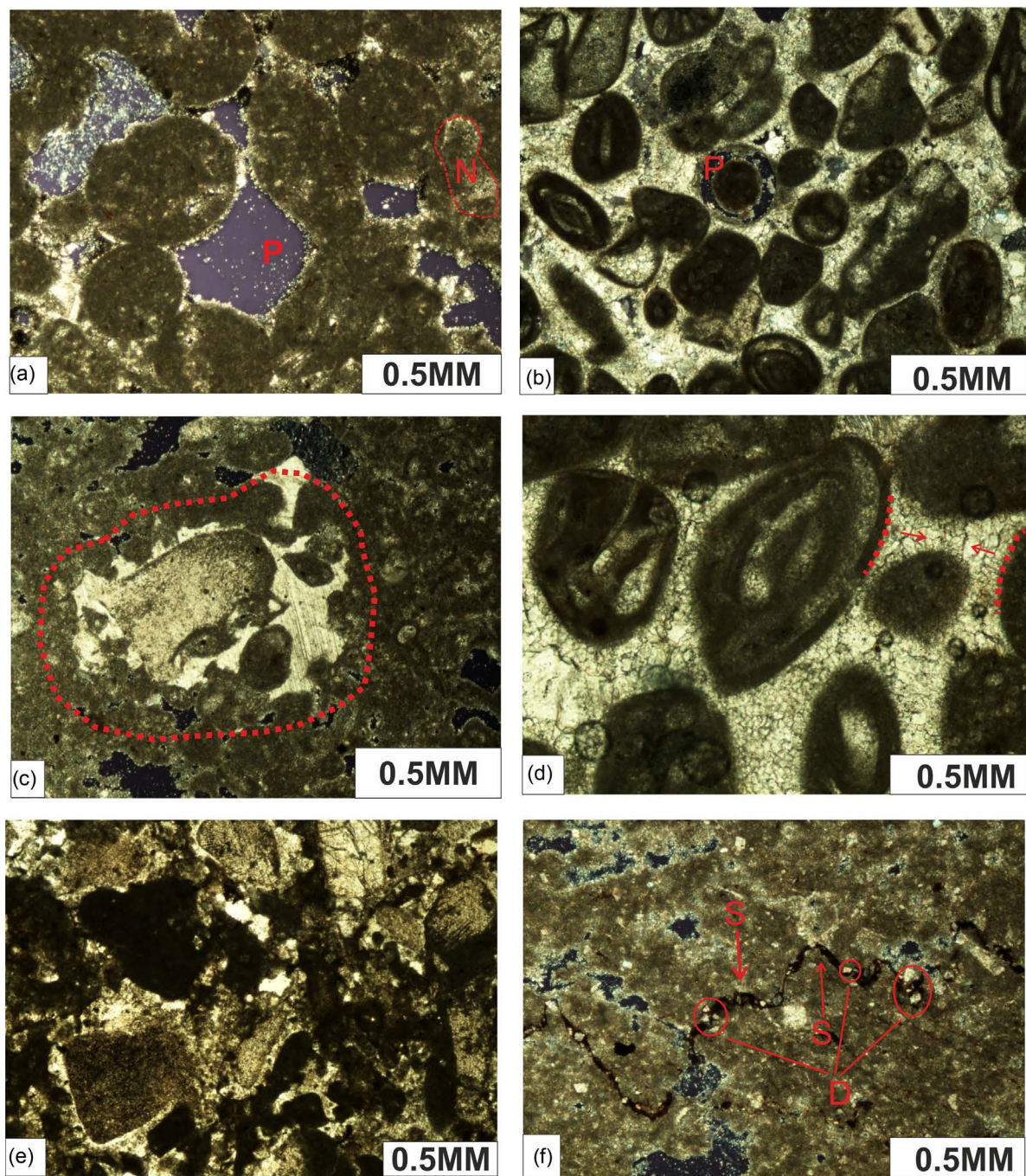
Figure 4. Main detected diagenetic processes in the Ilam formation.

Equant Cement and fill the space between of grains. This type of cement mainly observed in form of moderate to large size crystals, and is able to develop in various diagenesis environments such as meteoric to burial [27].

5.1.3. Poikilotopic Cement

This type of cement mainly exists in large size because it contains several crystals (**Figure 4(d)**). Ahmad and Bhat (2006) [34] believed, the formation of this cement type is based on low-speed grow of calcite crystals during burial environment and can be filled free space [35]. This pervasive and widespread cement has filled inter-crystal and inter-grain's porosity and caused of significant decline in porosity and permeability [32]. The

mentioned cements are coarse in size due to low-speed growth of crystal [27].

5.1.4. Drusy Cement

In this particular cement, dimension increment occurred toward the inter-grain and between grains centers. It also created in both burial and meteoric environments near the earth level [27]. This cement fills the inter-grain and between-grains spaces and caused of a significant decline in porosity and permeability in grain supported facies. However, it is formed in shallow burial which mostly have close relationship with meteoric diagenesis [27].

5.1.5. Syntaxial Cement

One of the most important cements in the studied interval is Syntaxial cement, and is a witness to the free-water involvement [27]. The cement accumulates around a singular grain mostly echinoderm with composition of HMC. Vados, metoric and burial environments are favorable for formation of this cement. This cement with dark and cloudy appearance is created in marine diagenesis setting and cements with clear and bright crystal are related to burial and meteoric beds [36].

5.2. Neomorphism

During this process, primary crystals consumed and will replace by new crystals, which have a similar chemical combination [36]-[38]. As [39] represents, the process mainly occurs in present of water, diagenesis and wet environments, where dissolution and sedimentation are happening. In the other words, neomorphism is related to the growing some of crystals costs due to losing some other crystals and according to the [36] required calcium carbonate will provided from dissolution of small crystals and inter-grain's water. In the studied interval neomorphism has important effect on porosity and subsequent reservoir quality.

5.3. Micritization

[40] states that this process can take place as a result of consecutive activities of microorganisms such as, alga, fungus and cyanobacteria, that are exist on allocems surface. In Ilam Formation, micritization process was developed around the skeleton fragments. Although in some cases, the internal structure was loosed as a result of the intensity of micritization, which can be due to the high activities of microorganisms and inadequate water rotation [33] [34]. In many cases, intensive bacterial activities destroyed entire internal structures of lime fragments (**Figure 4(b)** and **Figure 4(d)**).

5.4. Stylolitization

Stylolite is rough and ridged surface contact between the rock mass which mainly created in more 500 meter depth [41]. In the some space with high content of clay mineral, stylolite and dissolution seams are more observable [42] [43]. Stylolitization process can have negative or positive effects on reservoir quality. Stylolite acted as a blocking force against fluid flow and results declining of reservoir quality. In other hand, stylolite can enhance the reservoir quality on the some condition with passing of the flow and consequently in fact increasing permeability by connection of pore type [44].

5.5. Dolomitization

Dolomite occurred in Ilam Formation in singular and scattered rhombus forms but with low frequency. However, they have centralized around the stylolites and dissolution seams. Dolomite crystal centralization around the stylolites and disbandment channels demonstrates that they are generated from fluid with pressure dissolution in last stage of burial process see [7]. In fact, pressure dissolution caused of required magnesium concentration [45]. [14] recognized that dolomitization is more likely to have positive effect on the quality of reservoir. According to the [45] and [46] studies, the lime mud-which composed of more thickness of interval-Played a role as main supply of magnesium for dolomitization. Scattered dolomite crystals along the stylolite and pressure dissolution seams can be seen in some sample; therefore it is justified for formation term of burial model dolomitization [7]. The dolomites crystal with size ranged from tiny to middle presumed probably origin from hydrocarbon dissolution during migrating fluid when stylolite were active channels for flows see [7] [47].

5.6. Dissolution

Dissolution is an effective diagenesis process which mainly caused of secondary porosity such as moldic, vuggy and channel type. Dissolution process can take place in meteoric, marine and burial environments [27]. Microscopic dissolution and its consequence porosity will be discussed in details in porosity section.

5.7. Porosity

Different types of visual porosity observed in Ilam Formation are described in ongoing part.

5.7.1. Moldic Porosity
Selective dissolution happened among aragonite grains of limestone and remains empty space in the grain place which are similar to the primary grains shape [33] [48] (**Figure 4(b)**). This porosity is fabric selective, which mostly resulted during the meteoric and burial diagenesis environments [27] [39].

5.7.2. Intraparticle Porosity
Intraparticle porosity is type of porosity which has low frequency in the studied interval. In some sample the inter-grain pores may not be connected together appropriately. [27] represented which often this porosity formed during meteoric diagenesis.

5.7.3. Intercrystaline Porosity
Mainly, intercrystaline porosity not preserved among carbonate rocks, because these are considerably sensitive to the burial pressure and primary porosity was destroyed [27]. But in some cases this porosity was remained, especially when primary cementations are occurred.

5.7.4. Vuggy Porosity
This type of porosity observed in large forms (more than 1.16 mm). Vuggy porosity is nonselective fabric and has larger that grains size and mostly results of meteoric dissolution [27]. The most common porosity among the studied wells is vuggy porosity (**Figure 4(e)**).

5.7.5. Fracture Porosity
Tectonic forces are main agent for occurring of this porosity. Fracture porosity in carbonate rocks is a common feature and happened during burial diagenetic stage [27].

6. Reservoir Characterization and Flow Units

Different parts of Ilam Formation are studied by petrography and petrophysics data in order to investigate the Reservoir characterization and flow unit determination. Analyzing the well logging that is achieved from petrophysic technique are used in order to determine the quality of reservoir in different zones, and additionally for determining the best zones for developing the oil fields [49]. Reservoir quality determined by calculating the porosity, and verifying the lithology type [50]. According to the [9] classification, Ilam's reservoir is a diagenetic reservoir. Since, dissolution is the main key in increasing the quality of diagenetic reservoir. Identifying the reservoir zones from non-reservoir zones (reservoir unit determination) and subsequent flow unit determination is an important step for the field developing plans. There are different parameters for identifying the reservoir zones from non-reservoir zones such as, analyzing the common petrophysics logs and using petrology features which all was used in this study and represented in **Figure 5**. Total porosity of these zones evaluated via Geolog software and presented in **Table 2** which are according to the [51] standard. Also, porosity distribution over the studied field is depicted by Surfer software (**Figure 6**). Two and three-dimension models of distribution demonstrates that highest amount of porosity occurred in Northwest of the field (**Figure 6**).

7. Conclusion

Detailed petrographic analyses, have led to identification of 10 micro-facies which are represented as a carbonate ramp depositional model. According to the studies, Ilam Formation endured three different diagenetic environments: meteoric, marine and burial diagenesis. Various digenesis processes have been recorded for this interval,
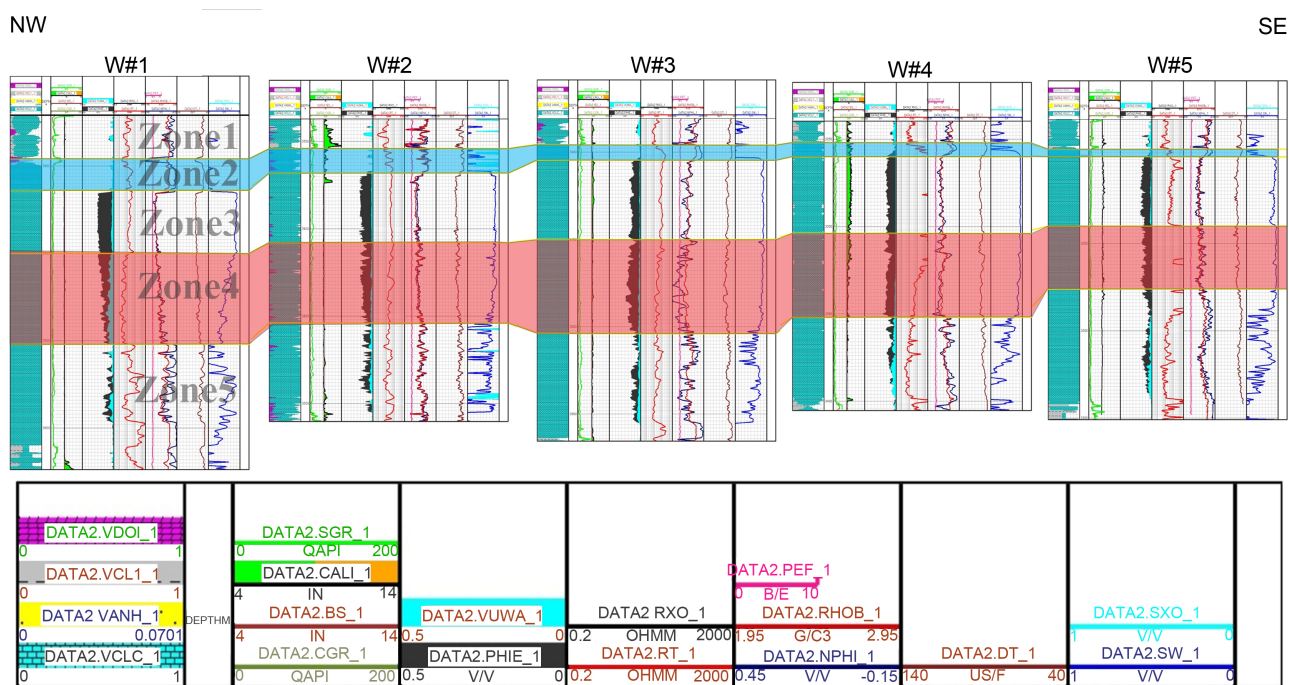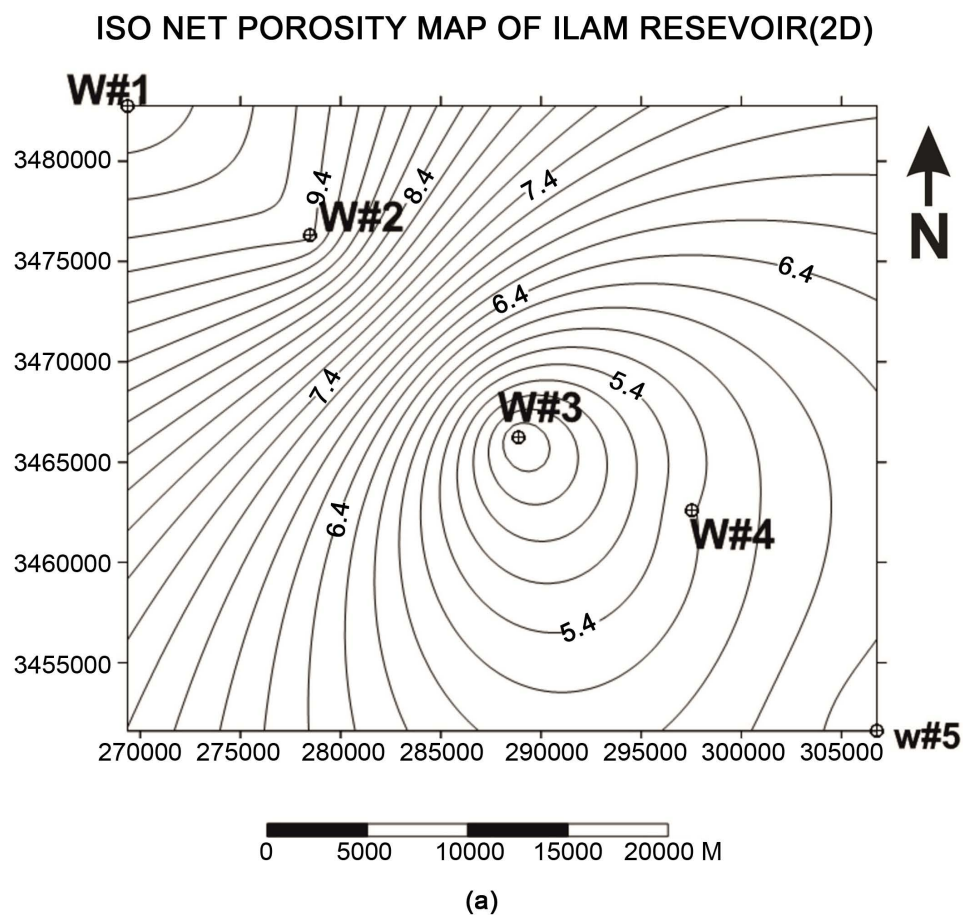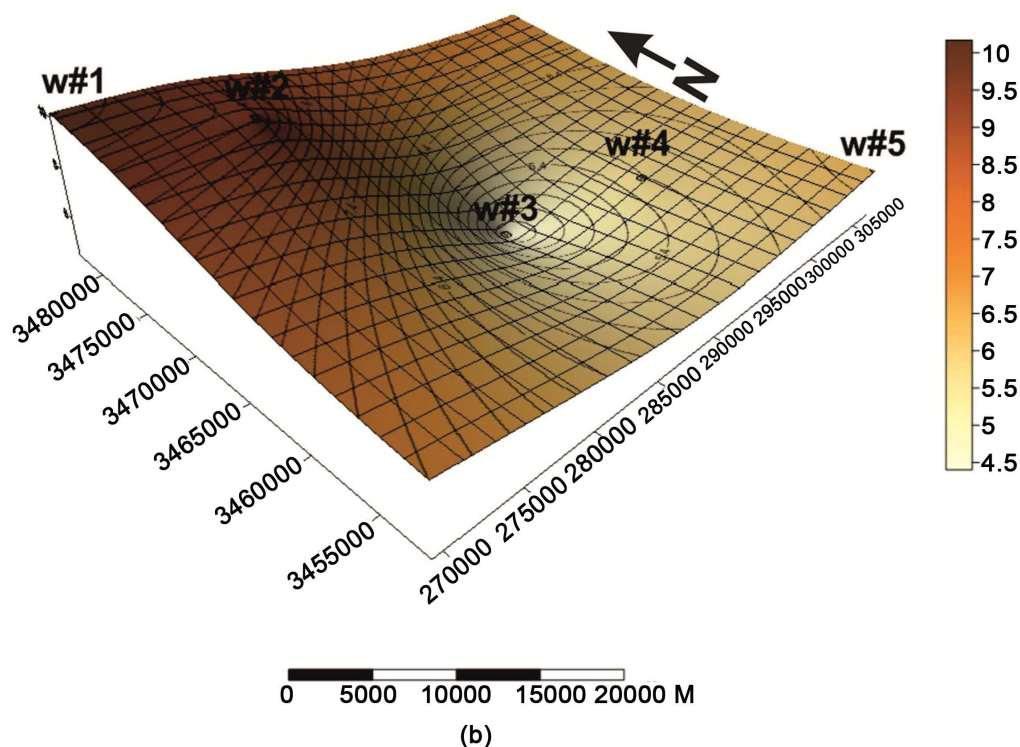
NW   SE

Figure 5. Flow unit determination across the studied field.

ISO NET POROSITY MAP OF ILAM RESEVOIR(2D)

(a)

ISO NET POROSITY MAP OF ILAM RESEVOIR(3D)

(b)

Figure 6. (a) Two-dimension model of porosity distribution over studied field; (b) Three-dimension model of porosity distribution over studied field.

Table 2. Average porosity and reservoir quality of determined flow unit.

Zone	Porosity %	Qualitative evaluation
I1	4.72	Poor to fair
I2	1.9	Poor
I3	11.86	Good
I4	8.61	Fair to good
I5	7	Fair to good

such as dissolution, cementation, micritization, neomorphism and dolomitization. From these processes, only dissolution created reservoir quality by producing different types of porosity, especially vuggy types. This study revealed that Ilam's reservoir is a diagenetic reservoir in the studied field. In order to achieve more reliable view from reservoir quality evaluations and also determination of reservoir unit using petrography and petrophysics data, the mentioned reservoir was divided into five units. Evidence shows that in unit-I1 and I2 there are significant numbers of mud supported facies, approximately no diagenesis processes recorded in these zones, which lead to the low porosity and poor reservoir qualities. Unit-I3 includes clear lime and has the highest amount of porosity presenting good quality, which endures more dissolution. Unit-I4 and I5 have moderate porosities and their reservoir qualities are fair to good. Also, according to the two- and three-dimension models of porosity distribution over the 5 units in horizontal extension, it can be stated that more percentage of porosity occurred in northwest of field.

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