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Diagenetic Effects and Porosity Evolution of Zubair Formation in West Qurna Oil Field, Southern Iraq

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ABSTRACT

This present study includes the petrography, lithofacies analysis and depositional development for the Zubair Formation in six boreholes (WQ-1, WQ-13, WQ-15, WQ-60, WQ-148 and WQ-356) within the West Qurna oil field. Zubair Formations was deposited within Mesopotamian Zone during the Barremain stage which belongs to the Early Cretaceous epoch. The Zubair formation in the study area affected by many diagenetic processes through and after the deposition. There are three diagenetic zones in this succession; the lower part of the Zubair Formation is characterized with three effected porous zone, which is separated by high compacted and cemented sandstone. The middle part of this formation is showing high compacted sandstone with appeared the overgrowth quartz and micro-quartz cementation. While the upper Zubair Formation is affected by compaction shale alternative with high compaction overgrowth quartz. The quartz arenite sandstone affected by the compaction in low amount follows by chemical dissolution led to made the secondary quartz precipitated on the original grains this decrease the primary porosity, the increase of compaction process destroyed the quartz and rock fragment grains this associated with chemical solution which led to precipitate extra grains of quartz as a small grain decreasing the porosity. After this process the changing in chemical and physical properties of depositional basin led to precipitate the calcite cement, and finally as results of organism activity calcite were dissolved and produced the secondary porosity. The effective porosity values distribution in the studied succession, where appeared in the lower unit one moderate permeable zone in all studied wells separated by impermeable zone in WQ-60 to became two zone. Whiles the middle unit characterized by two moderate and two high permeable zones. The first moderate zone is appeared in the lower part of middle unit within WQ-60 , 15 and 1, while the second is appeared in the upper part of this unit within WQ-15, 1 and 356.The upper unit is showing one limited moderate permeable zone within WQ-60 and 15.

KEYWORDS: *Diagenetic Effects, Porosity Evolution, Zubair Formation, West Qurna Oil Field, Southern Iraq*

INTRODUCTION

The Zubair clastic succession was deposited in the Mesopotamian basin during the Early Cretaceous epoch within the Barremain stage. This study is including the petrography and facies analysis of the Zubair sequence in six wells WQ-1, WQ-13, WQ-15, WQ-60, WQ-148 and WQ-356 in the West Qurna oil field. The studied area is situated in the south of Iraq within the zone of Mesopotamian. The West Qurna oil field is covering an area of 340 km², the West Qurna oilfield lies 65km away from Basra in southern Iraq (Fig. 1).

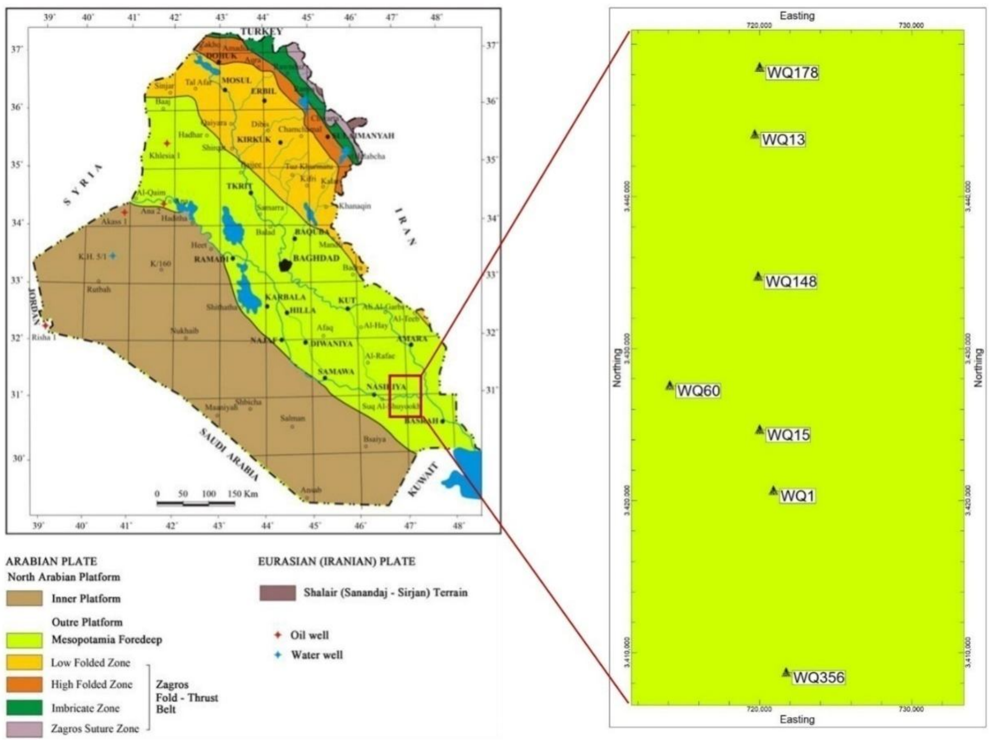


Figure 1: shows a map of studied boreholes with the tectonic setting of Iraq (Ali and Al-Zaidy, 2020).

The Zubair succession represents a Barremain sequence which belongs to the Late Tithonian-Early Turonian Megasequence. The formation was deposited in a large intra shelf basin contemporaneous with a new tectonic phase of sea floor spreading in the southern part of Neo-Tethys. The differential subsidence and the resultant thickness changes occurred across transverse faults. The axis of this basin was shifted towards the eastern Mesopotamian Zone into the Tigris Subzone from its previous position on the Salman Zone and western Mesopotamian Zone (Jassim and Goff, 2006).

Al-Zaidy (2020) studied the lithofacies analysis and stratigraphic development of the Zubair Formation in Majnoon and Suba oil fields. That suggests the Zubair Formation was deposited during three depositional stages of transgression system tracts, which was ended with appeared the shale lithofacies within the well-sorted quartz arenite lithofacies to mark the mfs in the Suba oil field. While, the Majnoon oil field the Zubair succession is characterized by three depositional cycles were represented by sequential of delta plain and delta front association with dominance of shale units. Addition to, study the lithofacies distribution and stratigraphic framework of this succession in Kifl oil field (Al-Zaidy, 2019).

Ali and Al-Zaidy (2020) studied the petrography, lithofacies analysis and depositional development for theZubair

Formation in WQ-1, WQ-13, WQ-15, WQ-60, WQ-148 and WQ-356 within the West Qurna oil field.

Zubair/Ratawi succession as a clastic shelf was covered by the shallow marine sediments of Shuaiba Formation following by prograding of the Zubair and Ratawi succession (Jassim and Goff) (Fig. 2).

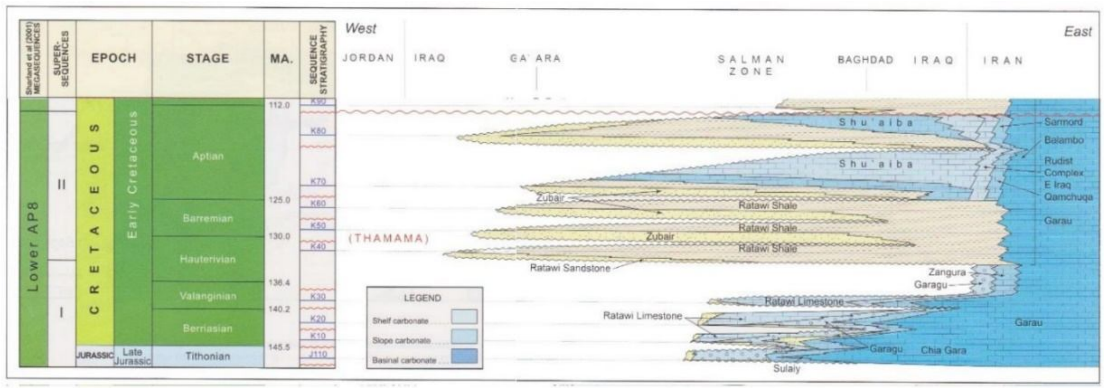


Figure 2: Chronostratigraphic cross section shows Early Cretaceous succession (Aqrawi et. al. 2010).

The purpose of this study is determination of diagenetic effects with the porosity and permeability evaluation of Zubair succession in the West Qurna oil field in Southern of Iraq.

METHODOLOGY

The current study was completed in three stages:

- Sampling and description stage; this stage is represented by going to the South Oil Company (SOC) where the samples are collected (Table 1).
- Laboratory stage; during the laboratory stage the samples were chosen and preparing thin sections. The petrographic study and diagenetic features tetermination are based on the study of thin sections of cuttings and core from the selected boreholes from Balad Oil Field.
- In this stage, study and process the available well logs were utilized in calculated the volume of shale and porosity. The following equations and steps were used in calculating the volume of shale, total porosity and effective porosity (Fig. 3).

Table 1: Thickness and coordinate sampling of the studied succession in West Qurna oil field

Name	Top	Bottom	Thick	Longitude	Latitude
WQ-1 Zubair	3074.5	3425.9	351.4	34420680.42	720900.03
WQ-13 Zubair	3279	3637	358	3444122	719863
WQ-15 Zubair	3081	3420.5	339.5	3424700	720000
WQ-60 Zubair	3407	3571	344	3427600	714100
WQ-148 Zubair	3125	3472	347	3434800	719900
WQ-356 Zubair	3070	3380	310	3408734.91	721733.92

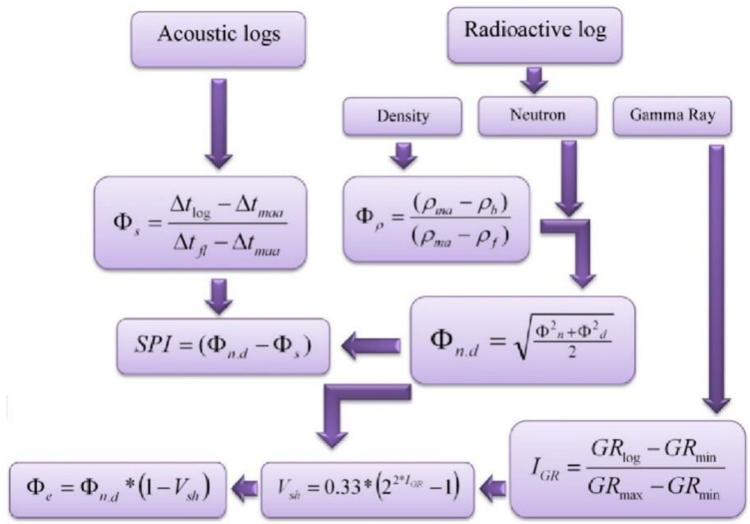


Figure 3: Diagram showing steps and equations which used in the present study (Al-Zaidy et al., 2013).

Diagenetic Processes:

Diagenesis processes deformed the original pore types and geometry of a sandstone bodies, therefore these controls and effects upon ultimate porosity and permeability properties. Early diagenetic stages correlate with depositional environment and sediments composition. Later diagenetic stage in cross facies boundaries and depending on regional fluids migration patterns (Burley, 1984). Effectively predicting sandstone quality and types depends on predicting diagenetic history (stages) as a product of depositional environments, sediment composition, and fluid migration patterns.

Diagenesis may also play an extremely important role in post-depositional modification of porosity and rocks types, causing either decrease in porosity as a result of compaction and cementation or increasing of porosity owing to solution processes. Thus, the economic importance of a particular sandstone unit as a reservoir rocks for petroleum (Boggs, 1995).

Diagenesis process refers primarily to the reactions which take place within the sediments between one mineral or rock and another, or between one or several minerals and the interstitial or supernatant fluids within the sediments (Selley, 2000).

Surdam et al. (1989) define the diagenetic zones by subsurface temperatures and reaction with rocks. Depending on geothermal gradient with depths to these zones can vary. Table (2) summarized major diagenetic processes and their impacts on pore geometry and types.

Table 2: Diagenetic environments and processed according to Surdam et al. (1989)

Zone of diagenesis	Temperature	Major diagenetic processes	
		Preserves or enhances porosity	**Destroys porosity**
Shallow	<80°C or 176°F (<5.00 to 10.00 ft)	• Grain coatings (inhibit later overgrowths cementation) • Non-pervasive carbonate cements that can be dissolved the rocks later	• Clay infiltration • Carbonate or silica cement (in some cases irreversible) • Authigenic kaolinite • Compaction of ductile grains
Intermediate	80-140°C or 176–284°F	• Carbonate cement dissolved • Feldspar grains alteration and dissolved	• Kaolinite, chlorite, and illite precipitate as a result of feldspar dissolution • Ferroan carbonate and quartz cement
Deep	> 140°C or 284°F	• Feldspar, carbonates, and sulfate minerals dissolved	• Quartz cement (most destructive) • Kaolinite precipitation • Illite, chlorite form as products of feldspar dissolution • Pyrite precipitation

There are three of diagenetic processes were distinguished in the studied succession, as follows:

1. Compaction
2. Cementation
3. Dissolution

The effects of diagenesis on sandstone reservoir units including the destruction of porosity in studied rocks by compaction and cementation, and enhancement of porosity by solution for that it is control on regional variations and developments of reservoir rocks quality, the main processes are:

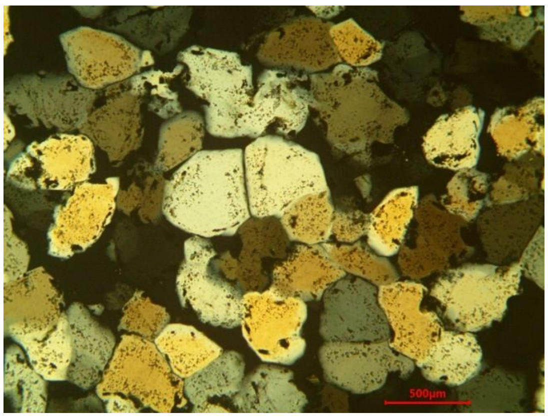
Compaction:

The compaction is the process of diagenesis when the volume reduction and consequential pore- water expulsion within sediments (Worden and Burley, 2003). The degree of compaction dependent on sorting, clay content, percentage of ductile fragments and burial depth or tectonic stresses (Wright and Blatt, 1982).

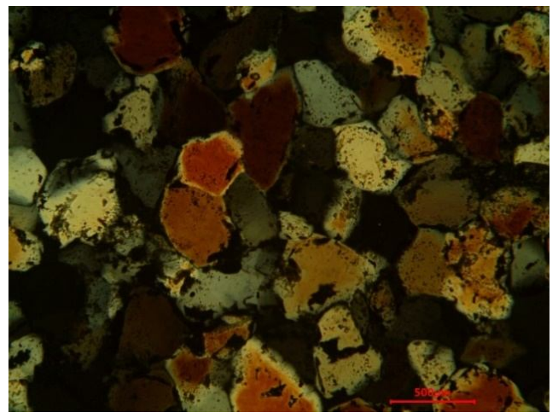
There are two types of sandstone compaction, physical and chemical (pressure solution) (Boggs, 1995).

- The mechanical compaction causes rearrangement of the grain packing, fracturing or deformation of carbonate grains and reduction of the porosity. It is particularly important in mud-dominated sediments as pelagic oozes, chalk and shelf lime mud such as Shattered micrite (Scholle, 1981) (Plt. 1.A).
- The chemical compaction (Pressure Solution) is the dissolution of carbonate rocks along planes as a result of the compaction (pressure) of overburden or tectonism such as stylolite. During deep burial, pressure-solution is more sustained than at shallow depths and is important in reducing both porosity and permeability. (Moore, 1989)(Plt. 1.B).

Plate (1)



A-Physical compaction
Ternary concourse to grain of quartz
Contact relation between grains
even sutured contacts (WQ-2 / 3228m)



B-Chemical compaction contacts
evolve through straight-elongate
to concave – convex (WQ-1 / 3277)

Cementation:

The cementation process is refer to growth or precipitation of the minerals in pore spaces within the rocks (Worden and Burley, 2003) so they have a special importance in reservoir studies. In the studied area, there are four types of cement: Silica cement, Carbonate cement, Iron oxide cement, Clay cement.

Silica cement:

Quartz overgrowths:

Quartz overgrowths generated by the precipitation of silica directly from aqueous solution in pores as well-ordered, low (alpha) quartz. The most common form of quartz cement is an overgrowth. Syntaxial rim cement with the same crystallographic orientation and optical continuity as that of the detrital grains. Overgrowths are one variety of Krynine, (1946) sedimentary (low-temperature) quartz and are mega-quartz which described in Folk's (1968) size classification of sedimentary clastic rocks. This type of cement is abundant in the sandstones of Zubair Formation in the studied sections (Plt.2A).

Micro-crystals quartz cement:

Other polymorphs of silica precipitate that occurs as cements in sandstones are fibrous microcrystalline quartz. Almost all occurrences of these polymorphs are in silcretes, indurated products (authigenic) of surface silica diagenesis (Summerfield, 1983) (Plt.2B).

Clay cement:

The average of this cement is the source of this cement is partly from dissolution to rock fragment and feldspar. This cement has an important effect on permeability (Worden and Burley, 2003) (Plt.2C).

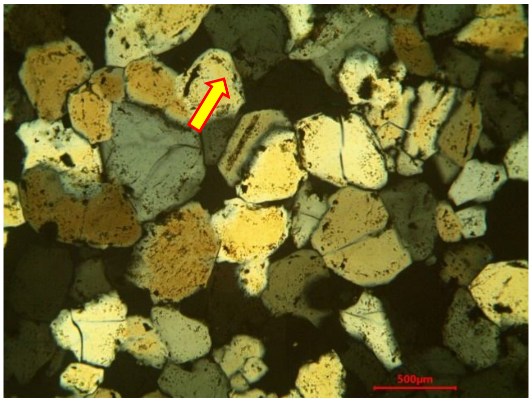
Carbonate cement:

The carbonate cement is also uncommon in sandstone of Zubair Formation. Some sandstone has carbonate cement with silica and iron cement. The average of it is 1% in the studied wells. Sometimes it is appearing as patches between quartz grains. The source of carbonate cement from Ratawai and Shuaiba Limestone Formations plate (Plt.2D).

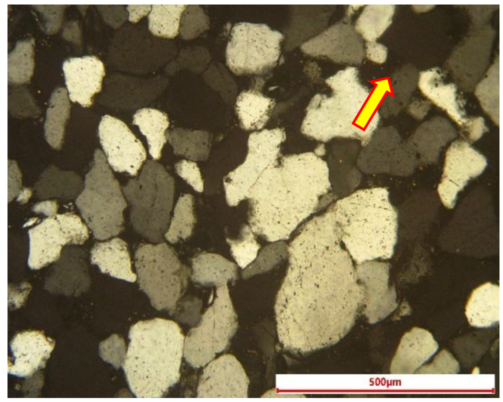
Dissolution:

Rock fragments and low stability silicate minerals dissolved because of increasing burial temperatures. There are two type of dissolution; the first is the pressure solution (see compaction) and the second is the dissolution which leads to increase in secondary porosity (Boggs, 1995) (Plt. 2E).

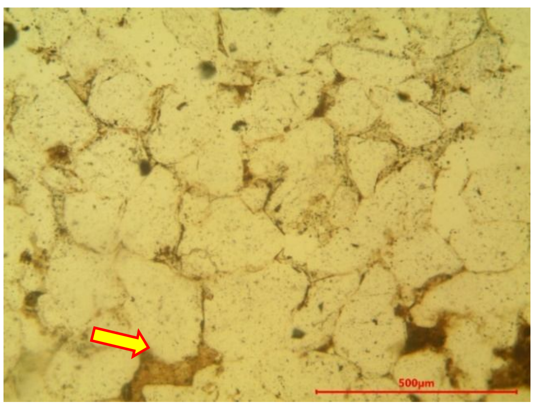
Plate (2)



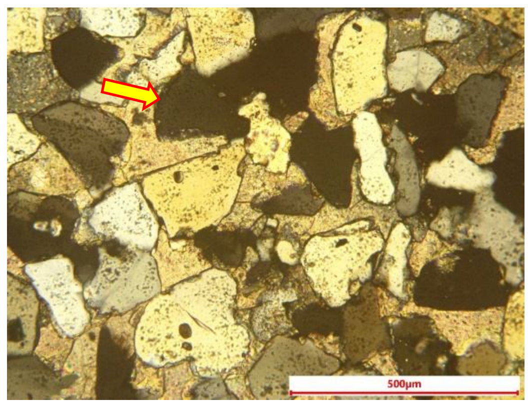
(2A) Quartz overgrowths



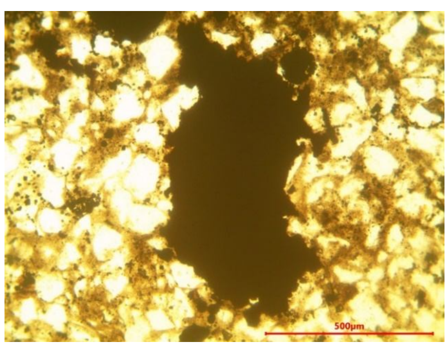
(2B) Micro crystalline Quartz cement (WQ-1/ 3277)



(2C) Clay cement (WQ-1/3240)



(2D) Carbonate cement (WQ-1/3240)



(2E) Dissolution (WQ-3/3225)

Diagenesis History:

The diagenetic regimes concepted are a broad framework that related of diagenesis processes to the development of sedimentary rocks and depositional basins. Three conceptual regimes of diagenesis stages are commonly recognized in this type of rocks: early stage of diagenesis (eogenesis), burial stage of diagenesis (mesogenesis) and uplift-related stage of diagenesis (telogenesis). This terminology and stages were adopted from a scheme developed initially by Choquette & Pray (1970) to describe the diagenetic processes of carbonate rocks, but is now more generally applied in all types of rocks: correctly so, as the same fundamental processes and controls operation in clastic rocks diagenesis and in carbonate sequential diagenesis. Alternative schemes (e.g. the Russian system including such terms as catagenesis and epigenesis have been used but are less commonly applied in this type of rocks. Because of the maximum temperature of burial, the effect of variable long time is difficult to affect by the kinetic control as diagenetic reactions.

After the clean sand deposited, it affected by low degree of compaction followed by chemical dissolution to made the secondary quartz precipitation on the original grains that were decreasing the primary porosity. The increasing of compaction process destroyed the quartz and rock fragment grains; this is associated with chemical solution that leads to precipitate extra small grains of quartz to decrease the porosity ratio. After this process the changing in chemical and physical properties of depositional basin leads to precipitate the calcite cements. And finally as a result of organism's activity, calcite was dissolved and produced the secondary porosity.

The Zubair Formation in the study area is affected by many types of diagenetic processes throw the deposition which represented by Figures (4, 5, 6, 7, 8 and 9). There are three diagenetic zones in this succession; the lower part of the Zubair Formation is characterized with three effected porous zone, which is separated by high compacted and cemented sandstone. The middle part of this formation is showing high compacted sandstone with appeared the overgrowth quartz and micro-quartz cementation. While the upper Zubair Formation is affected by compaction shale alternative with high compaction overgrowth quartz. The quartz arenite sandstone affected by the compaction in low amount follows by chemical dissolution led to made the secondary quartz precipitated on the original grains this decrease the primary porosity, the increase of compaction process destroyed the quartz and rock fragment grains this associated with chemical solution which led to precipitate extra grains of quartz as a small grain decreasing the porosity. After this process the changing in chemical and physical properties of depositional basin led to precipitate the calcite cement, and finally as a result of organism activity calcite was dissolved and produced the secondary porosity.

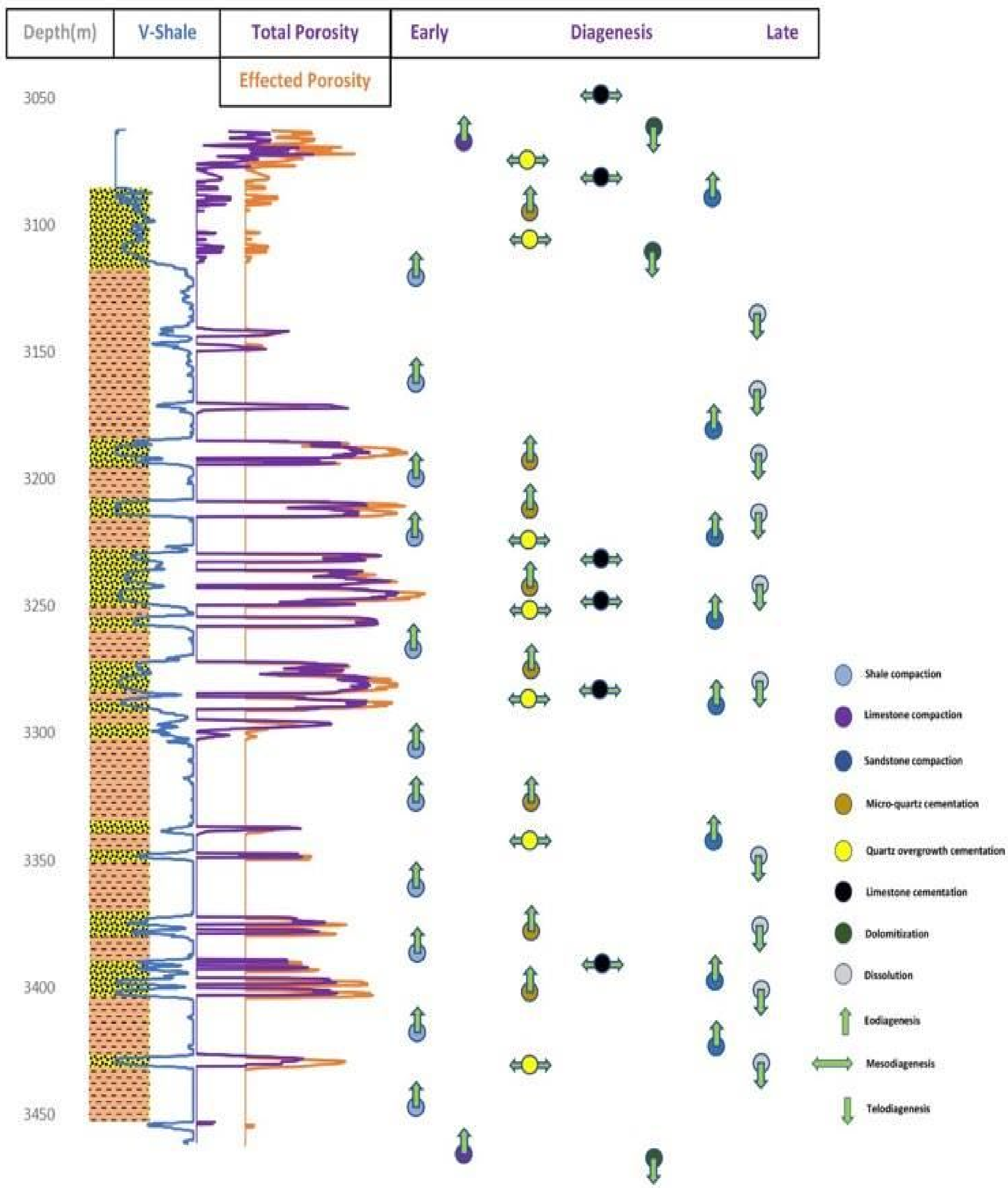


Figure 4: Lithologic columnar section shows the diagenetic processes and developments of Zubair Formation in WQ-1

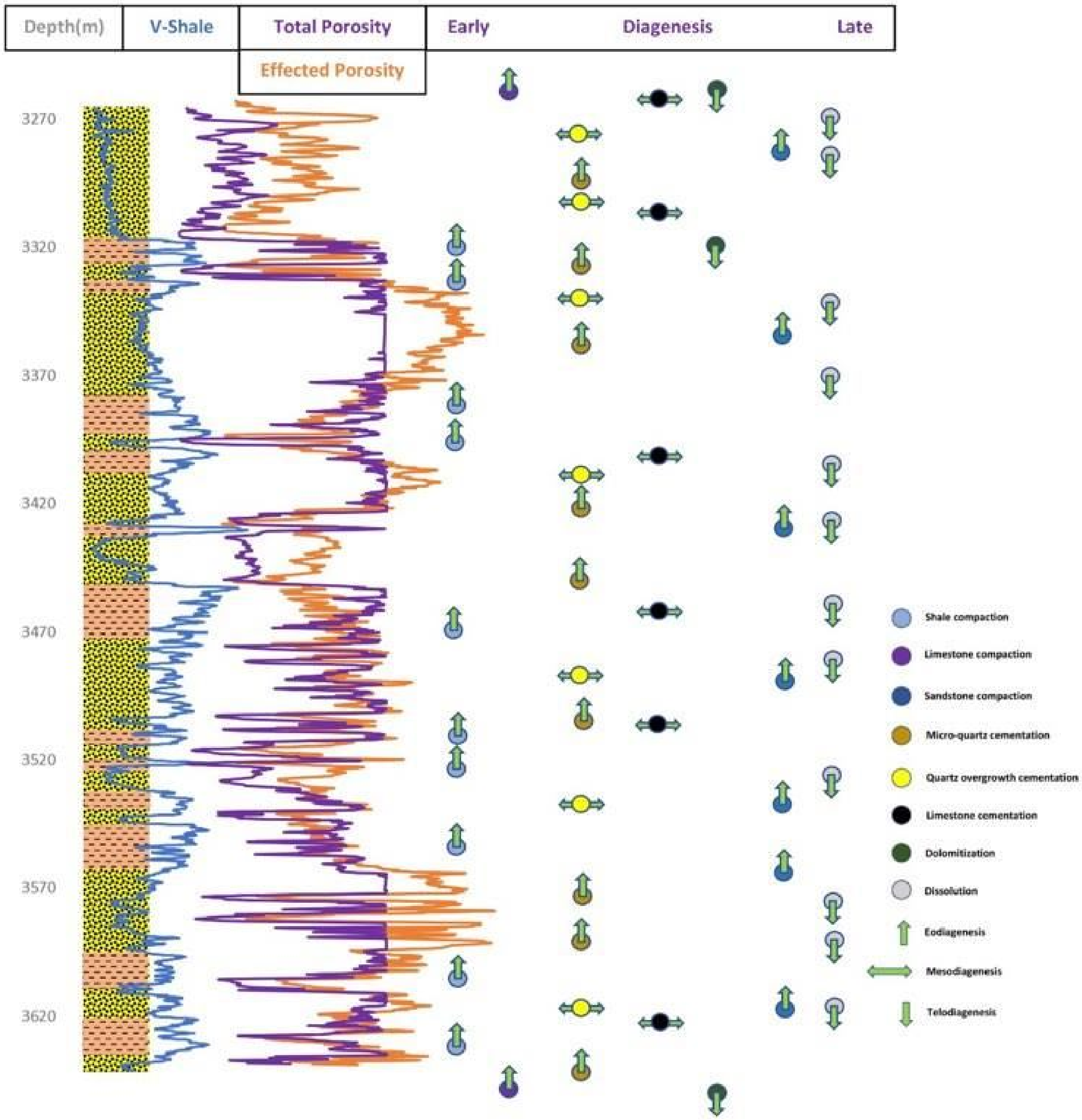


Figure 5: Lithologic columnar section shows the diagenetic processes and developments of Zubair Formation in WQ-13

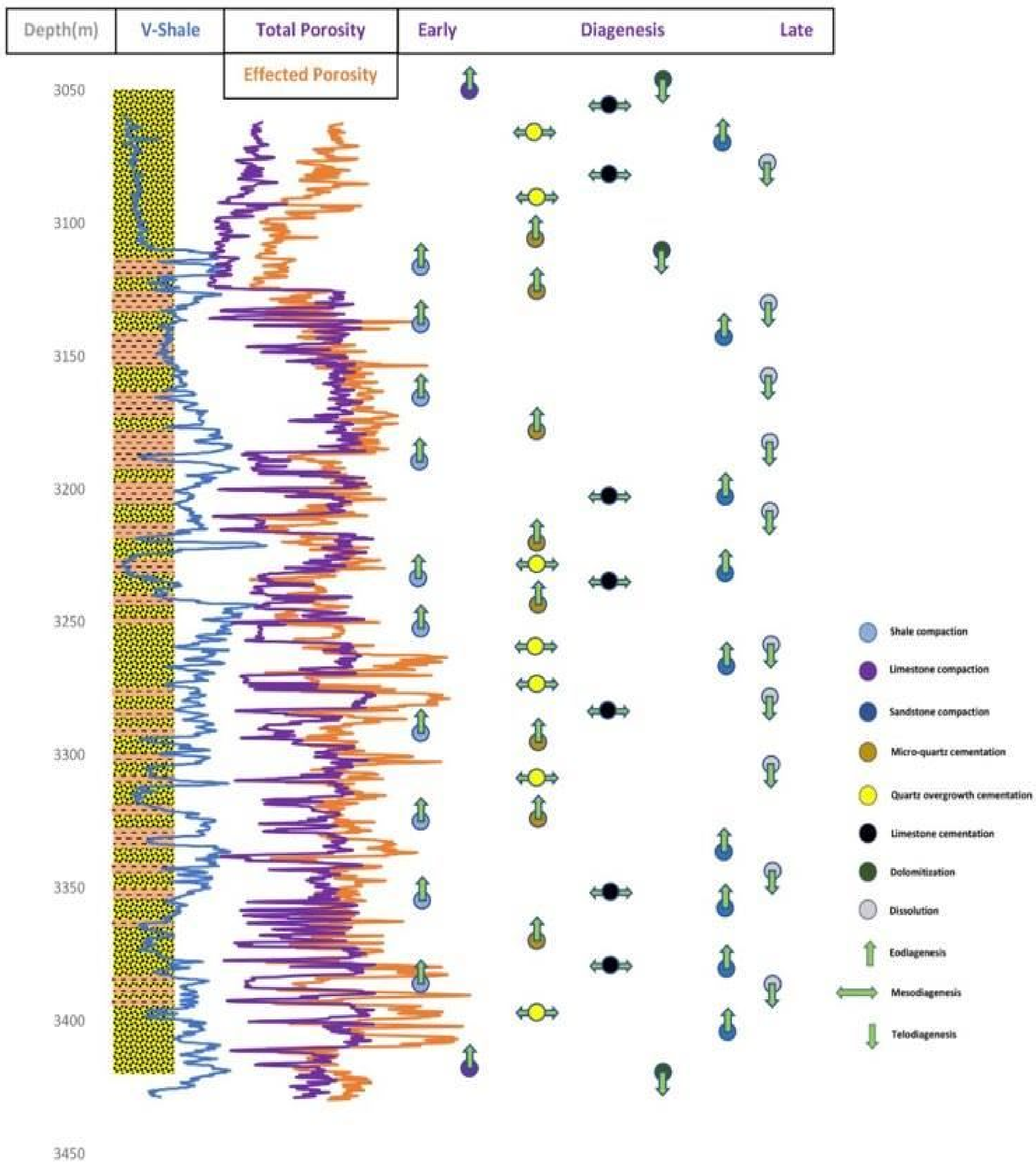


Figure 6: Lithologic columnar section shows the diagenetic processes and developments of Zubair Formation in WQ-15

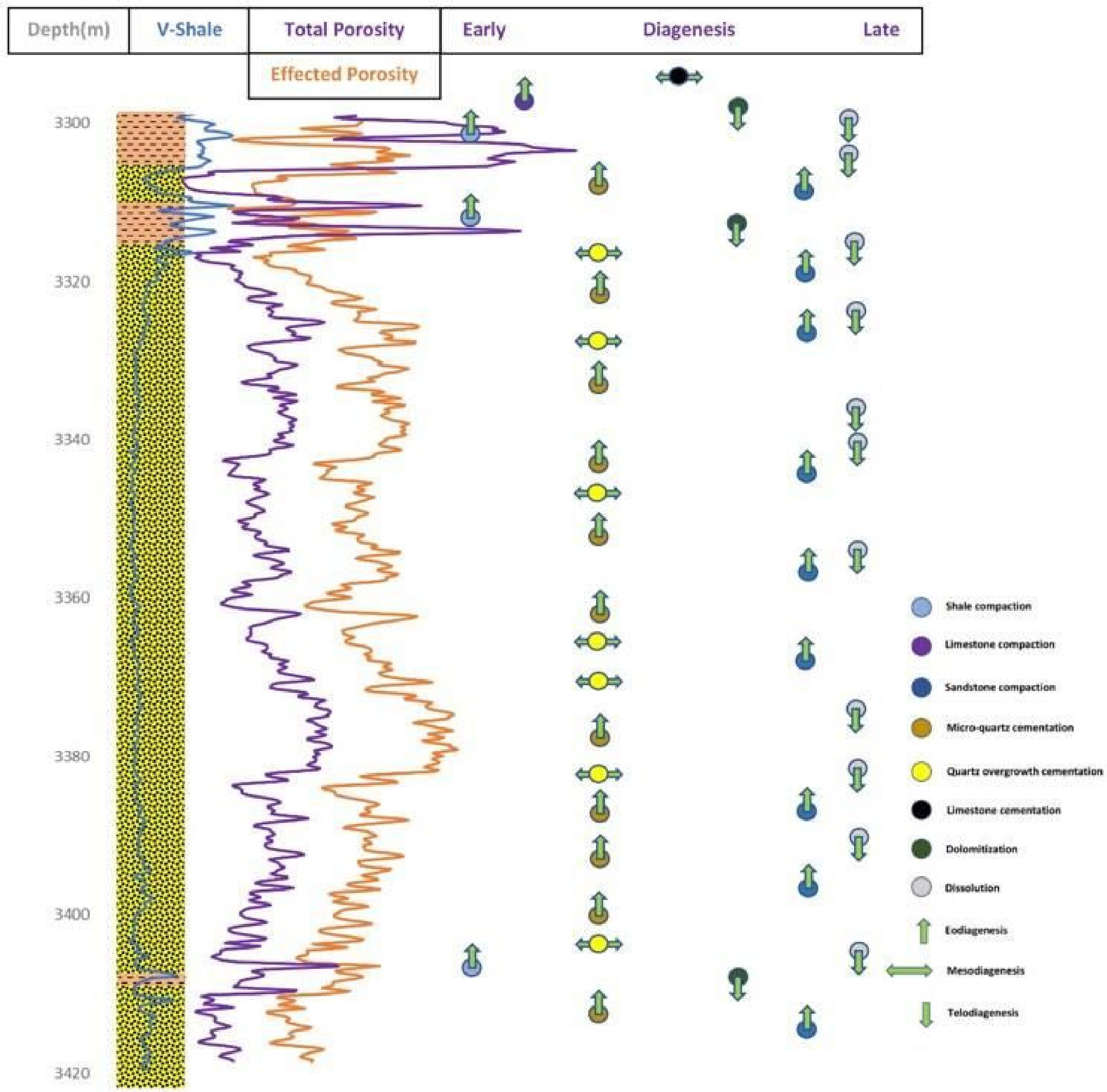


Figure 7: Lithologic columnar section shows the diagenetic processes and developments of Zubair Formation in WQ-60

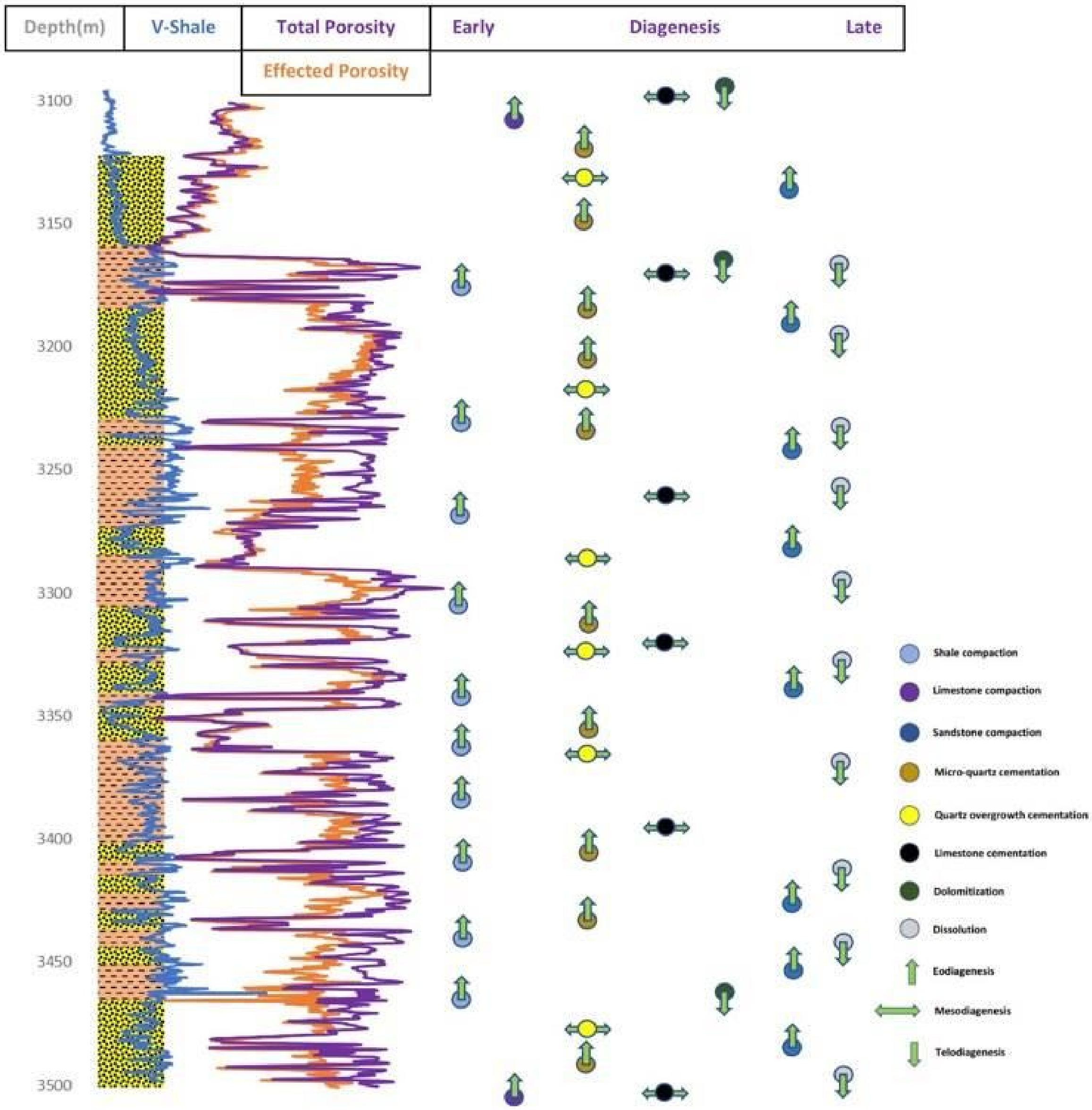


Figure 8: Lithologic columnar section shows the diagenetic processes and developments of Zubair Formation in WQ-148

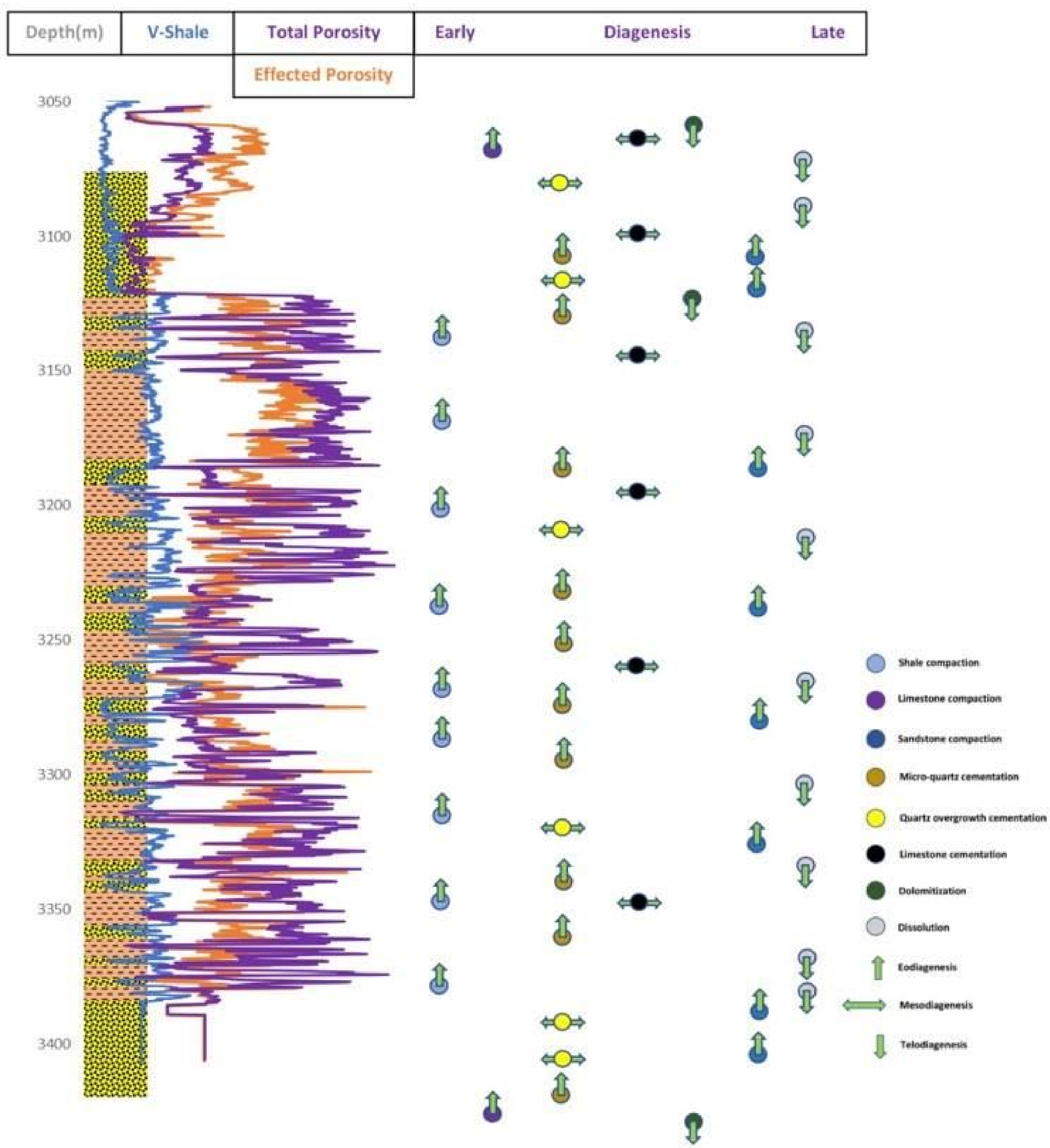


Figure 9: Lithologic columnar section shows the diagenetic processes and developments of Zubair Formation in WQ-356

Effective porosity zones

The amounts of internal space and pores within the grains of pores space in a given a volume of the rock unit is measuring of the amount of the fluids in these rocks withhold and if these pores are interconnected and able to transmitted the fluids is called (Asquith and Gibson, 1982).

The porosity of the sandstones of Zubair succession decrease towards the east of the Balambo-Garau Basin. The percentage of porosities is approximate about 30% within the Salman Zone and decreasing to about 15% close to borders of Iran toward east direction. The Permeabilities in this succession ranges approximately from 20 to 1800 mD with a mean value is about 700 mD (Jassim and Al-Gailani, 2006). A better understanding of the relationships between the forming and development of the porosity, diagenesis, and the stratigraphic succession of the Zubair

Formation is crucial to development of new playing concepts. In all wells, the stacking patterns of clastic fabric units and diagenetic processes are systematic within the systems tracts and staking patterns. Therefore, distribution of the porosity and permeability is closely related to relative sea-level changes and tectonic eustasy and development.

Higher values of the porosities moderately occurred in the middle and lower units of Zubair Formation to the north direction of studied area, and highly values in the limited parts within middle unit to south direction (Fig. 10 and 11). The various stages in the development history of the depositional sequences and stratigraphic framework of the Zubair Formation with late stage of diagenetic processes modified the above logical interpretation of the evolution of porosity in the facies.

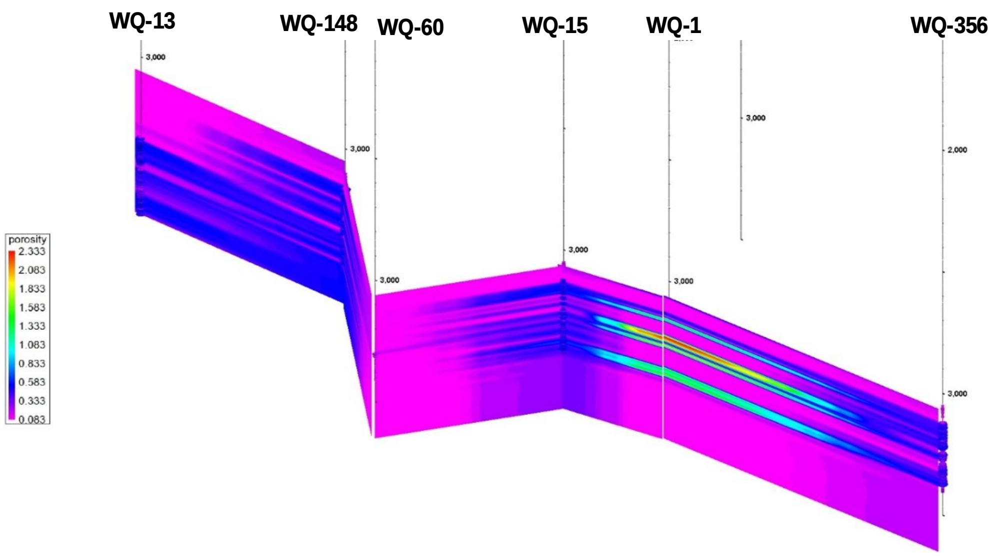


Figure 10: Cross section shows the total porosity of log in Zubair Formation

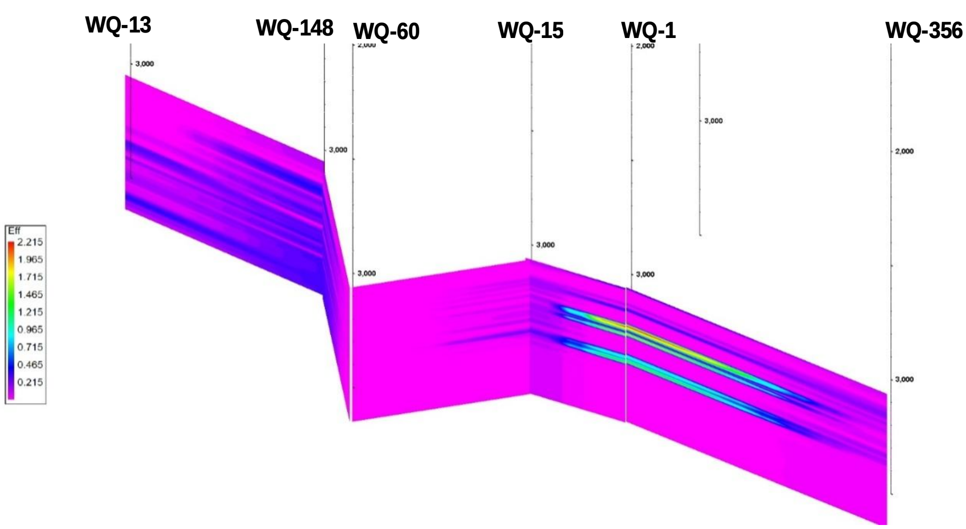


Figure 11: The Effective porosity of Zubair Formation

CONCLUSIONS AND RESULTS

The Zubair Formation in the study area is affected by many types of diagenetic processes throw the deposition. There are three diagenetic zones in this succession; the lower part of the Zubair Formation is characterized with three effected porous zone, which is separated by high compacted and cemented sandstone. The middle part of this formation is showing high compacted sandstone with appeared the overgrowth quartz and micro-quartz cementation. While the upper Zubair Formation is affected by compaction shale alternative with high compaction overgrowth quartz.

The effective porosity values distribution in the studied succession showing the following:-

- The lower unit appeared one moderate permeable zone in all studied wells separated by impermeable zone in WQ-60 to became two zone
- The middle unit characterized by two moderate and two high permeable zones. The first moderate zone is appeared in the lower part of middle unit within WQ-60 , 15 and 1, while the second is appeared in the upper part of this unit within WQ-15, 1 and 356

  The first high permeable zone is showing in all studied wells except WQ-356 within the middle part of this unit. While the second high zone is appeared in upper part of middle unit within WQ-13, 148, 60, and 15
- The upper unit is showing one limited moderate permeable zone within WQ-60 and 15 (Fig. 12).

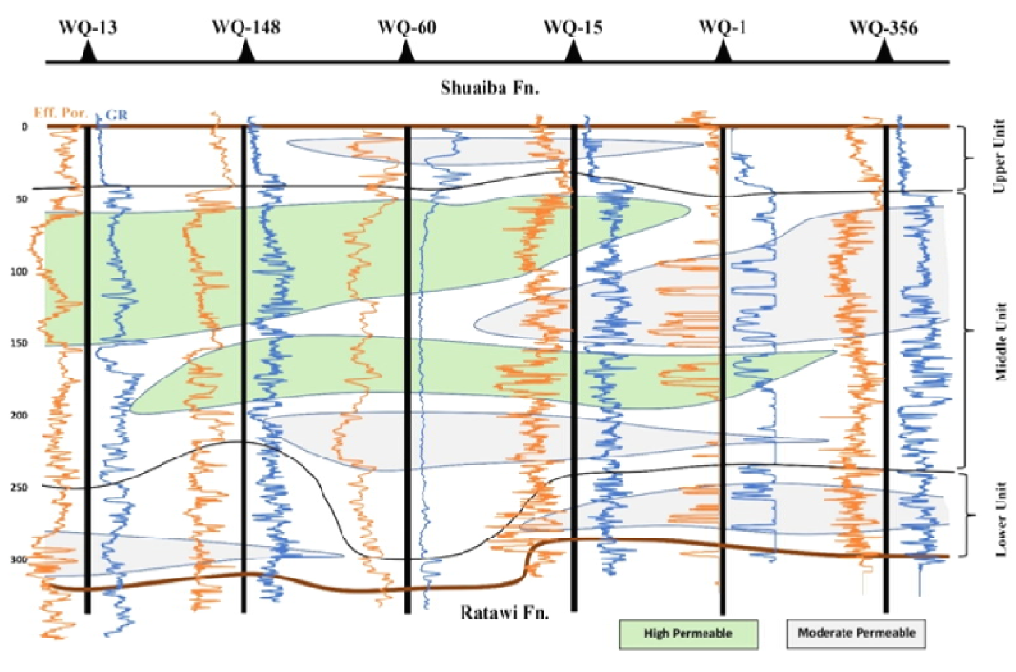


Figure 12: Cross section shows effective porosity zones the study area.

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