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Identification of Depositional Lithofacies and Their Impact on Reservoir quality of Etel Reservoir, UU pool, Sirte Basin

Eman A. Khmakem[1], Abdalftah M. El Mezweghy[2]
Essam M. Elmarghani[3]

1,2- Geology Engineering Department, Faculty of Petroleum, Gas and Renewable Energy Engineering, University of Zawia - Libya
3- Exploration Department - Waha Oil Company,Libya
e_elmarghani@wahaoil.ly

Abstract

This study has been conducted on 73 feet of cores of Etel carbonate with full package of composite wire line logs to model lateral and vertical extent and regional connectivity within Etel formation. The main objective of the study is to Recognize and define the different environmental lithofacies distribution and establish diageneses process that effecting on reservoir quality within different lithofacies types at each core level to construct a regional variation. A detailed Petrographic study by thin-sections & XRD test compiled with detailed log analysis showed three main depositional facies have been recognized in Etel formation which have been subdivided into nine Microfacies. The Etel Formation in UU pool comprises of Carbonate/ Evaporates sequence. It is typically Limestone, Dolomite and Anhydrite. The diagenetic processes of this formation that have been distinguished are; Micritization, Recrystallization, Dolomitization, replacive Anhydrite, Dissolution, and Cementation with late burial diagenesis as compaction, Fracture and late Cementation. The highest measured porosity and permeability values are recorded in the Dolomitized Bioclastic Wackestone facies.

Keywords: Petrophysical properties, petrography, diagenesis process, lithology facies., reservoir quality

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تحديد أنواع الصخور الرسوبية وتأثيرها على جودة خزان إيتيل، حوض يو يو، حوض سرت

إيمان خماخم[1]، عبد الفتاح المزوغي[1]، عصام المرغني[3]

1،2– قسم هندسة الجيولوجيا، كلية هندسة النفط والغاز والطاقة المتجددة، جامعة الزاوية – ليبيا

3– قسم الاستكشاف، شركة الواحة النفطية – ليبيا

الملخص

اجريت هده الدراسة على 73 قدم من العينات اللبية لتكوين الايتيل الدولومايتى مع بيانات متكاملة من منحنيات سرود الكهرباء وذلك لغرض تحديد ونمذجة امتداد طبقة الايتيل افقيا على امتداد تتابعها الإقليمي، كان الغرض الأساسي من الدراسة التعرف وتحديد و توزيع السحنات الرسوبية المختلفة لهدا التكوين و كذلك تحديد عمليات النشأة المتأخرة و تأثيرها على جودة المكمن النفطي في امتداده الإقليمي. اجريت دراسة بثروغرافية متكاملة مترافقة مع تحليل الاشعة السينية ومع بيانات منحنيات سرود الأبار، اظهرت هده الدراسة ثلاث سحنات رسوبية رئيسة لتكوين الايتيل الكربونى التي قسمت بدورها الى تسع سحنات ثانوية. يتكون تكوين الايتيل في منطقة الدراسة رئاسيا كل من الحجر الجيري والدولومايت وصخر الانهدرايت. تم التعرف على عمليات النشأة المتأخرة لهدا التكوين متمثلة في كل من التجيير، اعادة التبلر، الدلمتة، احلال الانهدرايت، الذوبان، السمنتة مع عمليات متأخرة من كل من عملية ضغط الطبقات، التشقق والسمنتة المتأخرة. تم تسجيل اقصى مسامية ونفاذية لتحديد جودة المكمن في سحنة صخر الدولومايت العضوي.

الكلمات المفتاحية: الخصائص البتروفيزيائية، علم الصخور، عملية التحول الصخري، أنواع الصخور، جودة الخزان

1. Introduction

This study contains the results of a detailed Sedimentological and Petrographical Analysis undertaken on 3 core samples from UU-71 pool, in the Beda Platform of the Sirte Basin (Fig 1). These cores are Core 1 (7585'- 7612'), core 2 (7820'-7836') and core 3 (7853'-7883') and they are cut from the Etel Formation comprising mainly

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limestone and shale interbedded with anhydrite and dolomite. In the stratigraphy chart for the western Sirte Basin (Fig2).

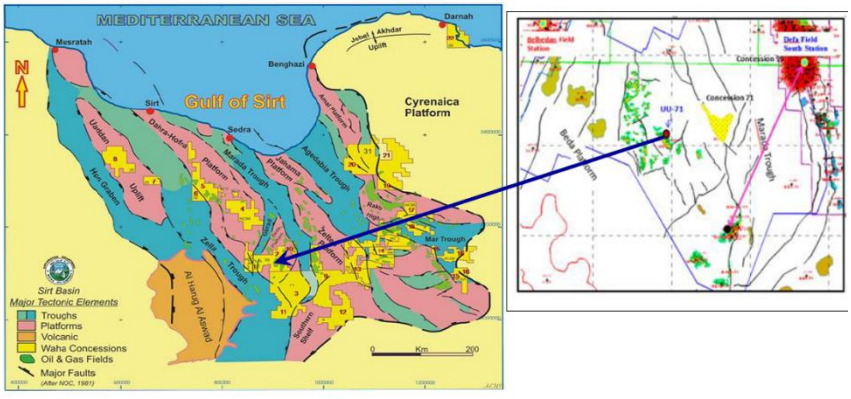

Fig.1 Location Map of the Concession 71 and UU-Pool

The Upper Cretaceous Etel formation is overlain by Lower Sirte Shale Equivalent of the same age and underlain by the unconformity boundary of the Basal Sand. The main aims of this study are based on gross core and associated Petrographical analyses and cover the following aspects: Identification of the main Facies and Microfacies, Inference of the depositional environment and Identification of the diagenetic processes that affect the reservoir quality.

1.1. Location of the study area

The studied pool UU-71 is in the Beda Platform of the Sirte Basin (Fig 2), on the northwestern part of Concession 71 is around 1,136,684 acres.

1.2. Geology of the area

Concession 71, Geologically, it covers mainly the platform area in between the deep Zella Trough to the west and Marada Trough to the east. The area, structurally, represents the platform relay area between the intense Zella and Marada Extensional troughs. Therefore, the common trend of normal faults is SSE-NNW, whereas the accommodation zones show a SW-NE trend. The area also forms southern extension of Beda Platform, and it is bounded by the southern continuation of Marada Trough. The main exploration objective of this part is Etel formation dolomite.

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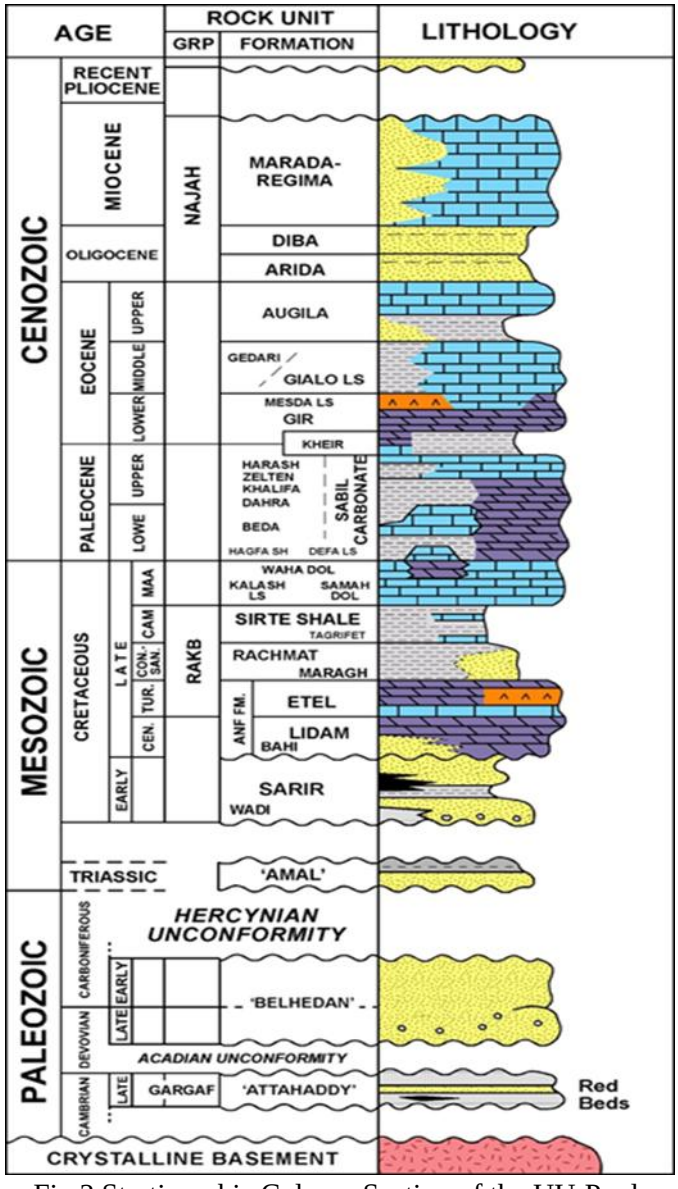

Fig.2 Stratigraphic Column Section of the UU-Pool.

2. Methodology

2.1. Petrography

The cores were described, logged and photographed at the geological laboratory of the Libyan Petroleum Institute (LPI). On

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the basis of core analysis, 27 thin sections from UU-71 Pool were selected and examined Petrographically in order to describe and study the abundance of constituent grains, matrix and cements. The prepared thin-sections were stained with Alizarin Reds and Potassium Ferri-cyanide following the methodology of Dickson (1966) to distinguish between Ferron-, non-Ferron calcite, dolomite and iron-rich dolomite. The terms to describe the crystallization fabric follow Friedman (1965), and those for the carbonate classification follow Dunham (1962). The Etel Formation comprises of carbonate/ evaporates sequence. It is typically limestone, dolomite and anhydrite. Three Facies and nine Microfacies within Etel Formation have been recognized. These Facies are Subtidal/Back shoal (Dolomite/Limestone) Facies, Lagoonal (Limestone/Dolomite) Facies, and Intertidal/Supratidal (Anhydrite/Dolomite) Facies.

2.2. Facies and Microfacies analysis

2.2.1. Subtidal/Back shoal (Dolomite/Limestone) Facies

This facies Includes 3 Microfacies as following, Dolomitized Bioclastic Wackestone Molluscan Peloidal Wackestone / Packstone and Dolomite Bioclastic Grainstone.

2.2.1.1. Dolomitized Bioclastic Wackestone

This Microfacies consists of v. fine to coarse-grained, poorly sorted with Wackestone depositional texture. Bioclasts comprise abundant Mollusca (Gastropoda) fragments (Plate: 3) and common Peloids (Plates; 1& 2), The matrix is composed of fine to very fine crystalline dolomite (anhedral, euhedral, Plate: 1). Microscopic porosity is negligible (0%), and measured porosity is negligible (2.20%). Some pores have been filled by slightly non-Ferron calcite cement.

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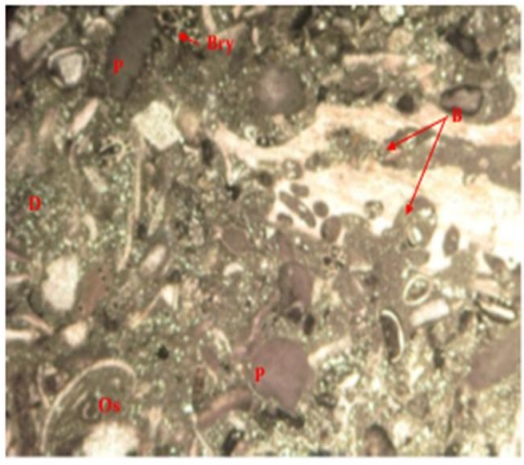

Plate.1.
This photomicrograph shows Peloids (P), Ostracoda fragment (Os) and bryozoan fragments (Bry). Note that Bored shell fragment (B) with Wackestone depositional texture. Matrix composed of fine to very fine crystalline dolomite (D). Subtidal/Back shoal Dolomite/Limestone facies: Dolomitized Bioclastic Wackestone Microfacies

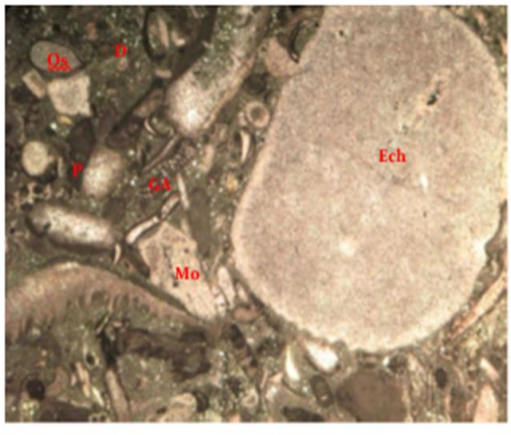

Plate.2. shows poorly sorted with Packstone texture. The main grain types are large echinoderm (Ech), Mollusca (Mo), Ostracoda (Os), peloids (P) and rare green algae (GA). Ground mess composed of very fine crystals of dolomite (D). Subtidal/Back shoal Dolomite/Limestone facies: Dolomitized Bioclastic Wackestone Microfacies.

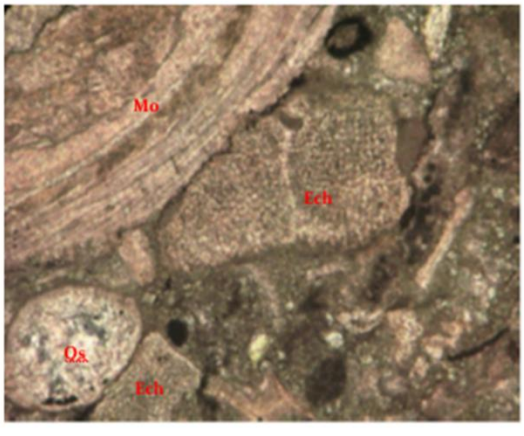

Plate.3. shows Mollusk (Mo), Echinoderm (Ech) and Ostracoda (Os) fragments. Subtidal/Back shoal Dolomite/Limestone facies: Dolomitized Bioclastic Wackestone Microfacies

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2.2.1.2. Molluscan Peloidal Wackestone/Packstone

This Microfacies is characterized by v. fine to coarse-grained, poorly sorted with Wackestone/Packstone depositional texture. The main grain types are fragments of mollusks, Peloids and Ooids, other Bioclasts common includes echinoderm, Miliolida, small foraminifera with rare bryozoans and Ostracoda fragments. Ooidal nucleus composed of Peloids, bryozoans, Miliolida, echinoderm and unidentified Bioclastic. The matrix is consisting of Bioclastic debris, Micrite and very fine crystals of dolomite Microscopic porosity is negligible (0 %) and measured porosity is negligible (1.46%). Pores have been cemented by non-Ferron calcite (blocky) and slightly Ferron dolomite.

2.2.1.3 Dolomite Bioclastic Grainstone

This Microfacies consists mainly of one type of replacive dolomite with Grainstone depositional texture. These sediments have been completely replaced by medium crystals of dolomite (subhedral, anhedral, and euhedral). Grain types are composed mainly of unidentified grains (could be Ooids). Microscopic porosity is good (15%), includes small vugs, inter-crystalline (Plate :6) and rare moludic types. Pore spaces have been partially or completely filled by dolomite (Plate:6) and slightly anhydrite.

2.3.1. <u>Lagoonal (Limestone/Dolomite) Facies</u>

This facies Includes 2 Microfacies as following: Dolomitized Bioclastic Packstone, Dolomite, Wackestone / Packstone.

2.3.1.1. Dolomitized Bioclastic Packstone

This Microfacies composed of v. fine to coarse-grained, poorly sorted with Pack-stone depositional texture. The main grain types are large Mollusca, echinoderm fragments and common Peloids, bryozoans, with rare Ooids Miliolida, small foraminifera and Ostracoda fragments. The matrix composed of Bioclastic debris, Micrite and very fine crystals of dolomite. Measured Porosity is poor (6.46 %). Pore spaces have been filled by non-Ferron calcite (blocky) and Ferron dolomite (Plates:4).

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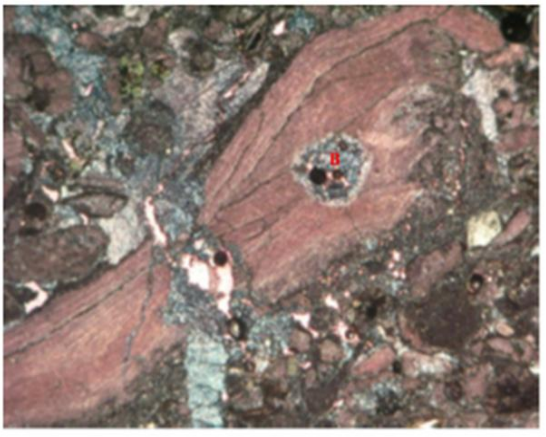

Plate.4. shows bored (B) large shell fragment, which has been filled by Ferron dolomite (FD). Note that fracture has cut sediment is filled by Ferron dolomite. Lagoonal Limestone/Dolomite facies: Dolomitized Bioclastic Packstone Microfacies

2.3.1.2. Dolomite, Wackestone/Packstone

The Microfacies consists of v. fine crystals of replacive dolomite with Wackestone/pack stone depositional texture. The main grain types are very fine to fine grains of unidentified Bioclastic fragments and Peloids with rare Mollusca, Ostracoda, small Forams and Brachipoda fragments. Microscopic porosity is fair (13%), includes intercrystalline, small vuggy and moludic types. Measured Porosity is good (17.75%). Pore spaces have been filled by crystals of Ferron dolomite (Plates: 4) and anhydrite (Plate:5).

Plate.5. Photomicrograph shows laths of anhydrites have completely filling porosity(A). Intertidal / Supratidal Anhydrite /Dolomite facies: Bioturbated Dolomite Mudstone Microfacies

This facies Includes 2 Microfacies as following: Dolomitized Bioclastic Packstone, Dolomite, Wackestone / Packstone

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2.4.1. Intertidal/Supratidal (Anhydrite/Dolomite) Facies

This facies Includes 4 Microfacies as following: Anhydritic Dolomite-Mudstone, Pelletal Mudstone and Anhydrite Bioturbated Dolomite-Mudstone

2.4.1.1 Anhydritic Dolomite Mudstone

This Microfacies composed mainly of very fine crystals of Anhydrite, which has replaced carbonate Micrite sediment (could be very fine dolomite crystals). Microscopic porosity is negligible (0 %) and measured porosity is poor (5.53%).

2.4.1.2. Pelletal Mudstone

This Microfacies consists mainly of rare pellets with mudstone depositional texture. Anhydrite nodular has been partially replaced original carbonate sediment. Nodular anhydrite grows and coalesces. The matrix is dominantly composed of Micrite and anhydrite. Microscopic porosity is negligible (1%), includes micro-fractures and measured porosity is negligible (2.50%). Pore spaces have been completely filled by anhydrite.

2.4.1.3. Anhydrite

This Microfacies composed mainly of anhydrite, which is divided to two types: anhydrite nodule and crystals, (Plate; 7). Microscopic porosity is negligible (0%).

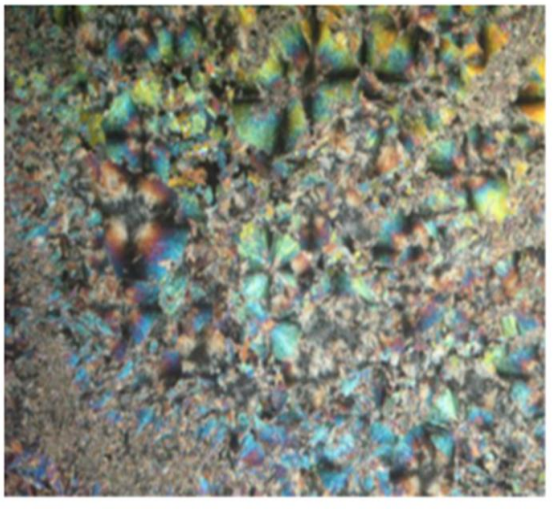

Plate.7. Photomicrograph shows nodules of anhydrite crystals have arranged in radial shape. Intertidal / Supratidal Anhydrite /Dolomite facies: Anhydrite Microfacies

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2.4.1.4. Bioturbated Dolomite Mudstone

This Microfacies consists of mudstone depositional texture with highly Bioturbated. The matrix dominantly composed of very fine crystalline dolomite. Macroscopic porosity is negligible (3%), includes microcrystalline and micro fracture types. Measured porosity is poor (5.15%). Pore spaces have been filled by anhydrite (Plate: 5) and slightly Ferron dolomite.

3. Diagenesis

The main diagenetic processes which were recognized during petrographic study of Etel Formations are; Micritization, Dolomitization, replacive anhydrite, dissolution, and cementation with late burial diagenesis as compaction, fracture and late cementation.

3.1.1 Micritization

The Micritization processes is one the first stages of diagenesis seen in the upper part of Etel formations (Plate; 1& 2). It occurred soon after deposition. Micritization takes two forms: first, is Micritization of the outer portions of grains and second is the complete transformation of grains into Peloids. Micritization is a common process in shallow water environments and has been interpreted to result from boring (Plate: 4) by microorganisms including endolithic algae and fungi. These processes take place in a marine phreatic zone.

3.1.2 Dolomitization:

Petrographic study shows that the replacive fabric consists of microcrystalline (< 20μm crystal size) to medium size with anhedral to subhedral (Plate:8 &9). Replacive dolomite crystal size is believed to be a function of the original sediment fabric. Microcrystalline dolomite has possibly replaced lime mud whereas the larger crystals have possibly replaced Bioclasts.

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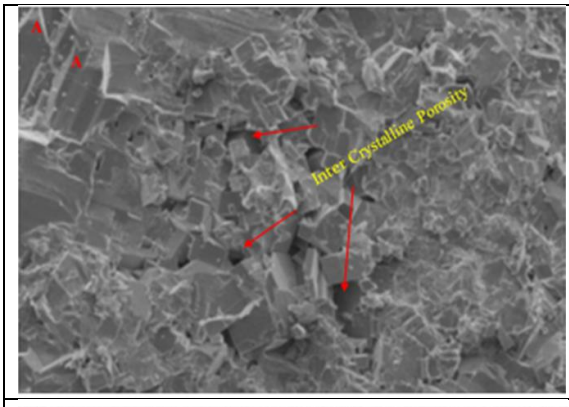
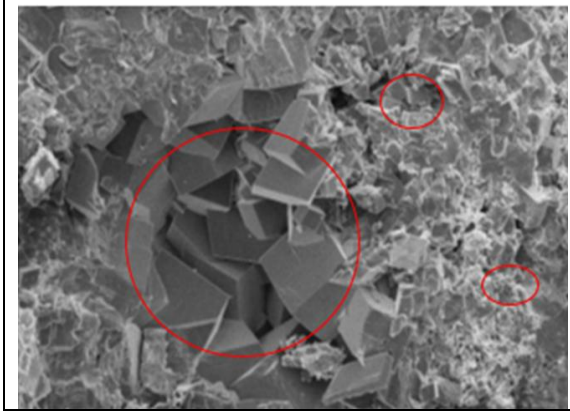
	**Plate.8. SEM photomicrograph shows inter-crystalline porosity (Blue arrow). Note that anhydrite has partially filled porosity (A).**
	**Plate.9.SEM photomicrograph shows crystals of dolomite have partially filled porosity (Red circles),**

3.1.3 Anhydrite:

two forms of anhydrite are seen to be present, nodular and very fine crystalline which have completely replaced original sediments.

3.1.4 Dissolution:

The diagenetic phenomenon is responsible for the creation of large volumes of secondary porosity within the Shoal limestone facies. in Etel Formation restricted in lower part and absent in upper part and includes small vugs (Plate:6) and rare moludic with micro fracture. Many of the biomoldic pores are partially or completely infilled by non-Ferron calcite and dolomite and slightly by Ferron dolomite. A meteoric origin is inferred for dissolution which postdates Micritization and where moulds are infilled by meteoric calcite cement.

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3.1.5 Cementation:

Cementation is the most important diagenetic process to have affected the

carbonate sediments within the cored interval. porosity in Etel formation included non-Ferron calcite (blocky & overgrowth), non-Ferron - slightly Ferron dolomite and anhydrite cements (Plate; 5&6).

3.1.6 Compaction and Fractures:

Compaction is represented by pressure solution, slightly mechanical compaction observed in Etel formations. Fractures do not greatly affect reservoir quality, (Plate: 4).

3.1.7 Rare Diagenetic affected:

Pyrite crystals with rare glauconitic and Phosphatic grains are observed. Few amounts of organic material are present in Etel formation (Plate: 8), additional to some of shell fragments has been partially replaced by silica.

Table .1. Summary Diagenetic stages of carbonate facies of Etel formation

Diagenetic features	Diagenetic Stages	
	Early	Late
Micritization		
Recrystallization		
Dolomitization		
Dissolution		
Cementation		
anhydrite		
Compaction		
Fracturing		
Late cementation		

Increase in time →

4. Reservoir quality

The reservoir characteristic of facies and Microfacies were recognized within Etel formations (Fig 3), as following

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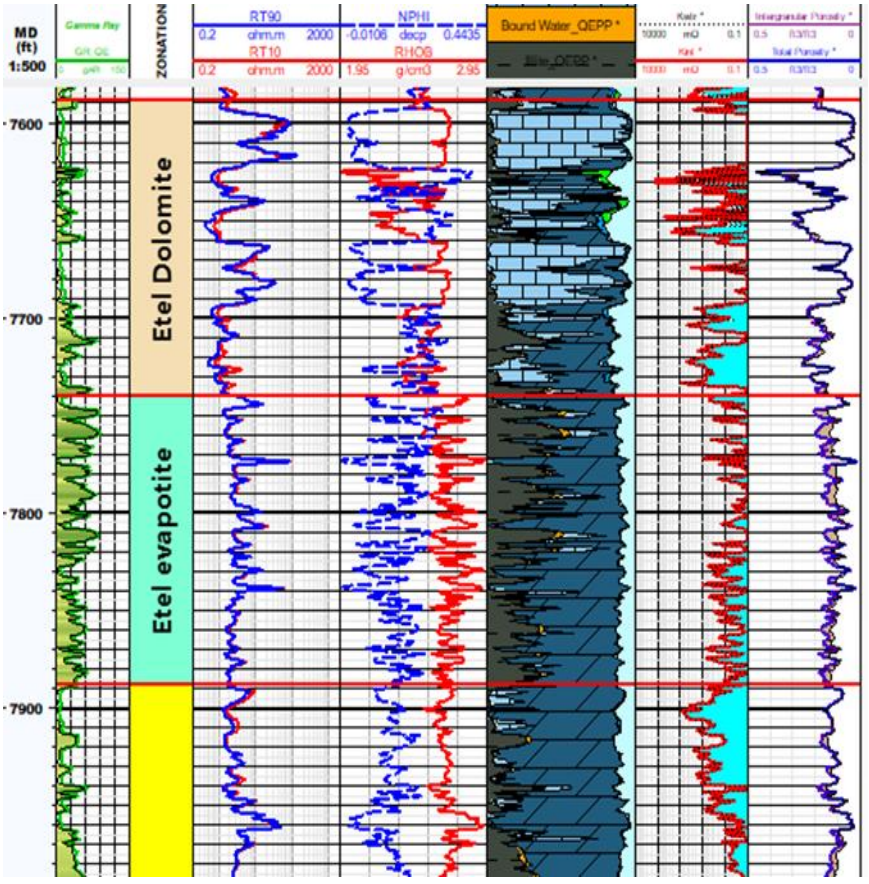

Fig.3 Petrophysical analysis of Etel Formation over UU-Pool

4.1. Subtidal/Back shoal (Dolomite/Limestone) Facies:

Microscopic porosity in this facies ranges from negligible to good (0% to 15%), presented by inter-crystalline, and small vugs. Measured porosity is negligible ranges from (1.46% to 2.20%), and horizontal. Permeability is negligible and ranges from 0.010mD to 0.018mD. The highest measured porosity value is recorded in the Dolomitized Bioclastic Wackestone, whereas the lowest measured porosity value is recorded in the Mollusca Poloidal Wackestone/Packstone Microfacies (Fig 4).

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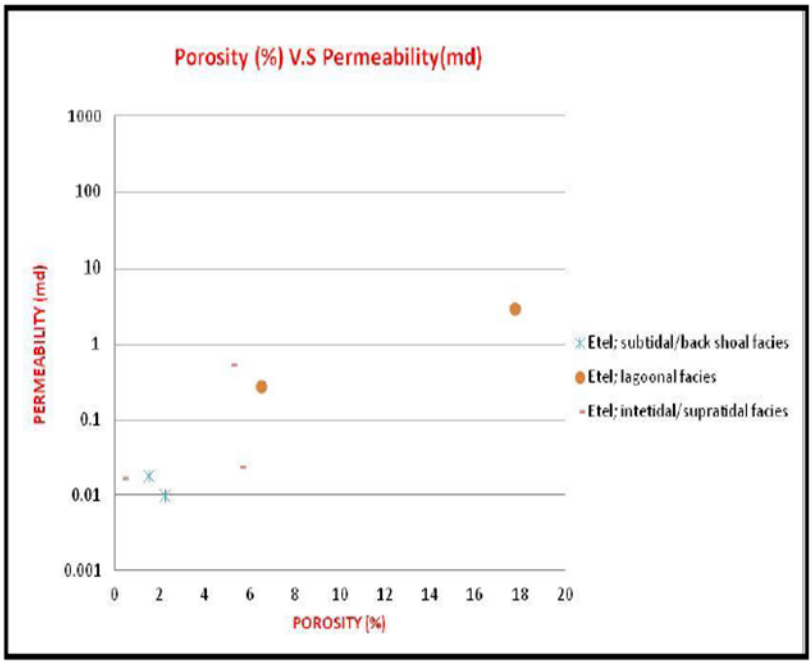

Fig.4 Relationship between Porosity and Permeability in Etel formation.

4.1.2. Lagoonal (Limestone/Dolomite) Facies:

Microscopic porosity in this facies is negligible to fair ranges from (0% to 13%), and includes intercrystalline with rare small vugs and moludic types. Measured porosity is poor to good and ranges from (6.46% to 17.75%), and horizontal permeability is poor to fair and values ranges from 0.284mD to 2.968mD. The highest measured porosity value is recorded in the Dolomite Wackestone/Packstone Microfacies (17.75%) and horizontal permeability value is 2.968mD, whereas the lowest measured porosity value is recorded in the Dolomitized Bioclastic Packstone Microfacies (6.46%), and permeability value is 0.284mD.

4.1.3 Intertidal/supratidal (Anhydrite/Dolomite) Facies:

The microscopic porosity in this facies is negligible (0% to 3%), includes rare micro- crystalline and micro- fractures types. Measured porosity is negligible to poor and ranges from (0.34% to 5.53%), and horizontal permeability values ranges from 0.0mD to 0.537mD. Generally; the cements and slightly compaction.

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5. Summary and Conclusion

1- The Etel Formation comprises of carbonate/evaporate sequence. It is typically limestone, dolomite and anhydrite.
2- Three main depositional facies occur in Etel formation with nine Microfacies. They are Subtidal/Back shoal (Dolomite/Limestone) Facies, Lagoonal (Limestone/Dolomite), Facies and Intertidal / Supratidal (Anhydrite/Dolomite) Facies.
3- The main diagenetic processes that have affected Etel Formation are: Micritization, Dolomitization, anhydrite, dissolution, cementation, compaction and fractures.
4- Etel Formation considers poor to fair reservoir. The porosity is enhanced by partial dissolution and reduced by cementation such as non-Ferron calcite, non-Ferron -Ferron dolomite, anhydrite.

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