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Depositional Environment and Petrophysical Properties Studyof Mishrif Formation in Tuba Oilfield,Southern Iraq

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Abstract

Mishrif Formation is considered as one of the main productive reservoirs in southern of Iraq that comprises an important place into the stratigraphic column of the middle Cretaceous. It reflects the continuous deposition on a shallow carbonate platform developed during theUpper Cenomanian – Early Turonian period. Core samples were collected from selected wells in Tuba oilfield, southern Iraq (Tuba-4, 5, 6,7,8,and 12).Petrographic and microfacies studies have been made by means of microscopic examination of (150) thin sections. Microfacies analysis showed the occurrence of rudist, red and green algae, large and small benthic Foraminifera, Echinoid and Pelloidal zone and they form the major part of micrite or spary calcite groundmass. Five main Paleoenvironment were identified within Mishrif succession represented by deep marine, shallow open marine,restricted open marine, rudist biostrom and shoal. In which there were distinctive distribution of main andsubmicrofacies of diverse in both effect and intensity by dissolution, dolomitization,neomorphism, cementation and micritization. The most effective diagenesis processes were both dolomitization and dissolution. On the other hand, well log analysis revealed the domination of primary porosity (Interparticle and Intraparticle) and minor content of secondary porosity (Vug, moldic and channel). Five reservoir units were identified in the studied sections of Mishrif Formation (mA, mB1-1, mB1-2,mB2-1and mB2-2). These units characterized by a high total porosity located within shoal, shallow open marine and rudist biostrom facies. The reservoir facies of good oil prospects that have been diagnosed are: mud dominated Wackstone, grain dominated, bioclasticpelloidal and/or pelloidalGrainstonemicrofacies,Bondstone,rudistPackstone,coralline algal Wackstone–Packstonemicrofacies and dolomiticLime Mudstone - Wackstonemicrofacies.

1- Introduction

The stratigraphic column of southern Iraq is characterized by thick Cretaceous succession of important hydrocarbon accumulations within many formations. Mishrif Formation is considered as an important middle Cretaceous carbonate formation deposited during the Cenomanian-Early Turonian [1].The Cenomanian-EarlyTuronian interval is also regarded as an early subcycle within alarger cycle (megasequence) of Cenomanian- early Campanian [2](Fig.1).Mishrif Formation acquires special importance because its petrographic and petrophysical characteristics make it an oil reservoir.Sedimentological studies include microfacies and depositional environment models were carried out by ELF, (1995) [3] and AL-Khayat, (1998) [4].Both studies specifically concerned with reservoir sequence stratigraphy and unitslayering (Fig.2).Mahdi,(2004) [6] wasstudied the sequence stratigraphy and reservoir characterization of the Mishrif Formation, this study implied high-resolution sequence stratigraphic model, that relies on a time-based correlation scheme of deposition.AL-Obaidi,(1996) in Al-Kilaby, (2009) [5] studied the vertical and horizontal distribution porosity and permeability values which were geostatically processed trying to relate the result to the stratigraphic formationin west Qurnah oil field.

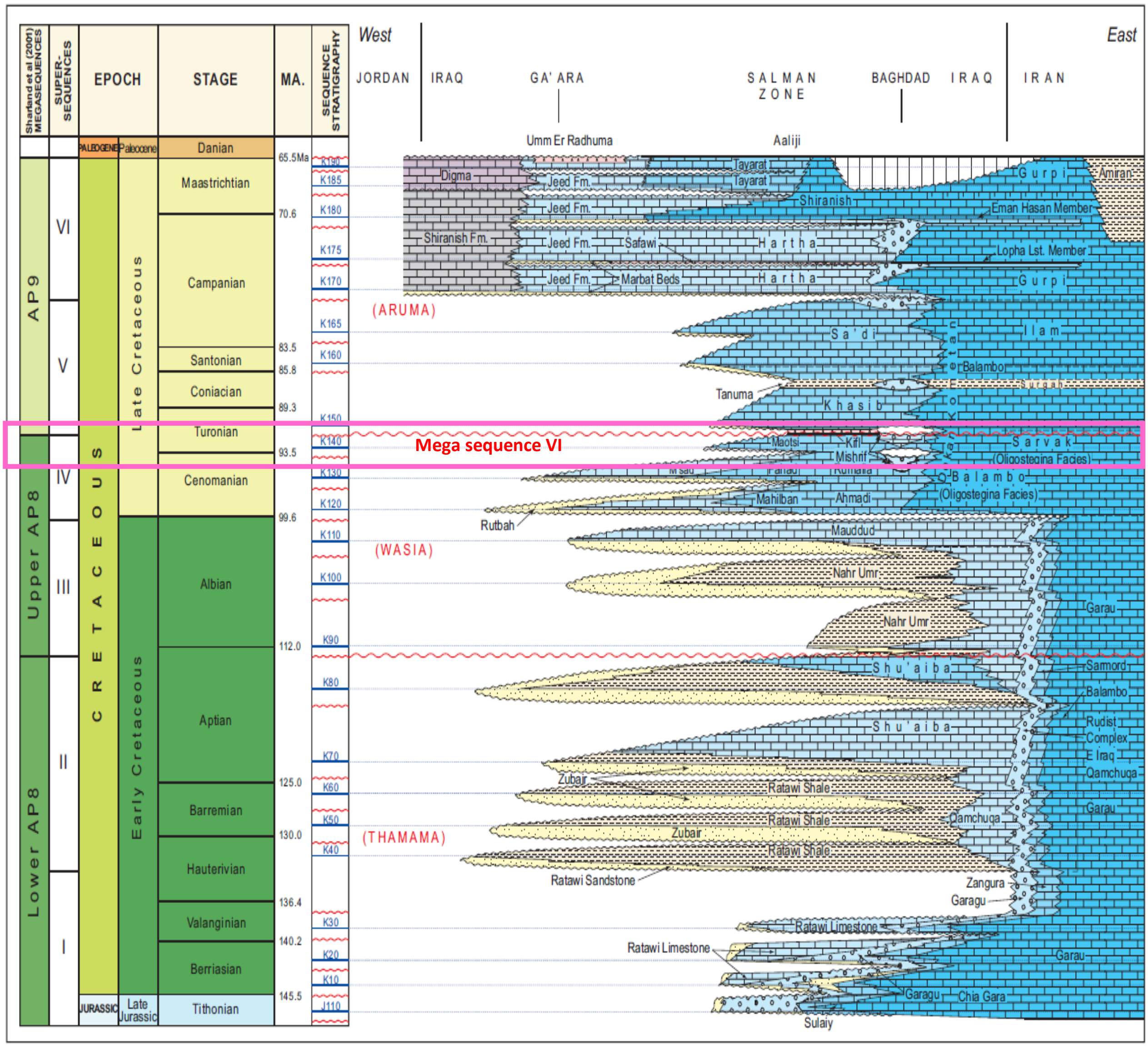


Fig.(1): Cretaceous chronostratigraphy of Iraq.Aqrawi*et al* (2010) [7].

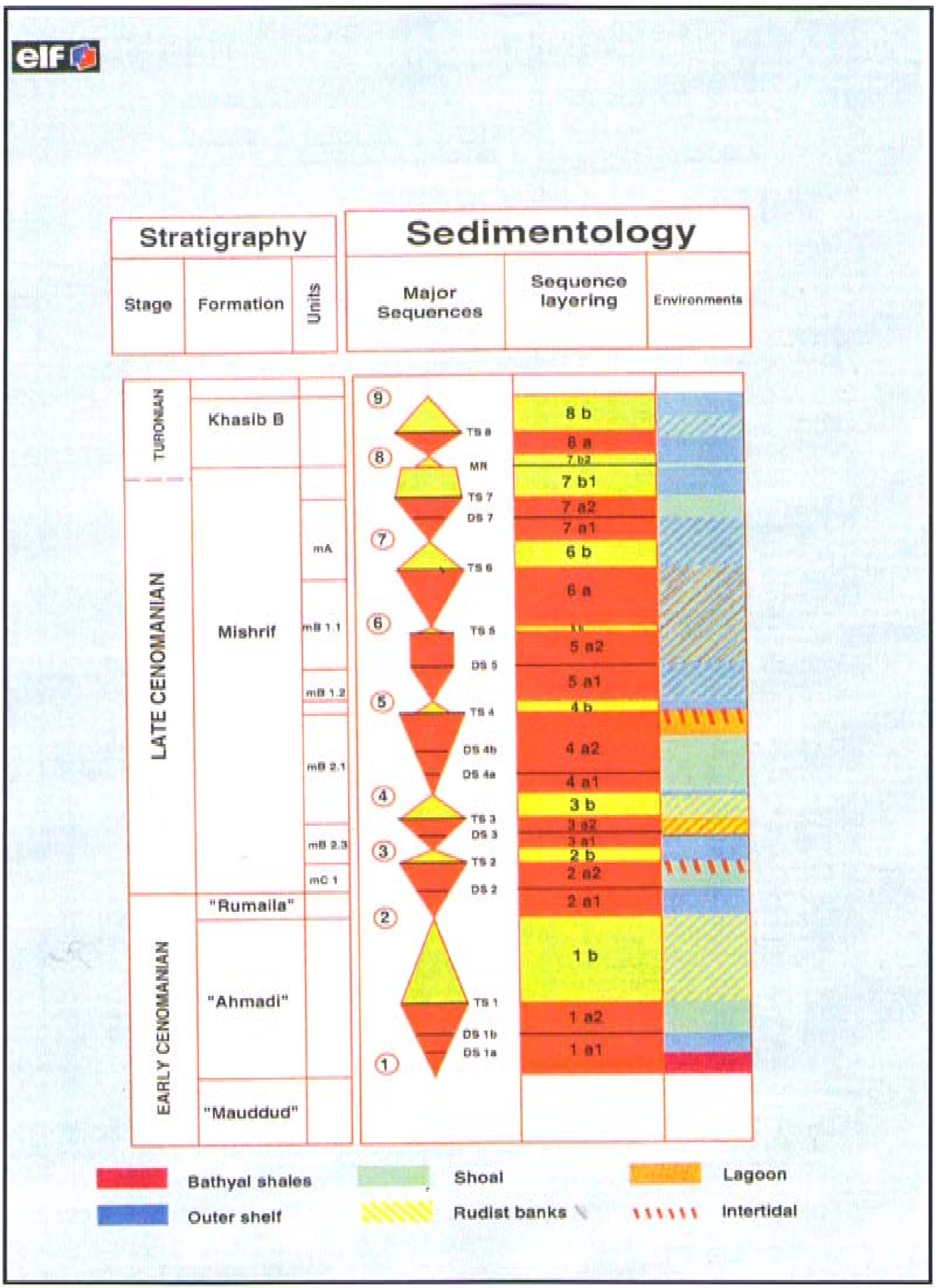


Fig.(2):Reservoir sequence stratigraphy and unit layering ELF, (1995) [3].

2. Methodology

Detailed petrography and microfacies analyses were done through the examination of more than 150 thin sections that taken and prepared from core samples of Tuba -12 and Tuba-5. The study also involved ananalysis of petrophysical properties using data acquainted from the available open hole logs of (Tuba 4, 5, 6, 7, 8, 12) (Fig.3) such as (Spontaneous Potential, Gamma Ray, Density, Sonic, Neutron and Resistivity logs) .Petrophysical data were analyzed and plotted using Exceland interpreted by Interactive Petrophysics software (IP).The present study was carried out on the basis of petrographic, microfacies and petrophysical analyses in order to reach the main goals represented by the identification of depositional environments, extension and distribution of petrophysical characters of Mishrif reservoir facies in Tuba oilfield.

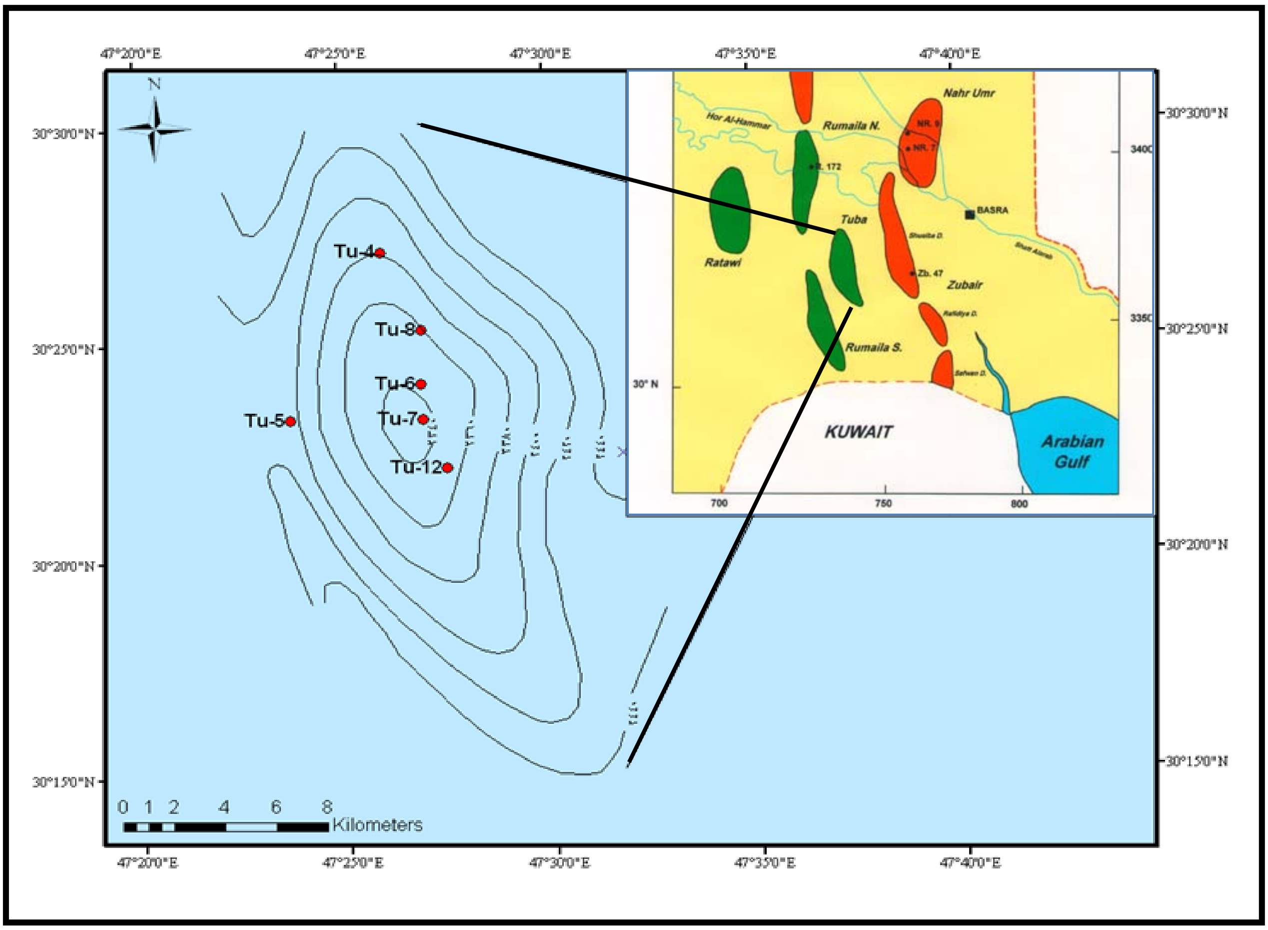


Fig. (3): Base map of Tuba oilfield shows location and distribution of the studied wells.

3. Microfacies analysis and Diagenesis

Microfacies is the total of all sedimentological and paleontological data which can be described and classified from thin section, peels, polished slabs or rock samples(Flugel),2004 [8]. In the present study the carbonate rocks of the MishrifFormation were classified according to(Dunham),1962 [9]who include the description of the major skeletal and non-skeletal components,also concerning standard microfacies analysis of(Wilsons), 1975 [10].

The major microfacies identified in the Mishrif Formation are:

1- Dolostone and Dolomitic LimeMudstone- Wackstonemicrofacies.
2- Benthonic Foraminifera LimeMudstone – Wackstonemicrofacies.

3- Bioclastic and Foraminifera bioclasticPackstonemicrofacies.
4- Algal Wackstone – Packstonemicrofacies.
5- Coralline algal bioclasticPackstonemicrofacies.
6- EchinodermalrudistPackstonemicrofacies.
7- Rudist bioclasticPackstonemicrofacies.
8- Pelloidalbioclastic and PelloidalGrainstonemicrofacies.
9- Boundstonemicrofacies.

4. Paleoenvironment

Many studies and researches described the Paleoenvironment of the Mishrif Formationsetting,and most of these studies were based on the fossil content of thisFormation. In this study five depositional environments were identified within Mishrif'ssuccession, which are represented by one or more microfacies they are: Restricted shallow marine, shallow open marine, shoal, rudist biostrom and deep marine environments. (Fig.4a and 4b) show distribution models of these identified environments and evolution of ramp to shelf into the basin.

4.1. Restricted shallow Marin environment:

The restricted shallow environment is found to be represented by dark argillaceous shale. Thefacies association consists mainly of benthonicForaminifera Wackstoneand Mudstone to wackstone. The benthonic Foraminifera are abundant and diverseincluding*Cisalveolinafallax,Cycledomiairanica,Rhipidionina, Pseudolituone*sp, *Quniqueloculina*sp, *Nuzzazatagr*.*gyre,Vavulamminapicord* (PL.1a,1b). Larger benthonic Foraminifera have specifically taken good bio-indicator low energy restricted open inner shelf lagoon close to inter- bank depositional setting. Dolomitization, cementation, neomorphism and dissolution are the main digenesis processes affecting on various particles (PL.1c).This microfacies is typically representative of quite shallow open marine environment and corresponds to Wilsons(SMF-8) in (FZ-7).

4.2. Shallow open marine environment:

The open shallow marine environment dominates into the upper part of Mishrif succession below the upper unconformity surface that separates the Mishrif and overlying KhasibFormation, in addition to its dominance into the middle part of the Mishrif succession. The open marine environment represented by:

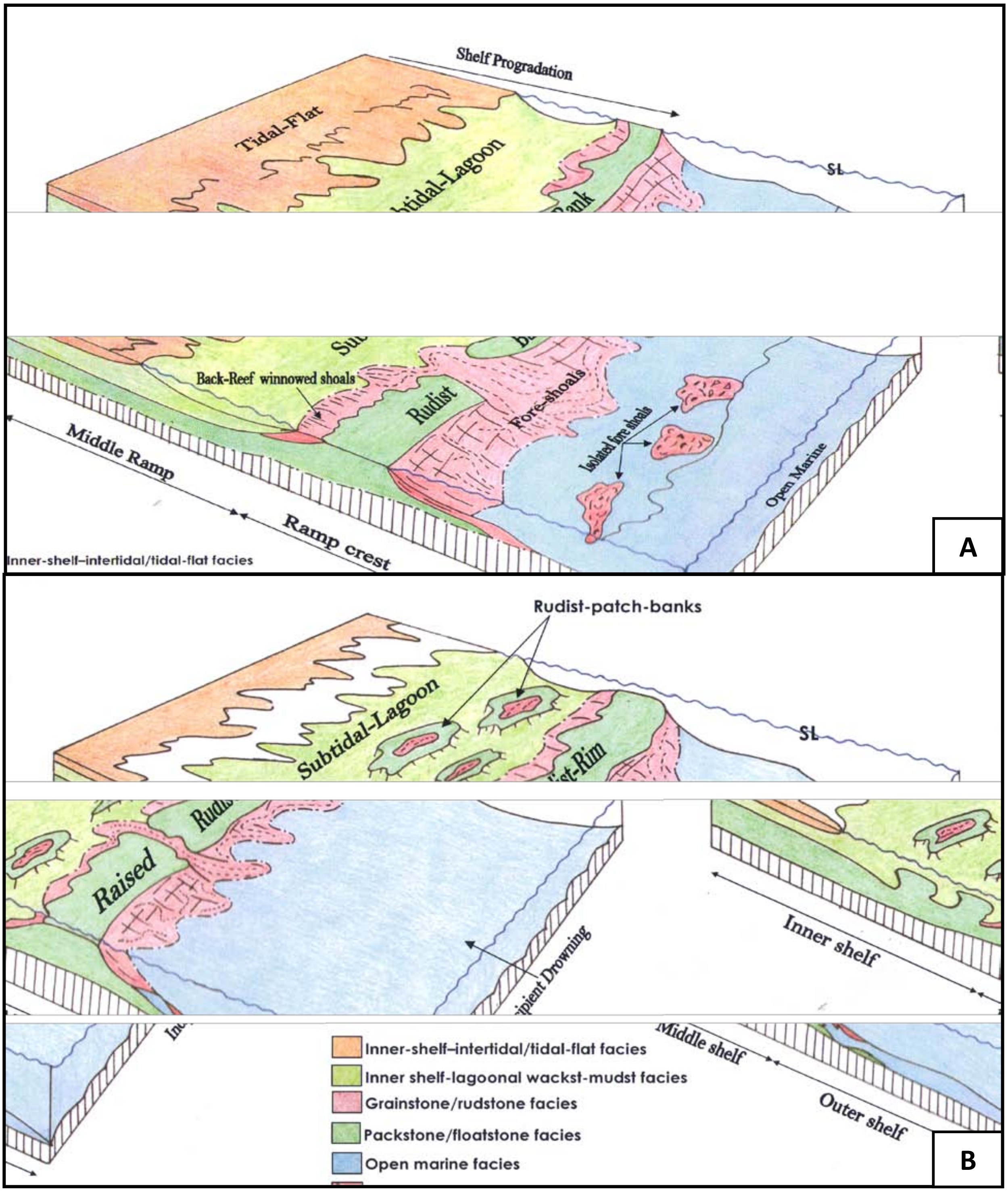


Fig.(4): Mishrif depositional model modify by Chevron, (2006) [11].

A- Mishrif depositional Model -1: Accretionarybiostrom thickening Rudist/ oregano detrital barrier-bank complexes on ramp crest

B- Mishrif depositional Model-2: Incipiently drowned-rimmed-shelf evolved from depositional ramp with continuous raised rim.

4.2.1Bioclastic andForaminifera bioclasticPackstonemicrofacies

This microfacies consistsof somePelloids associated with benthonic Foraminifera represented mainly by*Qatariadukhani*,with bioclasts ofsize ranged between (sand to coarse grain) (PL.1d). Other important fossils included in this microfacies association are calcareous algae, pelecypoda and mollusks (PL.1e). They are generally affected by neomorphism and selective dissolution making interparticleporosity. This microfacies is similar to the standard microfacies(SMF-16) of the facies zone (FZ-7), which represents the shelf lagoon environment with moderate circulation.

4.2.2. Algal Wackstone – Packstonemicrofacies

The algal Wackstonemicorfaciesare micrite and microsparite matrix, in addition to very rare planktonic Foraminiferaof *Globigerina*with rare smallbenthic Foraminifera of *Discorbis,*sp, algalclasts include*permocalculus*ssp and *Dacycladacean* algae (PL.1f). The bioclasts and coralline algal (*permocalculus*ssp) debris are selective dissolute, opened in some parts and partially cemented in others by fine to medium granular and equigranular mosaic cement. Thismicrofacies represents collaboration in action of near or at storm-wave base of turbidity character in shallow open marine environment with moderate circulation toward the upper slope.

4.3. Shoal environment

The shoal environment was formed in a high energy environment within intertidal conditions. These facies consists of medium to coarse grainsrepresented by three main submicrofacies which are:

4.3.1.EchinodermalrudistPackstonemicrofacies

The shoal association is composed of common to abundant randomly oriented fragment with syntaxial rim cement,moderately packed; almost of uniform sorting (PL.2b).Rudist debris is commonly coated by isopachous rim cement, whereas the Ecoinoid plates are characterized by syntaxial rim cement. Intensive dissolution process specifically created composite intraparticle and vug porosity of open channel network system, partially to completely cementation by fine to coarse equigranular mosaic cements. This microfacies is mainly linkedto open shoal depositional site and represented reservoir unit (mB1).

4.3.2.Pelloidal and bioclasticPelloidalGrainstonemicrofacies

This submicrofacies is dominated by pelloid with mollusks, rudist fragments and echinoids with syntaxialrim cement. Pelloids usually occurred in high energy zone such shoal and beaches. In some cases the high energy conditions are constant, e.g. tide, wave and currents. In other instances the environment is only periodicallysubjected to storm induced high energyconditions, which remove the mud andleave coarse grains sediments behind gravel and boulder rich sediments (almost rudist and mollusk) are common around patch reef or behind barrier reefs [12]. Selective dissolution process created well developed separate moldic and vug pore type undergone into continuous coarsening of dissolution action that finally established a composite vug porosity system (PL.2c). The interparticle porosity partly undergone into intensive cementation by fine coarse equigranular mosaic and by isopachous rim cement created anon connected porosity pattern (PL.2d). This dominance of porosity made the microfacies good reservoir unit(mB1).

4.3.3. Coralline algal bioclasticPackstone- Grainstonemicrofacies

This microfacies composed of common permocalculs debris and common rudist debris and fragments (PL.2e). About 10% of skeletal grains are greater than 2mm in size and redeposited under high energy depositional conditions of shoal tendency of rudist bank above the fair weather wave base setting.

Dual type diagenetic processes have been affected on rock fabric. Firstly is the destructive type by intense selective dissolution of the micritizedbioclasts by micritic envelope rings under the Vados and / or upper meteoric Phereatic zones, which characterized by well developedinterparticle pore system. Secondly is the intensive cementation process of almost complete constructive stage isequigranularspary mosaic of the interparticle pores and partial moldic pore under dominance of porosity that made this facies good reservoir unit (Mb2) (PL.2f).

4.4. Rudist biostrom environment

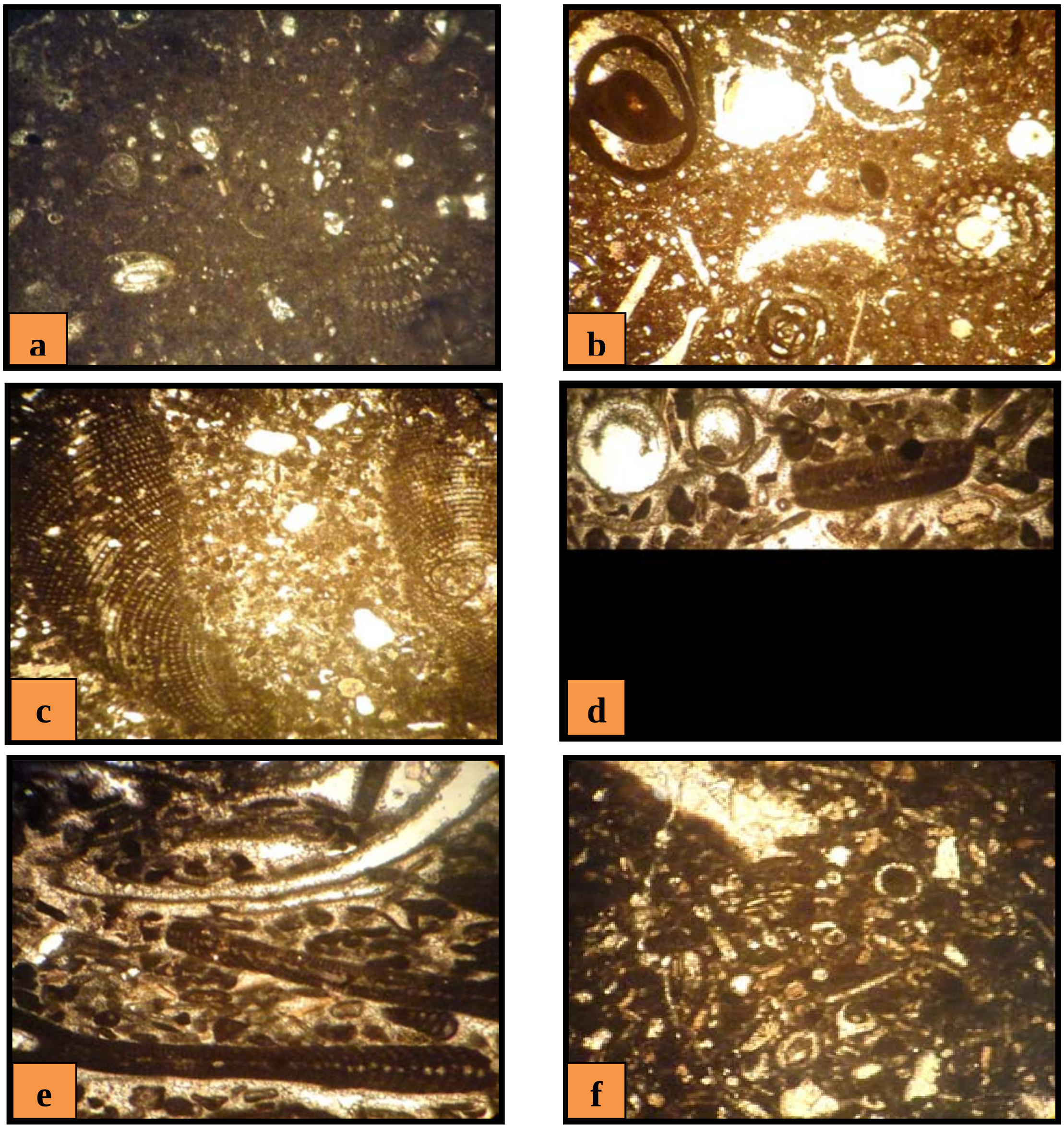
This environment has two of the most important reservoir facies in thewhole succession of the Mishrif carbonates in the studied area. It consists mainly of rudistbioclasticPackstonemicrofacies (PL.3c) and boundstone (floatstone) microfacies (PL.3a, 3b), less than 10% of rudist fragments are ranging in size between 2mm to 2cm. The microfacies is characterized by well developedintrabioclastic pore system, partly of open network character and other part cemented by equigranular mosaic cement and characterized by well developed solution micro channel oil impregnated (PL.3b).The boundstone microfacies are similar to the standard microfacies(SMF-6), which presents in the reef or fore reef environment within the facies zone (FZ-4) reflects high energy water.

4.5. Deep marine environment

Deep marine environment represented by faciesoffine grained skeletal lime DolomaticLime Mudstone to Wackstone. The skeletal grains consist mainly of planktonic Foraminifera such as *Hetrohelix*, *Oligostegina*, *Globigerina* (PL.3d). The bioclasts are mostly echinoderms debris and rare of calcisphere. This microfacies was recognized within the upper part of underlying Rumaila Formation and also in anther occurrence that was distinguished within the intermediate part.

The effect of dolomitization on the characters of this microfacies appeared to be having developed significant amount of intercrystalline secondary porosity in which dolomite crystals are euhedral to subhedral. Late diageneticdolomitization, whichincreases the porosity of the rock when compaction and cementation processes are absent. Thus enhancing reservoir quality [13](PL.2e,2f).

Plate (1)



a-Large and smalle benthonic Foraminifera in Mudstone-Wackstonmicrofacies.(Tu-12, depth 2444m) 4x

b-*Cisalveolinafallax, Quniqueloculina*sp, *Rhipidionina,* in benthonic Foraminifera Wackstonemicrofacies (Tu-5, depth 2426 m). 4x

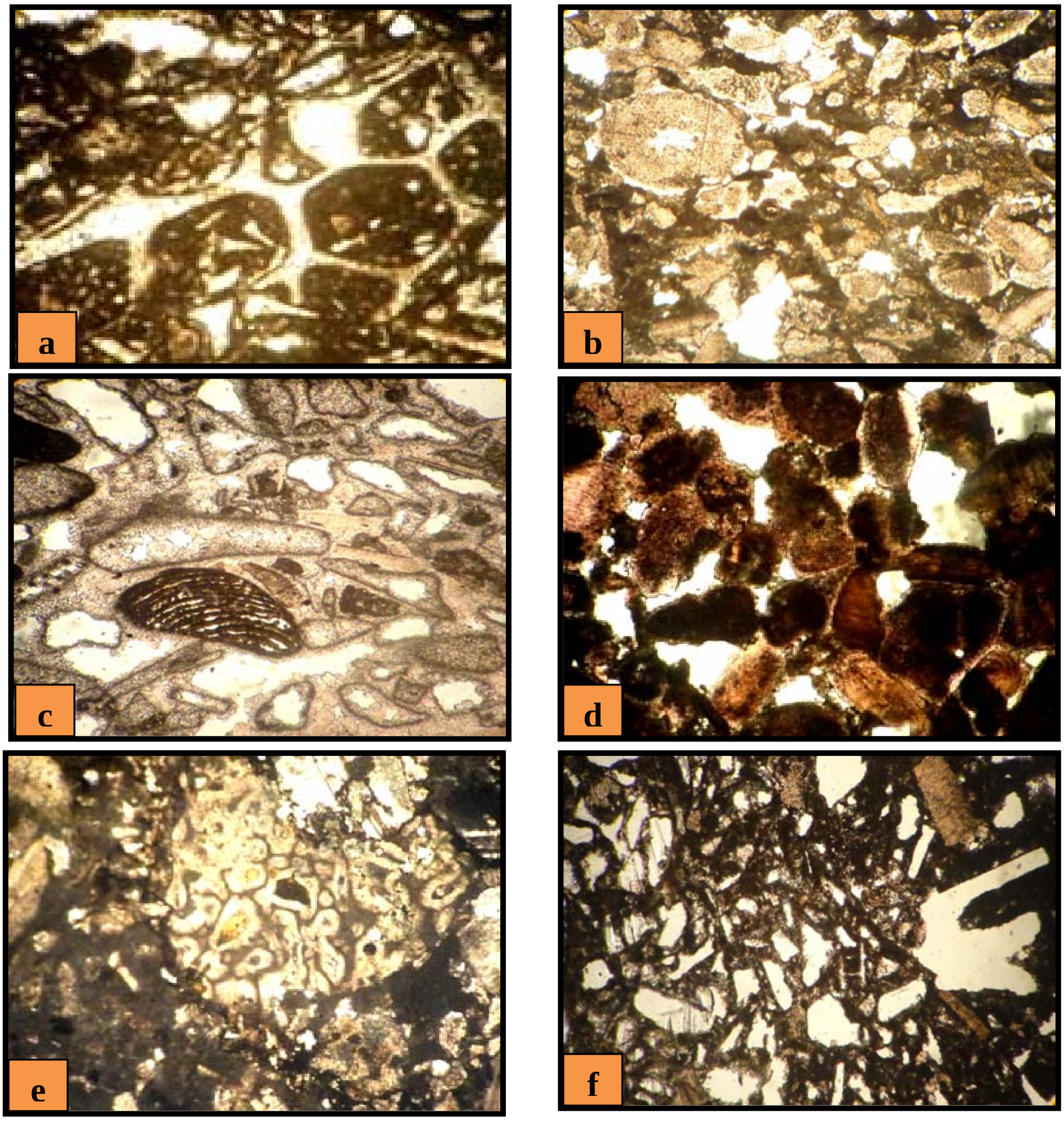
c- Equatorial section in index type larger Foraminifera *Cycledomiairanica* embedded in a neomorphosed mud dominated fabric (Tu-5, depth 2430 m). 4x

d-*Qatariadukhani* in Foraminifera bioclasticPackstonemicrofacies. (Tu-5, depth 2446.8 m).4x

e-BioclasticPackstonefacies show Mollusk and pelecypoda with selective dissolution.(Tu-12, depth 2385m).4x

f- Algal Wackstone- Packstonefacies. (Tu-12, depth 2438.5 m).4x

Plate (2)



a -*Dacycladacean* **algae in Algal Wackstone –Packstonemicrofacies. (Tu-12, depth 2430.5m).4x**

b -EchinodermalrudistPackstonemicrofacies. (Tu-12, depth 2442 m).4x

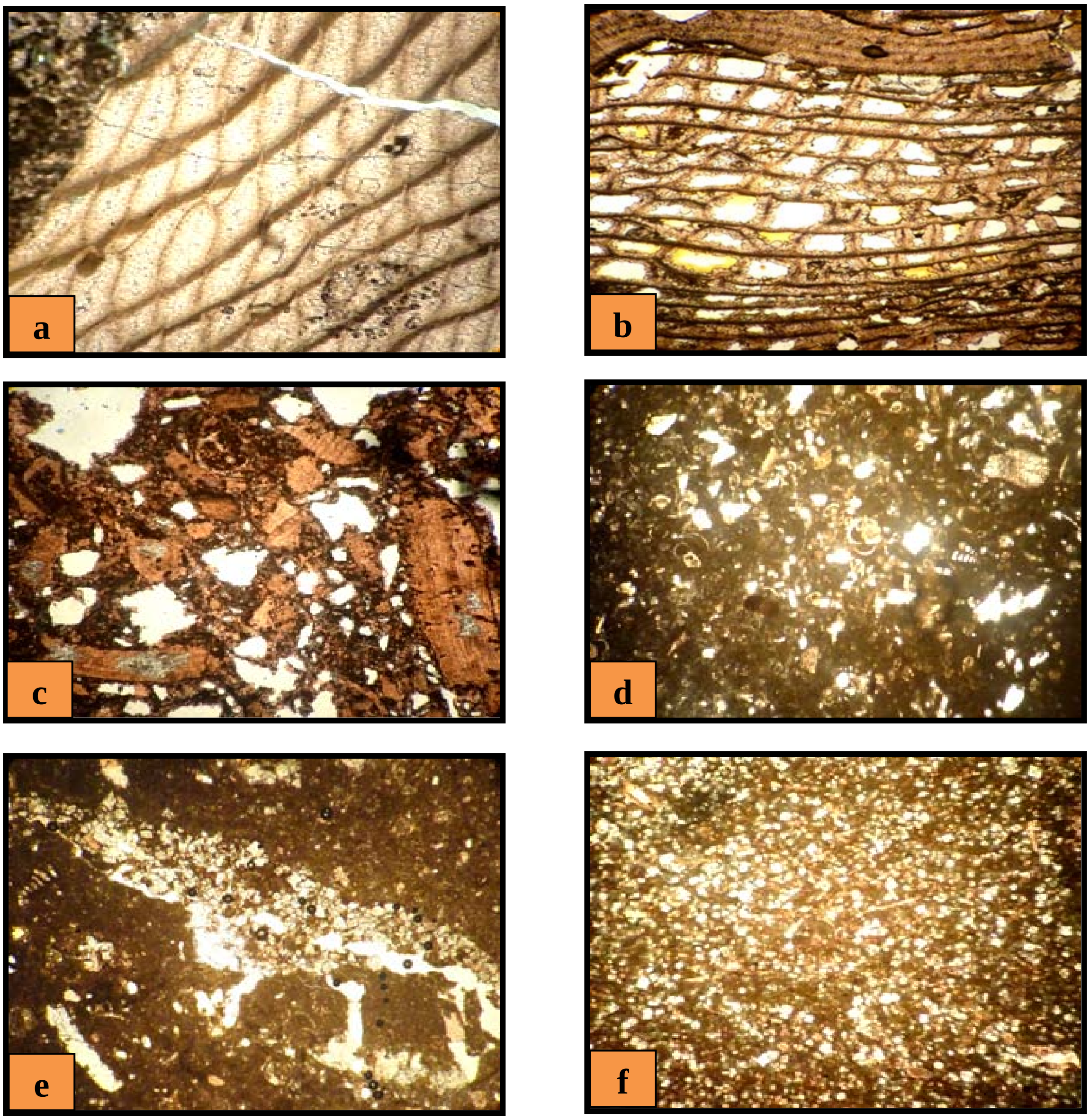
c -BioclasticPelloidalGrainstonemicrofacies show selective dissolution process created well developed separate moldic and vug pore type. (Tu-5, depth 2468.5 m).4x

d - Interparticle porosity in PelloidalGrainstonemicrofacies. (Tu-12, depth 2428.6 m).4x

e - Coralline algalbioclasticPackstone- Grainstonemicrofacies. (Tu-12, depth 2401 m).4x

f - High dissolution of Permocalculs debris and rudist debris and fragments in Coralline algalbioclasticPackstone- Grainstonemicrofacies. (Tu-12, depth 2438.5m).4x

Plate (3)



a - Boundstonemicrofacies, most of the Intraparticle pore system occluded by well developed fine- coarse equigranular mosaic cement. (Tu-5, depth 2464.5 m).10x

b -Well developed solution micro- channels and oil impregnated. (Tu-12, depth 2438 m).10x

c - Rudist bioclasticPackstonefacies. Mostly of open character and rarely cemented, partly well improved by solution micro- channels and oil impregnated. (Tu-5, depth 2467.5 m).4x

d-Mudstone-Wackstonemicrofacies with planktonic Foraminifera such as *Hetrohelix*, *Oligostegina*, *Globigerina*.(Tu-5, depth 2423.5 m).10x

e-DolomiticWackstonemicrofacies. Well developedintercrystalline porosity enhanced by micro-mesovug and solution micro channel. (Tu-5, depth 2440 m).4x

f-Dolostone microfacies. (Tu-5, depth 2482 m).10x

5. Reservoir characterization

The study of reservoir characteristics of Mishrif Formation rocks gives a better understanding about how these rocks produce oil and also estimates their hydrocarbon potential. The primary and secondary porosities were calculated for Mishrif's reservoir rocks and also the rare shale volume and its influence on oil production besides the water and hydrocarbon saturationswith the aid of the available open whole logs records. Whereas,well logsare very important and indirect tool to obtain the measurements of formation properties exposed by the well borehole acquired by lowering a device or a combination of devices in the borehole [14].

5.1. Porosity logs

Porosity is an important rock property because it is a measure of potential storage volume for hydrocarbon [15], It is represented as a decimal fraction a percentage and is usually represented by the Greek letter Phi, ϕ [16].

Through thin section examination of Mishrif succession in Tuba oilfield wells, five types of porosities were identified: Interparticle, intraparticle (as primary porosity) and vuggy, moldic, channels (as secondary porosity).

5.1.1 Total porosity

It reflects the total porosity of the rock filled with oil or water because it responds primarily to the hydrocarbon filled porosity [17].The total porosity was determined directly from the reading of the Neutron log of the borehole(Tuba – 4, 5, 6,7,8,12),which followed by correction using Schlumberger chart.

Total porosity can be also computed from the density log which is a lithology porosity log measuring the true bulk density of the formation in gm./cc units which in fact dependson the density of the rock matrix material of the formationand the liquid filled the porosity. An equation proposed by [18]is used to compute the total porosity depending on neutron and density log:$Ø_{N.D} = (Ø_{N.} + Ø_{D.}) / 2$

This equation is used to define the total porosity in the Mishrif facies and its variation through the studied area.

5.1.2.Secondary porosity

Porosities like vuggy, moldic, and channels are considered as secondary porosityin origin formed after deposition because of the effect of diageneticprocesses [19]. Secondary porosity can be computed by the difference between the total porosity and the primary porosity which computed from the sonic log: SPI = Ø total – Ø sonic.

Figure (5) shows the relationship between total porosity and secondary porosity, the secondary porosity is less than the primary porosity. The secondary porosity in spite of being relatively higher in some interval of (Tuba- 4), especially in the upper part of formation due to the dolomitization processes effect, but the primary type remains the highest. This means that the effect of diagenesis on the porosity of Mishrif Formation is relatively low.

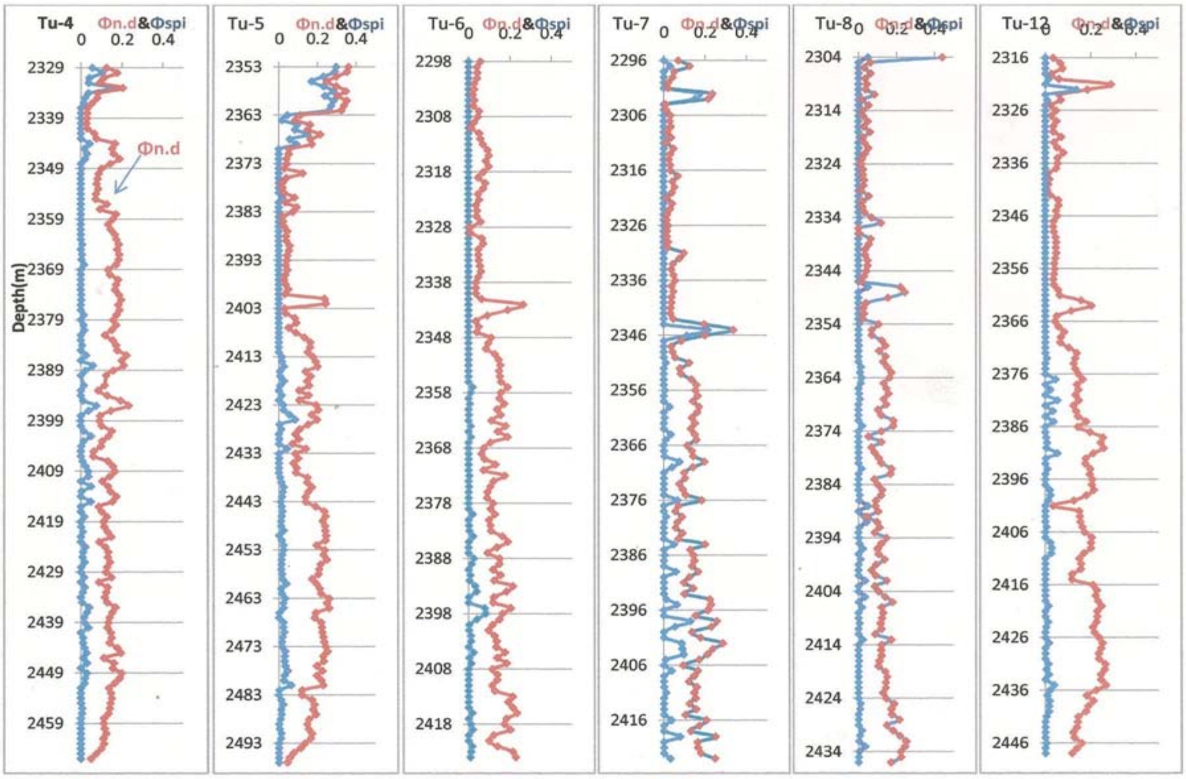


Fig. (5): Relation between Total porosity and Secondary porosity in studied wells.

Porosity quantity and distribution within the Mishrif succession along the studied area can be divided into four categories namely: very high porosity (> 25%), high porosity (15-20%), low porosity (5-10%) and very low porosity (< 5%) (Table 1), also five reservoir units were identified by using the geologic log interpretation and microfacies analysis (Fig.6).

(Table 1):porosity distribution within the Microfacies in Mishrif succession.

No.	Average Total porosity	Microfacies type	Environments
1	> 25%	Boundstone and Echinodermalrudist and Rudist Packstonemicrofacies	Shoal/ Rudist biostrom
2	15-20%	bioclasticPelloidal and PelloidalGrainstone	Shoal
3	15-10%	Algal Wackstone – Packstoneand Coralline algal bioclasticPackstonemicrofacies	Shallow open marine
4	<10%	Dolostone and Dolomatic Mudstone- Wackstonemicrofacies	Deep open marine

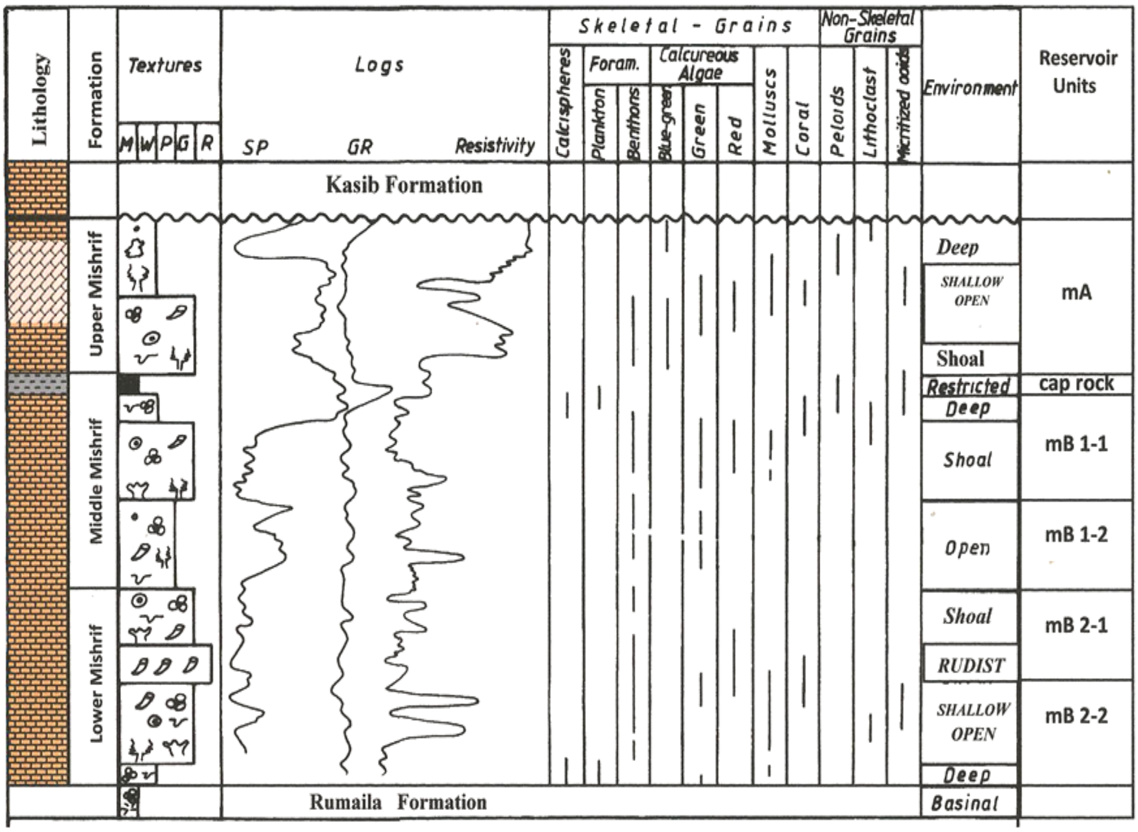


Fig. (6): Standard lithostratigraphic type section of Mishrif succession in study area.

6. Porosity combination crossplot

The crossplotis used to identify main mineral mixture from sonic density and neutron logs to provide the lithology dependent quantities [20].

The calcite presented the main mineral through the Mishrif succession in Tuba oilfield, in addiction to scattered dolomite which was obviously seen mostly in the upper part of the studied section(Fig.7) and (Fig.8).

7. Volume of Shale (Vsh):

It can be clearly seen that Vsh reveals untrue high values of both log derived porosity and water saturation, whereas Vsh negatively affecting on resistivity behavior leading to minimally recorded values [21].In general, calculated Vsh values of the most of studied wells are less than 15% (Fig.9).

8. Bulk volume of water and hydrocarbon:

On one hand, residual oil saturation (ROS) and moveable oil saturation (MOS) values are varying along the depth intervals of the studied area. It can be clearly noticed that ROS is less than MOS in the studied wells except Tu-4 which means that permeability is significantly high especially in the middle and lower partsof the Mishrif Formation(mB1 & mB2). Also these values would increase gradually in some parts of it showing permeability values ranging between moderate to high. While in the upper part MOS and ROS are mostly in convergence.However,ROS is slightly higher than MOS in unit mA, revealing high permeabilities (Fig.10).On the other hand, bulk volume of oil in un invaded zone (Bvo) and bulk volume of oil in invaded zone

(Bvx) arefluctuated around the same values in unit mB.In the upper part of the studied formation Bvoishigher than Bvx, whichreports improvement in both permeability and porosity (Fig.11).

Figures.(12, 13, 14, 15, 16, 17) show hydrocarbon zones, lithology, porosity and the relationships between different petrophysical parameters (MOS, ROS, Bvo and Bvx) in thestudied wells.

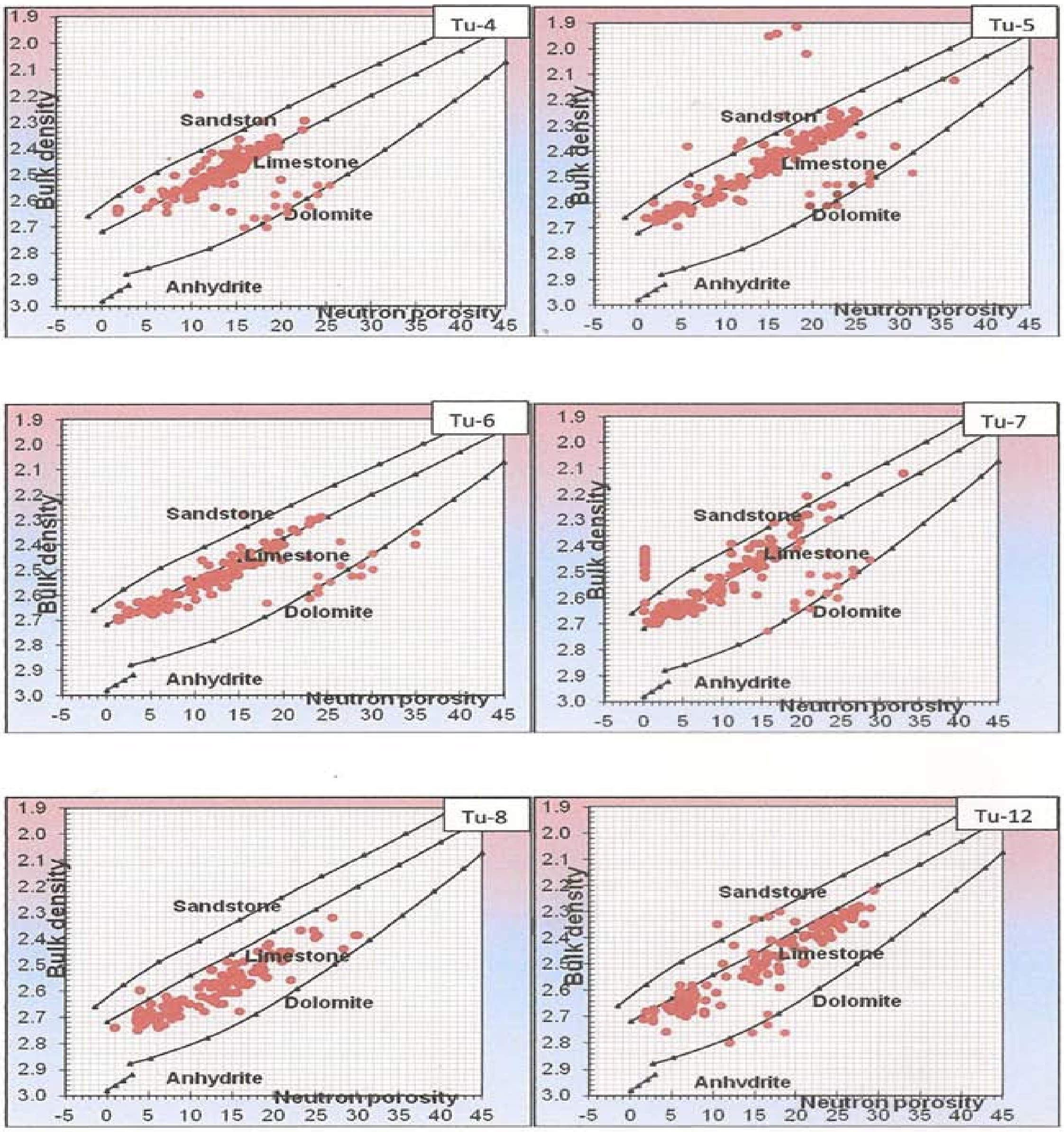


Fig. (7): Neutron – Density Crossplot for studied wells.

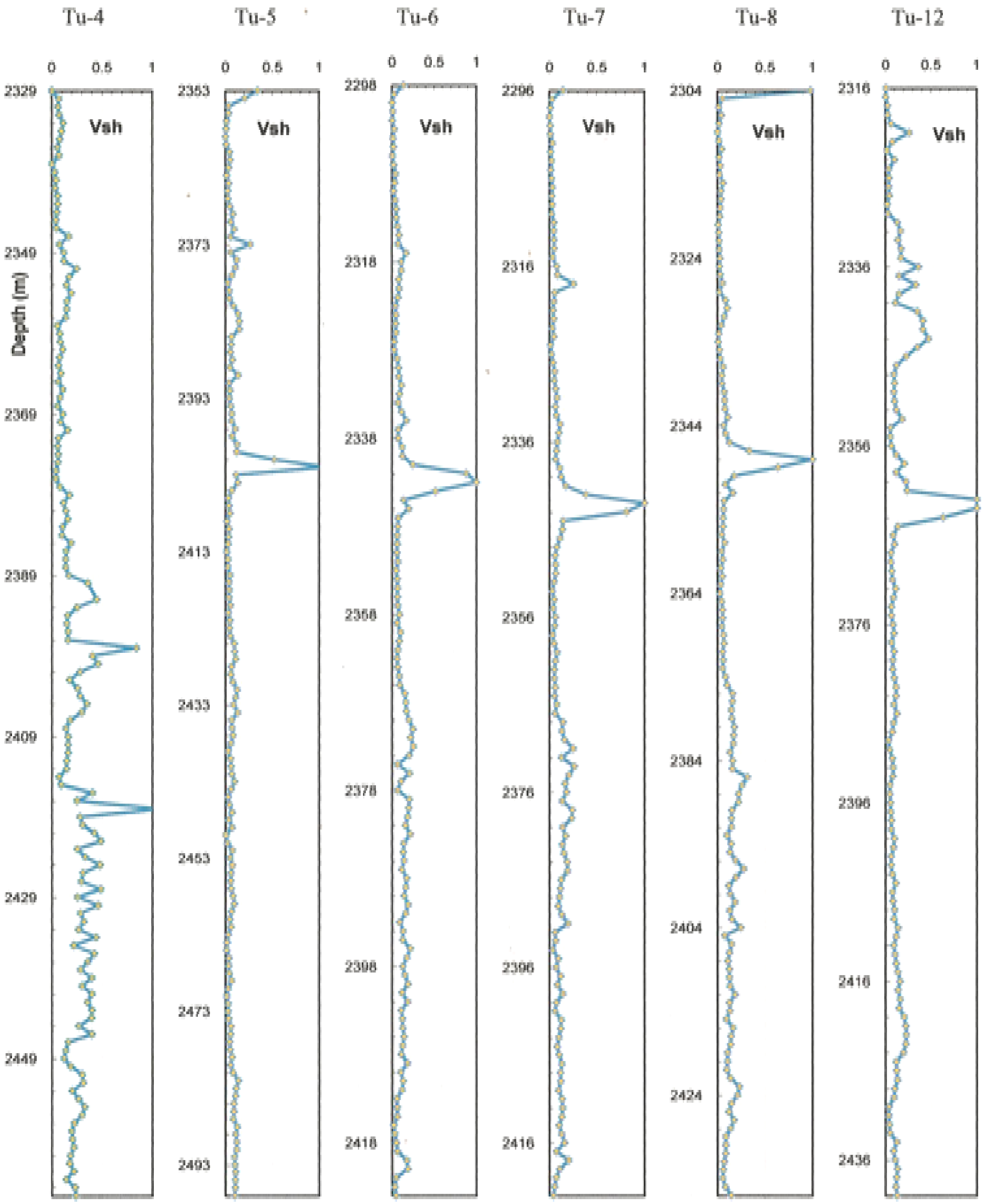


Fig. (9) : Relation between V shale and depth for wells study

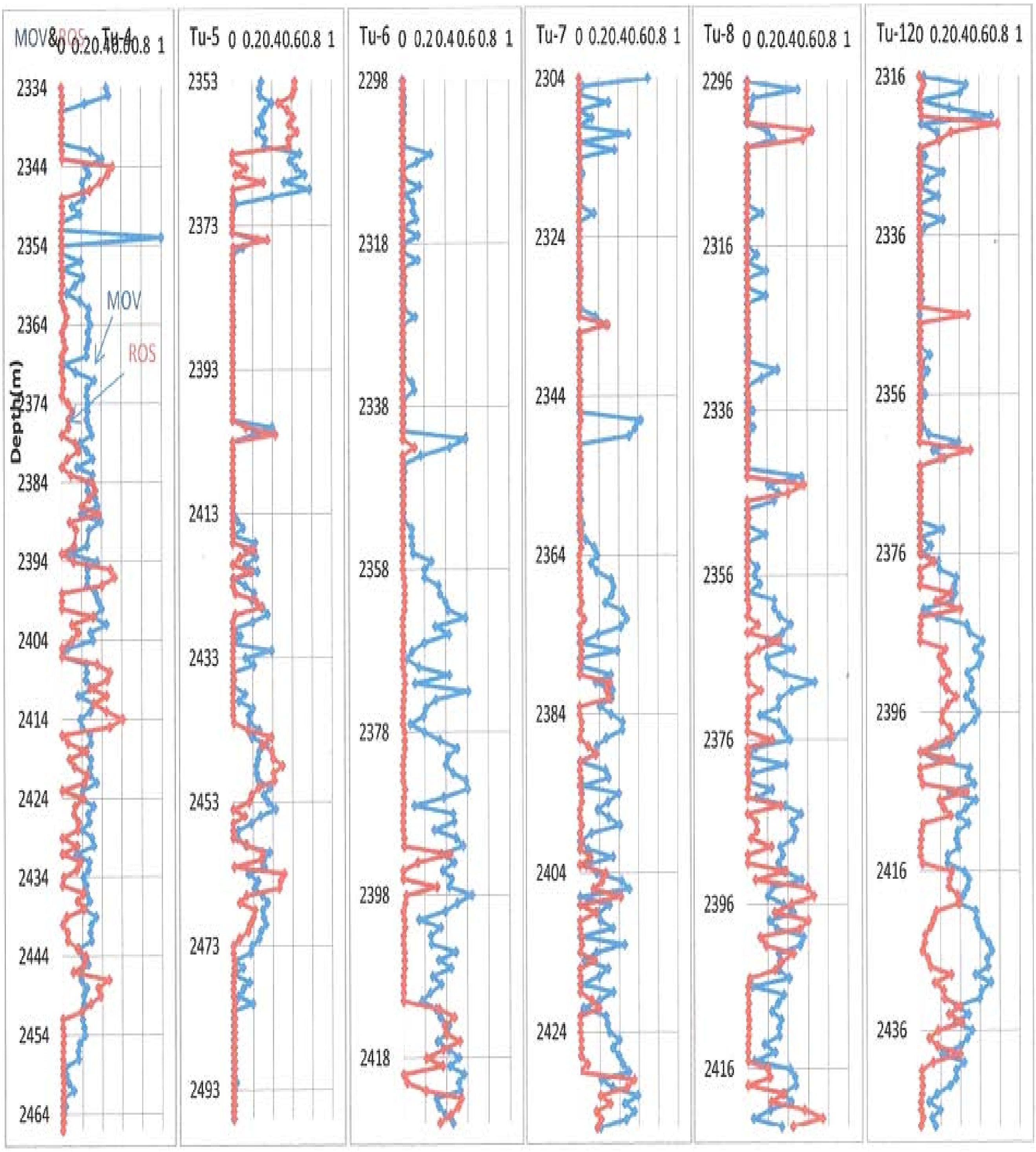


Fig. (10): Relation between bulk volume of moveable hydrocarbon (MOV) and bulk volume of residual hydrocarbon (ROS) for studied wells

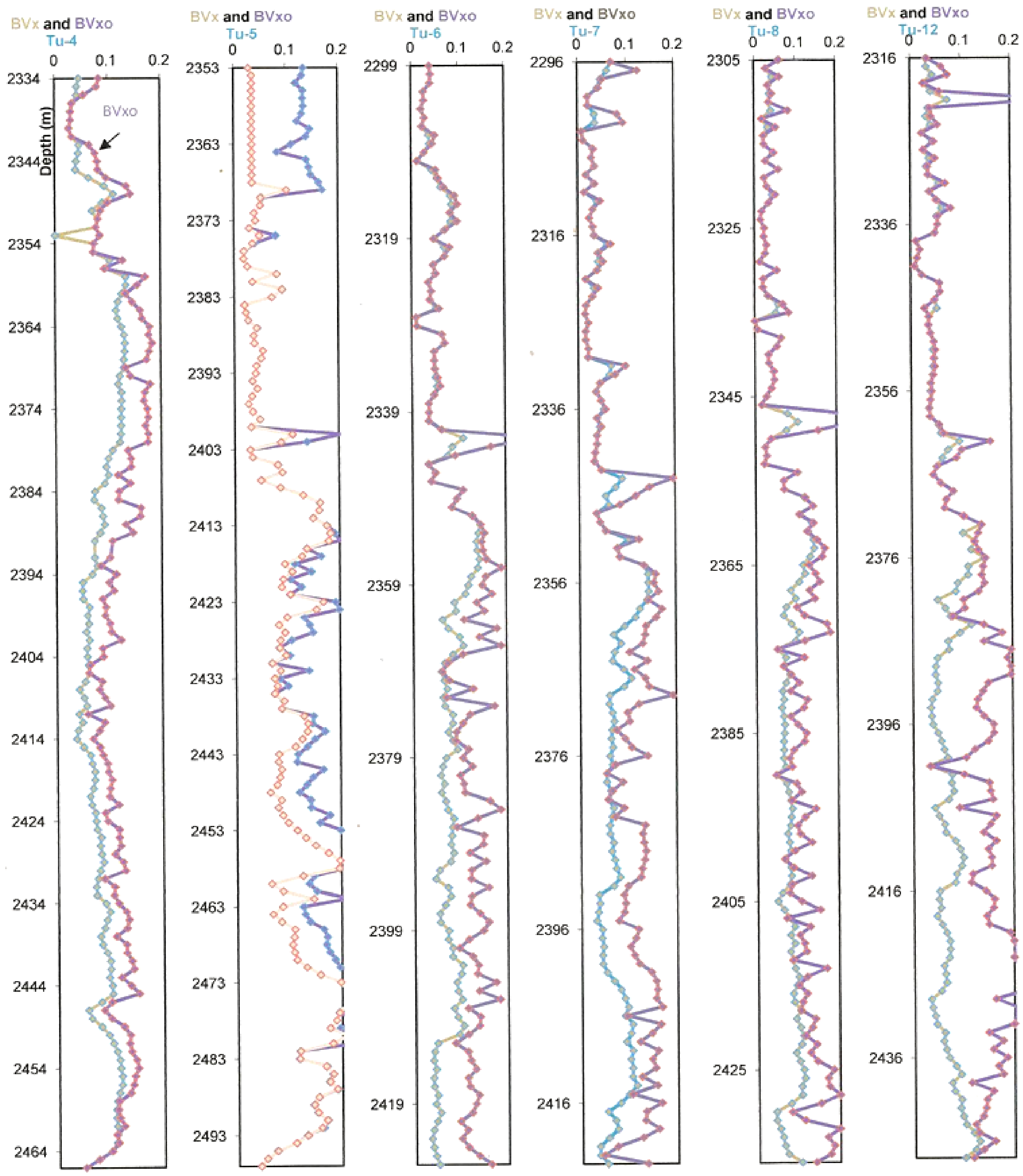


Fig. (11): Relation between BVX and BVxo for studied wells

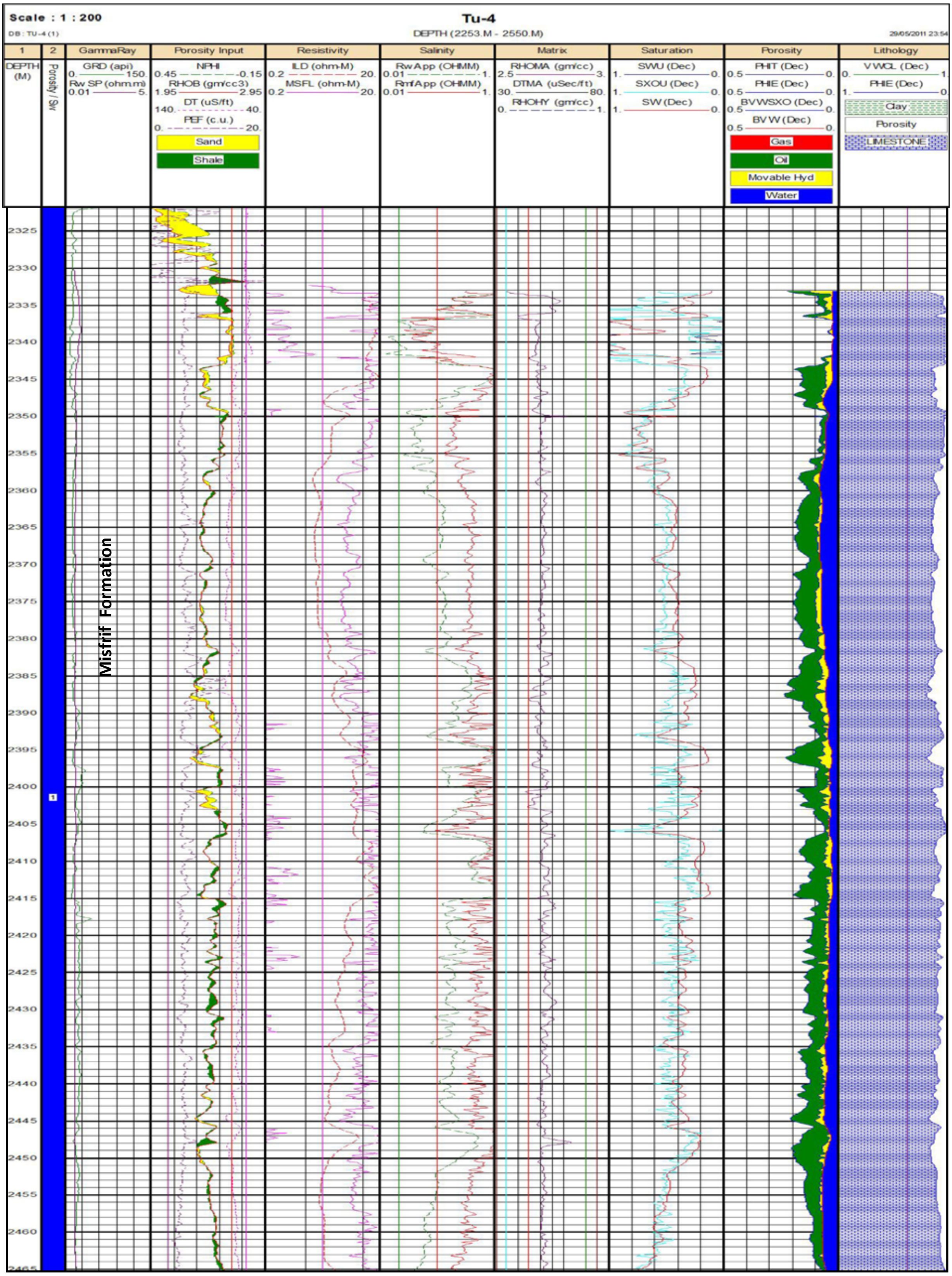


Fig. (12): Represent the petrophysical analysis by IP program for well (Tu-4).

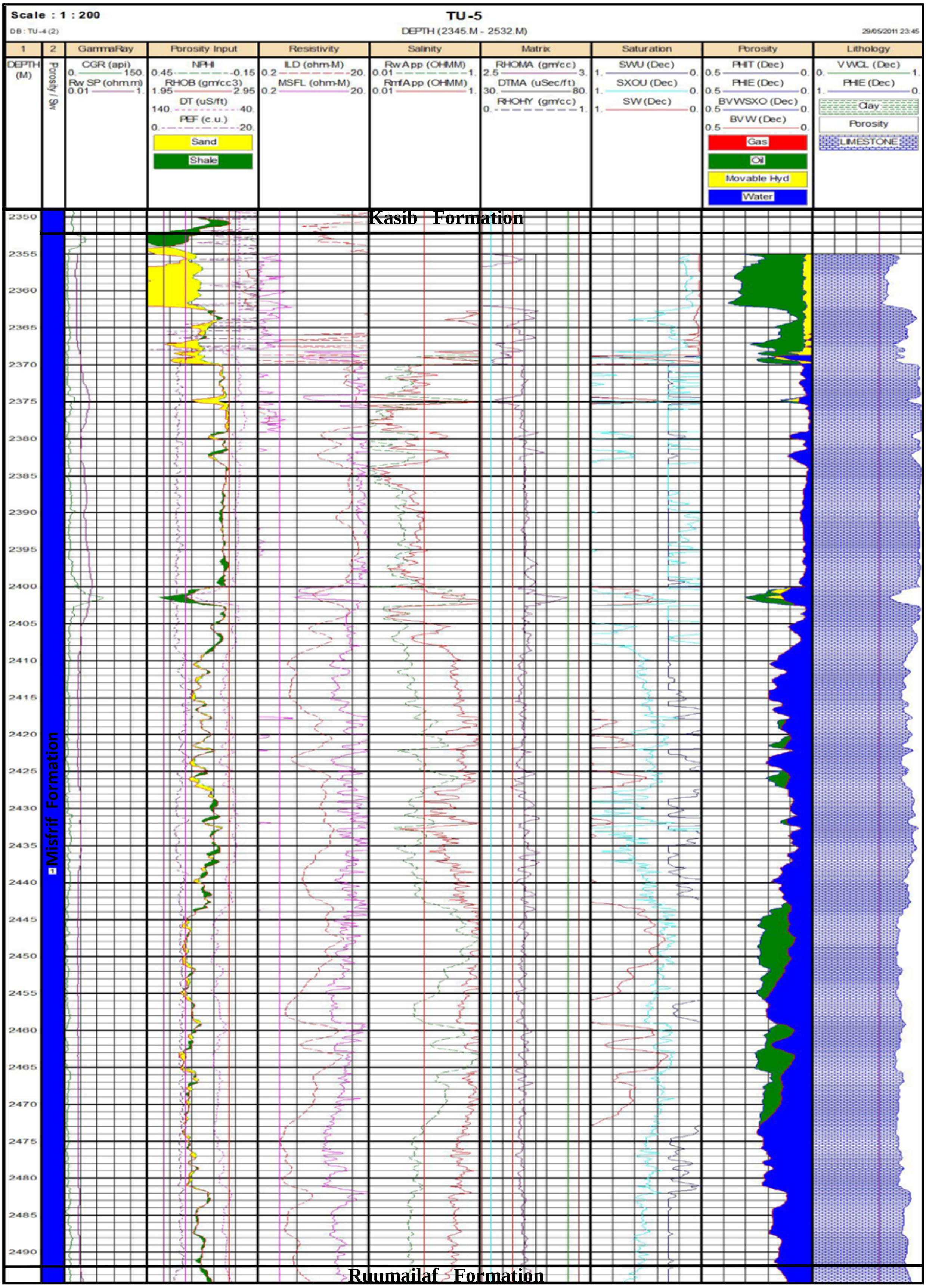


Fig. (13): Represent the petrophysical analysis by IP program for well (Tu-5).

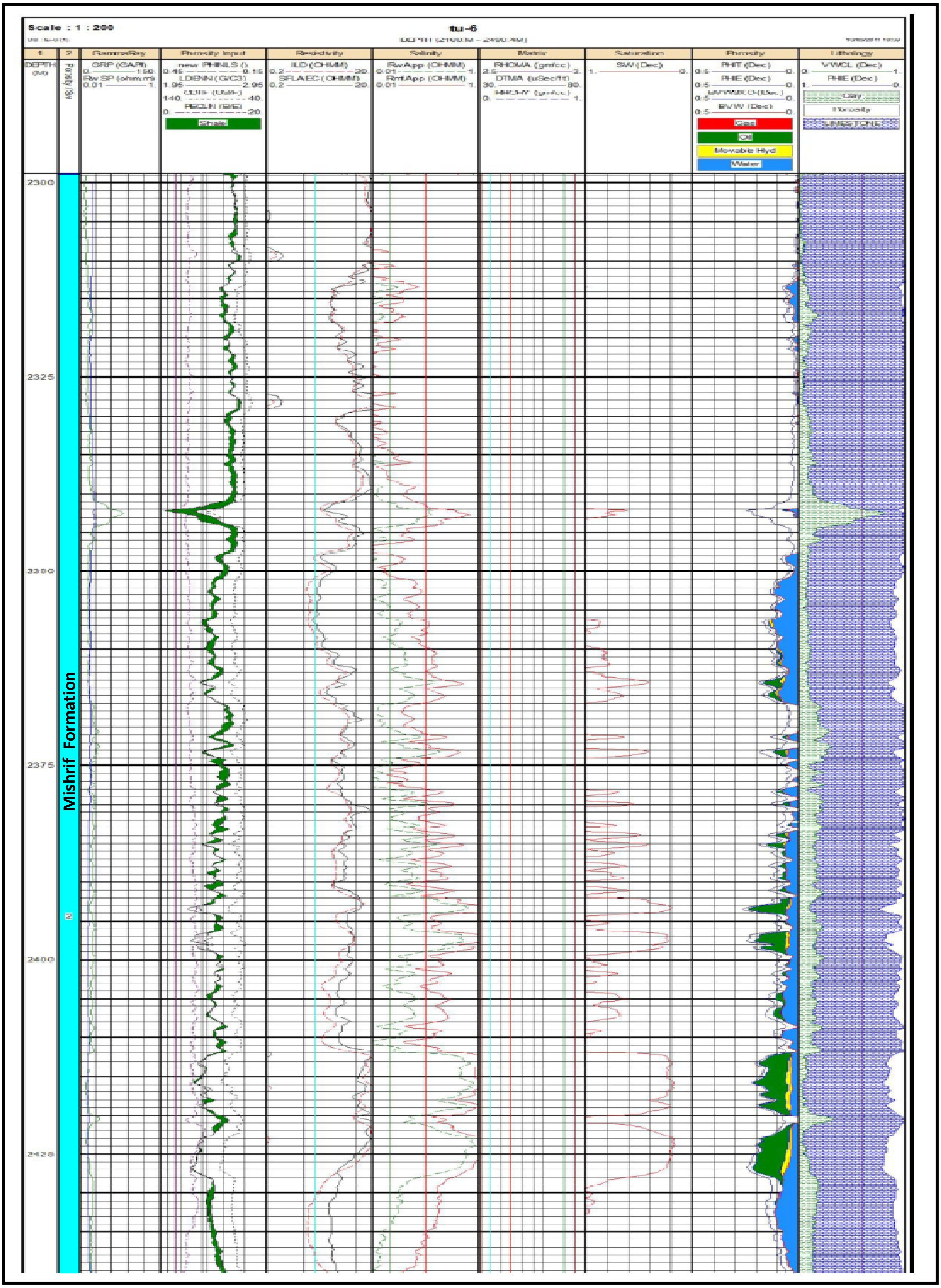


Fig. (14): Represent the petrophysical analysis by IP program for well (Tu-6)

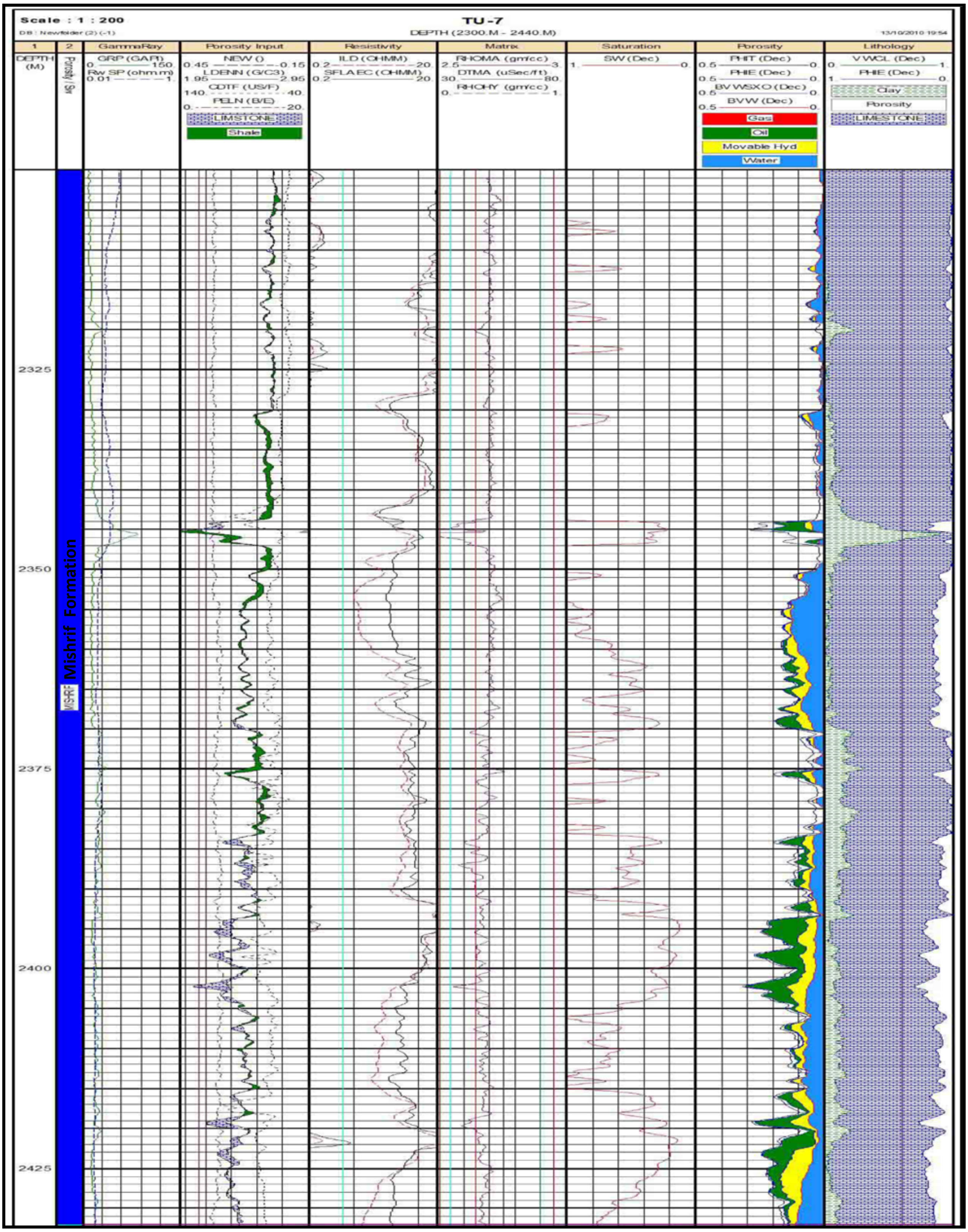


Fig. (15): Represent the petrophysical analysis by IP program for well (Tu-7).

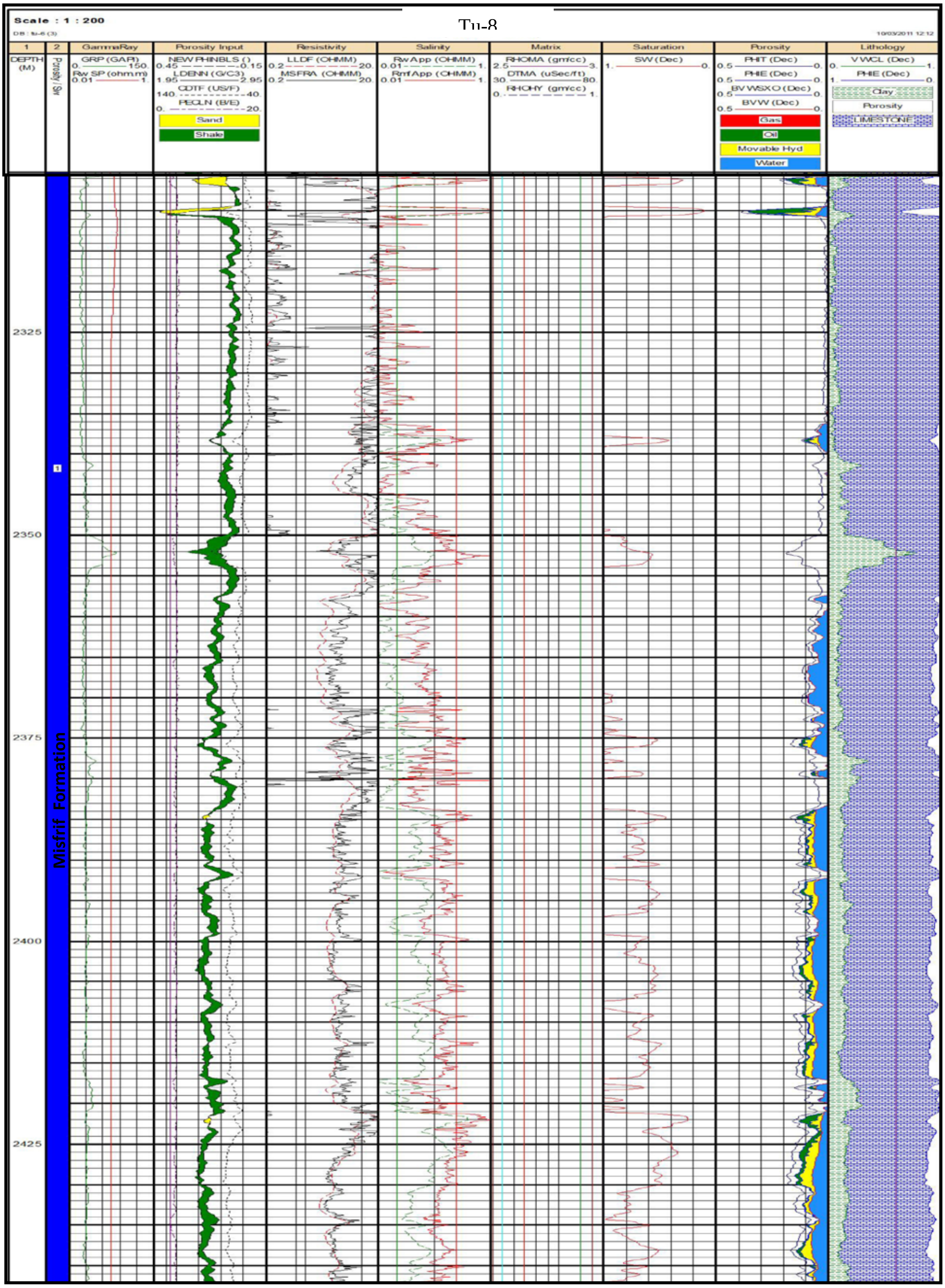


Fig. (16): Represent the petrophysical analysis by IP program for well (Tu-8).

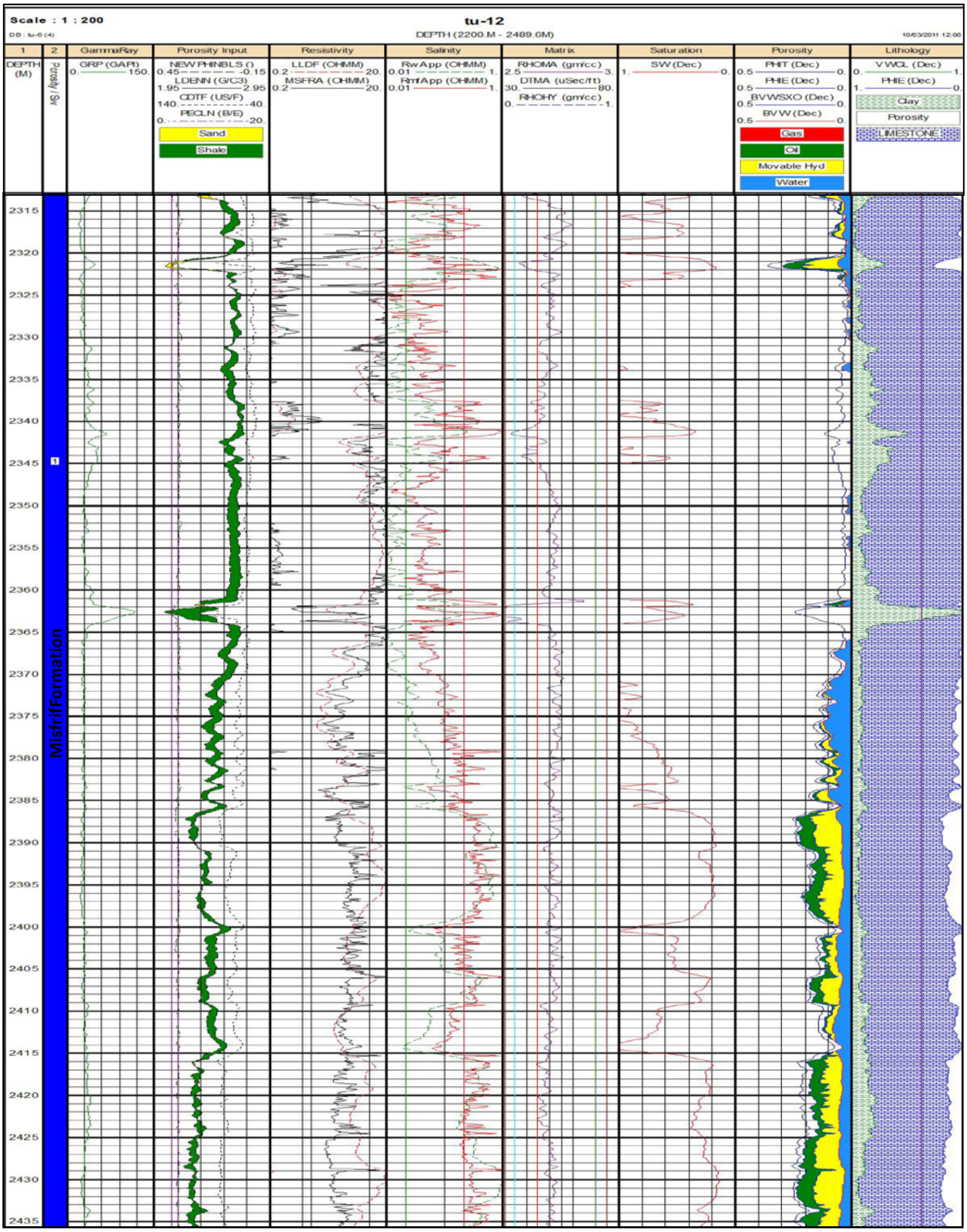


Fig. (17): Represent the petrophysical analysis by IP program for well (Tu-12).

Conclusion

The Mishrif Formation in the studied area is a result of continuous deposition on shallow carbonate platform that developed throughout the middle Cretaceous in Southern Iraq. Petrographic study and microfacies analyses distinctly revealed fivemain subenvironment. These are shallow restricted, shallow open marine, shoal, Rudistbiostrom and deep marine environments.

A diagenetic process affected on Mishrif microfacies that has both early and late phases.The most effective processes are dissolution and dolomitization thatcontributed tothe forming of porosityand also they have made significant enhancement in the quality of Mishrif reservoir rocks, especially the shoal and the open marine facies. The other processes such as micritization, neomorphism and cementation are less than in microsparite matrix. Cementation that has been observed petrographically shows various types such as syntaxial rim cement, granular and equigranular cement.

Both porosities (primary and secondary) in the studied succession were computed using the data acquainted from neutron, density and sonic logs.Interparticle and intraparticle typeformed,the primary porosity and it comprise the majority of reservoir units in the whole succession. In contrary to that,secondary porosity was in fewer amounts than primary owing to the small effect of diagenesis.

On the basis of geologic log interpretation and microfacies analysis, Mishrif Formation was subdivided into five reservoir units (mA,mB1-1,mB1-2,mB2-1,and mB2-2). These reservoir unitsare characterized by high total porosity.

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