تلفیق داده‌های سنگ‌نگاری، پتروفیزیکی و لرزه‌نگاری سه بعدی: نگرشی بر سرشت نمایی مخزن میشریف میدان رشادت واقع در خلیج فارس

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Petrographic, Petrophysics and Seismic integration: an Approach to Characterize Mishrif Reservoir on Reshadat Oil Field in the Persian Gulf

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چکیده

میدان رشادت در مرکز خلیج فارس، یک تاقدیس با جهت یافتگی شمال- جنوب و در آن بخش بالایی سازند سروک (میشریف) دربردارنـده مخـزن نفتـی است.

مخزن میشریف در این میدان به ۵ بخش مخزنی تقسیم می‌شود. بخش بالایی (A) بهترین زون مخزنی شناخته شده است. فرایند دیاژنز از قبیل انحلال، دولـومیتی شدن و درز و شکاف باعث افزایش کیفیت مخزن شده است. تحت تأثیر فرایند دیاژنز (انحلال)، نفتگیر چینه‌شناختی از نوع دیاژنتیکی ایجاد و زونهای A, B بـه صورت نازک‌شدگی نفتگیر را به وجود آورده‌اند. فرسایش شدید میشریف سبب افزایش تراوایی و در نتیجه افزایش کیفیت مخزن شـده اسـت. مطالعـات نـشان می‌دهد که دگرشیبیهای محلی در بخش جنوبی یال میدان نفتی رسالت، زونهای مهم مخزنی را در این بخش ایجاد کرده و در نتیجه کیفیت مخزنـی زونهـای C, D افزایش یافته است .

وارونه‌سازی اطلاعات لرزه‌نگاری به پاگیری صوتی، سبب تشخیص بهتر واحدهای سنگ‌شناسی شده است. تبدیل ژرفـایی (Depth conversion) بـا افقهـای موجود، با اطلاعات چاه به دقت هماهنگی دارند. وارونه‌سازی (inverted impedance) رخساره‌ها و تغییرات تخلخل را که در میدان سازند میـشریف بـر روی اطلاعات لرزه‌نگاری دیده نمی‌شد، به وضوح قابل تشخیص کرده است .

تلفیق تفاسیر لرزه‌ای و وارونه‌سازی لرزه‌ای، اطلاعات به دست آمده سازند میشریف را به شدت افزایش داده است. مطالعات نشان می‌دهد کـه سـتبرای بـا ارزش زون مخزنی قسمت باختری و شمال باختری این میدان افزایش و به سمت مرکز و جنوب کاهش می‌یابد .

کلید واژه‌ها: سنگ‌نگاری، پتروفیزیک، لرزه‌نگاری سه بعدی، مخزن میشریف، دیاژنز، میدان رشادت، خلیج فارس

Abstract

Reshadat Oilfield is an anticline with an approximately North- South trend. The Upper Sarvak Formation is a potential reservoir in this area. Mishrif Reservoir in this field has been divided into five zones. Zone A, (the uppermost) is recognized as the best reservoir zone. Diagenetic processes including (dissolution, dolomitization and fracturing) improved reservoir qualities. As a result of diagenetic process (dissolution), stratighraphic trap (diagenetic) has been created, and zones A and B are shaped into pinch out trap. Weathering dramatically improves the reservoir permeability and thus controls the extent of this diagenetic trap. Investigation shows that local unconformity in the southern flank of Reshadat oilfield, created the highest reservoir zones in this part. Consequently; reservoir quality of zones C and D have been improved.

The inversion of the seismic data to acoustic impedance has allowed for better definition of the main lithological units. The inverted impedance clearly highlights facies and porosity variations within Mishrif interval which not apparent on seismic data. Depth conversion has been performed and accurately ties the interpreted horizons to the available well data. The combination of seismic interpretation and seismic inversion has improved our understanding and definition of the Mishrif reservoir. Applying reasonable cutoffs for porosity and permeability, reveals valuable zones (A&B) in this portion of the field. These zones are located in west and northwest of Reshadat Oil Field.The study shows that thickness of valuable zones are increasing towards the west and the northwest and decreasing in the center and south of the field.

Keywords: Petrography, Petrophysics, 3D Seismic integration, Mishrif reservoir, Diagenesis, Reshadat oil field, Persian Gulf.

Introduction

Seismic amplitude is the property of the interface between two acoustic layers. Acoustic impedance is a property of rock layer itself. The interpretation of the acoustic impedance data produces more accurate and detailed structural and stratigraphic definition that can be obtained from seismic interpretation. In general acoustic impedance has a strong relationship to petrophysical properties such as porosity, lithology and fluid saturation. The study has taken the form of an initial interpretation of data followed by an inversion to acoustic impedance and subsequent fine-tuning of interpretation on the impedance data. The advantage is a reduction of wavelet and tuning effects and the generation of 3D geological model matching the original seismic data. By resolving tuning effects, the resolution of the seismic data is improved, enabling features such as pinch-outs to be more precisely mapped.In addition reservoir properties such as porosity can be estimated from of the inversion process.

In this study after a brief description of the main structural features, the geological setting and data integration will be discussed. In addition the depositional setting and seismic inversion as a tool to increase the seismic resolution for better description of the reservoir property will be presented. It is important to mention that one of the main results of the study is time and depth maps of horizons of the main target area that is top Mishrif and top Khatiyah and the 3D model both in time and depth for the study region.

Structural Features

Three principal factors have influenced the formation of the structural anomalies in the Persian Gulf and the surrounding oil fields (Bashari, 1988): 1) movement of deep seated salt, resulting in domal growth and diapiric structures; 2) movements in the basement rocks, resulting in generally north- south trending folds in the overlying sediments and the late Tertiary Zagros (Alpine) orogeny, causing north west– southeast trending, sharp, elongated folds, parallel with the Mobile Belt of the Zagros (Fig.1). The commencement of the movement of salt formation of the salt domes may have been directly associated with the movements in the basement rocks. The first readily definable movement within the Persian Gulf geosyncline began during the Jurassic. As this time basement block faulting and/or flowage of the Cambrian salt originated many of the structural features known today. Most of the structures that produce oil from the Jurassic and Cretaceous reservoirs in the Persian Gulf area began their growth at this time. At the end of the Triassic, a positive element developed a north–south trend in the central part of the geosyncline, which more or less divided the geosyncline into two separate but related basins. This central positive, now referred to as the Qatar Arch, caused drastic thinning and changes in facies in most of the Mesozoic and Tertiary formations. Following the Lower and Middle Cretaceous activities, only minor and local tectonism is noticed until the Alpine orogeny in late Mio-Pliocene time. At this time the Zagros folds were formed and, undoubtedly, some of the already existing individual structural features near to the zone of intense folding, though not affected directly, experienced some accelerated growth. The more distant structures on the Arabian Peninsula and the Arabian side of the Persian Gulf remained stable and showed little or no effect of the orogeny.

Geological Setting

Reshadat Oil Field is located in central part of the Persian Gulf. This field is an anticline with an approximately north-south trend (Fig.1) and is believed to be of salt tectonic origin. The available seismic data seems to suggest that the salt structure increases at increasing depth.

Interpretation

Seismic inversion

The seismic data has been inverted by using Jason workbench package. In the following after discussing the synthetic seismogram generation which is an essential step before any detailed seismic interpretation the inversion results will be discussed.

Generation of Synthetic Seismograms

Synthetic seismograms were generated for some wells. The acoustic velocities from the sonic logs were multiplied by density log to compute new acoustic impedance log. This impedance was converted to reflectively, which then converted from depth to time using an appropriate wavelet to produce a synthetic seismogram. Figure 2 shows the construction of a synthetic seismogram for the well A. Note that the Ilam limestone is high acoustic impedance (Al), the Laffan Shale is low Al, and similarly the upper part of Mishrif reservoir is low one . There is then a transition zone of lower part of the Mishrif to higher Al of Khatiyah limestone. There are two low Al layers in Khatiyah. The Kazhdumi shale is low Al and is also characteristic of the upper part of the Shuaiba limestone. It should be noted that Al increases in the lower part of Shuiaba.

Seismic Inversion

The ultimate aim of the inversion process is to reconstruct the acoustic impedance profile of the subsurface from seismic, well data and other prior information. This of course can be achieved to perfection since these profiles contain details, which is far beyond the seismic resolution. To obtain the best result, all available data (i.e. seismic- and well data) and prior information (e.g. of the wavelet and stratigraphy) have to be used. From the acoustic impedance profiles in the well and the stratigraphic layering, provided by the interpretation, an earth model can be constructed by interpolating the profiles along the layers of the volume. The low-frequency part of that model should be a good estimate of background trend of the acoustic impedance of subsurface, depending on distribution of the wells and quality of the interpretation. The high frequency variation of acoustic impedance is extracted from the seismic reflectivity, by deconvolving the wavelet in order to extend the bandwidth to the high side and thus to increase resolution. An implicit, and not always correct assumption is that acoustic impedance transitions are step like. By merging the seismically derived variations and low-frequency part of the earth model, a broad-band estimate of acoustic is obtained.

Data Integration

To optimise the understanding of reservoir it is necessary to combine geophysical, geological and petrophysical measurement and knowledge. However, the integration of information from different disciplines is in practice not easy to achieve. Inversion of seismic data to acoustic impedance has proved to be an excellent vehicle for integrated studies.

Figure.3, interpreted seismic cross line through Reshadat Field, shows Mishrif reservoir is shaped into pinched out trap.

On the Reshadat anticlinal structure, two NW-SE trending faults define a crestal graben, approximately 5 km long in the area around well IM_R1.The graben affects the sequence between the top Hith Reflection and top Laffan shale event. Evidence of NW-SE faulting becomes apparent only for horizons deeper than Laffan shale, making the Turonian unconformity (Fig.4).The top Mishrif reservoir does not produce a clear seismic event so it was not directly picked from the seismic data. Almost the Mishrif limestone has no impedance contrast with overlying Laffan shales in this area. Therefore no seismic event is associated with top Mishrif Reservoir (Fig.5).The computed acoustic impedance cube represents a real property and can be used for reservoir characterization. A quantitative reservoir characterization requires calibration of acoustic impedance with key reservoir properties such as porosity using well data (Fig. 5). Middle Cretaceous reef facies of the Mishrif limestone with good reservoir characteristics forms a key reservoir in Reshadat. Mishrif resevoir in this field has been divided into five zones (Figs. 6,7). Zone A, (the uppermost) is recognized as the best reservoir zone. The Mishrif reservoir in this area is part of more extensive reef deposition of the Middle cretaceous in the Persian Gulf. Applying reasonable cuts off for porosity and permeability, reveals reservoir zones (A&B) in this portion of field. These zones are located in the west and northwest of Reshadat Oil Field. The study shows that thickness of the reservoir zones are increasing towards the west and the northwest and decreasing in the centre and south of this field (Fig.6).

Depositional setting

Mishrif - Khatiyah Formations

Mishrif reservoir contains several lithologies. Each of them exhibits different sedimentological, and petrophysical properties and each represents a distinct sub-environment. Interfacies boundaries are not clear because adjacent facies grade laterally and vertically into each other. The formation consists of the following facies: Lagoonal/ back reef, rudist biostrom, algal boundstone, shallower sub-basinal (or outer reef margin), and deeper sub-basinal (slope margin) .The contact between Mishrif shallow marine reef facies and Khatiyah deeper marine facies is a gradual transition (Fig.7). There is thinning of the Mishrif on the crest of structures. This is largely related to the erosion during early upper Cretaceous uplift. It is believed that most of the present structures originated during upper Cretaceous uplift.(Bashari, 2005). The Khatiyah formation consists of interbedded limestone and shale with a total thickness averaging 120 meters in the Reshadat. In the deepest portion of the basin, thickness up to 300m has been observed (Bashari & Fathi, 2004).

The formation consists of grey to dark, dense argillaceous lime – mudstone. This limestone accumulated under conditions of low energy in a deep shelf setting. The Khatiyah deposits are pelagic carbonate sediments in association with some hemi pelagic sediments.

Sedimentological and geochemical studies have demonstrated Khatiyah sequences to be basinal deposits forming the source rock for the Mishrif reservoir. The Khatiyah limestone was deposited in an intra shelf basin, in which euxinic conditions favored preservation of organic matter, and do make a significant contribution to oil in the Mishrif reservoir.

Diagenetic Feature

The Mishrif reservoir has primary remnant and leached porosities. In the leached shelf grainstones to packstones associated with rudist bioherms, porosity ranges from 10% to 15% (Fig.8, 9). The rainstones associated with the high energy shoals and islands within the carbonate platform have high porosity ranging from 25%-35% with fair to good permeability. They have substantial remnant. Interparticle porosity enhanced by freshwater leaching. The leached skeletal grainstone is associated with rudist build-ups (Fig.10).

Dolomitization is rarely associated with vast sheets of Mishrif platform carbonate, but could be locally important because dolomitization may enhance the permeability (Fig.11). Extensive leaching has caused intense solution and brecciation (Fig.12) below the pre-Laffan (Coniacian) unconformity. Many of solution features are related to unconformity surface at the top of the Mishrif Reservoir.

Microfractures link horizontal or vertical stylolites seam to be common in the Mishrif rich layers (Figs 13, 14). Stylolites form in the mudstone and wackstones. Dolomite rhombs are concentrated along the horizons of compaction dissolution (Bashari, 2005).

Conclusions

The seismic interpretation on the Reshadat field has resulted in accurate definition of structure, thickness and facies variation at the top of Mishrif Reservoir.

The inversion of seismic data to acoustic impedance has allowed for a better definition of the main lithological units. The combination of seismic interpretation and seismic inversion together with log interpretation and petrographical study has improved our understanding and definition of the reservoirs. Depth conversion has been performed and accurately ties the interpreted horizons to the available well data. The inverted impedance clearly highlighted facies and porosity variation in the Mishrif interval which are not apparent on the seismic data. The best porosity conditions in the reservoir are associated with acoustic impedance values. Assuming that an analogous porosity- impedance relationship exists in a quantitative characterization of the reservoir can be made in terms of acoustic impedance.

In the Reshadat field best reservoir condition highlighted by low impedance value, are observed in north and west. Alkhalij field closed to Iranian border (Fig.1)is a diagenetic trap with no significant vertical closure, this reservoir was assumed to be sealed laterally by truncation and /or facies change and capped by Laffan transgressive shales (Balusseau&El-Demerdash,1996). Interpretation and results reveal strong evidence for R-6 be linked to Alkhalij field in Qatar, that constitute a potential prospect.

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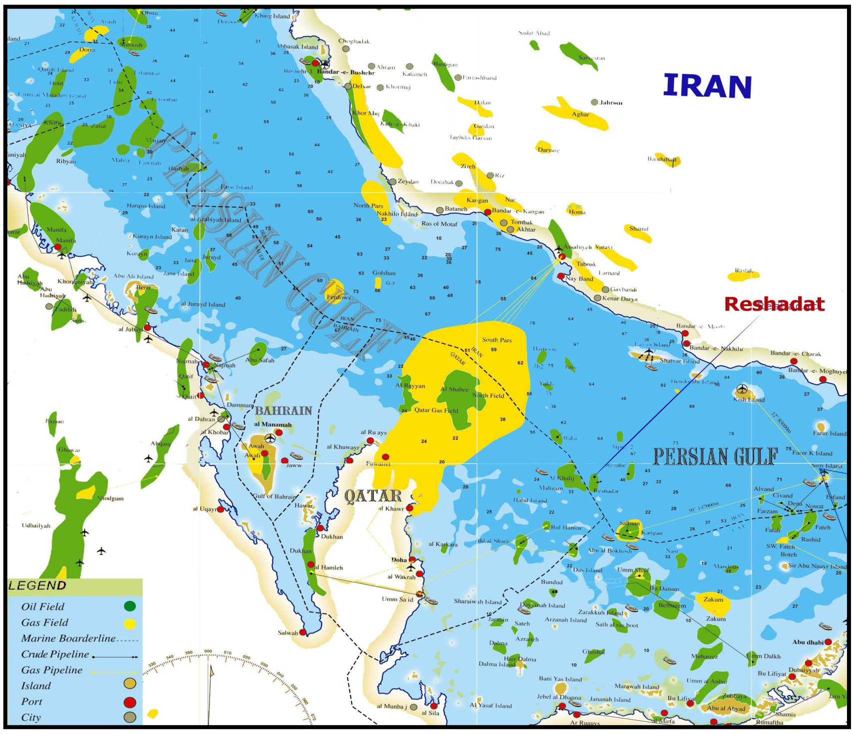

Fig.1- Oil and Gas field in the Pesian Gulf

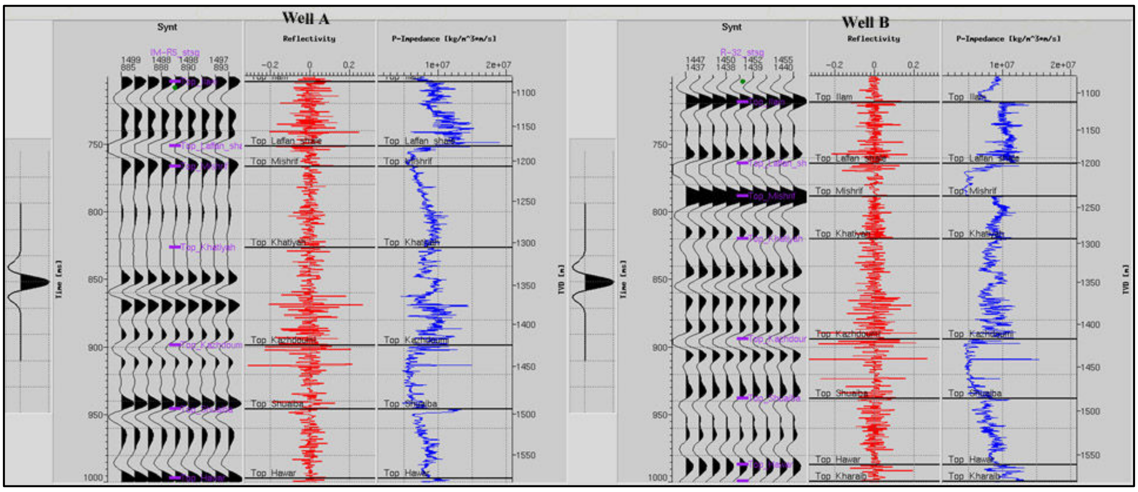

Fig..2- Comparison of the acoustic impedance contrast of the Mishrif with the Laffan Shale and the synthetic event at the top of Mishrif in well A & B. In well (A) the upper part of the Mishrif reservoir is porous and has no acoustic contrast with Laffan Shale. The weak black peak event at the top Mishrif corresponds to the sode lobe of the wavelet. In well (B) the Mishrif reservoir is tight and shows a strong acoustic contrast with Laffan Shale. The top Mishrif produces a strong black peak event on the synthetic seismogram (Jason Geosystem, 2003).

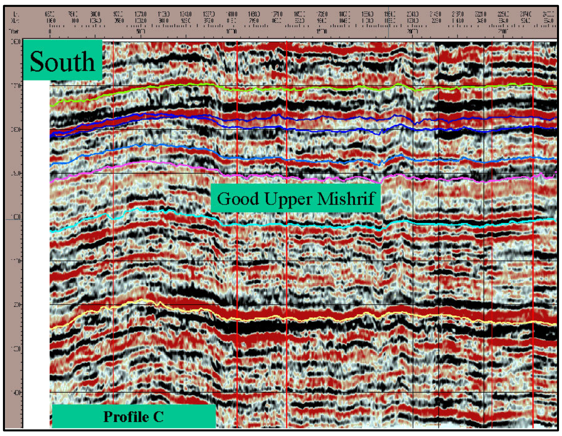

Fig. 3- Interpreted seismic cross line through Reshadat

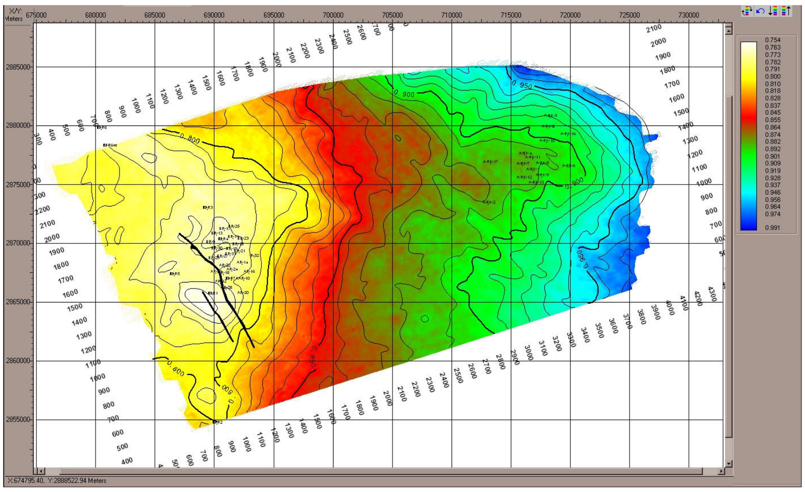

Fig.4- Reshadat: structural time map at the Top Mishrif Reservoir

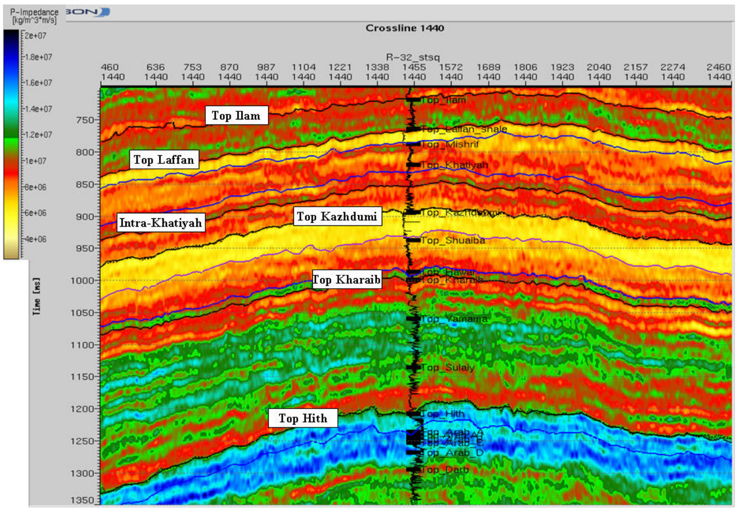

Fig.5- Interbedded acoustic impedance section through Reshadat Field

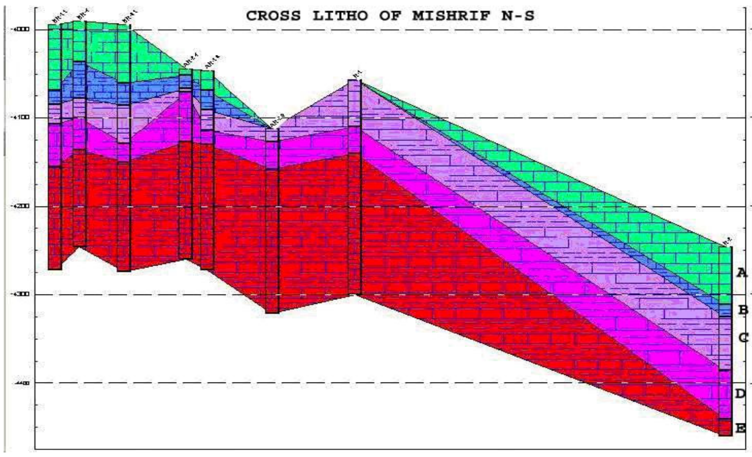

Fig.6- Cross Litho of Mishrif N-S

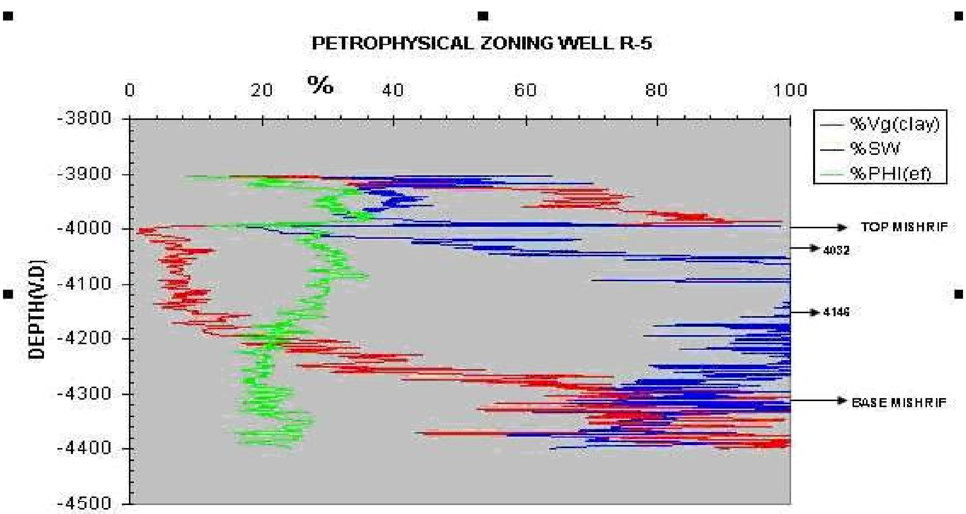

Fig.7- Petrophysical zoning well R-5

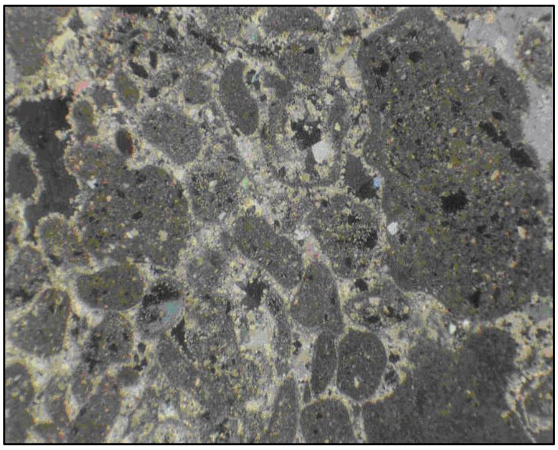

Fig.8- Intraclastic & bioclastic grainstone(Zone C)

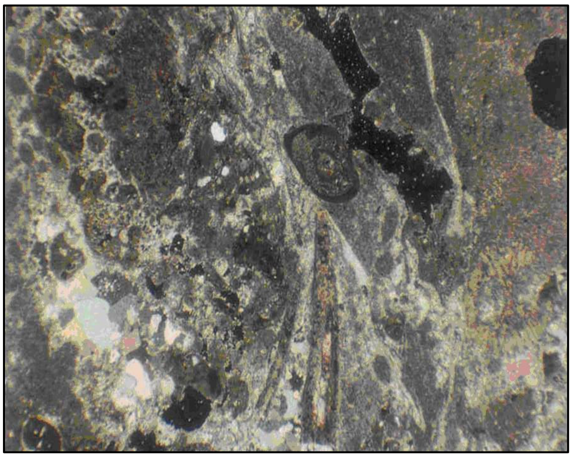

Fig.9- Bioclastic packstone porosity (vugg & mouldic)

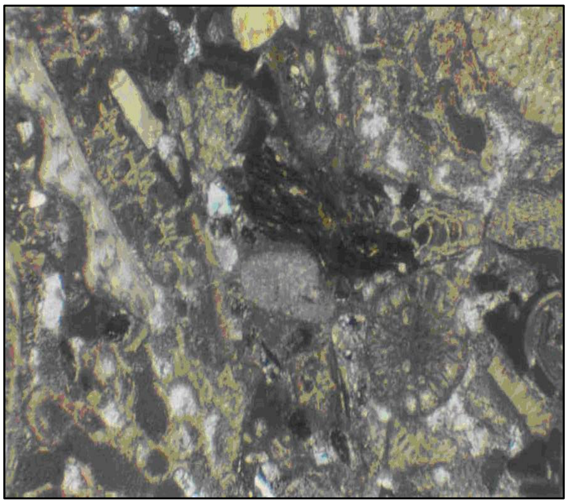

Fig.10- Bioclastic grainstone porosity: mouldic, intergranular (Zone E)

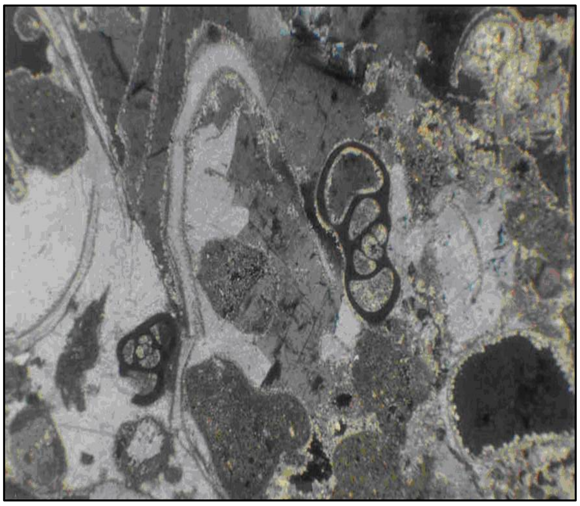

Fig.11- Dolomitized bioclastic packstone porosity: mouldic

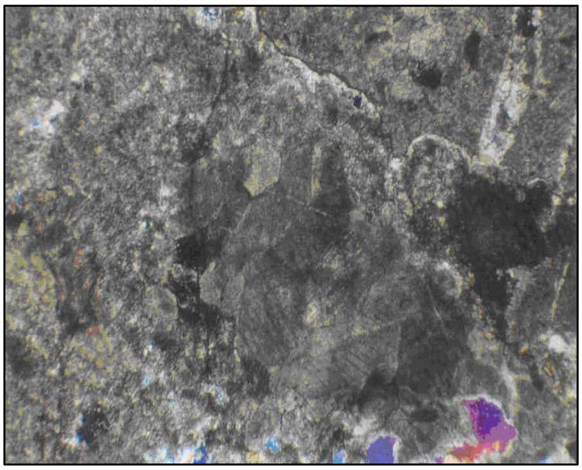

Fig.12- Bioclastic grainstone silisification, brecciation Dolomitization

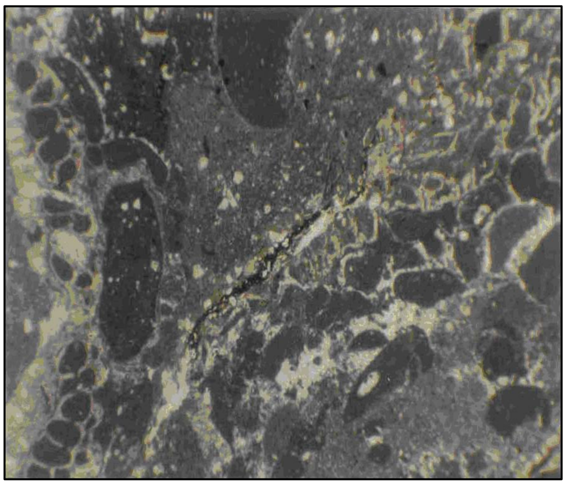

Fig.13- Dolomitized bioclastic grainstone bearing , hydrocarbon porosity: mouldy & fracture

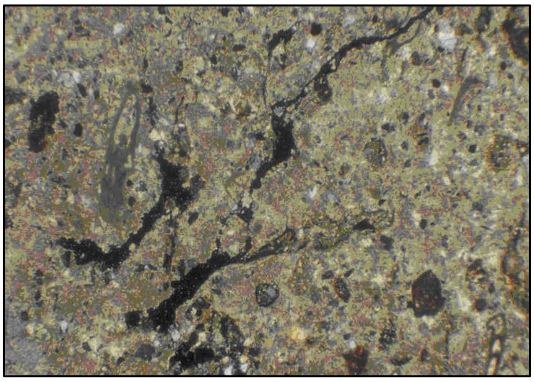

Fig.14- Fractured packstone

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