Egyptian Geophysical Society
EGS Journal, vol. 3, No. 1, 145-150 (2005)

SEISMIC CHARACTERISTICS OF THE NULLIPORE RESERVIOR IN RAS FANAR OIL FIELD, GULF OF SUEZ, EGYPT

Nadia A. Fattah

Geophysics Department, Faculty of Science, Cairo University

الخواص السيزمية لخزان البترول بحقل رأس فنار – خليج السويس– مصر

الخلاصة: تعانى عمليات إستكشاف البترول في منطقة خليج السويس من ضعف التقنية السيزمية الإنعكاسية، و ذلك بسبب وجود رواسب المتبخرات من عصر الميوسين المتأخر. بالإضافة إلي صعوبة إختراق الطاقة، والسرعة العالية للقطاعات الضحلة والتي تُنتِج متكررات إنعكاسية كثيرة التعقيد و هو ما يصعب فصلها عن الإنعكاسات الأولية العميقة.

و يختلف الحال جزئياً بحقل رأس فنار و ذلك لتواجد الخزان البترولي الرئيسى علي أعماق ضحلة لا تتجاوز ٢٠٠٠ قدم. ولذلك تتوارى مشكلة الإضمحلال الموجي لوقوع الخزان البترولي تحت قطاع المتبخرات مباشرةً حيث تخف حدة مشكلة المتكررات الإنعكاسية طويلة الفترة. و مع ذلك فإن التعرف علي الإنعكاسات السيزمية الأولية للخزان البترولي تواجه صعوبات تتمثل في تداخل رواسب المتبخرات مع طبقة الخزان البترولي والتي تتكون من المرجانيات.

و قد تم دراسة الخواص السيزمية لكلٍ من الخزان البترولي و رواسب المتبخرات المحيطة به في حقل راس فنار و ذلك بإستخدام المعلومات الجيولوجية و البتروفيزيائية والجيوفيزيائية المتاحة. و قد تم تكامل المعلومات المستخلصة من تسجيلات الآبار و المسح السيزمي السطحي حيث تم التعرف علي خواص الخزان السيزمية، و التي تتمثل في إستعراض موجي و سعة موجية قليلة مع عدم تجانس في حدوث الموجات. بينما تتميز تتابعات المتبخرات المحيطة بألخزان بوجود سعة موجية ملحوظة و تجانس موجي محدد في ترددات موجية ضيقة، ملحوظة.

ABSTRACT: *Exploration in the Gulf of Suez has always been severely hampered by the poor performance of the seismic reflection technique in the presence of the thick interbedded late Miocene evaporate sequence. In addition to the difficulty of obtaining energy penetration, the high velocity shallow section generates a large number of complex multiple trains which have no velocity discrimination to separate them from the deep primaries.*

The principal difference with Ras Fanar area is that the reservoir Nullipore (carbonates buildups) depth is only some 2000 feet, so the attenuation problem is much reduced and, in addition, the reservoir lies immediately beneath the evaporate section where there is less problem from long multiples. However, the reflection identification of the Nullipore reservoir in the field has long been a problem because of the interfingering of the anhydrites with the reefal facies of the Nullipore reservoir.

Seismic characteristics of the Nullipore (carbonate build-up) reservoir and the surrounding evaporate section in Ras Fanar Oil Field were studied using the available geological, petrophysical and geophysical data. Well data was integrated with the seismic data to achieve this task. The seismic expression of the Nullipore reservoir is a broad band, low amplitude, incoherent event, while the equivalent evaporite section which is surrounding the Nullipore shows reflections of significant amplitude and coherency restricted in a narrow frequency band.

INTRODUCTION:

Ras Fanar oil field is located in the western side of the Gulf offshore area, approximately 3 km east of Ras Gharib. The field lies offshore in water depth of about 30 meters, (Fig. 1), and was discovered in April 1978 by exploration well KK84-1. Ras Fanar oil field is a narrow, elongated pre-Miocene structure horst striking NW-SE and tilted towards the North East with an average dip of 20 degrees, (Fig. 2). The structure was defined by reflection seismic surveys carried out between 1974 and 1977. Several wells along the crest of the fault-block produce oil from the Nullipore carbonate reservoir (Belayim Formation).

Fig. 1 Ras Fanar Oil Field Location Map

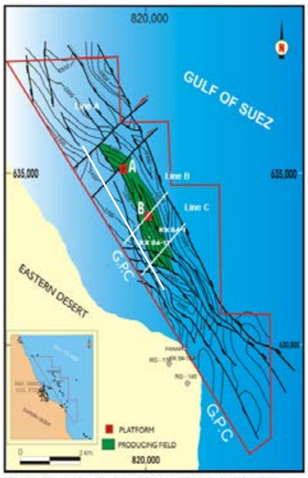

Fig. 2 Structure Contour Map on Top Pre-Miocene
(After Suez Oil Company)

The stratigraphic section (Fig. 3) relevant to the field is that of the Upper/Middle Miocene and Recent sequence.

The post-Zeit to Recent section consists predominantly of coarse clastic sediments. Zeit Formation is represented by thin rapidly intercalated anhydrite and clastic (shale and sands) sequence. South Gharib Formation consists mainly of thin anhydrite section with minor shale streaks. The Nullipore carbonates occur below the evaporites have traditionally been placed within Hammam Faraun Member of Belayim Formation.

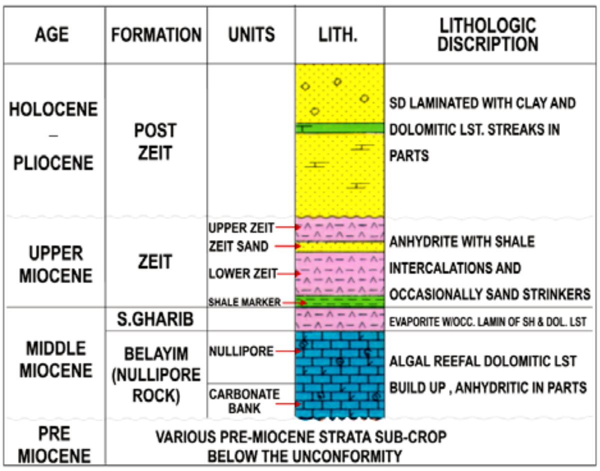

Fig. 3 General Stratigraphic Column of Ras Fanar Oil Field

The Nullipore rock is a bioclastic rich carbonate producing biota of varied fossil content mainly of red algae, Sultan and Moftah, (1986). The development of Nullipore carbonates is visualized as a two stage development. The lower unit referred as Nullipore platform (carbonate bank) facies, which is thought to be a sheet-like extending from Ras Gharib to the west of Ras Fanar field in the east. This sub-strata was the foundation for the development of the overlying reef buildups. The upper Nullipore comprises skeletal dolomites and limestone, with randomly occurring anhydrite filling the vugs and solution channels and cavities, with excellent reservoir characteristics resulted from the dolomitisation process.

Both Nullipore and carbonate bank have undergone extensive diagenesis resulted in an extremely heterogeneous reservoir in both vertical and horizontal distributions. This extensive diagenesis was continued post to the time of migration and accumulation of oil by the effect of highly saline formation water where the upper part of the reservoir has much higher porosity, (El-Naggar, 1988). This led to the deposition of what is called Nullipore equivalent which is dominantly anhydrite with thin interbeds of dolomite. Laterally, the Nullipore is replaced by an almost tight nodular anhydrite with some dolomite matrix in flank wells.

Over the field extent, various pre-Miocene strata subcrop below the Miocene unconformity.

GEOPHYSICAL PROBLEMS AND DATA QUALITY

A major geophysical problem on this field has always been the difficulty of defining the top of reservoir on seismic data, due to the highly reflective and tectonically disturbed nature of the overburden.

The field was covered by a total eight two dimensions seismic surveys through the period from 1974 to 1982 by different contractors. The quality of the seismic data, (Fig. 4) varies to the recording technique imposed by the surface conditions. The use of long arrays was a common feature of recording techniques. This leads inevitably to an inherent lack of high frequency signal in the energy source, which implies a long source array.

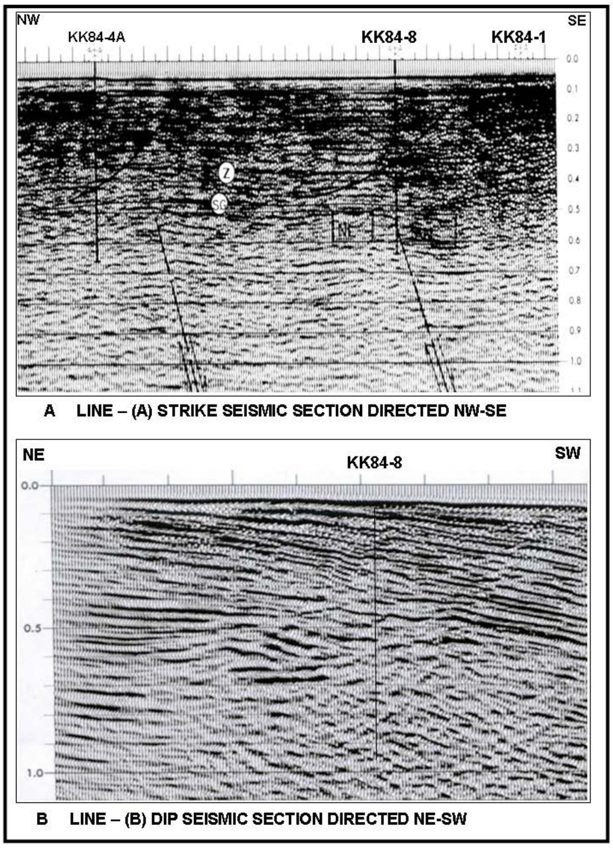

Fig. 4 Seismic Data from Ras Fanar Oil Field

The data quality at reservoir level also suffers throughout the area from attenuation of high frequencies by the rapid intercalation of anhydrite and shale in the Zeit Formation, followed by absorption and scattering at the top and base of the South Gharib evaporites. Stack response is further impaired by ray-path distortion by the high dip of the strong velocity contrasts within the Zeit and South Gharib Formations. This problem has been addressed in recent years by advances in depth migration and pre-stack migration techniques, but these methods were not available in 1983.

The above mentioned effects combine to reduce the signal-to-noise ratio at the reservoir level, below the South Gharib evaporites. Several attempts at reprocessing selected lines from the survey have been undertaken by various contractors during the 1980's, but with limited success. The seismic data acquisition and processing in the Gulf of Suez area are notorious, and only in recent years the industry has developed tools and techniques capable of addressing these problems. The advent of workstation interpretation technology has offered various display methods which may be targeted at improving the interpretability of the seismic data. Using this tool, the data were now considered to be marginally within the range of interpretability and in this study a seismic interpretation of the principal reservoir levels has been carried out.

ELECTRIC LOG RESPONCES OF NULLIPORE RESERVOIR:

Stratigraphic correlation, for some wells drilled in Ras Fanar oil field, was constructed using the available electric logs (Gamma Ray, Neutron/Density and Sonic logs) along NW-SE direction, (Figs.5 & 6). Sonic correlation as well as velocity analysis of the reservoir and the overlying evaporite (base South Gharib) reveal great similarity and minor difference between Nullipore and the above evaporite section. Also, several intervals within the carbonate have similar response of the above evaporite. This leads to the difficulty of seismic interpretation of the Nullipore distribution.

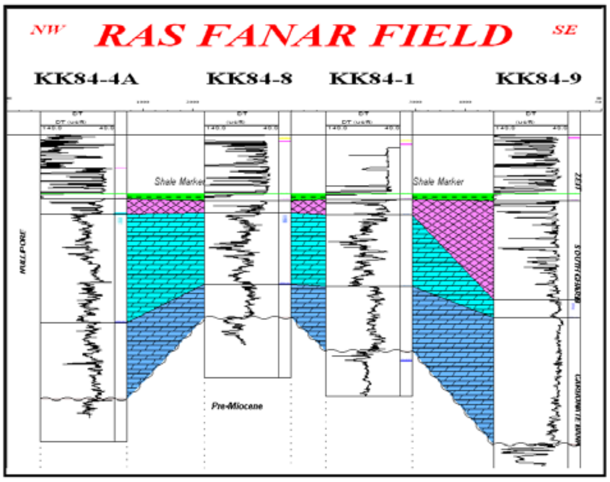

Fig. 5 Sonic Log Correlation along NW-SE Direction, Ras Fanar Oil Field. (Shale Marker is a Datum)

Sonic correlation, (Fig. 5) of the Nullipore build-up and the overlying evaporite indicate clear difference only in the crestal wells KK84-4A, KK84-8 and KK84-1 in which Nullipore was penetrated above the oil-water contact. On the other hand, there is a great similarity and minor difference between Nullipore and the above South Gharib evaporate in the southern direction (well KK84-9) in which the Nullipore was penetrated below the oil - water contact.

The Neutron/Density correlation, (Fig. 6), also demonstrates that the Nullipore thins to south and south east direction away from the crest of the horst, with the evaporitic facies thickening from the South Gharib Formation downwards. Thus a well like KK84-3 that may have encountered Nullipore below its present total depth, (Fig. 7).

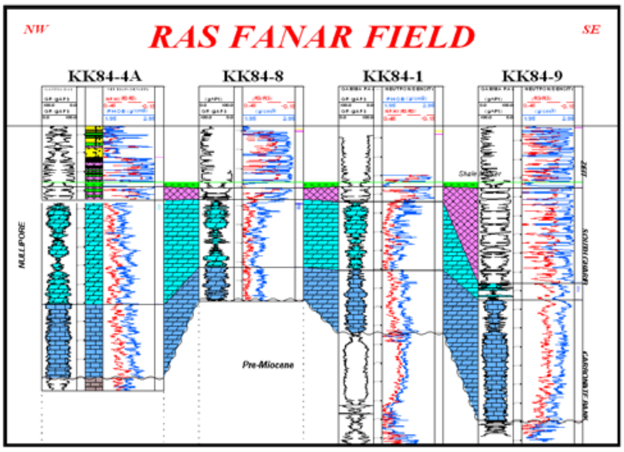

Fig. 6 Log Correlation (Neutron/Density and Gamma Ray) along NW-SE Direction, Ras Fanar Oil Field. (Shale Marker is a Datum)

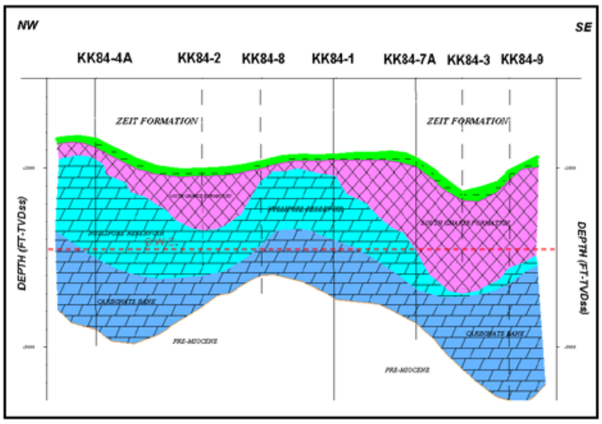

Fig. 7 Geological cross section along NW-SE direction, Ras Fanar Oil Field

It is also recognized that the correlation within the carbonate build-up reveals drastic changes, as there are several intervals within the carbonate have similar response of the above anhydrite. The correlation shows the essential differences between the carbonate bank and the overlying Nullipore facies. The former shows a flat sonic with minor acoustic impedance contrasts, whilst the latter shows strong contrasts.

DEFINITION OF NULLIPORE BOUNDARIES:

The seismic sections passing through wells KK84-4A and KK84-12, (Figs. 8 & 9), indicate that the amplitude and continuity of the events within the Belayim Formation decays as the crest of the horst is approached.

The high amplitude continuous events were thought to indicate a predominantly interbedded anhydritic section, whilst low continuity zone represents the Nullipore facies. The reflection generated by top Nullipore is relatively weak where it interferes with the reflection generated by the base Shale Marker. The strong coherent reflection of Shale Marker is in fact generated by the sharp increase in acoustic impedance contrast with the anhydrites overlying and underlying this shale.

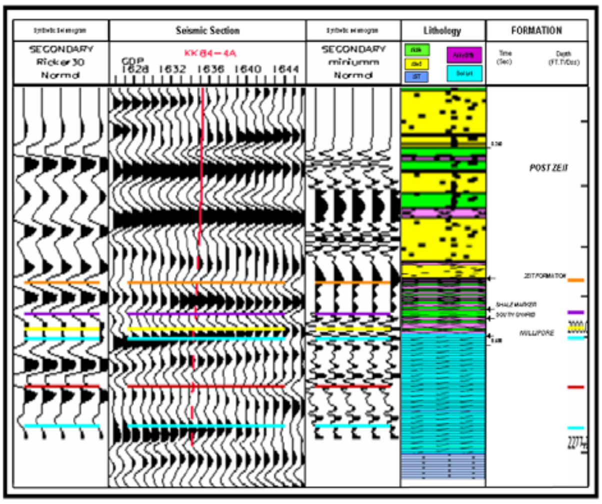

Fig. 8 Synthetic Seismogram of Well KK84-4A, Tied with Seismic Section in Dip Direction

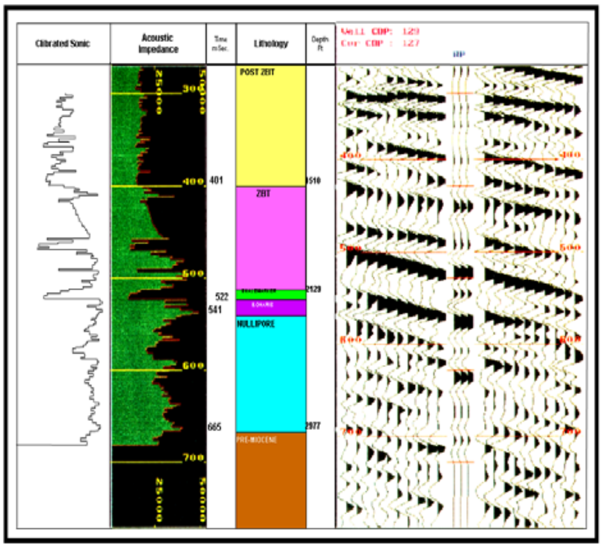

Fig.9 Synthetic Seismogram of Well KK84-12, Tied with Seismic Section in Dip Direction

Deep investigation for the data derived from the above mentioned wells indicated that there were distinct character differences between the data at these wells. The synthetic seismograms from these wells were tied with the surface seismic sections, passing in dip direction through these wells show that the strong black peak on the section, which is picked between Shale Marker and South Gharib, is caused by an increase in the acoustic impedance of the Zeit below the Zeit Sand. The Shale Marker below the Zeit Formation is associated with a smaller peak below the Lower Zeit unit.

There is a drop in acoustic impedance at or just below the top of the Nullipore and this cause a low amplitude reflection below the Shale marker peak. Because the South Gharib tends to be thin, there is an interference between these reflections. Bubb and Hatlelid, (1977) stated that there is a pronounced velocity contrast which commonly exists between the carbonate buildup and adjacent strata, especially the evaporites of high velocity, resulting in differences in seismic travel time through these strata.

In general, the true Nullipore character will be of low amplitude incoherent events whilst the evaporite equivalent should show reflections of significant amplitude and coherency.

RECOGNITION OF CARBONATE-BUILD-UPS ON THE SEISMIC SECTION:

The procedures for recognition and interpretation of carbonate buildups from a grid of seismic data follow the seismic stratigraphic techniques which were described by both Vail et al. (1977), and J. N. Bubb et al. (1977). Vail, et al. 1977, described an approach to seismic stratigraphy. He described the stratification patterns interpreted from seismic reflection terminations and configurations and summarized their use for recognition and correlation of depositional environment. He concluded that the seismic facies analysis is an approach of recognition and mapping of seismic facies units within the seismic sequences, based on objectively defined seismic parameters such as reflection configuration, continuity, amplitude, frequency, and interval velocity.

Bubb and Hatlelid, (1977), mentioned that the direct criteria include seismic parameters that directly outline the buildups such as: (1) reflections from top and sides of buildups and on lap of overlying reflections onto buildups; and (2) patterns of seismic facies change between buildup and enclosing strata. Such changes may occur in amplitude, frequency, or continuity of reflections from within the buildup, or between the buildup and the laterally adjacent time-synchronous or younger on-lapping reflection. The indirect criteria as mentioned by Bubb and Hatlelid, (1977), include a phenomenon called Drape which occurs in reflections overlying the buildup because of differential compaction of strata in the buildup and the enveloping strata.

Following the above mentioned criteria, the interpretation of the seismic data in the studied area is presented in Figure 10.

Seismic section, (Line C), is a dip section where the Nullipore reservoir was built-up towards the west. The carbonate build-up can be seen by the following observations:

A. Reflection from top and front of buildup,
B. On-lap of the evaporite section of the South Gharib Formation onto the Nullipore buildup,

C. Change from continuous, parallel reflections into discontinuous reflections,
D. Numerous diffraction along the boundary between the carbonate buildup and the surrounding evaporite section,
E. Drape over the buildup where a strong contrast in lithology of carbonate buildup and off-buildup evaporite sediments, and
F. Abrupt change in dip of reflections.

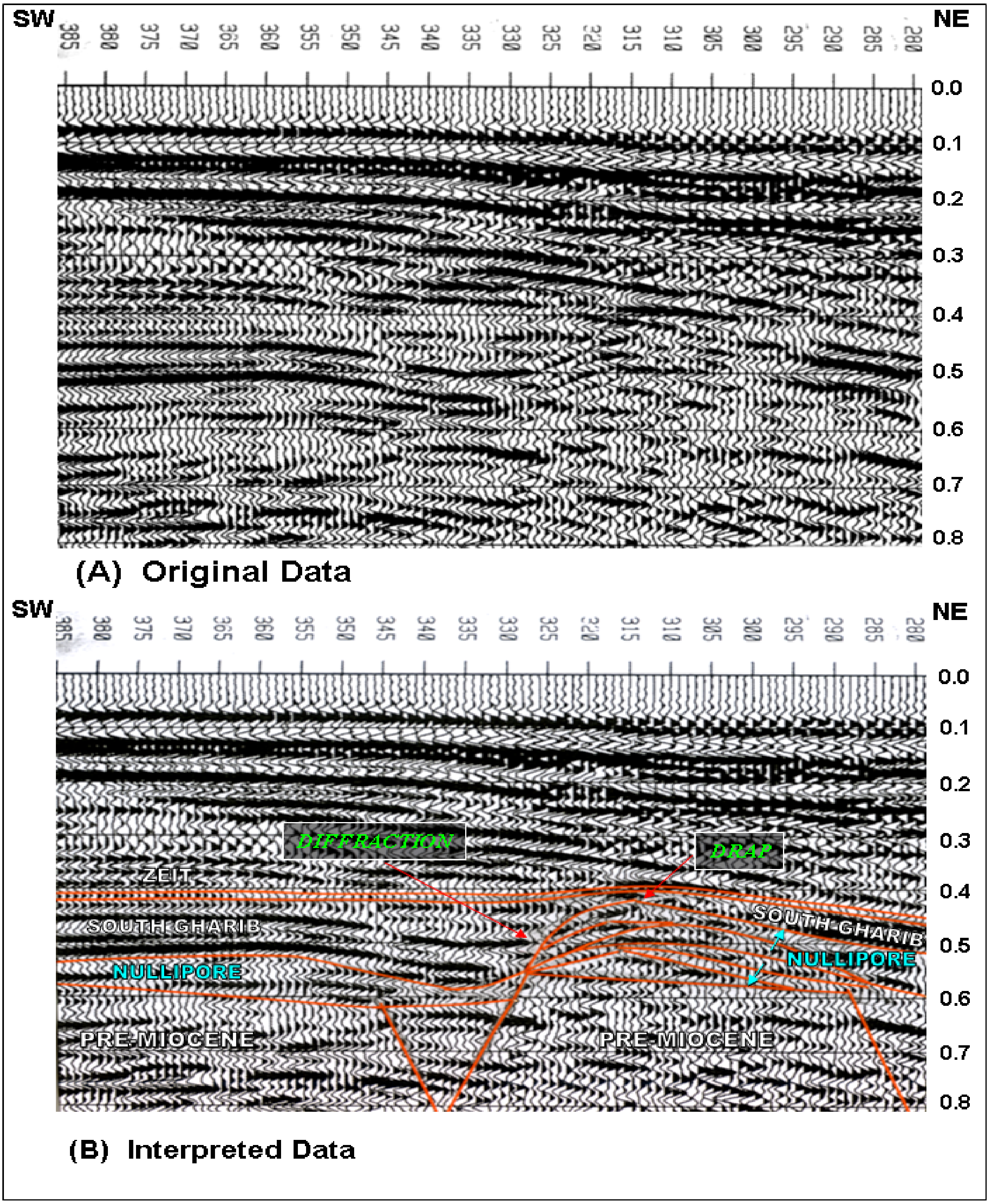

Fig. 10 Original Data and its interpretation of Line - c

CONCLUSION

Seismic recognition and interpretation of the reef buildup reservoir of the Belayim Formation (Nullipore), in Ras Fanar Oil Field are important because of variations in reservoir seismic characteristics of strata within and associated with the buildup. The seismic characteristics of these carbonate buildups were studied through the integration of both surface seismic data as well as the bore hole geophysical and geological data. Tying of synthetic seismograms data with the surface seism data is an important procedure to aid in recognition and interpretation. Modern computer processing also aids in presenting more sophisticated graphic displays of the seismic parameters of the Nullipore reservoir. Well logs correlation can aid in understanding the configuration and distribution of the reef buildups.

From the synthetic seismograms derived from the wells drilled in the field, it can be concluded that the Nullipore character is of low amplitude incoherent events whilst the evaporite equivalent should show reflections of significant amplitude and coherency.

REFERNCES

Bubb, J.N. and Hatlelid, 1977, "Seismic Recognition of Carbonate Buildups.", AAPG, Memoir 26, P.185-204.

El Naggr, A., 1988, "Geology of Ras Gharib, Shoab Gharib and Ras Fanar Oil Fields.", 9th E.G.P.C. Exploration conference, P.203-211.

Sultan, F.; and Moftah, I., 1986, "A Geological, Geophysical and Engineering Approach to Field Development, Ras Fanar Field.", 8th E.G.P.C. Exploration conference, P.173-186.

Vial, P. R.; Mitchum, R. M., and Sangree, J. B., 1977, "Stratigraphic Interpretation of Seismic Reflection Pattern in Depositional Sequences.", AAPG, Memoir 26, P.117-133.