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Analysis of Zero Offset Vertical Seismic Profiling Data Processing To Evaluate the Oil and Gas Reservoir in Well “X”, Murzuk Basin, Soutwest Libya

Abdel Razak Saad Mohamed[1], Adi Susilo[2], Sukir Maryanto[2]
[1,2,2](Geophysics, Faculty of sciences, Brawijaya University, Malang, East Java, Indonesia)

Abstract:- The Murzuq Basin, SW Libya, is one of the high potential area of oil and gas on the North African Saharan Platform. The Mamuniyat Formation in Well “X” of Murzuq Basin is the primary reservoir target in our study. The present study in Well “X” is base on well log data and Zero Offset Vertical Seismic Profiling (ZVSP). This research focuses in ZVSP data processing. The processing of ZVSP includes wavefield separation and corridor stacking. The wavefield separation is done by using a frequency-wave number (F-K filter) and Median filters which intended to isolate the ZVSP data into the upgoing and the downgoing wavefields. Meanwhile, the well logs of interest are: Gamma Ray Log, Acoustic Log, Bulk Density Log, P-wave Velocity Log, and Caliper Log. Base on the ZVSP Data processing and correlation with well log analysis shows that the sandstone at Mamuniyat formation in Well “X”, Murzuq Basin, Soutwest Libya contains significant accumulation of oil and gas. At the top of the Mamuniyat formation there is some crossover between the Gamma Ray, density, P-wave velocity, and Acoustic Impedance, possibly indicating the presence of gas. This crossover is very thin (~ 52 ft). This well also show a much thicker (~148 ft) at the top of the Lower Mamuniyat formation until buttom of Melez Shuqran formation, possibly indicating the saturated with gas, oil, and water. In addition, base on analysis of reservoir connectivity in Mamuniyat formation the sandstone reservoir in Upper, Middle and lower Mamuniyat, and even Melez Shuqran are becoming thicker from SE to NW.

Keywords:- Zero Offset Vertical Seismic Profiling, Mamuniyat Formation, Murzuq Basin, Libya.

I. INTRODUCTION

The Murzuq Basin is located in southwestern Libya (Figure. 1). The acquisition of the Zero Offset Vertical Seismic Profiling (ZVSP) and borehole data was done in Well “X” in Murzuq Basin during the summer 2010 with the purpose to evaluate the oil and gas reservoir at the Mamuniyat Formation. The Murzuq Basin also called the Djado Basin in SW Libya is sub-circular in shape and clearly visible on satellite images. The Murzuq Basin, covers an area of some 350.000 km^2, extending southwards into Niger [1].

In Figure 1, early Palaeozoic tectonism created a series of NNW trending arches and sub-basins across North Africa, filled with siliciclastic continental and shallow-marine deposits. This Early Palaeozoic tectonism effectively controlled the distribution of Upper Ordovician hydrocarbon reservoirs and the distribution of Silurian"Hot Shale" source and seal rocks which onlap early-formed fault blocks in Murzuq Basin [2, 3].

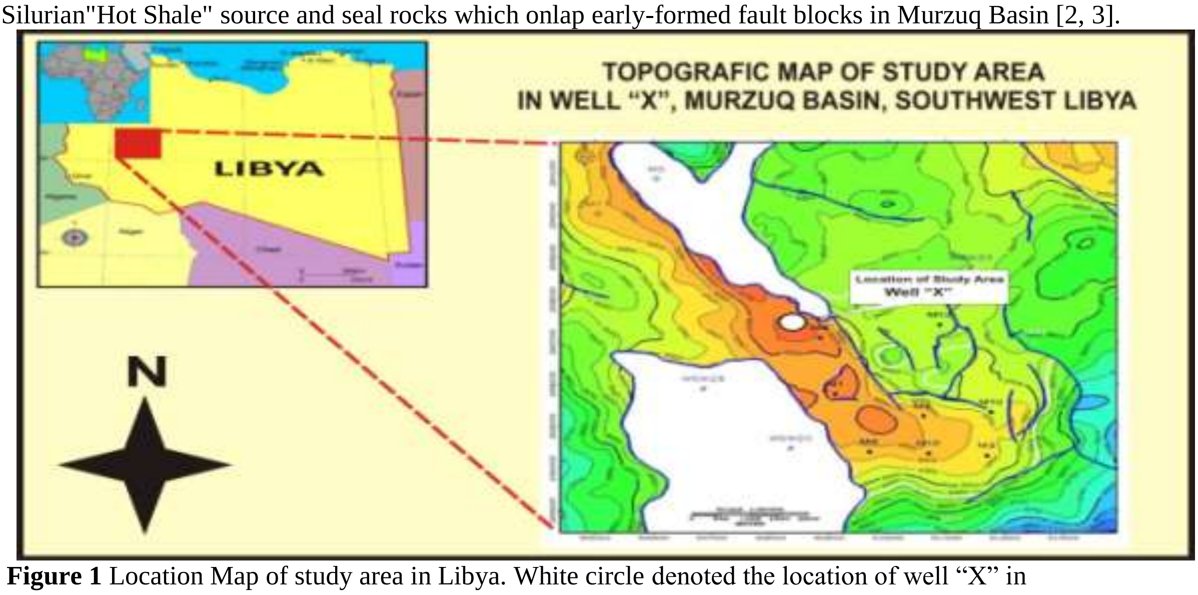

Figure 1 Location Map of study area in Libya. White circle denoted the location of well “X” in Southwestern Libya .

To provide high quality interpretation, we will analysis the Zero Offset Vertical Seismic Profiling (ZVSP) data than joint interpretation with well log data and geological information to evaluate the oil and gas reservoir. A Zero Offset Vertical Seismic

Profiling (ZVSP) is a measurement procedure in which a seismic signal generated at the surface of the earth is recorded by geophones secured at various depths to the wall of drilled well [4, 5, 6, 7]. In contrast to surface seismic, which records only upgoing reflections, VSP is able to record both the upgoing reflections and the downgoing wavefield as they propagate in to the earth [8, 9, 10]. For this reason, VSP are usually used to assist in the interpretation of surface seismic.

II. EOLOGICAL SETTING OF MURZUQ BASIN

Libya is situated on the Mediterranean coast of North Africa, and has an area of about 1,775,500 km^2. Libya has been the site of deposition of vast blankets of continental debris and of several incursions of the sea with consequent accumulations of a wide variety of sedimentary rocks. Figure 2 shows the country is divided into four Palaeozoic and one Mesozoic Basins.

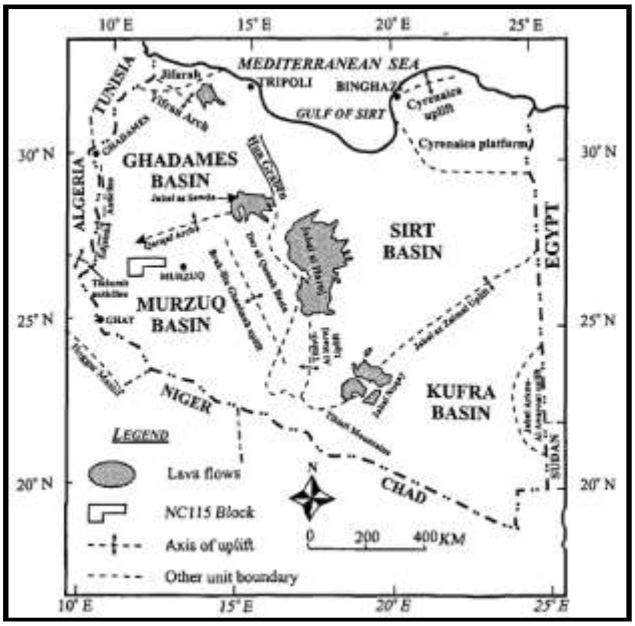

Figure 2. Simplified geology of Murzuq Basin in SW Libya [11, 1].

The Murzuq Basin of SW Libya forms one of a series of Palaeozoic intracratonic sag basins on the Saharan Platform. The structural fabric imparted to the North African continental lithosphere during the late Proterozoic, Pan-African event has played an important role in controlling the subsequent structural and stratigraphic evolution of the basin [12, 13, 14]. The structure of the Murzuq Basin is quite simple. The subhorizontal or gently dipping strata is faulted and the faults are most frequently parallel to the axis. Tectonic movements affected the basin to a greater or lesser degree from early Palaeozoic (Caledonian) to Post-Eocene (Alpine) times [12, 2, 15]. Uplift of the northern flank of the basin, the east trending Qarqaf Arch, was initiated during "Hercynian" epeirogenesis, which promoted trap formation through localised transpressional fault reactivation of subsurface fault systems.

III. OBSERVATION

The goals of Zero Offset VSP data processing is to create a final trace, often called a corridor stack, that can be directly compared a surface seismic profile. This created trace can be used as a way to calibrate the surfaceseismic section by identifying the depth at which reflection are produced on the VSP data and relating them to two way travel time events on surface seismic record. Note that VSP data show events in one way traveltime and surface seismic is in two way traveltime, if VSP data is to be processed it must be shifted to two way traveltime .

Processing of Zero Offset VSP is usually simpler than processing of offset VSP data. Offset VSP data includes p-s wave modes, geometry, and migration among other complications. Zero Offset VSP involve only the passage of two wavefield traveling in opposit directions. In this section the two main process applied to this data are applied: wavefield separation and corridor stacking but the firs steps are we must reformatting and increasing gain recovery of VSP data.

1- Wavefield Separation

The VSP data are useful because one is able to time-to-depth tie two wavefield: the downgoing pulse traveling into the earth and the upgoing reflections to the surface coming from acoustic impedance contrasts. Depend on the scop of a particular study, one needs analyse only one of these. For example, the upgoing wavefield (or reflections) can be used to build corridor stacks that allow recognition of the depth at which reflections are being produced.

Conversely, the downgoing wavefield can be used to provide an indicator of the source wavelet. This information is useful in deconvolution procedures to increase the vertical resolution of surface seismic profiles [8].

2- Corridor Stacking of VSP Data

A corridor stack is a summation of portions of the traces in an upgoing vertical seismic profile that have been shifted to their two way arrival time at the surface [8, 7].The corridor stack trace can be obtained to identify primary and multiple events. The fact inside outside corridor stack are in two way travel time and represent a zero offset track makes them suitable to be used with surface seismic to tie depths with travel times. They can also be used identify multiples in surface seismic so that they can be removed during early processing.

IV. RESULT AND DISCUSSIONS

1- Total Wave field

The data were then checked for quality control to make sure that all the traces were present, and the amplitude was enhanced by applying automatic gain control (AGC). Compensation for amplitude decay due to spherical divergence was then applied using an exponential gain function of T**2 where T is the recorded time. The data were formatted before display as each system requires its own format to display the data in that particular format. Figure 4.2 show the VSP data before gain recovery and Figure 4.3 show the VSP data after gain recovery at 3 component and display of the selected shots with the observed events marked with different arrows.

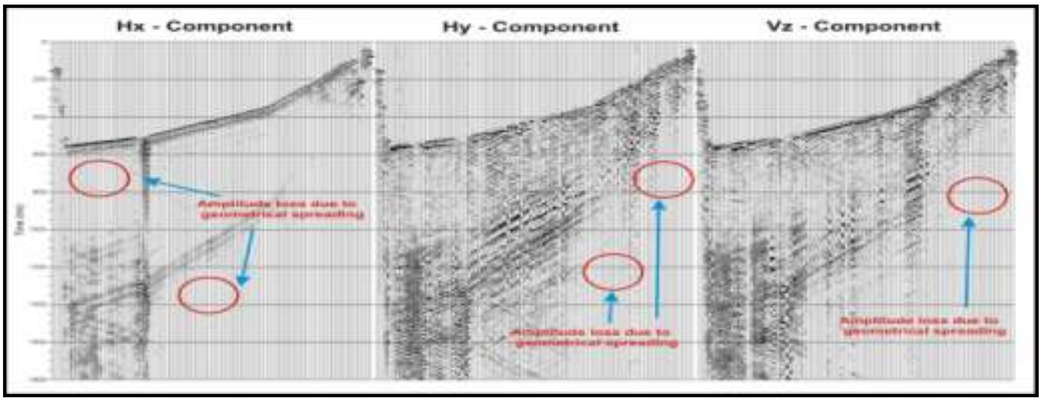

Figure 3. Display the seismic raw data in 3-component before gain recovery for each of th VSP survey with total depth up to 1800 micro second in “X” Field in study area. Shows the traces seismic at Horizontal component (Hx and Hy) and Vertical component (Vz).

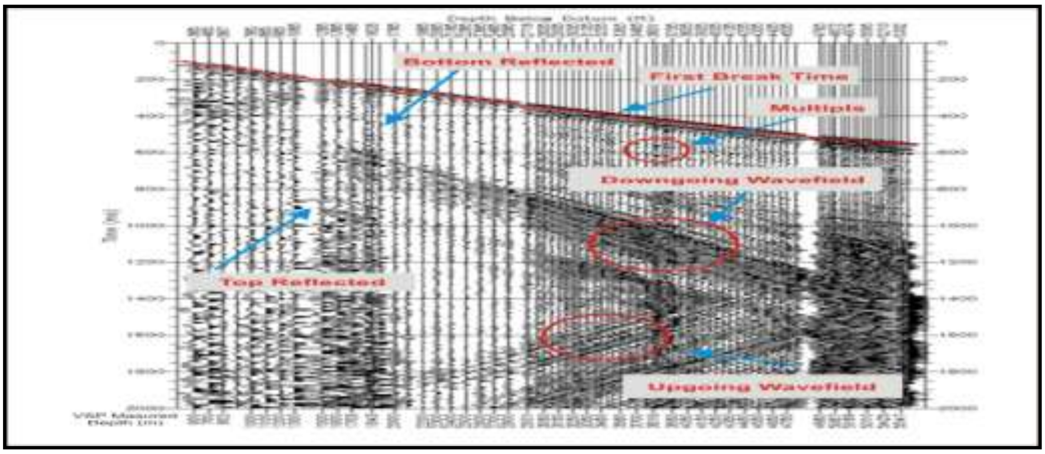

Figure 4. Display the total wavefield seismic raw data after near-trace gather stack in 3-component and applied gain amplitude recovery.

These events are:
1. The amplitude attenuation at larger travel times due to spherical spreading, transmission losses and internal friction (figure 3).
2. Different types of arrivals such as first break time marked by red line (figure 4),
3. Different types of reflected events, downgoing wavefield, and upgoing wavefield marked by blue arrow (figure 4)

Different types of noise e.g. multiples, marked by red circles (figure 4).

2- F-K filter

We continued improving the quality of upgoing P-wave energy by passing the data through F-K analysis, removing the residual energy by F-K filter. In general, the F-K filtering method is used to isolate downgoing (by first aligning them, applying a median filter and shifting back), and then subtracting the separated downgoing wavefield from the total wave field to get the upgoing wavefield. The common f-k transform technique implicitly models the input data as a sum of a number of plane waves and transforms the VSP data into the f-k domain. In this domain the downgoing events reside in the positive wave number quadrant and the upgoing events in the negative quadrant. The upgoing wavefield is separated by operating on the positive quadrant events. A window (-5 – 5 cycles/KF) was used to attenuate the residual tube waves and aliased energy. Figure 5 shows the upgoing P-wave energy after F-K filtering.

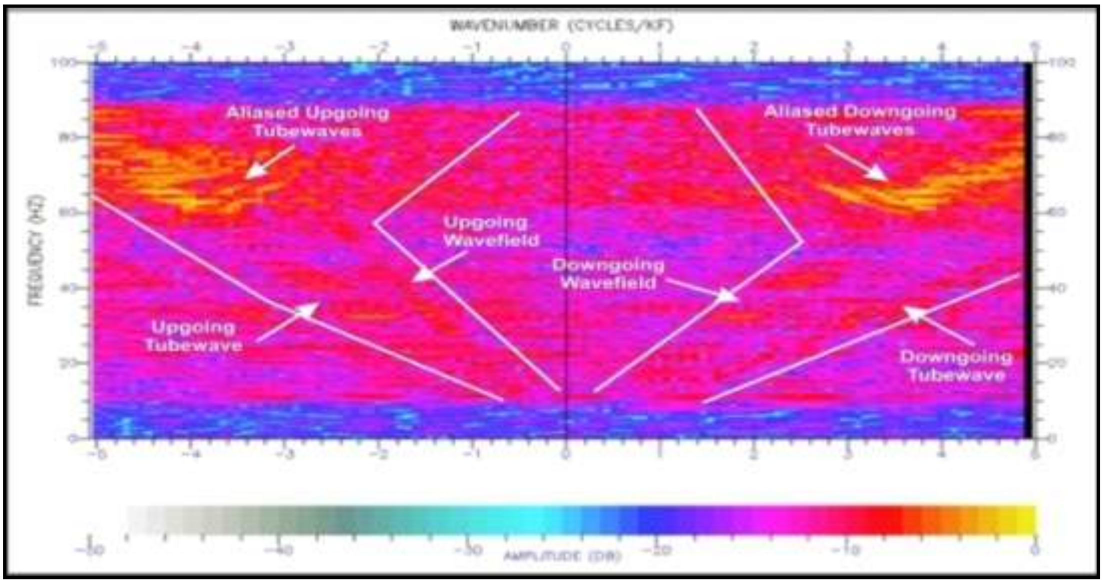

Figure 5. F-K Display of the total wavefield.

In Figure 5, shows the total wavefield after f-k filtered with a dip reject of +/- 4 ms/trace (Fig. 7). The glitches are not removed and remain as the time domain operator of the f-k filter. The higher frequency, 16 ms/trace aliased dip appears as a negative dip 60 to 80 Hz event (yellow closure) and the lower frequency (0-10 Hz) ground roll is not completely removed. The primary events are virtually identical to the input shot gather. Random noise, band limited to 15-90 Hz, is added with an RMS magnitude 1/3 that of the primary events. Random noise is reduced only by the smear of the time domain operator and still remains within the pass band of the spatial filter. Random noise is not smeared as can be seen in the absolute rejection of the large amplitude noise glitches.

3- Downgoing and Upgoing Wavefiel

VSP wavefields consist of a superposition of the downward and upward travelling (or simply downgoing and upgoing) wave trains, and all the unwanted signals we call noise. Both the downgoing and upgoing wavetrains are useful, but need to be separated before they can be studied and utilized. Different methods have been used for VSP wavefield separation. The most commonly used methods in production runs so far have been median F-K filtering. Figure 6 and Figure 7 shows the aligned Downgoing and Upgoing VSP wavefields respectively after separation using the median f-k filter methods on a zero phase 7(18) - 90 (36) Hz (dB/oct) bandpass filter. The direct arrivals of the total wavefield data were aligned at 200 *msec.*

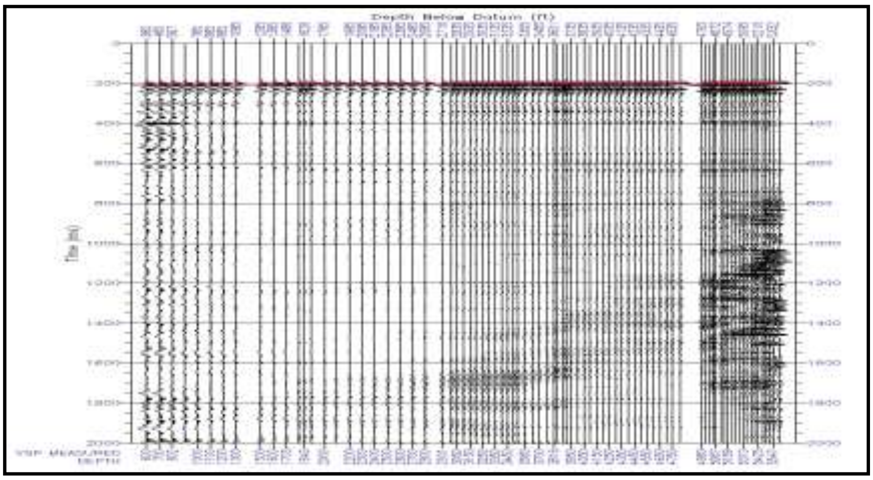

Figure 6. Downgoing wavefield of VSP data after separation using the median *f-k* filter methods aligned at 200 ms.

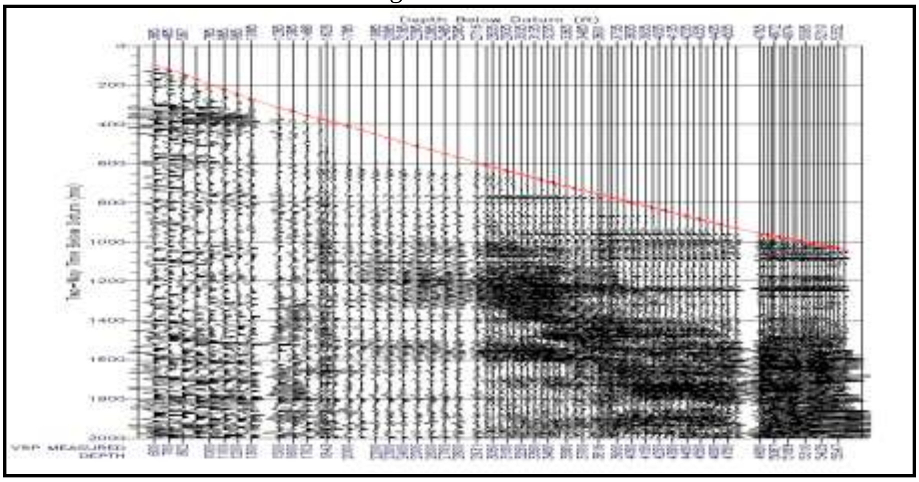

Figure 7. Upgoing wavefield of VSP data after separation using the f-k filter methods aligned at Two-Way Time. Red line shows the first break time.

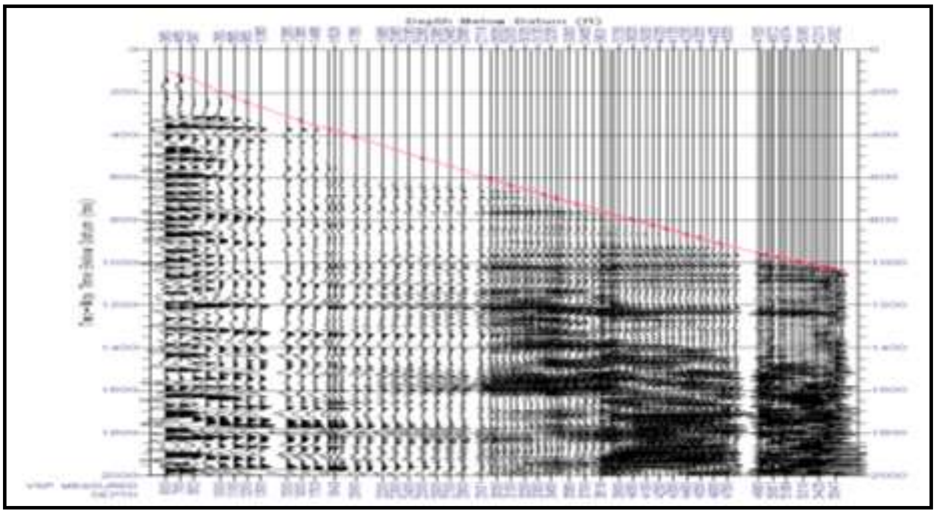

Figure 8. Enhanced Deconvolved Upgoing wavefield of VSP data aligned at Two-Way Time at study area. Red line shows the first break time.

Additional, Figure 8 shows the Upgoing VSP wavefield after Deconvolution. A 1200 msec operator derived from the upwaves was applied to the upgoing wavefield, followed by a zero phase 7(18) - 90(36) Hz(dB/oct) bandpass filter.

4- Corridor Mute & Corridor Stack

Figure 9 illustrate corridor mute and corridor stack. A corridor stacks was produced by stacking the whole data within the Enhanced Deconvolved Upgoing Wavefield (Figure 10). A 7(18) - 90(36) Hz(dB/Oct) Zero phase bandpass was then applied. This trace was then duplicated 16 times in order to produce the corridor stack.

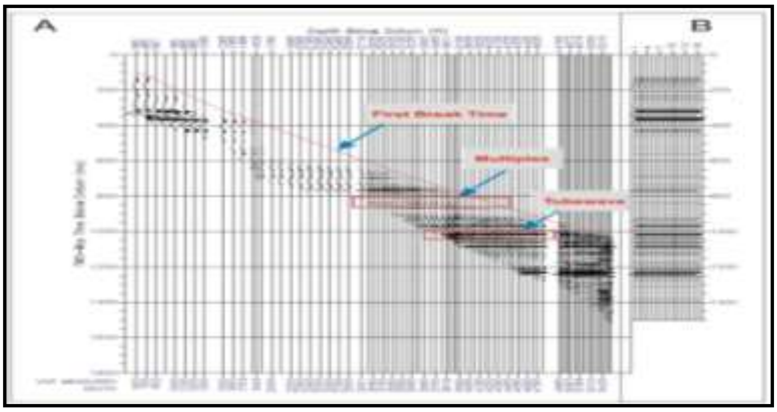

Figure 9. Corridor Mute and Corridor Stack of VSP data at study area.

In Figure 9, panel A shows the corridor mute and Panel B shows the corridor stack. In Panel A, a 50 ms pass window from the first break time was applied to isolate the outside corridor. The resultant stacked traces are shown in Panel B. This inside corridor corresponds to the data muted and contains both primary reflections and multiples. The corridor panels for both data sets essentially are the same ovr the depth of intrest (from surface to 160 m or channel 60) this means that no strong multiples are present in the data. The event denoted by "w"in the panel may represent a weak multiple from the regional unconformity at 200 ms. For later times below the area of intrest no conclusion can be drawn about the presence of multiples because the events do not intercept the first break pulse.

The VSP corridor stack (zero phase 60Hz) reverse normal polarity was spliced into seismic line IN-LINE 332 with no shift.

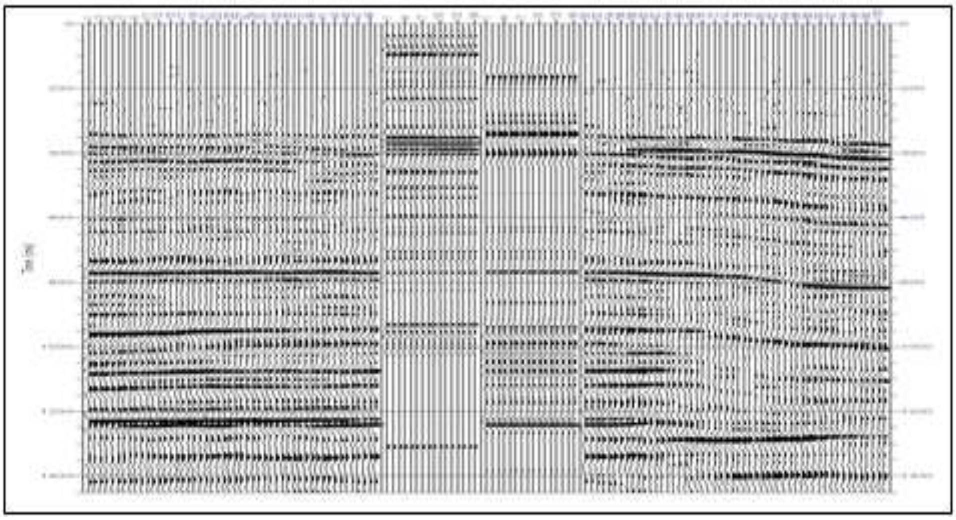

Figure 10. Corridor Stack and syntetic seismogram spliced into surface seismic of VSP data at study area.

5 -Interpretation

The most commonly used data in reservoir description are well data and seismic data. Well data such as logs typically provide sufficient vertical resolution but leave a large space between the wells. On the other hand, the seismic data can provide more detailed reservoir characterization between wells. However, vertical resolution of seismic data is poor compared to that of well data. For this reason we decided to use vertical seismic profiling data and combine well logs data to produce a better reservoir evaluation (Figures 11 and 12).

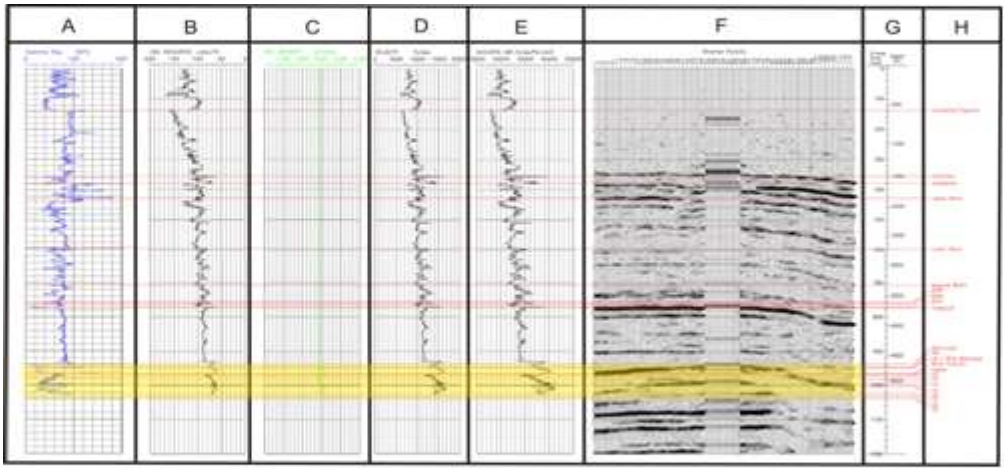

Figure 11 and Figure 12 show the Correlation between Well Logs and VSP data in study area. At depth 4872 ft below the surface, there is a sharp decrease in Gamma Ray curve at the top of the Mamuniyat formation, indicating that sandstone is the dominant lithology. The Density log is around 2.4-2.5 G/cm^3 for most of the Mamuniyat section, indicating clean and permeable zones. In order to make the porosity interpretation in the 30 ft drilled at Top Mamuniyat behind the casing, a synthetic sonic log has been created for the uppermost interval from 4875 to 4902 ft MD.

Figure 11. Correlation between Well Logs and VSP data in study area. A-E: Well Log Data (A: Gamma Ray Log; B: Acoustic Log; C: Density Log; D: P-wave Velocity Log; E: Acoustic Impedance Log); F: VSP Corridor Stack (60 Hz) spliced into surface seismic with reverse normal polarity was spliced into seismic line IN-LINE 332 with no shift; G: Two-Way Time (ms) and Depth (ft); H: Formation Layers. The Yellow highlight show the formation target at Mamuniyat formation.

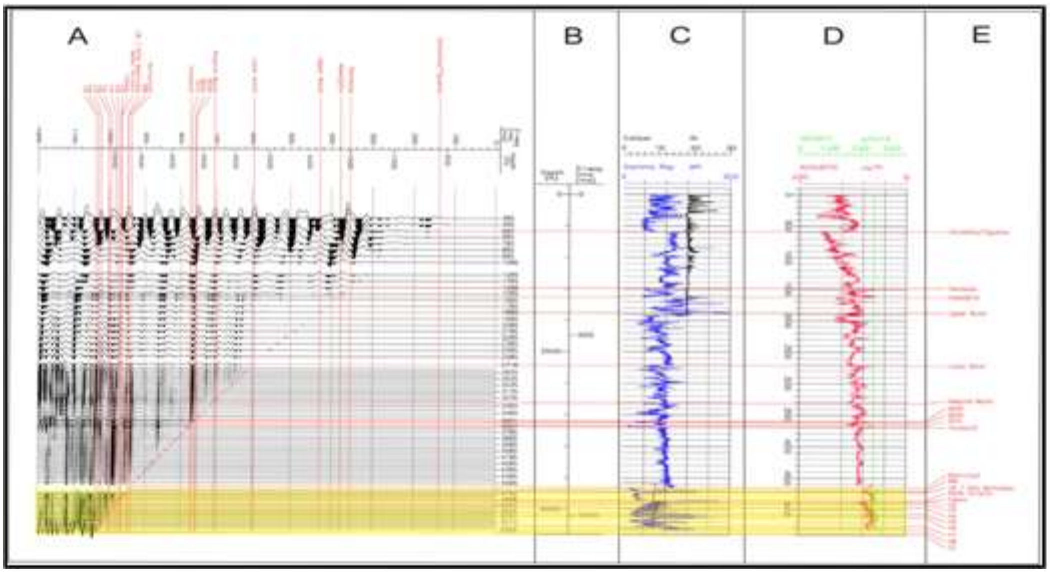

Figure 12. Correlation between Well Logs and VSP data at study area. A: Enhanced Deconvolved Upgoing wavefield of VSP data; B: Two-Way Time (ms) and Depth (ft); C: Caliper Log (Black) and Gamma Ray Log (Blue); D: Density Log (Green) and Acoustic Log (Red); E: Formation Layers. The Yellow highlight show the formation target at Mamuniyat formation.

The Mamuniyat formation is 200 ft thick (as expected from seismic interpretation) with a Net Reservoir of 170 ft, with an average porosity of 11.2% and Vcl of 4.7%. The Net Pay thickness is 165 ft, with an average porosity of 11%, water saturation of 34.6% and Volume of Clay of 4.9%. In the prognosis, based on 3D geological model the properties expected for Well "X" were NTG 75 % (actual 82%), porosity ranged between 10% and 12% (actual), and water saturation ranged between 27-32% (actual 34.6%). More detail about Petrophysical information at Mamuniyat formation show in Table 1, Figure 13, and Figure 14.

Zone/Interval Data	Top Depth (ft) in TVD	Bottom Depth (ft) in TVD	Gross Thick (ft)	Net Reservoir			Net Pay			
				Thick (ft)	Avg Poro	Avg Vcl	Thick (ft)	Avg Poro	Avg Sw	Avg Vcl
Mamuniyat	4872	5073	201	-	-	-	-	-	-	-
Mamuniyat Open Hole	4902	5073	171	156.25	0.116	0.036	152.25	0.116	0.237	0.036
Melez Shuqran	5073	5087	14	0.00	-	-	0.00	-	-	-
H2	5087	5128	41	8.50	0.133	0.238	0.00	-	-	-
H3	5128	5189	61	40.00	0.123	0.171	0.00	-	-	-
H4	5189	5282	93	69.00	0.110	0.105	0.00	-	-	-
H5	5282	5336	54	6.25	0.083	0.048	0.00	-	-	-
H6	5336	5485	149	55.25	0.098	0.127	0.00	-	-	-
H7	5485	5547	62	1.00	0.081	0.236	0.00	-	-	-
H8	5547	5600	53	0.00	-	-	0.00	-	-	-
Total and Average over all Zones			513	180.00	0.109	0.131	0.00	-	-	-

Table 1 Petrophysical information at Mamuniyat formation in study area.

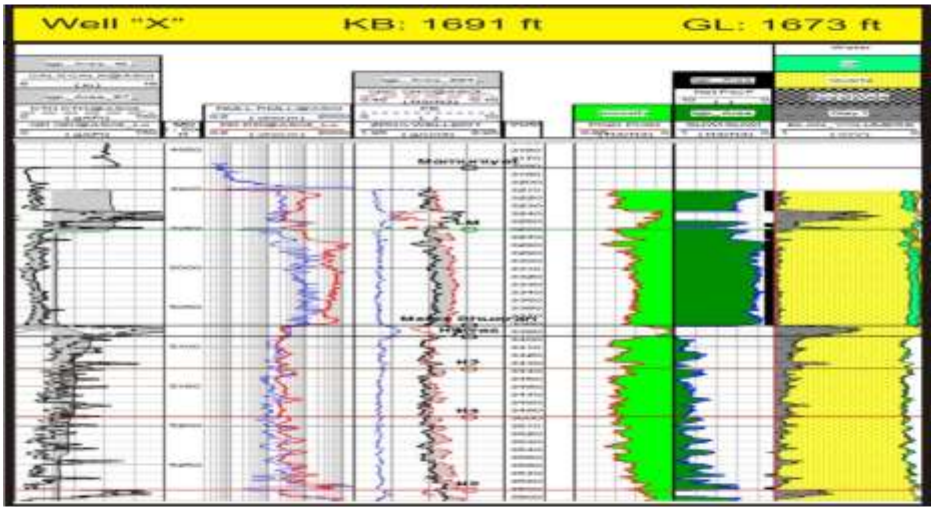

Figure 13. Petrophysical Chart at Mamuniyat Formation (4840 ft – 5290 ft MD) in study area.

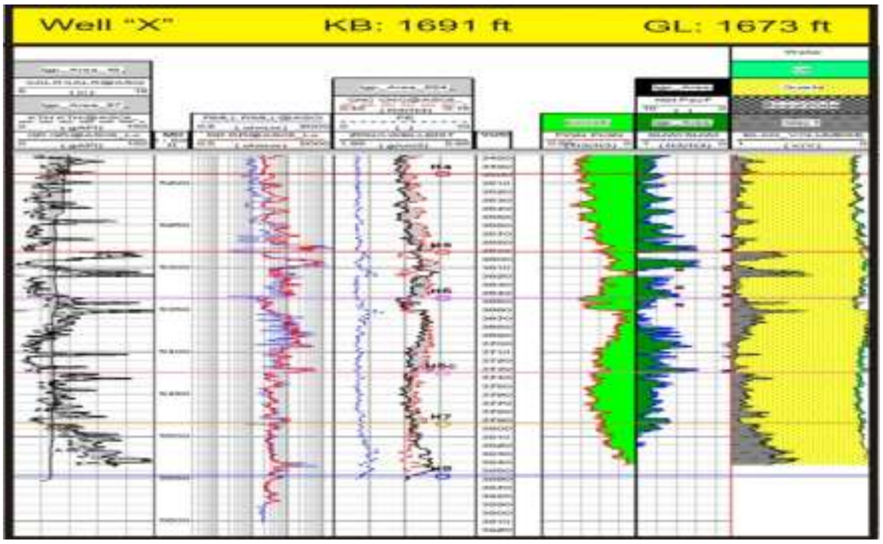

Figure 16 Petrophysical Chart at Mamuniyat Formation (5180 ft – 5580 ft MD) in study area.

At the top of the Mamuniyat formation there is some crossover between the Gamma Ray, density, P-wave velocity, and Acoustic Impedance, possibly indicating the presence of gas. This crossover is very thin (~ 52 ft). This well also show a much thicker (~148 ft) at the top of the Lower Mamuniyat formation until buttom of Melez Shuqran formation, possibly indicating the saturated with gas, oil, and water. The contacts between these fluids were interpreted based on the density cross-over, porosity, acoustic log curve (gas/oil/water), core data analysis.

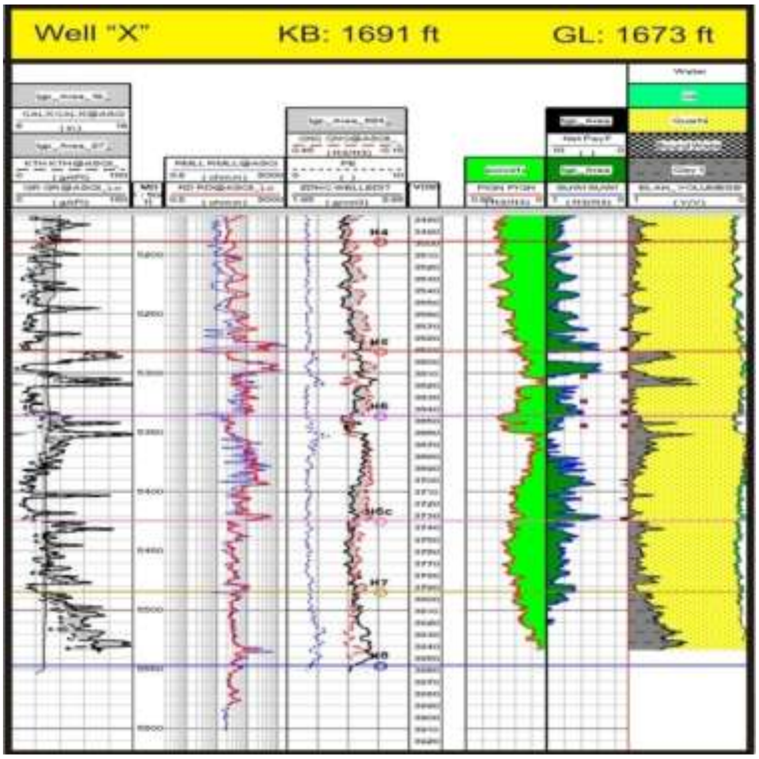

Figure 14. Petrophysical Chart at Mamuniyat Formation (5180 ft – 5580 ft MD) in study area.

nother interesting effect is seen at the top of Hawaz formation, where there is a sharp increase Gamma Ray curve and decrease of velocity, probably due to the lithologic change between sand and shale. This crossover is very thin then the increasing of depth the Gamma Ray curve decrease and following by the increasing of P-wave velocity curve, possibly properties net reservoir. Although Hawaz shows fair properties as a net reservoir, it doesn't produce oil because H4-H6 are in water. Well Oil Down is at -3382 ftSS (5073 ftMD) and field Oil Water Contact was at -3478 ftSS. The effective reservoir properties were obtained by applying the following cut off values:

1. Porosity min. 6 % (for Mamuniyat) - 8 % (for Hawaz)
2. Sw max. 60 %
3. Vclay max. 25 %

To improved structural configuration analysis within the reservoir connectivity in Mamuniyat Formation, we correlate the wireline log curves in Well "X" with two well near the well "X". The most useful wireline log curves to analysis reservoir connectivity in the Upper Ordovician succession of the Mamuniyat Formation is the gamma-ray log.

Figure 15 show a suite of wireline logs from three different wells A, X, and B that have been used to select the different lithologies in the Mamuniyat succession. For example, the gamma-ray log clearly identified and distinguished between Upper, Middle and Lower sections of the Mamuniyat Formation from Northwest to Soutwest of the Murzuq Basi.

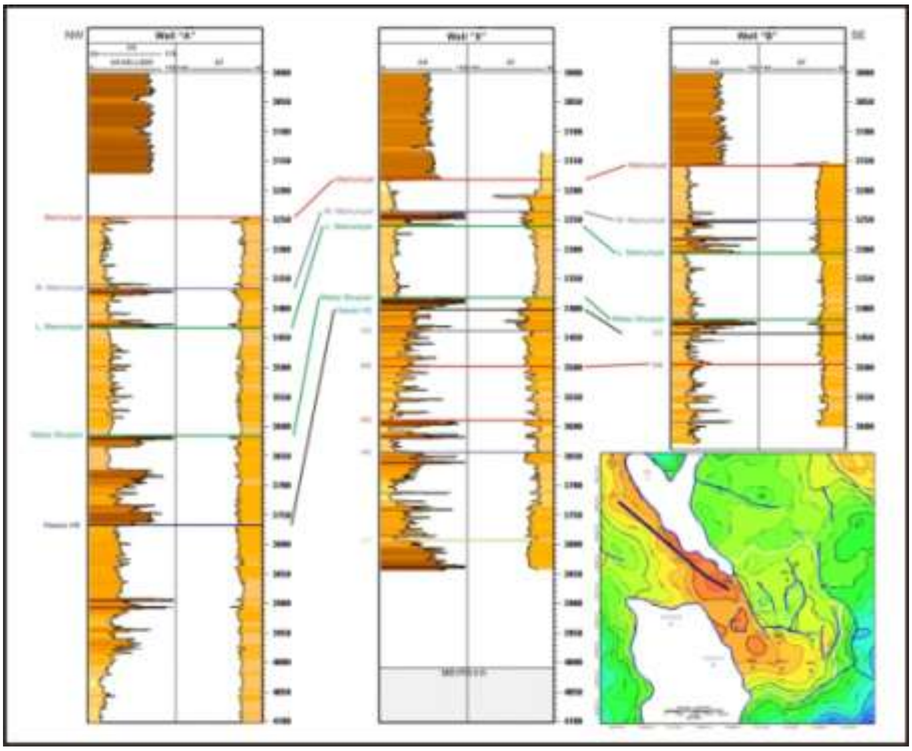

Figure 15. Suite of wireline logs from three different wells. From left to right: Well A, Well X, and Well B that have been used to select the different lithologies in the Mamuniyat succession from SE-NW.

Gamma-ray log shapes may be use to determined sandstone grain-size, depositional environment facies and the deposition between sands and shales in mixed siliciclastic sequences. Several principal gamma-ray log shapes are frequently used as a basis for identifying depositional facies, especially sandstone. In Figure 15, the sandstone reservoir in Upper, Middle and lower Mamuniyat, and even Melez Shuqran are present in Well “X”, and are becoming thicker towards Well ”A”.

Additional, Since the gamma-ray log is frequently an indicator of clay (shale) content, gamma-ray log shapes can be explained in term of variations in clay (shale) content. A bell shaped log, where the gamma-ray value increases regularly upwards from a minimum value, should indicate increasing clay content: a funnel shape, with the log value decreasing regularly upwards, should show the reverse, a decrease in clay content.

V. CONCLUSIONS

It has been demonstrated that with well processed and calibrated Zerro Offset Vertical Seismic Profiling (ZVSP) and well data, it is possible to achieve a high correlation between well data and seismic data; even when the two are measured at quite different scales. Many of the factors that cause noise for VSP data and it has been remove by filtering processing procedures.

Finally, base on the ZVSP Data correlation with well log analysis and geological information shows that the sandstone at Mamuniyat formation in Well “X”, Murzuq Basin, Soutwest Libya contains significant accumulation of oil and gas. At the top of the Mamuniyat formation there is some crossover between the Gamma Ray, density, P-wave velocity, and Acoustic Impedance, possibly indicating the presence of gas. This crossover is very thin (~ 52 ft). This well also show a much thicker (~148 ft) at the top of the Lower Mamuniyat formation until buttom of Melez Shuqran formation, possibly indicating the saturated with gas, oil, and water. However, No oil reservoir was found in the Hawaz formation although Hawaz shows fair properties as a net reservoir, it doesn’t produce oil because H4-H6 are in water. In addition, base on analysis of reservoir connectivity in Mamuniyat formation the sandstone reservoir in Upper, Middle and lower Mamuniyat, and even Melez Shuqran are becoming thicker from SE to NW.

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