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Enhancement of Seismic reflectors by using VSP and Seismic Inversion in Sindbad oil field, south of Iraq

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Abstract

The purpose of this research is to enhance the methods of surface seismic data processing and interpretation operations by using the produced information of vertical seismic profile (measured velocity and corridor stack). Sindbad oil field (South of Iraq) is chosen to study goals and it's containing only one well with VSP survey (Snd2) that covering depth from Zubair to Sulaiy Formations and 2D seismic lines of Basrah Survey. The horizons were picked and used with low frequency contents from well data for the construction of low frequency model and it was used with high frequency of VSP to make the high frequency model that compensated to seismic main frequency through inversion process. Seismic inversion technique is performed on post stack of 2D seismic data (2Br2) through Hampson-Russell CGG program. The inversion model of low frequency shows 88.5% matching with relative seismic impedance while high frequency model 93.3% matching with lower error percent. The two impedance sections which resulted from inversion model were convoluted with best wavelet from VSP data to make a new seismic section. The LFM section was similar to original seismic section while the HFM section shows real enhancement of the Flatspot (DHI) feature and recoverable some missing reflectors.

Keywords: Seismic data processing, VSP, Seismic Inversion, Sindbad oilfield.

تحسين العواكس الزلزالية بأستخدام تقنية المسح الزلزالي العمودي والمعكوس الزلزالي في حقل السندباد النفطي جنوب العراق

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قسم علم الأرض، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

الغرض من هذا البحث هو تحسين أساليب عمليات معالجة البيانات الزلزالية السطحية وعمليات التفسير باستخدام المعلومات التي تنتج عن المسح الزلزالي العمودي (السرع و الاثار الزلزاليه). لقد تم اختيار حقل سندباد النفطي (جنوبي العراق) لتلبيه الأهداف والحقل يحتوي على مسح زلزالي عمودي في بئر سندباد-٢ والذي يغطي الفترة العمقيه من تكوين الزبير إلى تكوين السلي وكذلك الحقل يتوفر فيه الخطوط الزلزالية الثنائيه الابعاد التابعه لمسح البصرة. استخدمت اعالي التكاوين مع المحتوى الترددي الواطئة من بيانات المجسات لبناء تطبيق المعكوس الزلزالي ذات الترددات الواطئة وكذلك أستخدمت الترددات العالي من الاثر الزلزالي المسجل للحصول على نموذج المعكوس الزلزالي ذات الترددات العالية والتي تعوض عن التردد الرئيسي الزلزالي المفقودة. تم تنفيذ تقنية الانعكاس الزلزالي على البيانات النضديه للخط (2Br٢) في برنامج هامبسون راسل. يظهر نموذج انعكاس التردد الواطئة نسبه ٨٨.٥٪ مطابقة مع الممانعة الصوتيه النسبية للخط

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في حين كانت نسبه نموذج التردد العالي ٩٣.٣٪ مع انخفاض الخطأ فيها بشكل واضح.تم اجراء عمليه تداخل موجي بين افضل مويجة مستخلصه من المسح الزالزلي العمودي مع مقاطع الممانعة الصوتيه الناتجة من عمليه المعكوس الزالزالي للحصول على مقاطع زالزاليه مضاف اليها محتوى ترددي جديد. لم يظهر المقطع الزالزالي المضاف اليه الترددات الواطئة اي اختلاف عن المقطع الاصلي بينما اظهر المقطع ذات الترددات العاليه تحسن ملحوظ في الدلائل الهيدروكاربونيه المباشرة (البقع المسطحة) وكذلك أستعادت بعض العواكس المفقودة في المقطع الاصلي.

Introduction

Seismic surveys can be divided into two main categories that are: surface seismic surveys and borehole seismic surveys [1]. Seismic observations in deep boreholes involve some specific requirements of technical and theoretical types, while in surface observations; the sensitivity is usually restricted by the seismic noise level in the region of the recording point [2]. VSP surveying is a vital tool in subsurface imaging and reservoir characterization. The technique has made significant advances since the 1930s, when geophysicists lowered the first geophone down a borehole to better investigate rock velocity [3]. VSPs allow geophysicists to infer-critical information that cannot be obtained otherwise. With VSPs, geophysicists can record waves traveling both down into the earth (direct and downgoing multiples) and back toward the surface (primaries and upgoing multiples). They add the depth dimension to seismic data, which enables several approaches to velocity estimation and deconvolution [4,5]. Acquisition, processing and interpretation of vertical seismic profile (VSP) data are essential in hydrocarbon exploration because of the important application of VSP in hydrocarbon exploration which is supporting and clarifying the interpretations of the subsurface geology made from surface-recorded seismic data [6]. Borehole seismic measurements have also overcome difficulties faced by both seismic processers and interpreters. They provide direct access to the measurement of attenuation (Q), estimation of geometric divergence, identification of multiples, correction of well data and their integration with seismic data and the phase analysis of seismic data [7]. The inversion defined as an attempt to predict rock properties (porosity, thickness, fluid content, hydrocarbon saturation, etc.) from seismic data [8,9] Other definition of seismic inversion is presented by [10] as the technique for creating sub-surface geological model using the seismic data as input and well data as controls. In 2010 seismic inversion defined as the process of converting seismic reflectivity data to rock property information ranging from Acoustic Impedance (A.I.) to petrophysical properties such as porosity, volume of shale, and water saturation [11]. Seismic inversion is easier to interpret the data in geological terms, because it focuses attention on layers and lateral variations within them, rather than on the properties of the interfaces between layers that cause the seismic reflections [12,13]. The objective of the current paper is to perform inversion over 2D seismic line with VSP impedance to get a new seismic section of higher resolution than original one, through utilizing Hampson-Russell CGG program.

Location of the Area and Data Source

Sindbad oil field is located in Basra city-southeast of Iraq, adjacent to Iraq- Iran border and approximately 16km southwest to center of Basra city as shown in Figure-1. The area has two wells (snd1, snd2). Only (snd2) has VSP data and it will be correlated with log data to seismic line named (2br2). The (snd2) well is drilled to Yamama Formation (Lower Cretaceous) and one type of VSP data (zero offset) is recorded from 3090m to end depth of the well (4376m).

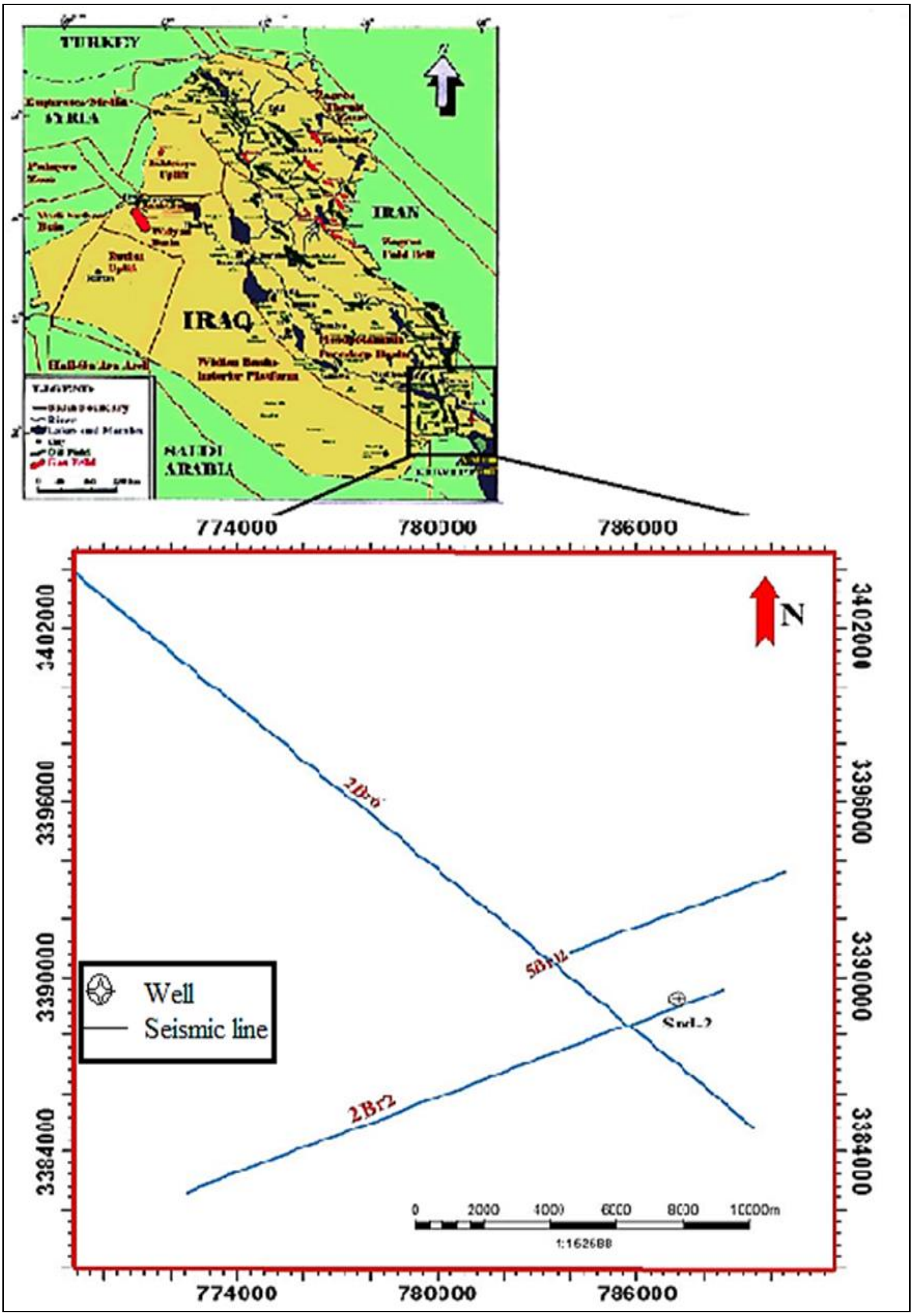

Figure 1- Location map of Sindbad oil field and seismic lines

Methodology

The seismic data, the most common occurrence with absence of low-frequency content which is lost during acquisition and processing of seismic [14], Therefore in seismic inversion process, the low frequency content must be compensated by building 3D geologic model of acoustic impedance (AI) from well logs to obtain absolute rather than relative (band-limited) inverted property values [15]

[16].The same theory could be used on the high frequency band limit in seismic data, which encourage us to try the high frequency model based on VSP impedance in this research as shown in workflow below Figure-2.

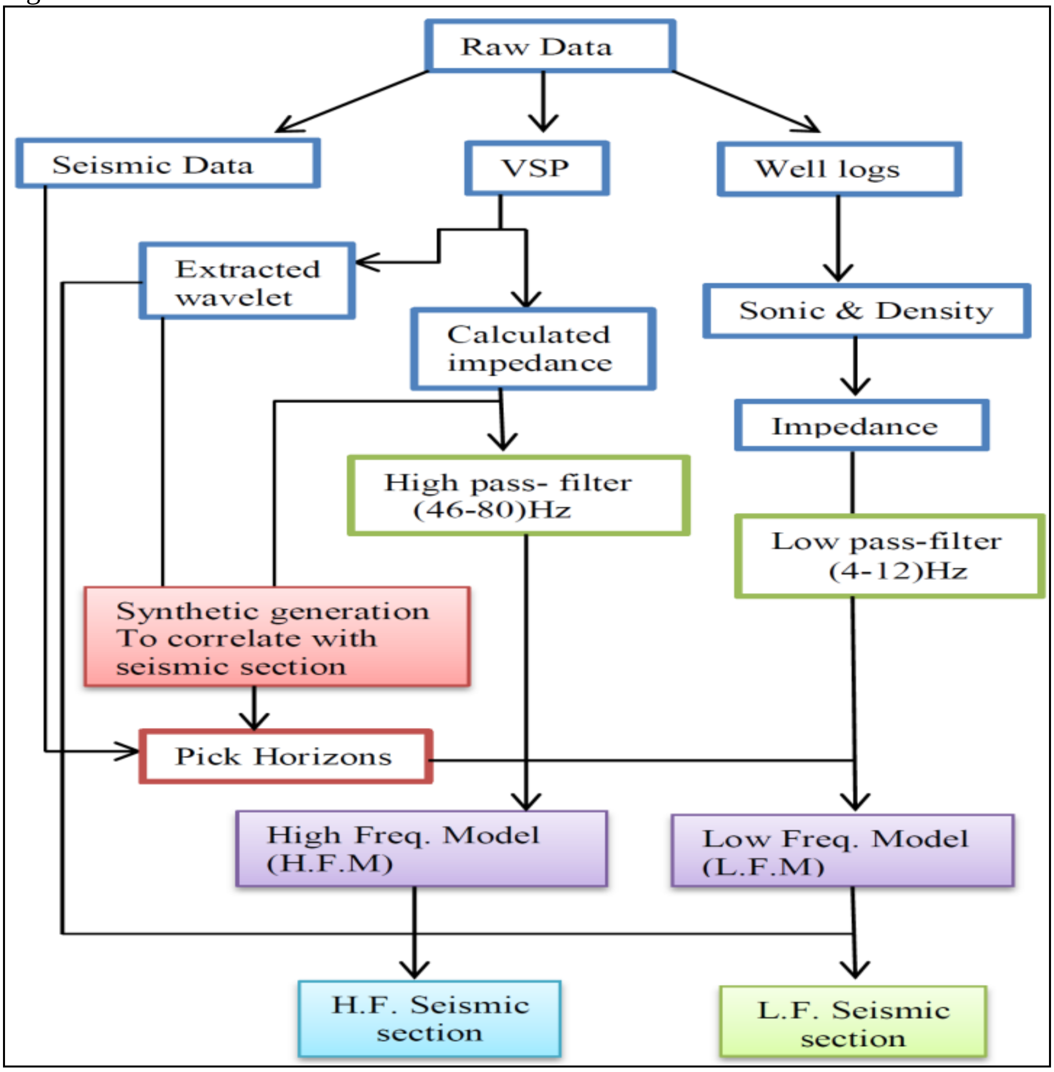

Figure 2- Shows the workflow of the inversion method.

The two models limited by the interpreted horizons, which have been corrected to tie the seismic, and this represents the time window limit for the models Figure-3. The initial low frequency model in this study was built from high-cut frequency filtered impedance logs for Snd-2 well and the four seismic horizons, the top and bottom are the upper and lower boundaries of the model window, while high frequency model builds from VSP corridor stack and the same horizons. The low frequency component of the reflectivity should be recovered and this done simply by extracting this component from well log data and add it back to the seismic. The inversion start with a low frequency model of the P-impedance and then training (testing) this model until obtains a good fit between the seismic data and synthetic trace and the same procedure applied to high frequency model (HFM) until matching.

Inversion analysis

The low frequency range between (4 -12 Hz) is compensated in building the initial model depending on the extracted amplitude spectrum from the 2Br2 seismic line and is shown in analysis window as in Figure-4. The high frequency ranges between (46-80 Hz) which is compensated in (HFM), it's depending on the impedance that extracted relatively from VSP corridor stack of Snd-2 well. The high frequency model built from VSP impedance and guided by horizons through the study area is shown in Figure-5.

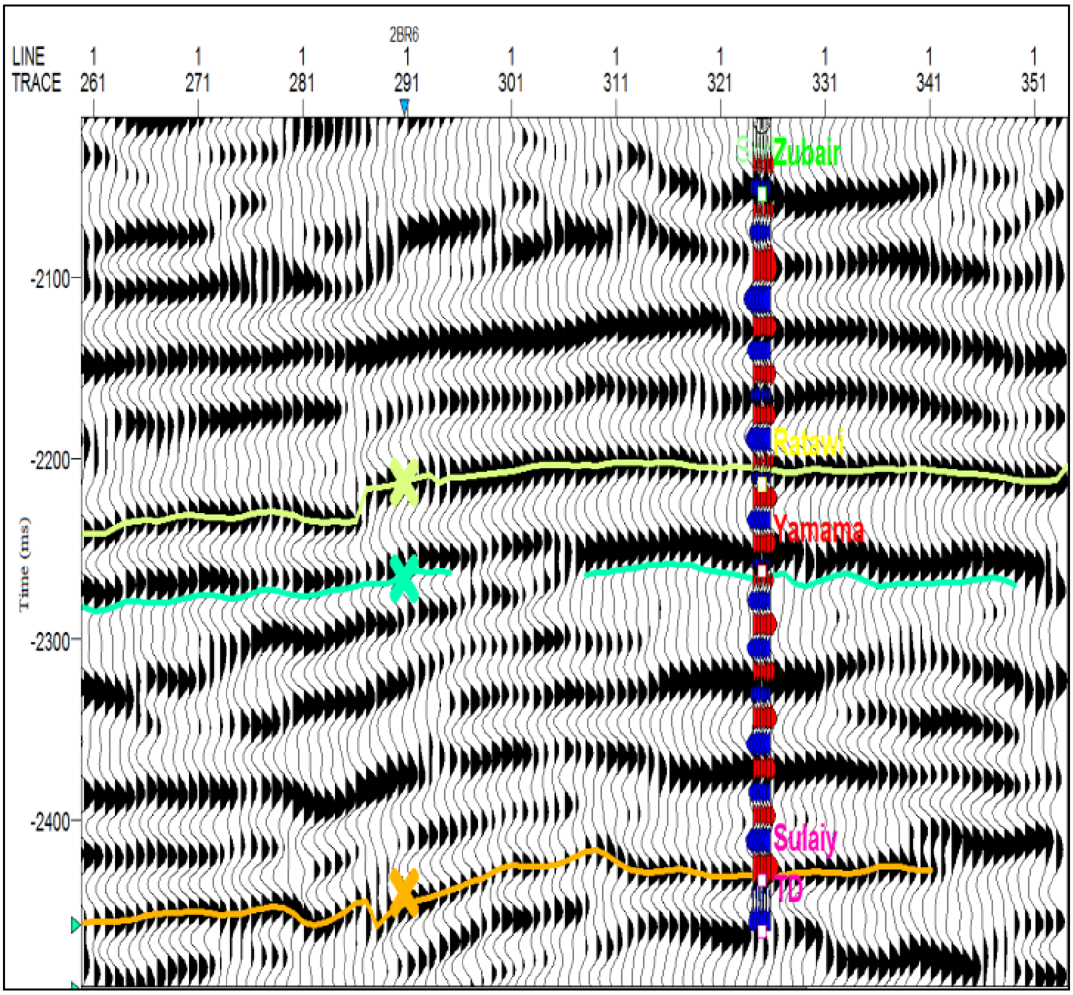

Figure 3-Shows the interpreted horizons after matching of VSP corridor stack with seismic line (2Br2).

In the inversion analysis window, one can test number of iteration and choose the best extracted wavelet that gives better correlation; here we use the extracted wavelet from VSP corridor stack of Snd-2 well. Figures-(4, 5) from left to right inversion analysis display, shows first the tops of Snd-2 well formations, inverted impedance (red curve) overlain on the original (blue curve) and original smoothed (black curve) impedance at same well for both operation. To the right of that, the selected wavelet (in blue), which is from VSP with bandwidth (6-80 Hz), and the synthetic traces calculated from this inversion result (red trace) followed by the original seismic traces (black trace) with a maximum correlation of 0.99% using that wavelet. Finally, the error traces, which is the difference between the inverted results and original, this inversion creates a synthetic trace which matches the real traces.

Results

As can be seen from the two inversion processes, there is a very good matching and very low error percent and that reflected on the matching of inverted impedance (red curve) in both cases (LFM and HFM) with the member of Yamama Formation (high impedance with cap rock CR and graduated to low impedance with reservoir members YA, YB & YC).

After determining and testing the main important parameter in the inversion analysis window, the final step of inversion process runs through the 2D seismic line to create 2D acoustic impedance line Figure-6, or through 3D seismic cube to get 3D impedance volume covering all study area, that could be used in any module to predict the petrophysical properties (porosity and water saturation) through the field.

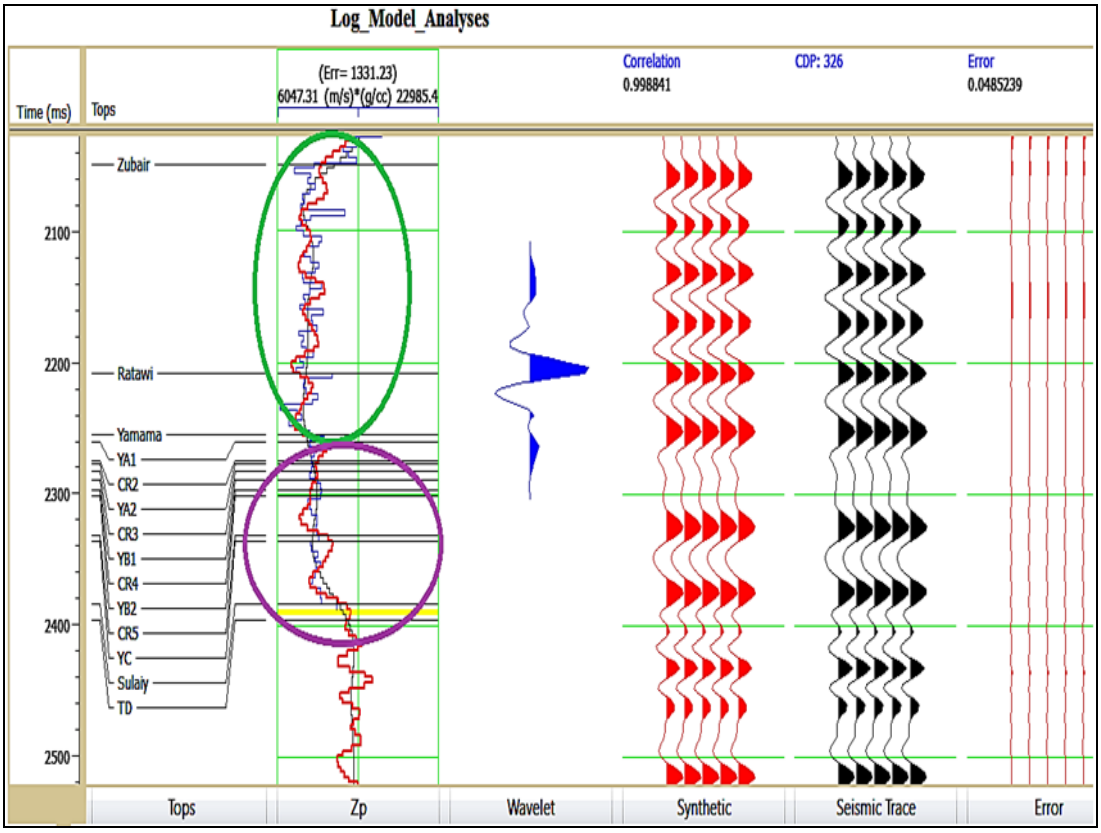

Figure 4- Shows the analysis window of the low frequency where model inverted impedance log (red curve) overlain on the original impedance (blue curve) and original smoothed (black curve).

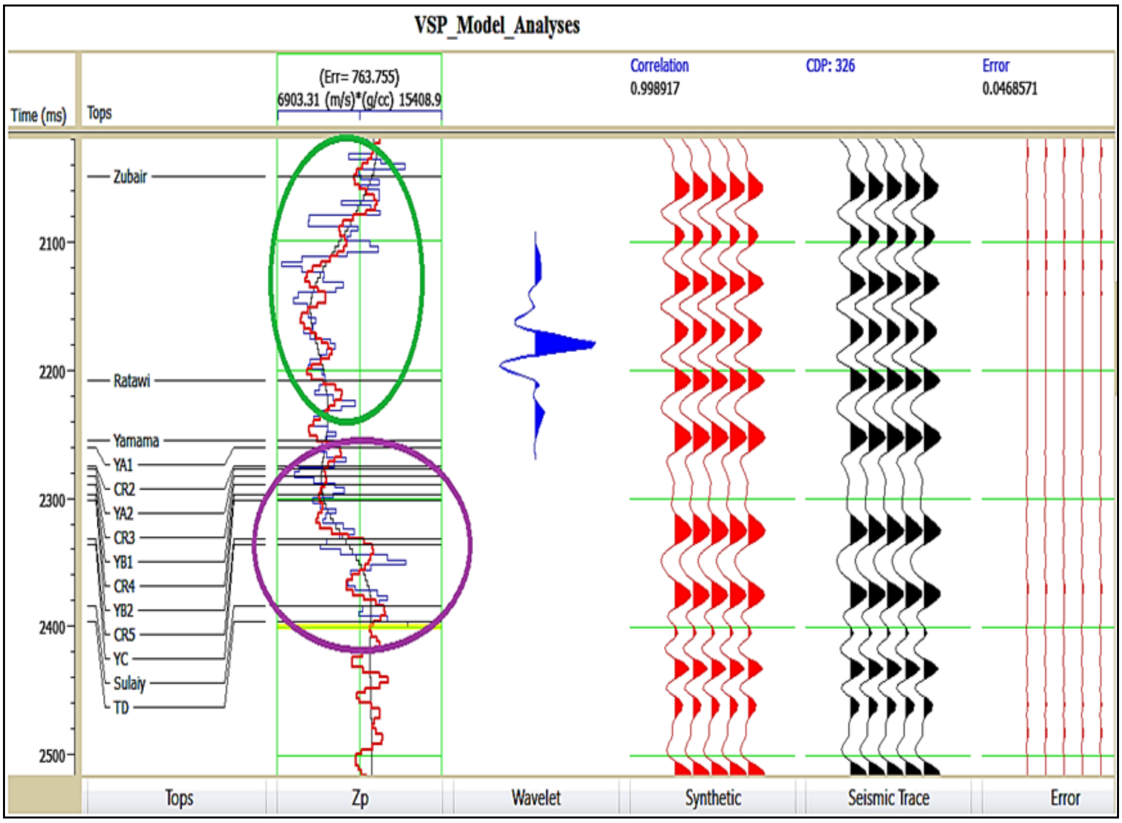

Figure 5- Illustrates the analysis window of the high frequency model where model inverted impedance log (red curve) overlain on the original impedance (blue curve) and original smoothed (black curve).

The results in Figure-6 for log model, the impedance section largely follows the behavior of seismic line with some enhancement for low frequency content and features, while the VSP model shows a geologic sense of impedance in the subsurface layer of seismic behavior with higher vertical resolution as in Figure-7 after zooming and changing the color scale to clarifying the thin layers.

After applying the modeled impedance of LF and HF to seismic line 2Br2, we get the supposed actual impedance section of the area. The seismic section could be converted to relative impedance depending on amplitude difference with time interval. Figures-(8, 9) explain the relation of matching between model impedance and the relative calculated impedance section. As seen from these cross plot the error percent of VSP matching less than log impedance matching with seismic relative impedance section.

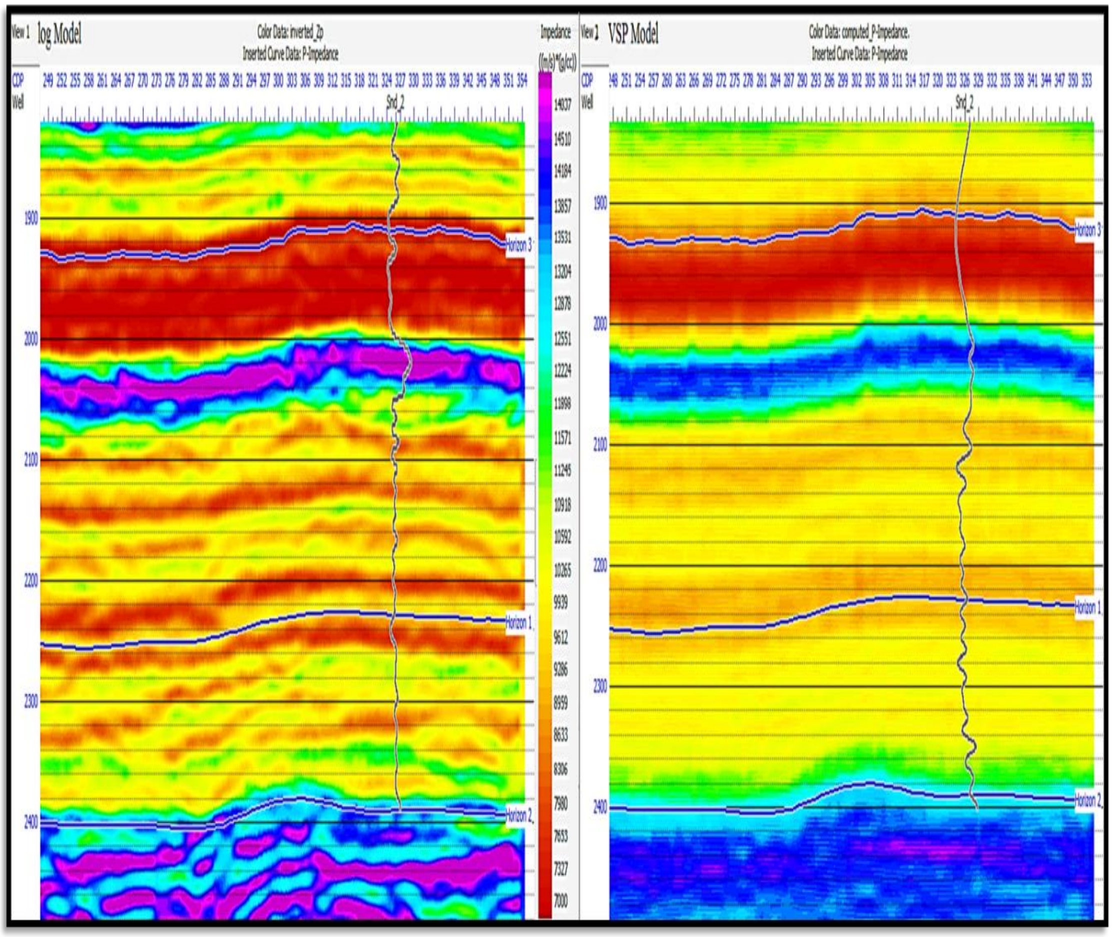

Figure 6-Shows impedance line of 2Br2 with impedance log of two models the left (log low frequency model) and right (VSP high frequency model)

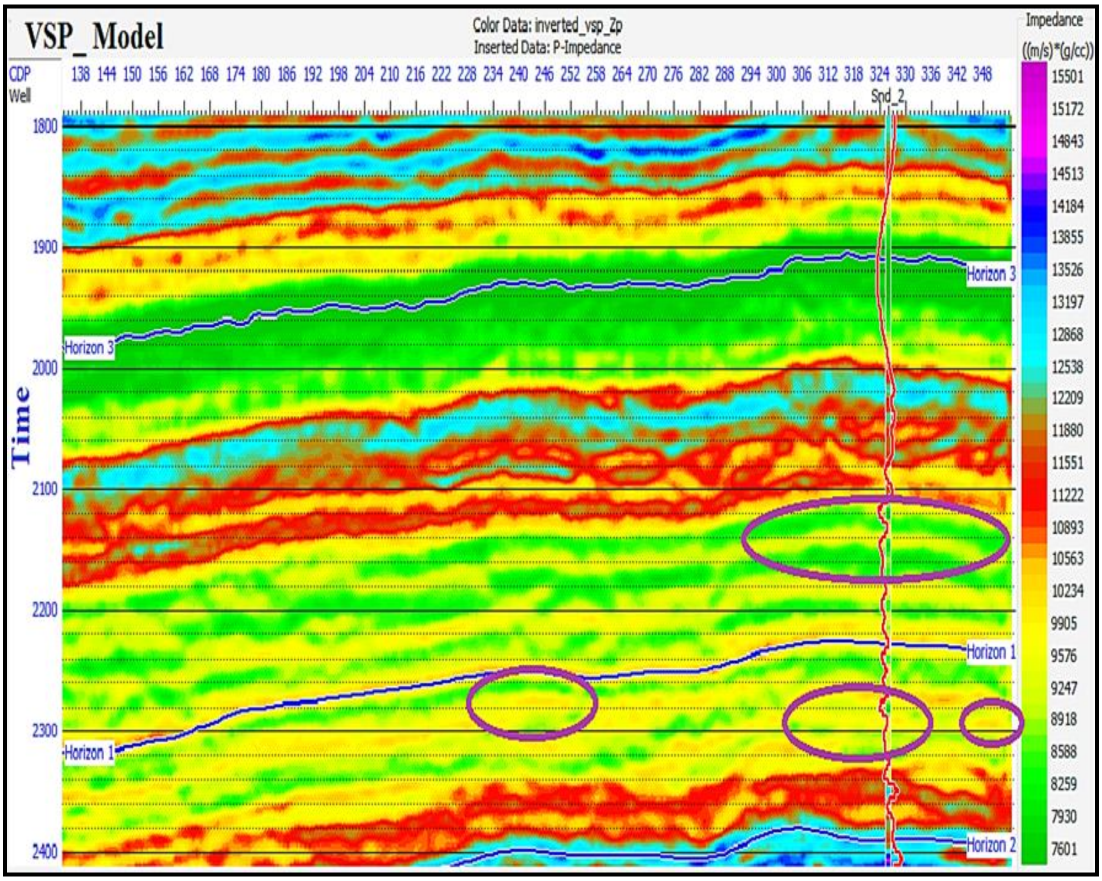

Figure 7- Illustrate the impedance section of (HFM) after zooming and changing the color scale.

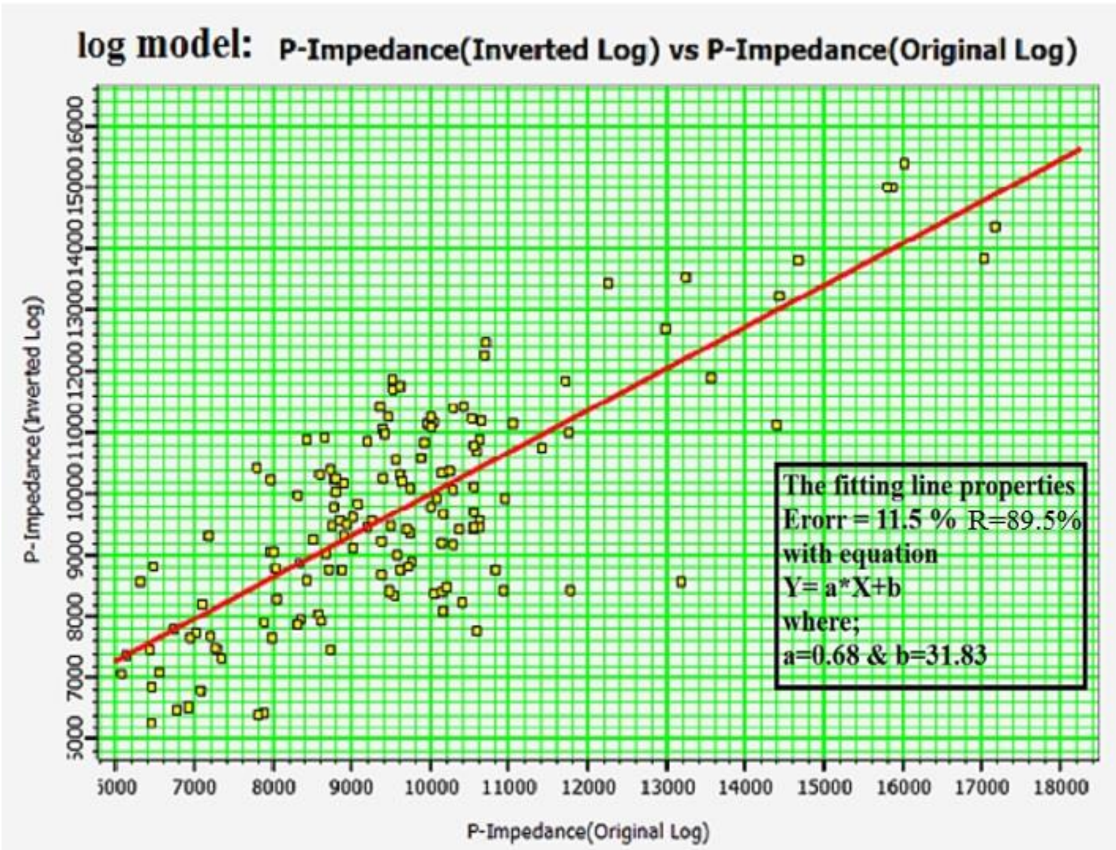

Figure 8-The cross plot between the relative impedance section (2Br2) and the modeled or actual section after low frequency model (log).

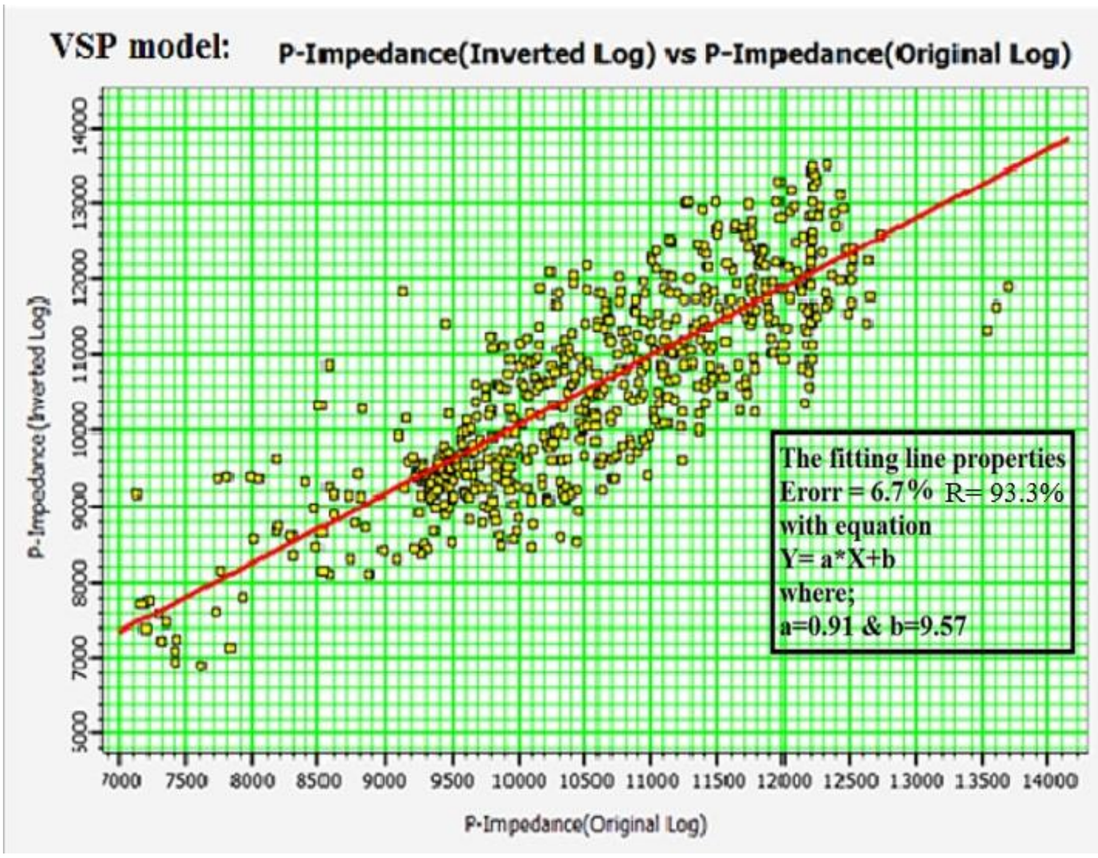

Figure 9-The cross plot between the relative impedance section (2Br2) and the modeled or actual section after high frequency model (VSP).

One of the best checks of impedance section is to reverse operation to seismic section and this could be done with a proper convolution of best correlation wavelet [3]. Here is done a convolution of the two resulted impedance section with VSP best extracted wavelet as in Figures-(10, 11).

Figure-10 of the two modeled seismic section including Snd-2 well location with impedance curves, the green circle in two cases shows the recovers of the missing bed or reflector in reservoir unit of Yamama Formation while the blue circle clarify the enhancement of the direct hydrocarbon indicators (flatspot) also in Yamama Formation. These signal enhancement of high frequency model distrusted in all 2Br2 section as to the southwest location there is also flatspot enhancement as in Figure-11, where the red circles in both section represent flat spot in last reservoir unit of Yamama Formation. The low frequency model which converted to seismic section in the two figures recently does not shows any changes from the original section (2Br2). All of these changes represent an increasing in vertical and horizontal resolution and it’s very important in 2D and 3D seismic survey interpretation.

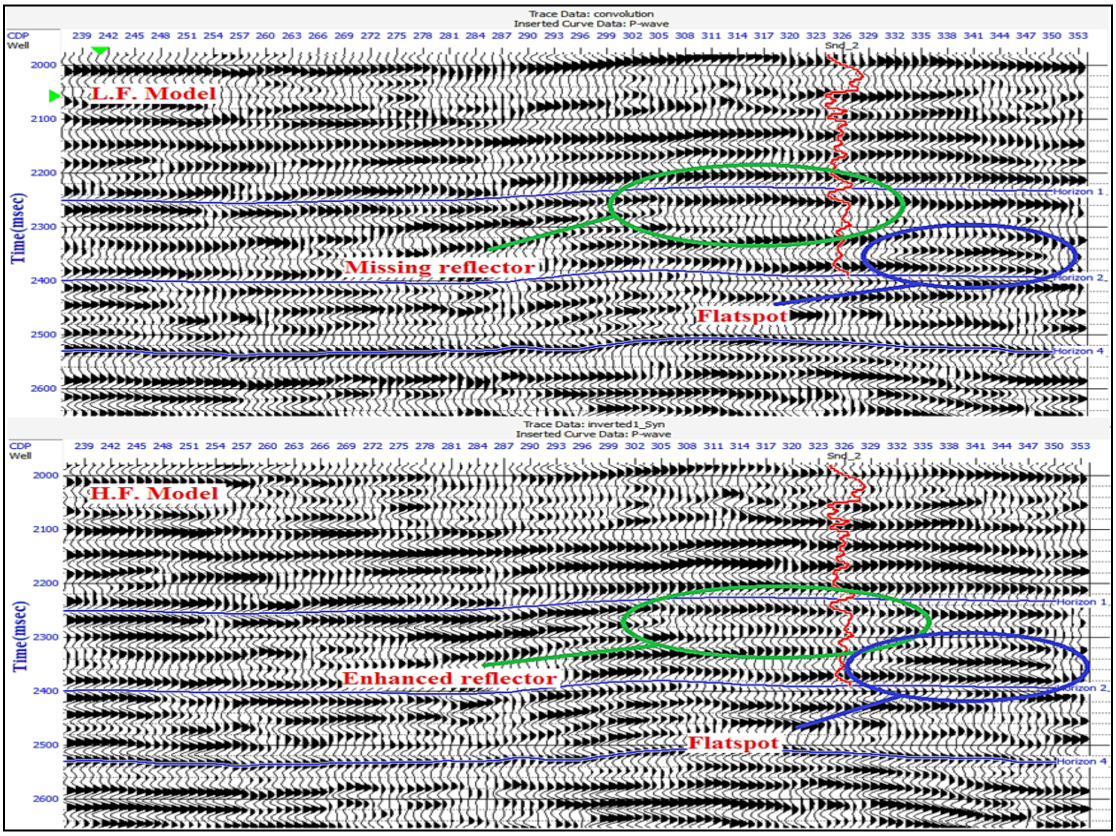

Figure 10-Shows the LFM seismic section (2Br2) (above) and the HFM seismic section (below) on the Snd-2 well location.

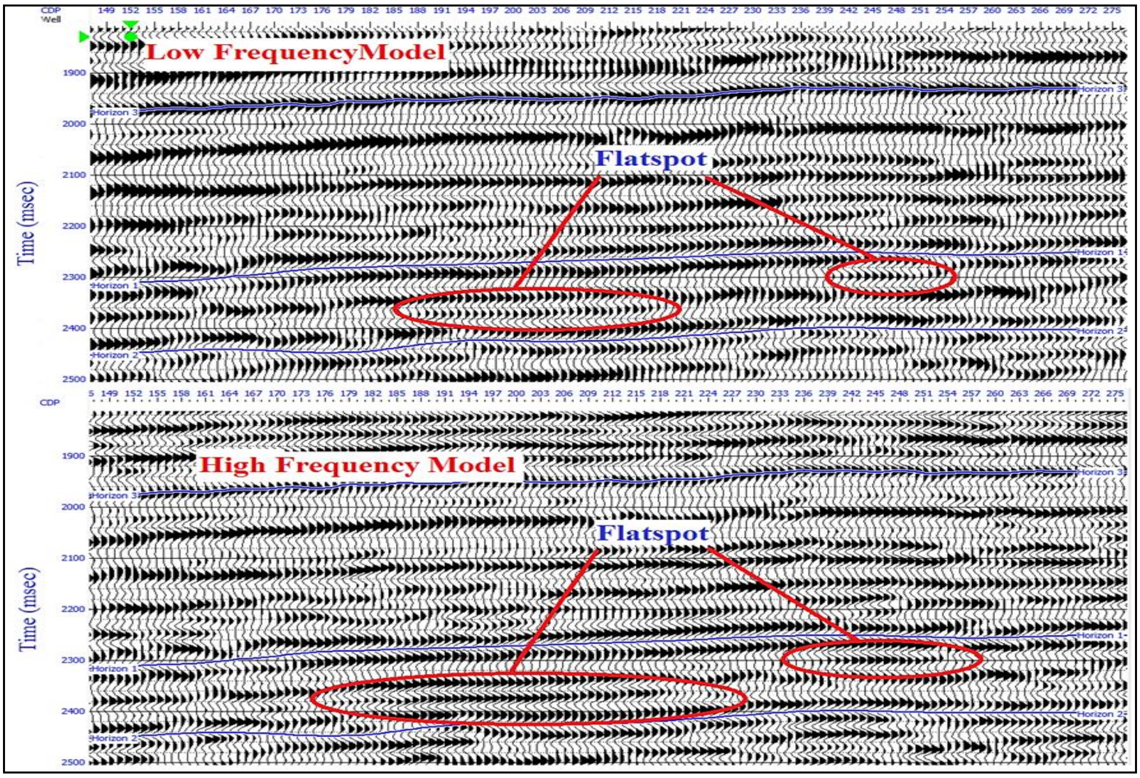

Figure 11- Shows the enhancement of seismic section (2Br2) after high frequency model especially on flatspot (DHI).

Discussion

Seismic reflection enhancement by combining the information of seismic 2D lines, well log (Sonic and Density) and VSP corridor stack are applied depending on a new attempt of seismic inversion method. The elastic properties of rocks mostly effects the seismic signature especially in features like direct hydrocarbon indicator (DHI).

In many situations, seismic interpreters made the seismic inversion process to get rock properties ((lithology, porosity and fluid content …..etc.), so they apply the low frequency inversion method depending on the impedance which calculated from logs then substituted it to seismic lines or volume, but this operation doesn't shows any essential changes in seismic sections or volume for the thin layers or small features (stratigraphic traps, faults..etc.) because its largely related with high frequency band of seismic waves (horizontal and vertical resolution).

In this paper many tries have been worked out to calculate the best high frequency impedance from logs but everyone goes to bad matching with seismic section impedance and noise traces of the produced section because of the different signature of HF of logs and HF of seismic data. VSP recording have mostly the same way to surface seismic so that its bandwidth closed to range of seismic which in turn a good impedance calculation with better matching.

Conclusions:

Based on the results and interpretation of vertical seismic profile survey, for Snd-2 well and its use in surface seismic data, the study comes with the following conclusions: Most of seismic inversion researches go to the low frequency initial model, here in this study one could to build the high frequency model depending on the VSP impedance. The low frequency impedance section gives an error percent of (11.5 %) matching with relative impedance of 2Br2 section while VSP high frequency impedance section gives (6.7 %). The impedance section of (HFM) shows a high resolution behavior to distinguish the thin event.

The last process of inversion (convolution by VSP extracted wavelet) in the LFM seismic section didn't give a valuable enhancement on the seismic signature while the HFM seismic section shows enhancement in all zone of VSP data, with recovering some missing or dim reflectors and its clarify the direct hydrocarbon indicators (flatspot) close to well location and in the middle of seismic section.

RECOMMENDATIONS:

According to the above study result and for the future work it is recommended to do the following procedures: Recording the S-sonic log with S-wave velocity of VSP in future work will be very valuable in the fluid content inversion analysis. Also P-wave VSP with impedance and any well log should be entered in the inversion of seismic data. For the Sindbad field it recommended to make 3D seismic survey for more geophysical and geological analysis about the oil reservation.

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References

1. Pereira A. M. and Jones M. **2010.** *Fundamentals of Borehole Seismic Technology*, Schlumberger, Sugarland, Texas, 265 p.
2. Galperin E. I., Nersesovand I. L. and Galperina, R. M. **1920.** *Borehole seismology and the study of the seismic regime of large industrial Centres*, Congress Cataloging, Holland, 316 p.
3. Farfour M. and Yoon J. Wang, **2015**. Borehole seismic data processing and interpretation: New free software, *Journal of Applied Geophysics*, **123**: 18-29.
4. Oristaglio, M., **1985**. A guide to current uses of vertical seismic profiles, *Geophysics*, **50**(12): 2473–2479.
5. Nasyrov D., Kiyashchenko D., Kiselev Y., Kashtan B. and Troyan V. **2015.** Velocity analysis with vertical seismic profile data using migration of surface-related multiples, *Society of Exploration Geophysicists*, **80**(6): 73–86.
6. Hardage Bob A. **2000.** *Vertical seismic profile: Principles third updated and revised edition*, Pergamon, Elsevier Science, New York, 551 p.

7. Campbell, A., Fryer, A., Wakeman, S. **2005.** Vertical seismic profiles—more than just a corridor stack**,** *Leading Edge*, **24**(7): 694–697.

8. Berge, T., B., Aminzadeh, F., Groot, P., D. and Oldenziel, T. **2002**. Seismic inversion successfully predicts reservoir, porosity, and gas content in Ibhubesi field, Orange Basin, South Africa, The leading edge. PP.338-348.

9. Krischer L., Fichtner A., Zukauskaite S. and Igel H. **2015.** Large-Scale Seismic Inversion Framework, *Seismological Research Letters*, **86**(4): 1-10.

10. Sukmono, S. **2002**. Seismic Inversion & AVO Analysis for Reservoir Characterization, lab of reservoir geophysics, department of geophysics engineering, FIKTM, institute Teknologi Bandung.

11. Kemper, M. **2010.** Rock physics driven the importence of workflow, The First break. 28, PP.69-81.

12. Lindseth, R. O. **1979**. Synthetic sonic logs-a process for stratigraphic interpretation, *Geophysics*, **44**: 3-26.

13. Ferreirinha T., Nunes R., Azevedo L., Soares A., Pratas F., Tomás P. and Romaa N. **2015.** Acceleration of stochastic seismic inversion in OpenCL-based hetero-geneous platforms, *Computers &Geosciences*, (78), PP. 26–36

14. Russell, B. and Hampson, D. **2006**. The old and the new in seismic inversion, CSEG RECORDER, 5p.

15. Barclay, F., Bruun, A., Rasmussen, K. B., Alfaro, J. C., Cooke, A., Cooke, D., Salter, D., Godfrey, R., Lowden, D., McHugo, S., Ozdemir, H., Pickering, S., Pineda, F. G., Herwanger, J., Volterrani, S., Murineddu, A., Rasmussen, A. and Roperts, R. **2008.** Seismic inversion reading between lines, *Oilfield Review*. **3**(2): 22p.

16. Al-Rahim M. Ali and Hashem A. Hassan, **2016.** Subsurface 3D Prediction Porosity Model from Converted Seismic and Well Data Using Model Based Inversion Technique, *Iraqi Journal of Science*, **57**(1A): 163-174**.**