CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 Discussion

In this chapter the special outputs and inverted-EEI results of this study will be discussed and the recommended further study with more focus on the proven gas in the Shuaiba formation will be proposed. As mentioned in the previous chapters, the 3D migrated-seismic CMP gathers or pre-stack time migration volumes and well log data from Block A, Oman have been analyzed for reservoir characterization to identify the fluid types using the application of extended elastic impedance (EEI) analyses included AVO gradient analysis, chi angle determination and EEI inversion method. The seismic volume of this study covers the inline from 2450 to 2830, the crossline from 20100 to 21000, and the time length of 4000 ms. The 4 wells were selected to use that consist of well A1, well A2, well A4, and well A8. The quality control to those data was also taken into account as mentioned in chapter 1.

From petrophysical reviews, there are 3 wells containing the oil-bearing reservoirs in the Natih formation which cover the zone of interest at the upper parts of well A1, well A2, and well A4. The oil net pays of wells A1, A2, and A4, based on those final well reports, are 16.8, 21.9, and 38.6 m respectively which are characterized by lower Poisson's ratio (0.29-0.30), lower bulk modulus (27-34 GPa), lower shear modulus (13-17 GPa), lower $\lambda\rho$ (45-58 GPa.g/cm^3), and lower $\mu\rho$ (32-42 GPa.g/cm^3) compared with the surrounding water-bearing reservoirs and shales. The aspect of anisotropy had not been expected in this study because the previous study stated that this area has no significant fractures creating severe velocity contrast.

According to the coefficients in well-ties, the good matches enable us to ensure the robustness of the time-depth relations and wavelet extractions. Next to chi angle determination, they are evidently high correlation coefficients to derive the optimum chi angles and then the EEI logs computed at those angles track very well with original parameter logs, except Sw, VCL, and NPHI logs. It means that the selected chi angles are reliable and their derived-EEI parameter logs can be used for quantitative interpretation (QI).

As **Figure 4.16** illustrated the same initial model can generate different results which is commonly known as the non-uniqueness of inversion, hence the good cares of wavelet and parameter selection are essential for ensuring inversion result.

The results including the inverted-EEI bulk modulus, inverted-EEI mu-rho, and inverted-EEI Vp/Vs can identify partially the effects of fluid type. That implies that those EEI volumes cannot anticipate the specific characteristics of oil-bearing reservoirs. It aligns with 2008's study (Peng et al., 2008) in which stated the weakness of EEI application for fluid identification in carbonate reservoir. They revealed that hydrocarbon and non-hydrocarbon zones in carbonate reservoirs provide similar EEI values even the use of optimal chi angle. In the aspect of lithology identification, all of EEI results provide a great tool for differentiating the rock types at each formation.

The inverted-EEI lambda-rho (EEI lambda-rho) proved to be the most sensitive elastic parameter to the variation in fluid types. In this study, the differences between oil-bearing reservoirs and water-bearing reservoirs in the Natih formation can be identified by using EEI lambda-rho result and its cross-plot with EEI Vp/Vs. To be noted that at position of well A4, the EEI lambda-rho result provides the best fit with the oil-bearing reservoirs (**Figure 4.29**). Moreover, the extents of those hydrocarbons can be delineated to both sides of well A1, A2, and A4 in sections of the EEI lambda-rho volume (**Figure 4.30, Figure 4.38, & Figure 5.1**).

Consequently, there are some seismic anomalies having similar characteristics of EEI lambda-rho result, which were namely indicated as Anomaly 1 and Anomaly 2 (**Figure 5.1**). These anomalies can be the new candidates for development drilling, which can reduce the risk and uncertainty.

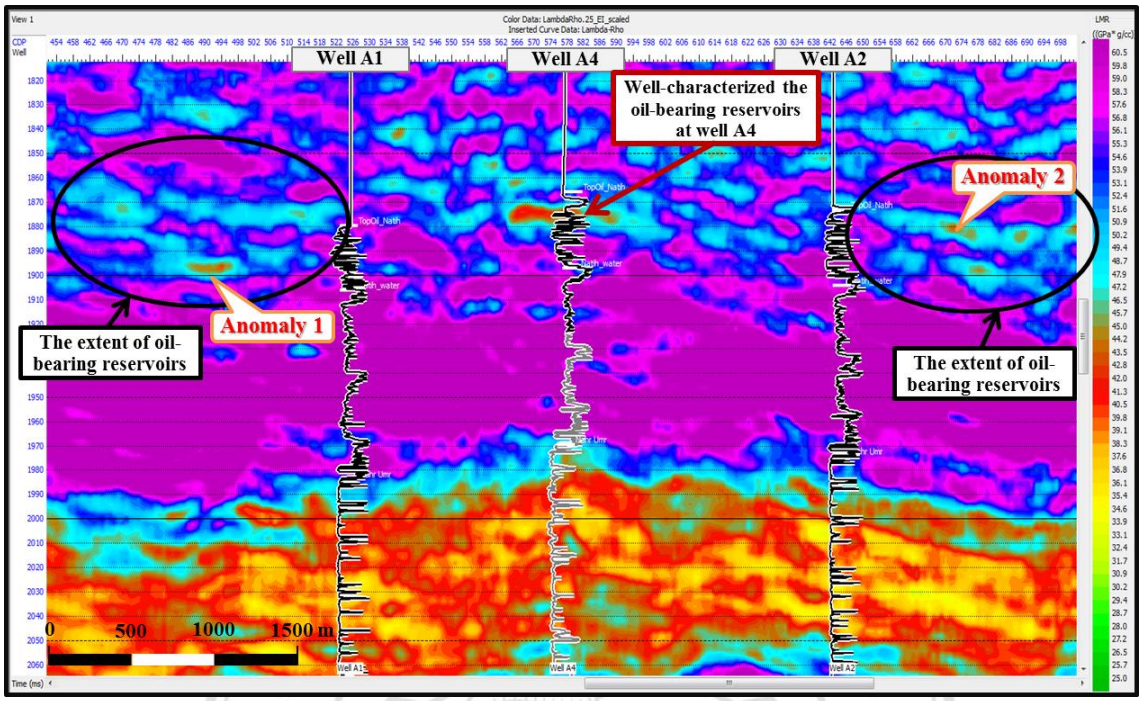

Figure 5.1. The section view shows the EEI lambda-rho characteristics with the oil-bearing extents to both sides of wells, highlighting by black circles. Anomaly 1 and anomaly 2 were indicated consequently to be the new development candidates.

Although the extents of oil-bearing reservoirs were identified as seismic anomalies, depicted in **Figure 5.1**, but the context of either structural or stratigraphic trapping together with petroleum system evaluation are required essentially to finalize the prospects and drilling locations. Moreover, the interpretation of EEI lambda-rho volume alone is not easy and unreliable since it can be interpreted as the same lithology with different range of pore fluid material, therefore the great caution must be applied for quantitative interpretation.

Another caution is the possibilities in range of lithologies, showed in all sections of inverted-EEI volumes, that the EEI values of thick shales in Nahr Umr formation is similarly low as the EEI values of oil-bearing reservoir in the upper part of Natih formation. It can be concluded that the finding of seismic anomalies (lower EEI value) might not be transferable to the facts of being hydrocarbons-bearing reservoirs.

One explanation to bear in mind is that the shallow overburden or diagenetic effect may cause the observed lower values for lambda-rho, mu-rho, bulk modulus, and shear modulus. The reason for low Vp/Vs or Poisson's ratio values extended outside the hydrocarbon-bearing reservoirs may be related by the different degree of consolidation and cementation in the rocks. The use of EEI volumes in conjunction with targeted-well log data is recommended to overcome the similar characters of EEI values, and then this combination can support and guarantee the interpretations.

With scope of this independence study (IS), only one cross-plotting between EEI lambda-rho versus EEI Vp/Vs volumes was performed, and then the fluid identification can be analyzed as a zone by using characterized parameters of oil-bearing reservoir.

To see the lateral extension, the horizon slices were extracted from horizons of interest and then all wells in this study were posted together with a blind well. First of all, horizon slice of EEI lambda-rho from near base Fiqa horizon (50 ms window) shows the clear interpretation which are the oil-bearing reservoirs at well A4 matched to anomaly and be highlighted by black dotted-free form and the result also matched with hydrocarbon-bearing reservoirs at blind well.

Next, the horizon slice of Near Natih E horizon extracted from volume difference between EEI lambda-rho and EEI Vp/Vs reveals some sweet spots locating at all hydrocarbon well locations (well A1, A2, A4, & blind well) and surroundings (**Figure 4.42**). Those sweet spots provide evidently the clues implying the regions of hydrocarbon accumulations. As same as previously, EEI bulk modulus horizon slice from near base Fiqa horizon shows that not all hydrocarbon wells matched definitely, but it could provide some clue implying the different between regions of hydrocarbon and non-hydrocarbon.

Interestingly, EEI shear modulus horizon slice from near base Fiqa horizon results the challenging sweet spots conformed the structure were depicted for prospective consideration. EEI Mu-Rho horizon slice from near base Fiqa horizon also results the good matching at well A4 and blind well and the highlighted sweet spots can be seen at which it could be probably the drilling candidate. Lastly, EEI Vp/Vs horizon slice from near base Fiqa horizon yields good matches of oil-bearing reservoirs at well A2 and A4 and good match of water-bearing reservoir at well A8. However, it still could not provide perfect interpretation due to the weakness of fluid identification and unknown anomalies.

Regarding all horizon slice interpretations, the prospective areas were carefully identified using the assumptions of structural conformation, anomalous agreement, and blind well matching. The identified prospective areas are namely N1-LR, N2-LR, and N3-LR on the expand view of EEI lambda-rho horizon slice (**Figure 5.2**), next N1-MR on the expand view of EEI mu-rho horizon slice (**Figure 5.3**), and then N1-Mu and N2-Mu on the expand view of EEI shear modulus horizon slice (**Figure 5.4**).

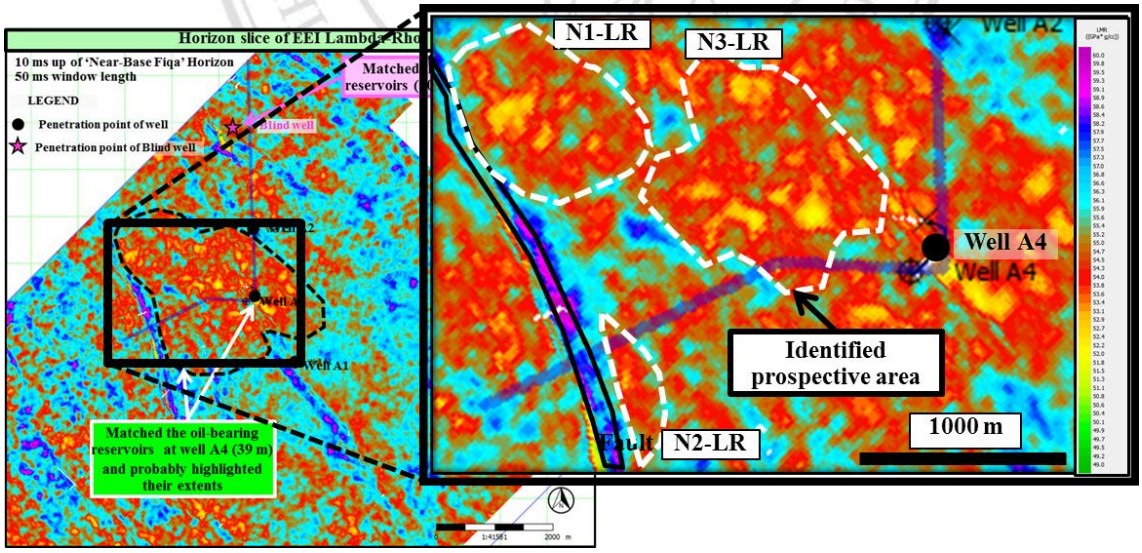

Figure 5.2. The expand view of EEI lambda-rho horizon slice showing the identified prospective areas which are N1-LR, N2-LR, and N3-LR.

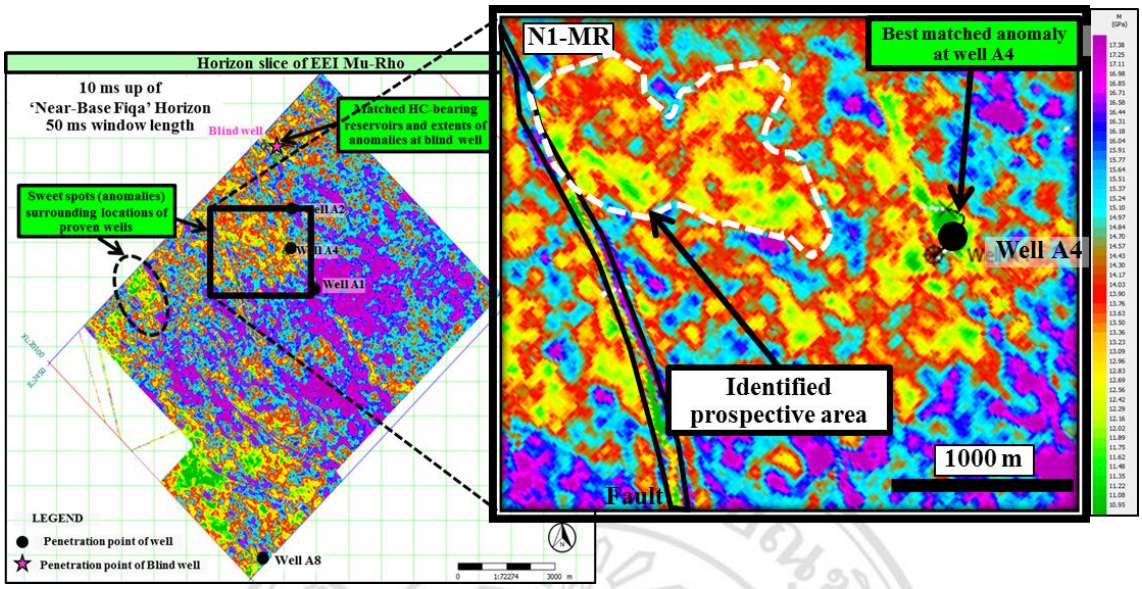

Figure 5.3. The expand view of EEI mu-rho horizon slice showing the identified prospective area which is N1-MR.

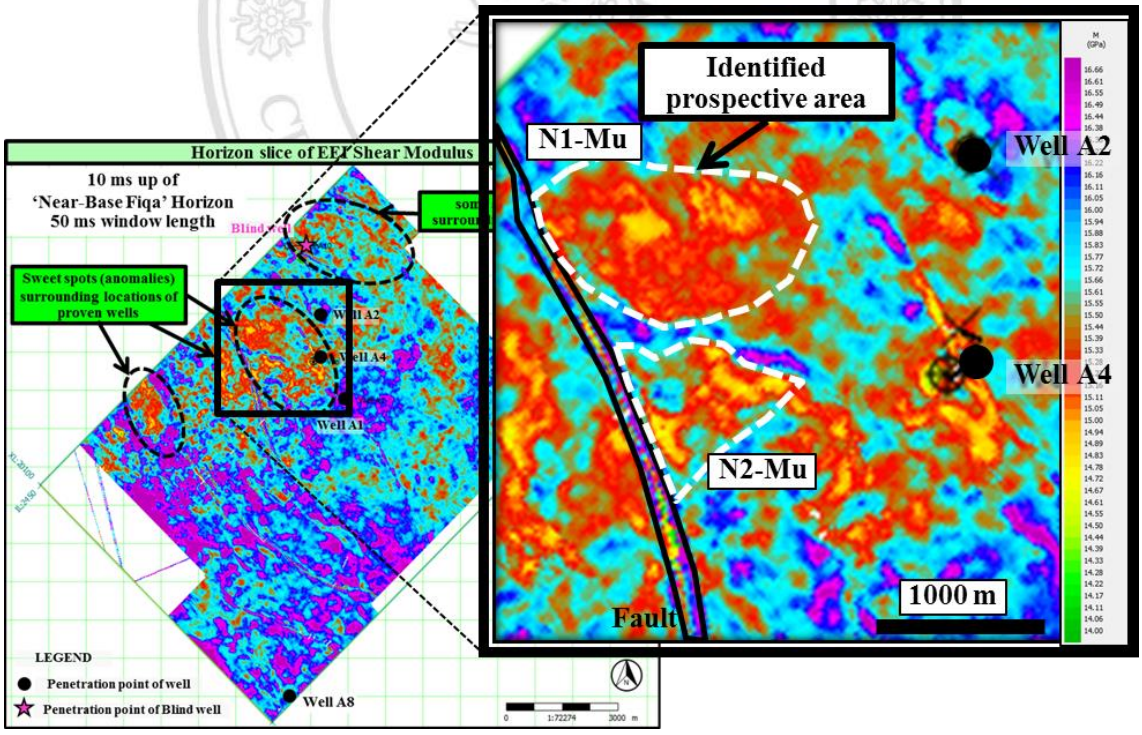

Figure 5.4. The expand view of EEI shear modulus horizon slice showing the identified prospective areas which are N1-Mu and N2-Mu.

Hence, the further works/studies for other volumes would be suggested in the future. It will have much more understanding in identifying the fluid types if both oil- and gas-bearing reservoirs will be analyzed by using EEI application, therefore, the further study with focus of Natih and Shuaiba hydrocarbon (oil and gas) pays is highly recommended.

5.2 Conclusions

In this study, the EEI inversion method had been applied to identify the fluid types observed in well log data (well A1, A2, & A4).

The inverted-EEI lambda-rho (χ=25°) volume together with lambda-rho log is the good tool for identifying the oil-bearing reservoir in the Natih formation, especially at well A4 showed the best. The other inverted-EEI volumes including EEI bulk modulus (χ=16°), EEI mu-rho (χ=-13°), and EEI Vp/Vs (χ=38°) can be used partly at some degree together with well-log combination. The weakness of fluid identification in this study has obtained because the similar characteristics (low lambda-rho, low bulk modulus, low mu-rho, and low Vp/Vs) of EEI results observed at some parts of water-bearing reservoirs, at the top of all wells (Fiqa formation) and at the thick shales interbedded thin-limestone in Nahr Umr formation.

The cross-plotting method helps to provide the valuable understanding in fluid type identification. The interpretations in selected horizon slice enable this study to obtain the prospective areas that can be evaluated later for drilling candidate.

In conclusion, the fluid type identification in the carbonate reservoirs of Natih formation can be accomplished significantly at only well A4 by using EEI lambda-rho result with equivalent well log data.