Integration of Surface Seismic Data with Geo-electric Data

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Abstract: - The project conducted integrates two infamous methods to find a relation between them and to give a better understanding of the area studied. The first method is seismic refraction, using 9 shots and 32 receivers, this method will give us a velocity model for the subsurface. The second method is geo-electric method, vertical sounding by Winner/Schlumberger arrangement and pseudo-section were conducted. This method gave a resistivity model of the subsurface. Finally these techniques were combined to give the maximum information about the area. The area being studied is the Dhahran techno valley, which lies above the proven Dammam reservoir.

Key-Words: Seismic Refraction, Integration, Geoelectric, Dammam Dome.

1 Introduction

The research proposed herein is a collaborative effort between King-Fahd University of Petroleum & Minerals and Schlumberger Dhahran Carbonate Research (SDCR). Our research effort is centered on the integration of surface seismic data with geo-electric data acquired in an area located in the Techno-Valley of KFUPM.

The basic hypothesis to be tested in this research is whether the distribution of seismic velocities in the near surface can be correlated to resistivity anomalies in the area of study. Our proposed research includes geo-electric and surface (reflection and refraction) seismic data acquisition using resistivity/seismic equipment of KFUPM and seismic equipment of SDCR, respectively. Electrical resistivity and seismic data will be inverted separately. The inverted data will be used to estimate a correlation function between the estimated parameters.

The main objective of the proposed research effort is to estimate the potential relationship between seismic velocities and the distribution of electrical resistivity in the area of study. This relationship might be used to reduce the level of uncertainty in the interpretation of the individual data sets.

2 Previous Works

In order to provide a better and accurate interpretation of complex geophysical structures (e.g., Salt Dome), integrated geophysical analysis has become popular in different combinations of geophysical methods as models of gravity-seismic (1; 2; 3) and gravity-resistivity (4). Since not many research has been conducted to seek correlation between seismic velocity and resistivity, we are motivated to examine The possible correlation between electrical anomalies and seismic velocities is a current research topic in the geophysical community even though such kind of correlation. This correlation has been reported on literature of deep crustal studies (5). State-of-the-art technology for resistivity tomography for near surface studies (6; 7) makes promotes conducting a work for seeking to conduct a comparative study of seismic velocity and resistivity. Nowadays, the use of different geophysical methods to increase the understanding of oil and gas reservoirs is an important trend in the oil industry (CBO, personal communication).

3. Field Geology and Profile Design

The area is located in the eastern province of Saudi Arabia, over the Dammam Dome structure (Figure 1). This area did not have many published information about it. The only source I could find was Wajimars, 1993 about the surface geology in Dammam dome. The area studied overlies Dammam reservoir which is a diaperic structure. Obviously when the near surface (weathered layer) is studied and understood this will provide a better estimate for the static correction (As according to course Geop 320) in order to improve the seismic reflection quality. As for previous studies conducted in dammam dome to better understand the weathering layer, I could not find any. The layer that is below the weathered layer is expected to be either Rus formation or the Dammam formation (Wajimars,1993), upon further analysis this will be clear. The beginning of the line was dug out and replaced with artificial trench. This can provide as a quality control factor for the study, because the velocity in lose sand is known. By comparing the expected velocity of the lose sand with the models velocity this can prove useful (figure 3). In particular the area lies in KFUPM's Dhahran Techno Valley (Figure 2).

Figure 1: Dammam dome in the eastern region of Saudi Arabia.

Figure 2: The location of the survey that was conducted.

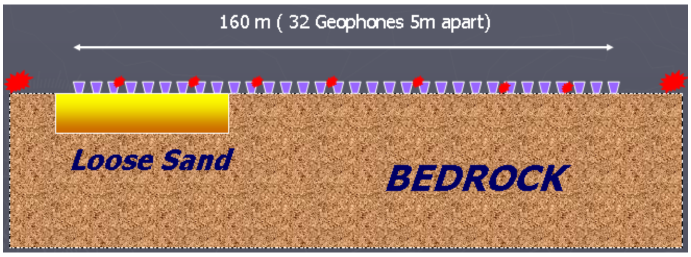


Figure 3: Model showing the field geometry and the loose sand and bedrock location based on geometry of the setup.

3.1. Seismic Refraction-

For the seismic refraction 32 3 component geophones where used. They were separated from each other by 5 meters, thus the seismic line is 160 meters in total. In order to increase the coupling the geophones they were placed a few of centimeters below the ground surface and buried with sand. Each 12 geophones were attached to a geode through a cable, finally the geode is connected to the recording unit. The accusation system used is Geometrics. The area was almost flat so there was no need to record the elevations we just assumed a flat surface. The source used is a hammer, attached to it is a sensor that signals to the system to record when the hammer hits the ground. The number of shots recorded was 9. The spacing for the shots was based upon to extract sufficient amount of information particularly at the center of the line. Each shot was recorded 7 times to increase the signal to noise ratio, a stack of 7 would increase the signal to noise ratio by nearly 2.6 times (Geop 315), this was suggested in the Geometrics manual. The length of the recorded is 2 seconds and the sampling rate chosen was .125 millisecond.

4. Data Analysis

4.1. Refraction Tomography-

The format used to record the data in the field is SEG-Y. All the programs used in processing the data accepted SU format, thus the data was converted form SEG-Y to SU format without merging the data. The data recorded was 3 component and in the process of acquiring all the components were placed sequentially after each other. Hence the H-1 , H-2 , V-3 components were all in the same file. So separation of the components was essential to further process the data. I used VISUAL SUNT to window out the data and separate the components. Suwind was the function used to separate the components. Now the data was ready for picking. After preparing the data, the next step was picking the first breaks. The program used to aid in the picking process is SeisOPT Picker, but the due to limitations on the size of the input files I could not merge the data then use it in SeisOPT Picker. So I did the picking for each shot record separately. The strategy used in picking the first arrivals was based upon the coherent arrival of the refracted wave, no automated pickers were used.

Near the shot location it is generally easy to pick the first arrival (Figure 4), but as the offset increases the signal to noise ratio decreases and makes if difficult to differentiate between the signal and noise. The hardest picks were when the shot was furthest away from the trench and pick was for the receivers that were inside the trench (Figure 5).

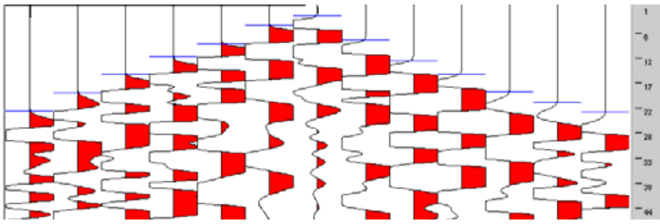


Figure 4: Easy picking first arrivals near the source.

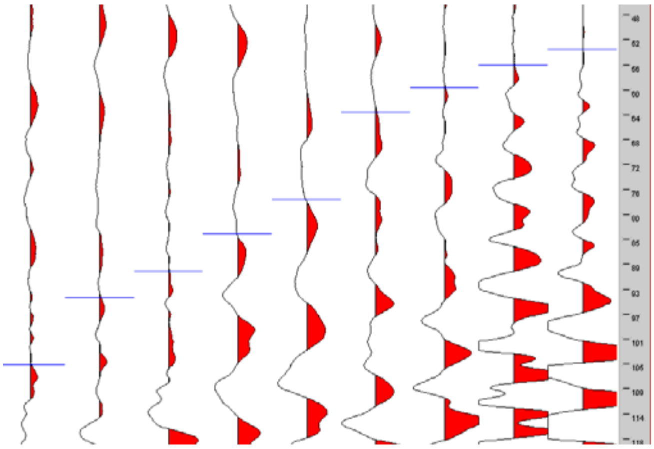


Figure 5: Very difficult to differentiate between the signal and noise.

This was due to the large reflection coefficient between the very high velocity of the subsurface layer and the very low velocity the sand (nearly 30% of the energy was reflected back into the subsurface). It might have been difficult to pick in the trench but it will later help us in identifying that the picks were correct if the sand is seen in the model. After picking the first breaks the data had to be ready for tomography and velocity profile representation.

The program used to give the velocity profile is SeisOPT@2D from Optim. The input for program is three ASCII files that contain the source locations, receiver locations, and first break picks all merged together. Due to the fact that the previous program did not merge nor export the data, this step had to be done manually. This problem may have been die to the format of my data was in SU while the program accepts SEG-2. After redoing the format to be accepted by the program the data was finally ready for processing and analysis. The program contains an auto-calculation feature that assumes resolution parameter values and does the calculations based on them. It was suggested by the manual that the first time running the program, I should

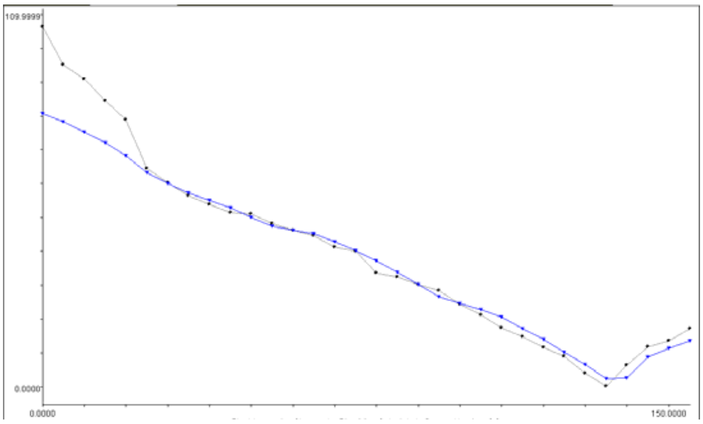


Figure 6: Big difference between the observed (black line) and calculated (blue line) picks. This must be edited to be more reasonable.

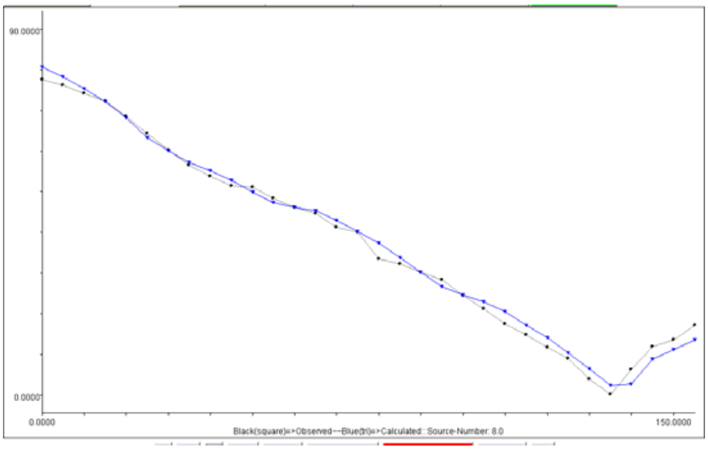


Figure 7: After editing the picks, notice that the error between the observed and calculated is much lower now.

use auto-calculation. It was also suggested (Dr.Cesar, 2007) to modify and edit the picks based on the first run. After analysis of the picks (Figure 6) I saw that some picks especially the very far ones from the source had to be edited (Figure 7).

In editing the picks the shots at the trench it must be seen to follow the same trend. After editing some of the picks to each other, most of the observed and calculated pick now coincide (Figure 8). To get optimum and the best result it is advised that the program be run 10 times while changing the number of cells with depth. Each run takes 2 hours to process; hence an automated process was needed to conserve time. The program had a batch processing feature that allowed for automatically processing all the profile with their different parameter, which is the number of cells versus depth. Finally 10 very closely related models were obtained of the subsurface.

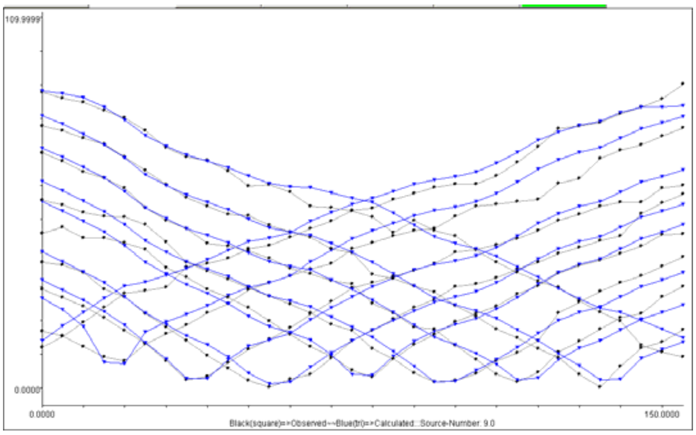


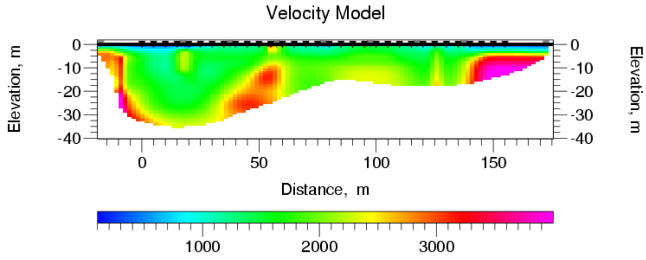
Figure 8: All the calculated and observed picks.

5 Observations and Interpretations

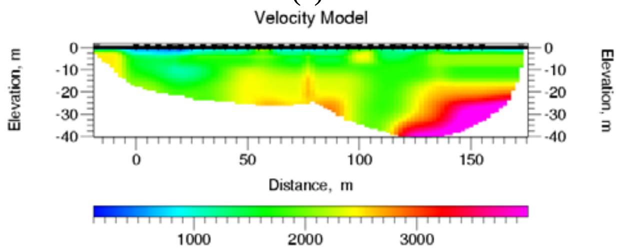
5.1. Refraction Tomography

After running the program I obtained 10 models of the subsurface of the studied area. Most models were fairly close to each other in interpretation to each other. Now I had the task to choose a suitable model to represent the area. The first thing I looked at was the error produced in each run. Each time the program calculates a model it finds the least square error between the observed and the calculated data. Some of the models had a fairly large error with respect to the others, so these models were disqualified. I narrowed it to three least error models (Figure 9).

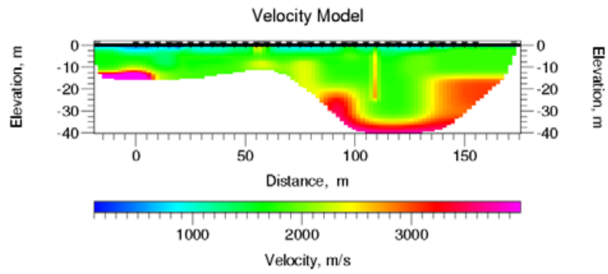
After that I used my previous knowledge of the area to see if it agrees with the model produced. One of the most striking features that are seen on the surface is the loose sand that made up the trench. The velocities in that area were supposed to be very low with respect to the other subsurface velocities. So the model I chose had to agree with the observations that were taken during the acquisition phase of the project. Although the depth of the trench is not quite known but it was suggested by Dr.Cesar,2007 that its about 1 to 3 meters deep, and this agrees with the model. I also used common sense and the most realistic model, based on the geology of the area and the structures seen here. The model I picked had to also agree with the pseudo section that was generated with the resistively method (figure 10).



(a)



(b)



(c)

Figure 9: The three least error models, had an error of 4.872072e-006, had an error of 5.523698e-006, had an error of 4.943083e-006

After taking all these issues into account I finally chose one model to represent the seismic velocities in that area. Before interpreting the data we must see the hit file in order to know where are the uncertainties in the model (Spatial variability of the data). The hit file basically just shows the ray paths that where generated and received, based upon the number of ray paths crossing each point, the ray paths is generated, thus if we have many rays crossing a point then it has a high hit count and high confidence. For the model that I chose there are zone where no ray paths cross but I will use the other models to compensate for this. Merging the models are done at the points of strength in order to get the full picture of the region. When looking at the model you can see that the velocity

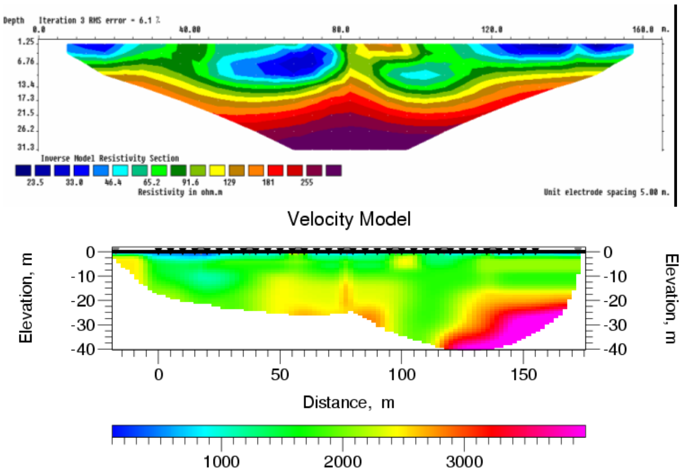


Figure 10: Both the refraction model and the resistivity model. They agree in the bulging structure in the middle (Resistivity map is a courtesy of Omar Ba-wazir).

values for the lose sand in the trench is coinciding with reality (V=800 blue color).

One of the most striking features in the model is a bulging relatively high velocity zone in the middle of the line. This could be interpreted to many things, one of which is that the area being studied lies on top of a salt dome and the near surface layer might be Rus formation which is many evaporates. Another plausible interpretation is that it is a very hard well sorted limestone, although the bulging structure is quite strange from limestone but a very small portion of limestone is exposed at the surface and we did have a hard time digging in order to place the geophone. The last interpretation of the high velocity zone is it might be due to pipes , cables , or rubble buried in that area. My personal opinion is that the high velocity zone in the middle is due to the second interpretation, which is a high velocity well sorted and very dense limestone. Limestone has a velocity range of 2500 –5000 m/s (Gaviglio,1989), Depending on the sorting and the if the pores are filled. The model suggests that it has a velocity of around 2500 m/s which lies in the range. In both sides of the line the bulging effect disappears. The end of the line I noticed that we have a fairly high velocity zone located at around 45 meters, I think this is due to its depth and composition. Finally between the structures mention weathered sand covers in-between them, having a velocity of 1500 m/s.

6 Discussion

Presents your own discussion on how the constrains contribute to understanding the crustal structure and tectonic evolution of the regions.

6.1. Seismic Refraction

I think the number of shots with the number of receivers is quite adequate to get an acceptable model of the subsurface. Increasing the number of shots and receiver would obviously increase the resolution of the subsurface. What would be more interesting is to increase the line length so we can see if the features reappear. We could also get samples from the outcropping structures in the field to analyze the velocity and compare it with the velocity calculated. Another interesting aspect is if we could use a stronger source that would penetrate deeper. Then we might get to see a diaperic structure. Finally if there was a function to merge some of the models it would probably give us the best interpretation.

7 Conclusion

By comparing the results from both techniques we were able to model the subsurface and confirm the interpretation with the other. We also were able to find relation between the resistivity methods and the seismic methods in this region. We could also conclude that there is lateral variation of velocity in this area. The range of velocities encountered ranged from 0 to 5000.

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