Mapping of Bedrock Using the High-Resolution Seismic Reflection Technique at Wadi Al Dawasir Region, Saudi Arabia

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SUMMARY

This paper critically evaluates the utility of seismic data to assist in the interpretation of bedrock. Four high-resolution seismic reflection profiles were carried out to provide estimates of the depth to the bedrock and to detect any geological faults present in the area, which may affect the hydro-geological system at Wadi Al Dawasir region, 690 km south of Riyadh city. The bedrock reflection is clearly present in all sites. The depth of the bedrock at site 1 was approximately 750 m, 800 m at site 2, 700 m at site 3, and 950 m at site 4. The bedrock depth obtained from the seismic agreed with the well information. We developed a clear understanding of the bedrock in the study area and mapped its depth as well as mapped some of the clear fault locations.

Key words: High-resolution seismic reflection; Bedrock; faults.

INTRODUCTION

The study area is located between Wadi Al Dawasir and Aflaj cities, and about 690 km south of Riyadh city. The investigated area is found within the Wadi Tathlith quadrangle. About two thirds of the quadrangle is underlain by basement rocks of the Arabian Shield, much of it consists of an almost flat pediment surface. The remaining part of this quadrangle is in the southwest is underlain by almost horizontally bedded Phanerozoic sedimentary rocks. Wadi Al Dawasir Area forms part of the interior homocline structural province Al-Faifi (2005). The study location is divided into four sites (Fig. 1).

Seismic methods have been widely used in detecting and mapping subsurface features, especially the layered sedimentary sequences in search of oil and gas reservoirs Burger et al. (1992). Advantages of seismic methods over other geophysical techniques are due to their high accuracy, high resolution, deeper penetration, and the amount of information that can be extracted including mapping of the structures, faults, and compactness of various layers Sheriff and Geldart (1995). Recently, these methods, including the high-resolution seismic reflection method, have been applied to map shallow subsurface structures, depth of water tables, and identification of engineering related problems Kearey and Brooks (1984). Since all the engineering and environmental problems are located at shallow depths (near surface), seismic reflection method is an excellent choice to achieve high-resolution images from this domain. Keeping in view the usefulness of this method, four high-resolution seismic reflection profiles have been conducted in the study area. The main objective of this study is to provide estimates of the depth to bedrock and in detection the geological faults.

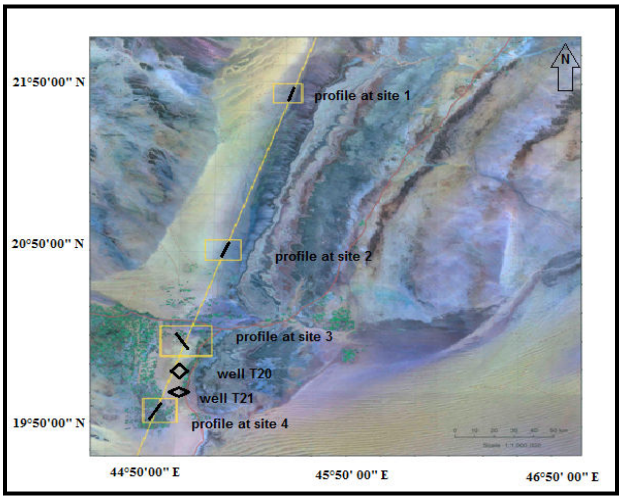

Figure 1. Map of study area with location of seismic profiles (Satellite image from Google Earth 2006).

Field Description

<u>Acquisition of the seismic data</u>

The basic purpose of the seismic data acquisition is to record the earth's response to input seismic pulse as a function of time. This record holds the time history of the ground motion either in analog or in digital form. The main objectives of different data acquisition techniques are to suppress the random as well as the coherent noise. The base of low velocity weathering layer produce a seismic interface with very strong reflection coefficient. In order to record seismic data for the present study, a multi-channel signal enhancement seismograph of GEOMETRICS INC. (Geode and Strata Visor NZ model) has been used. Four seismic profiles were shot in the survey area as shown in Fig. 1. The common depth point (CDP) seismic reflection methodology used in this study was similar to the method as applied to petroleum exploration, with the exception of scale. The high-resolution shallow reflection quality is strongly dependent on the field parameters e.g., Knapp and Steeples (1986) and the selection of a suitable energy source Miller et al. (1994). The source selected for this study was an IVI Minivib in a buggy style configuration. Three sweeps with a frequency range of 30–300 Hz were recorded individually at each shot station. Single 40-Hz geophone was planted every 15 m.

High-resolution seismic reflection analysis and interpretation

The acquired high-resolution seismic reflection data was processed to enhance signal to noise (S/N) ratio, for which Landmark's ProMax Software Package has been used. In general terms, processing procedure of the shallow seismic reflection data is similar to that of conventional seismic reflection data Steeples and Miller (1990); Feroci et al. (2000). However, the near surface layers generally have low velocity value that varies abruptly with lateral extension, which often make seismic reflections subtle and noisy. Hence, as compared to conventional processing techniques, more attention should be paid to some pitfalls of shallow reflection data e.g., spatial aliasing, removing of air-blast noise, ground roll, and refraction muting Steeples and Miller (1998); Steeples (2000). Frequent testing was carried out for refraction statics modeling. It was noticed that static is the major issue in this sand dune area especially in some part of the line where there is about 10-m elevation difference. First breaks have been picked for each shot and built refraction static model in generalized linear inversion (GLI) refraction static calculation software. The following are the key steps for refraction modeling and calculation.

– First break picking on all shot records of test line from 30 to 400 m offset.
– Model/calculate/out-put refraction static for whole line using the same offset range.

Signal to noise ratio was good in general. Frequent testing was carried out to improve the signal strength by applying filtering, surgical mutes, frequency–space (FX) deconvolution, etc. Deconvolution panel tests and stacks with different predictive distance were tried to enhance the frequency bandwidth and resolution of data. Autocorrelation before and after deconvolution was also generated to quality control (QC) the results. Based on the careful analysis on above test results, the
frequencies. Velocity picking for stacking and proper migration of data was another key area. Interactive velocity analysis along with the constant velocity stacks were produced at key locations along the lines for confident velocity picking. With ProMAX interactive velocity analysis package, one could QC the super gather (11 adjacent CMP's that lie close together) with and without applied normal moveout (NMO) correction, stack panel, semblance plot, and constant velocity stack panels to QC/ verify the velocity functions. Three-velocity passes were carried out with revision of velocities and application of residual static. The Kirchhoff common offset dip moveout (DMO) was applied to data on applied NMO correction with smooth best velocity functions and the process was revised by utilizing the third pass of velocities after DMO. The application of DMO helps to reduce the CDP scatter, dipping noise attenuation with impossible dips. The velocity analysis was improved which was more appropriate for migration as well as stacking. Fig. 2, 3, 4, and 5 present the final depth images for all the profiles acquired in the areas and predict locations of faults based on horizon discontinuities and in some minor cases fault reflections. Some faults are more obvious than others and thus solid lines indicate faults of high probability and dashed lines correspond to faults of lower probability. The strong reflection common to most of the section at depths ranging 700 to 1,000 m are predicted to be from the bedrock. In all fig., this reflection indicated by an arrow on the left side of the section and depth is in reference to the final datum at elevation 720 m above sea level.

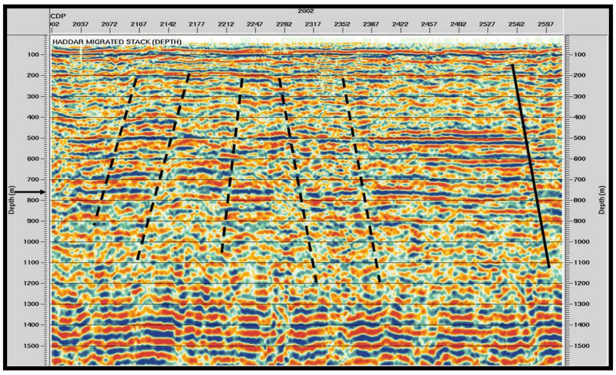

Figure 2. An interpreted seismic section showing the bedrock and faults at site 1.

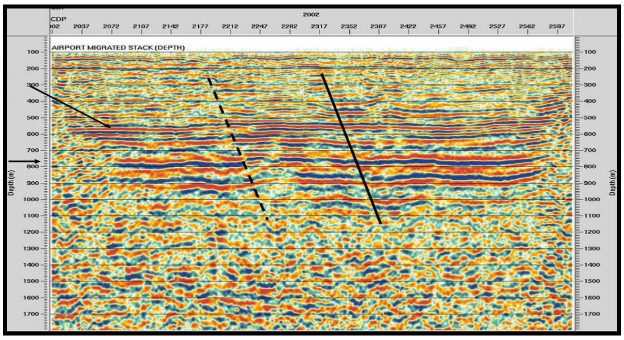

Figure 3. An interpreted seismic section showing the bedrock and faults at site 2, the additional arrow points to a reflection that is unique to this line.

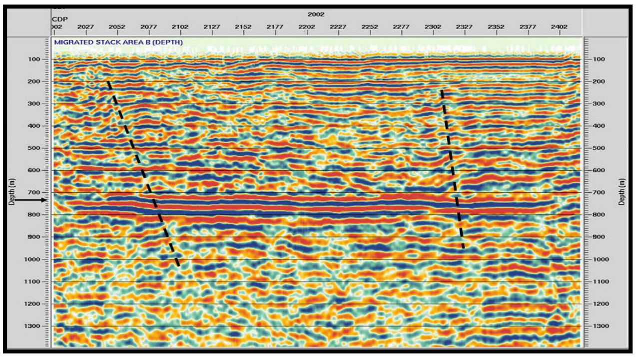

Figure 4. An interpreted seismic section showing the bedrock and faults at site 3.

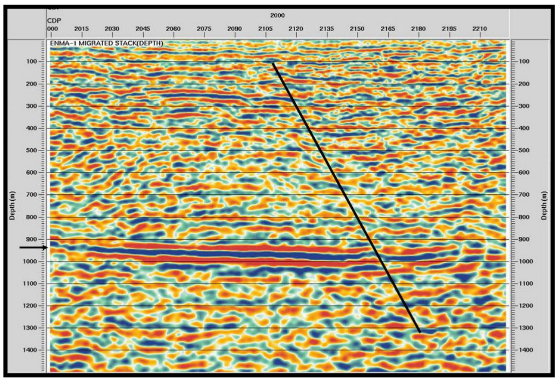

Figure 5. An interpreted seismic section showing the bedrock and fault at site 4.

CONCLUSIONS

The main purpose of this study is to map the bedrock layer using four high-resolution seismic reflection profiles. High-resolution seismic reflection methods were successfully used to map bedrock. The bedrock reflection is clearly present in all sections as a strong event. The large impendence change between the sediments and the hard rock is the cause for the strong reflection. We ended up with depths ranging between 700 m and 1,000 m for the bedrock with 750 m being a common depth value. The deepest we obtained is close to 1,000 m in the site 4. The Bedrock dips towards south of southwest of the area. Major faults (NW-SE trend) observed in the bedrock throughout the studied area. The shape and characteristics of the bedrock reflection varies along lines and from one area to another. These changes may be attributed to the nature of the transition from sediments to the bedrock and could be also related to the water content. The bedrock depth obtained from the seismic agreed with the well information.

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