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Using High Resolution Seismic Reflection for Imaging of a Shallow Gas Horizon within Urban Vienna, Austria

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SUMMARY

The current subway network of Vienna should be expanded to the south. For the planning it was necessary to drill several exploratory wells along possible corridors. In one of these exploratory wells gas was encountered in a 20 cm thick sand layer at a depth of 38 m below ground elevation. The gas bearing layer consists mainly of sand and gravel and might be part of braided stream deposits of Pannon D. In the course of this research project the lateral extension of this gas bearing layer should be mapped. Considering the resolution potential of seismic reflection at these depths and the strong velocity/density contrast the gas bearing sand would provide we decided to use this geophysical method for delineating the lateral extension of the gas bearing horizon.
Introduction

The current subway network of Vienna should be expanded to the south. For the planning it was necessary to drill several exploratory wells along possible corridors. In one of these exploratory wells gas was encountered in a 20 cm thick sand layer at a depth of 38 m below ground elevation. The gas bearing layer consists mainly of sand and gravel and might be part of braided stream deposits (Bernhard, 1993) of Pannon D. In the course of this research project the lateral extension of this gas bearing layer should be mapped. Considering the resolution potential of seismic reflection at these depths and the strong velocity/density contrast the gas bearing sand would provide we decided to use this geophysical method for delineating the lateral extension of the gas bearing horizon. Shallow seismic reflection imaging has proven to be a valuable tool for identifying small targets at these shallow depths (e.g. Bachrach and Mukerji, 2001; Büker et al., 1998; Eichkitz et al., 2009; Khattri et al., 1979; Miller et al., 1989; Schmelzbach et al., 2005; Shitivwiman et al., 1998; Sloan et al., 2010).

Study area and acquisition

The study area is situated in an urban part of Vienna, Austria near residences, business developments, and active transportation corridors. The seismic profiles align north-south along “Favoritenstrasse” road with the south end at “Stockholm Platz” (Figure 1). The Favoritenstrasse is a road with moderately to heavy vehicle traffic with a dedicated tramway line. This transportation system leads to the biggest problem encountered on this project, which was vehicle traffic generated pseudo random noise during the acquisition. To minimize this noise in our data we acquired all data at night when the traffic volume was the lowest and when the tramway was not operating.

Figure 1 Map showing the position of available wells and the geometry of the acquired seismic reflection data WL1001. In well KB 1103 in a depth of 38.2 m beneath ground elevation a horizon bearing gas was found. The seismic data was acquired next to a road with heavy traffic and a tramway. Therefore, it was necessary to perform acquisition at night to reduce random noise produced by traffic.
The aims of this project were on the one hand to delineate the lateral extension of the gas bearing horizon and on the other hand we wanted to test the general applicability of shallow reflection seismic in such an area of investigation. Furthermore, we wanted to test the effect of different geophone types, varying geophone and source distances, and different type of sources on the quality of the seismic reflection profile. The geophones and sources were positioned on the grass strip next to “Favoritenstrasse”. Adjacent to the seismic profile along this grass verge, were the three exploratory wells (KB-1100, KB-1103, KB-1105). In well KB-1103 the gas bearing horizon was encountered at a depth of 38 m below ground surface.

On all shot records we used two types of geophones (eight 10 Hz geophones grouped at each position and single 40 Hz geophones). Both types of geophones were deployed at the same time and both sets were live for all shots. In total the recorded seismic profile is 150 m in length. A Summit II+ seismograph with 191 active channels was used to record the data. For sources, we tested surface explosives, a 10-gauge Buffalo gun, and a sledgehammer. In figure 2 shot gathers for the two types of geophones and for the three different sources are displayed.

![Figure 2 Shot gathers](image)

*Figure 2 Shot gathers. The left side of each picture shows 40 Hz geophones with receiver spacing of 1 m. The right side of the pictures shows 10 Hz geophones with a receiver spacing of 2 m. Different sources were tested: (a) Explosives (4g Detonex), (b) 10 gauge Buffalo gun, (c) sledgehammer.*

**Processing of reflection data**

We conducted processing first on the shot gathers from the 40 Hz geophones for all sources and afterwards we performed processing on the shot gathers from the 10 Hz geophone groups. The data were processed using a standard processing sequence that included spherical divergence correction, multi-channel spiking deconvolution, single-channel spiking deconvolution, velocity analysis, surface consistent residual correction, NMO, stretch mute, AGC, CMP stacking, bandpass filter, F-K dip filter, and weighted trace mixing were applied. Additionally, we simulated different acquisition geometries by processing each input set with different geophone and shot station groupings. This
means that we used in one case every second source and receiver station, then in the second case
every receiver station and only every second shot station, and finally, we used each shot and receiver
station. Comparison of the four different data groupings through the processing flow shows that only
the section with the 40 Hz geophones and a receiver and shot spacing of 1 m leads to a high resolution
seismic with sufficient lateral resolution to be useful for our geological problem. In this case, the
nominal fold of 57 was achieved. Due to the high noise level in an urban environment, high fold is
essential for a quality seismic interpretation.
Comparison of the different sources for acquisition showed that best results can be achieved by using
explosives as energy source.

Interpretation

For the interpretation of the seismic sections it is important to have data with the highest lateral and
vertical resolution plus a high fold. Therefore, we have chosen to use the seismic section with an
average fold of 57 acquired with 40 Hz geophones and receiver and shot point spacing of 1 m.
Interpretation was principally done in the time domain, but we have also used depth converted seismic
section. Depth conversion of the seismic section was done with the help of stacking velocities. In the
seismic section a few structural elements (faults) are visible (Figure 3). These faults are interpreted as
lateral faults with an additional vertical component.

Figure 3 Interpreted seismic section in the time domain. The gas bearing horizon has a thickness of
20 cm, therefore it is not possible to resolve the top and bottom of this horizon. Nevertheless, the gas
bearing horizons appears as a “bright spot”.

The gas bearing sand horizon is only 20 cm thick (according to well KB-1103). Thus, it is not
possible to identify top and bottom of the horizon in the seismic section as this is below the seismic
resolution. Nevertheless, it is possible to illuminate this zone as it is within the seismic visibility.
Additionally, we can see high amplitude reflectors (bright spot, Khattri et al., 1979) in the seismic data caused by the gas bearing horizon. The gas bearing horizon terminates toward the south at the south dipping lateral fault. Below that horizon some downlapping reflectors can be seen that are interpreted to be progradational features. This horizon is cut by another lateral fault that vertically displaces it. Underneath this horizon other downlapping features are visible. This features mark the top of the Sarmatian sediments.

Conclusion

With the test profile WL1001 it was demonstrated that it was possible to detect a gas bearing horizon at a depth of around 38 m. The best results in an urban environment with high noise level can be achieved by acquiring the data at night and using a high fold seismic section. Using geophones with a resonance frequency of 40 Hz was additionally very helpful. With this experience it is possible to plan new seismic surveys using similar acquisition parameters to confidently identify similar geological feature conditions.

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References


