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# 3D Model Based Acquisition Design for Imaging the Deep Vienna Basin

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## SUMMARY

For imaging the deep buried structures of the deep Vienna Basin all available subsurface information of the investigation area are combined in a three dimensional model, including seismic velocity and attenuation. This model is used to design a target orientated acquisition design, by determining the main acquisition parameters and by applying ray tracing to get the illumination of the deep horizons. The different ray tracing options of the used software are compared to get adequate illumination results in respect to the calculation time. The result is used for pattern dimensioning and is compared with the Neogene Basin Survey, which is already carried out in the 1980´s and designed for the Neogene section above the deep Vienna Basin.

## Introduction

The Vienna basin is located in the east of Austria and consists of two major units: The uppermost *Neogene section* (floor 1 in Figure 1) - the actual Vienna basin, and the underlying *Northern Calcareous Alps* (floor 2 in Figure 1) - the *deep Vienna Basin*. Extensive exploration and hydro carbon production activities took place during the last decades in the sedimentary strata of the *Neogene section*. In the recent past the focus of interest was extended to the underlying *Northern Calcareous Alps*, which are assumed to be an area of high oil and gas prospectivity. Therefore a seismic image of these complex structures in the *deep Vienna Basin* is of high interest for the oil and gas industry.

Due to intense exploration and production activities in the *Neogene section* the build up of the uppermost 3000 meters is well known. In contrary the *Northern Calcareous Alps* underneath are rather poorly illuminated. This is caused by a bad signal to noise ratio and the lack of high frequencies in the seismic reflection signals coming from greater depths, which leads to a more blurred image of the area underneath the *Neogene Basin floor* (base of floor 1).

In order to illuminate and image the geological structures underneath the *Neogene Basin floor* it is necessary to design a target oriented seismic acquisition configuration. To set up such a configuration an improved seismic velocity model is required.

One objective of this study is to design a comprehensive model, which contains seismic velocities, geological structures and attenuation information as well. The final model covers an area of approximately 325 km².

A further objective is to use the velocity model and determine the most important parameters for a target orientated 3D acquisition design. These are bin size, maximum frequency due to aliasing, minimum and maximum offset, vertical and horizontal resolution, attenuation, migration apron as well as station and line interval. One focus is also on the ray tracing based illumination analysis. First the optimum adjustments for the used software is determined and compared with a well known ray tracing algorithm. Then the results are used to determine the minimum required maximum offset and the dimension of the pattern to get a suitable image of the deep subsurface.

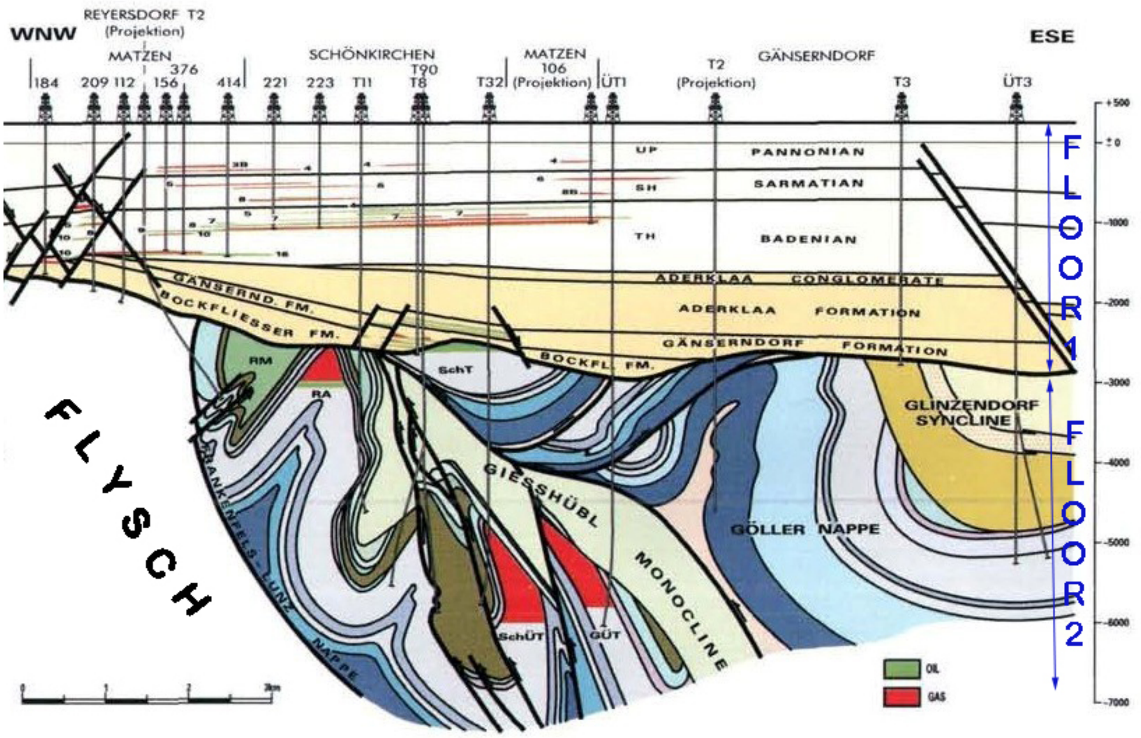


***Figure 1*** *Cross section through the Vienna Basin in the investigation area (after Hamilton et al., 1999). Floor 1 is representing the Neogene section and floor 2 the main target of the acquisition design (The Northern Calcareous Alps). The lower part of the picture represents a crude structural concept of the deep Vienna basin, based on geological understanding and well data.*

**Methodology**

Building a comprehensive model and the 3D survey designing consists of four main steps:

1) Setting up a velocity and structural model for the uppermost *Neogene section* and the underlying *Northern Calcareous Alps* from 3D seismic- and VSP-data using PETREL 2009
2) Extracting Q-factors from VSP data sets to achieve attenuation data
3) Determining the main acquisition parameters by using GEDCO`s *"Omni - 3D survey design and modeling"*.
4) Illumination analysis by using ray tracing, also with GEDCO`s software.

## 1) Velocity and structural model

The constructed model in Figure 2 consists of two main blocks: The upper block from the surface down to the *Neogene basin floor* includes 5 strong seismic horizons and a 3D-velocity field, which describes the well known Neogene. The lower block, which represents the deeply buried *Northern Calcareous Alps*, includes geological information as a crude structural concept. To achieve seismic velocity data a combined set of sonic log data and seismic velocities originating from checkshot data is utilised. To make these two kinds of data sets comparable and to obtain reliable velocity information, smoothing and downsampling to the same data point interval was crucial.

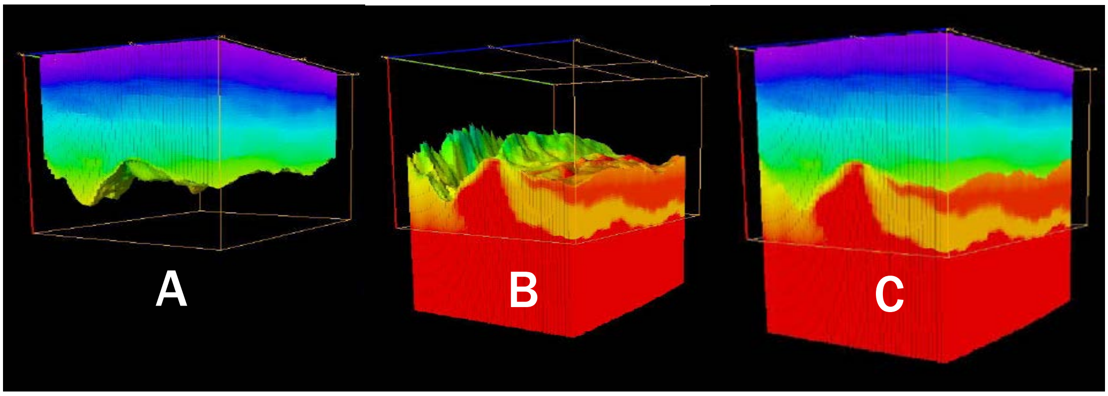


***Figure 2** Combination of velocity field **A** (Neogene section) and **B** (Calcareous Alps) results in the complete velocity distribution of the whole considered area **C**. Lateral velocity distribution in **B** is assumed to be constant.*

## 2) Extracting Q-values from VSP data

To achieve information of the attenuation of seismic waves in greater depths two approaches are applied.

### Approach 1: Spectral ratio method

Seismic waves, as they travel through elastic media, are facing a frequency dependent loss of amplitude, the so called intrinsic attenuation. To quantify this attenuation the Q-value is the governing parameter. Following De et al. (1993), the Q-value can be calculated from the logarithmic ratio of two spectra of the same seismic wave in different distances.
A set of VSP seismic data was utilised for this approach. To achieve reliable results with this method, input data itself has to fulfill strictly the requirements given in De et al. (1993).

### Approach 2: Forward spectra modelling

This method is based on the idea to compute synthetic spectra for every single trace. Comparison with the spectra of the original data sets and iterative improvement of Q-values was done consequently to obtain the artificial data set, that shows the best fit and the least variance (see Figure 3).

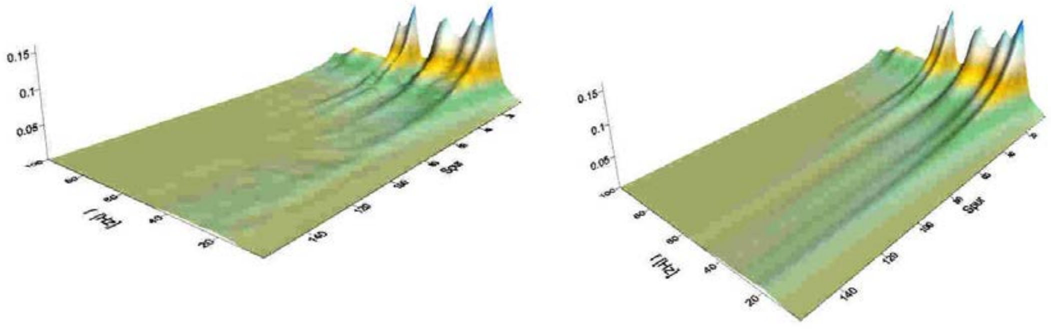

***Figure 3*** *Real (left) and artificial (right) spectra of the VSP data set. Comparison and iterative improvement led to best fitting results.*

### 3) Determination of acquisition parameters

To determine the main acquisition parameters for the seismic investigation of the second floor of the Vienna Basin three horizons are selected. These are generated out of the velocity model and are called "target layer". All three layers are located in the *deep Vienna Basin*, where Horizon 1 represents the *Neogene Basin Floor*, Horizon 2 includes the base of the *Giesshübl Monocline* and the *Reyersdorf Dolomite (RA),* and Horizon 3 the base of the *Frankenfels-Lunz nappe* (see Figure 1).
Table 1 gives a summary of the achieved parameters.

| | | Horizon 1 | Horizon 2 | Horizon 3 |
|---|---|---|---|---|
| **Bin size B after migration** | m | 25 | 14 | 15 |
| **Maximum frequency due to aliasing for B=25m** | Hz | 50 | 30 | 32 |
| **Maximum frequency, due to attenuation** | Hz | 32 | 31 | 30 |
| **Vertical resolution** | m | 46-51 | 55-61 | 60-68 |
| **Horizontal resolution** | m | 51-56 | 64-75 | 72-95 |
| **Maximum offset, due to 30° NMO stretch** | m | 25 | 14 | 15 |
| **Migration apron (NE-SE-SW-NW)** | km | 1.5-1.4-1.8-1.5 | 3.2-3.2-2.6-2.2 | 3.4-3.7-3.3-2.4 |
| **Station interval** | m | | 50 | |
| **Line interval** | m | | 1000 | |

***Table 1*** *Acquisition parameters, determined with the aid of the 3D velocity model.*

### 4) Illumination analysis

The illumination analysis is mainly used for pattern dimensioning. Therefore, at first, a 3D survey is created, which follows the determined acquisition parameters and is called *Deep Basin Survey*. Then the illumination (migrated fold) of the three horizons is computed for an all-live pattern. Further the inline and crossline offset is limited successive and the modified results are compared. So the maximum required offset and hence the required pattern dimension can be determined. Next, the result is compared with the survey, which was designed for the *Neogene section* and which was successfully carried out in the 1980´s. Therefore it is called *Neogene Basin Survey*.
The software provides several options to apply the ray tracing algorithm, which computes to every source-receiver pair the fastest travel path. This process can be very time consuming. The algorithms are tested with a 150 source-receiver pair survey and also a benchmark test with Hole's ray tracing algorithm (Hole et al., 1995) is made to check the accuracy.
As optimum options for calculating the illumination, which delivers affordable results in accuracy and calculation time, a minimum model resolution of 200 m in x, y and z direction and the option "intensive search" are used. Moreover, the velocity model has to be approximated with constant velocity layers. The illumination results for Horizon 2 are shown in Figure 4, where C is offset limited to 6 km in in- and offline direction. Hereby, the coverage of the horizon is still adequate.

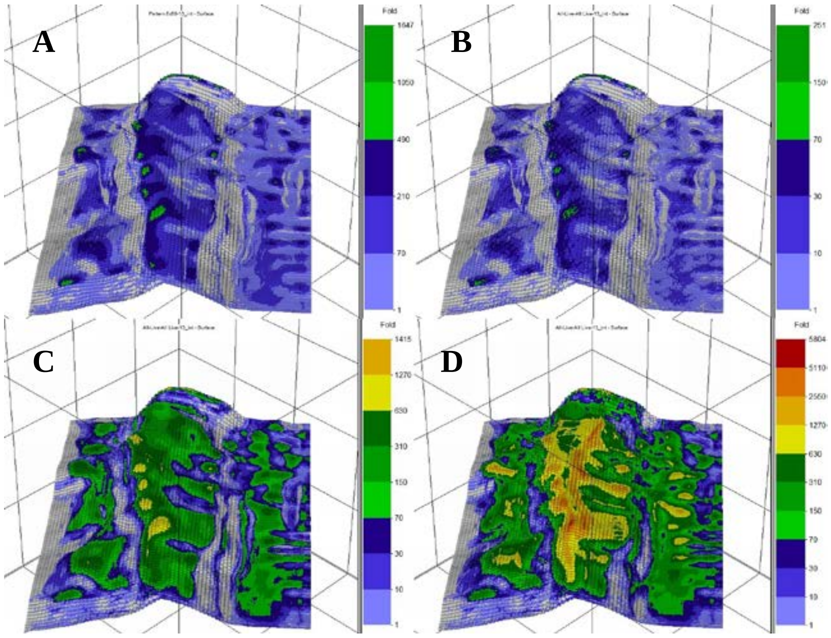


***Figure 4** Illumination results for Horizon 2 with the Neogene Basin Survey in **A** (Offset 1525m inline and 1625 crossline) and the Deep Basin Survey in **B**, **C** and **D**. The offset limitation is 1625m inline and 1525 crossline in **B**, 6000m inline and crossline in **C** and without limitation in **D** (all-live).*

## Conclusions

A comprehensive model that contains structural, velocity and attenuation information is a valuable data input for designing a target oriented seismic data acquisition configuration. Combined velocity data originating from sonic logs and checkshots as well can be used to improve an existing 3D velocity field.
The VSP data set used for calculating the attenuation does not meet the strict demands on data quality. Therefore the spectral ratio method leads to unstable results. Using the forward modelling approach the results are sufficiently reliable.
The main acquisition parameters for the survey design can be determined fast by using the three dimensional velocity model and are mainly affected by input parameters and computation method of the software. Nevertheless, the resolution will be relatively worse, due to the low achievable frequency and the migration apron will be large, due to the great depths.
The illumination of the main target (Horizon 2) by using the *Deep Basin Survey* has an increased fold (factor 1.3), a much higher maximum offset (factor 7.2), but also more active channels (pattern 12x240) in comparison to the *Neogene Basin Survey* with a pattern of 8x60.

## Acknowledgements

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