Geophysical detection of deep aquifers in the Styrian Basin

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Abstract: The combination of seismic reflection and geoelectric investigations allows an uninterrupted visualization of deep aquifers all the way from the ground surface. On the basis of this visualisation, the geological position of existing wells can be identified, thus enabling their balanced management. The location of new boreholes can also be optimised, in order to exploit coarse-grained aquifers.

Key words: seismic reflection, geoelectric, deep aquifers, Styrian Basin, Miocene

INTRODUCTION

In the summer of 2002 three new high-resolution seismic lines were measured to investigate the shallow subsurface of the north-eastern part of the Styrian Basin. Figure 1 shows this part of the basin, together with the location of the seismic investigations, which are described in the following paper. The Styrian Basin is filled with up to 3000 m of Neogen sediments. Water suppliers were prepared to drill up to 250 m in order to reach water reservoirs of sufficient quality and quantity. An investigation into the structure and lithology (clay or sand) of the subsurface was therefore necessary.

To distinguish between clay and sand layers in the first 100 m a resistivity survey was carried out. The interpretation of such a geoelectric investigation is usually straightforward. Areas with a resistivity smaller then 100 Ohmmeters are clays, and areas of about 200 Ohmmeters and higher are medium or coarse-grained sandy sediments, which are potential aquifers. It is not possible to determine whether the aquifers are full of water or dry using this technique. The geological interpretation can become complicated if the total depth of sediment is smaller than the penetration depth of the resistivity survey. In this case it may be difficult to distinguish between bedrock, which has a high resistivity, and high resistivity (dry) sands. The resolution of geoelectric investigations decreases rapidly with investigation depth.

Seismic reflection methods can be used to visualise the subsurface, from approximately 50 meters beneath the surface down to any arbitrary depth. In this example the field parameters for the seismic data acquisition were designed to visualise down to 500 m depth. The receiver distance was 5 m and the source distance was 10 m. Approximately 40 g of explosives were used as the energy source, which were detonated electrically at ca. 1 m depth. Two of the seismic lines (A and B) were situated in the assumed direction of the bedrock and sediment dip, and one seismic line (C) connected the lines A and B. An existing seismic line (D), which crosses line A, was also available for the interpretation.

Scientific paper

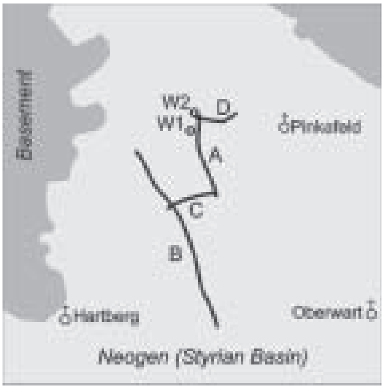

Figure 1. Map of the seismic lines and the situation

The following paper presents this example, where the combination of these two geophysical methods was used to visualise the subsurface, from ground level down to 500 m depth.

SEISMIC REFLECTION, WELL LOGGING AND INTERPRETATION

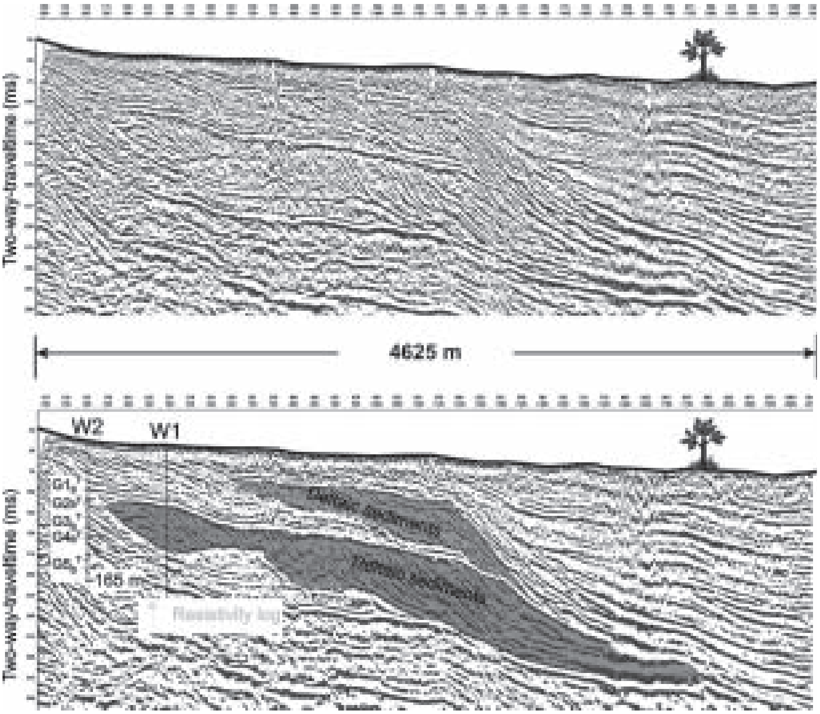

Figure 2. Seismic line A. Upper figure - unmigrated seismic line; Lower figure - migrated and partially interpreted seismic line, with the geological input from W2 and the resistivity log from W1. T and B represent the top and bottom of the gravel-layers G1 to G5 respectively. The positive scale of the resistivity log increases to the right. There is a vertical exaggeration of 1:5

The seismic reflection line A has a total length of 4625 m. The upper part of Figure 2 shows the unmigrated time section of line A. The borehole W1 was drilled 20 years prior to this seismic study. A resistivity log and its interpretation were available as an input for the geological interpretation of the seismic line. On the basis of the interpretation from seismic line D, the well W2 was drilled in the winter of 2001/2002. Technical problems were encountered during the drilling works, and the borehole collapsed after the drill-bit was extracted due to the presence of coarse-grained sediments (gravel) and excessive water flow into the borehole. For this reason, only lithological information was available from the cutting material.

The lower part of Figure 2 shows the interpretation of the migrated time section and the input information from the two wells. From an inspection of the borehole W2 cuttings it could be seen that there are alternating clay and gravel layers. The resistivity log from well W1 has maximum values of about 300 Ohmmeters (right side) representing sands, which could be exploited as aquifers. The interpretation of the seismic facies shows a 35 m thick prograding delta sequence including sands, with high resistivity sands particularly at the top. Sands are also present at the tops of deeper prograding sequences.

Due to the technical problems encountered during drilling, it was not possible to take a borehole log from W2, and so only formation tops are available from the cutting inspection. This shows a succession of gravel/pebbles and clay layers, which is in complete contrast to the well W1. At the time of preparing this paper, two new wells are being drilled near the well W2. The deltaic sands at the centre of the seismic line, particularly at their top, are a good target for deep-water aquifer prospection.

RESISTIVITY SURVEY

The near subsurface area was investigated with a resistivity survey. The 2D-geoelectric profile and the geological information from well W2 is shown in Fig. 3. The resistivity of clay is smaller than 100 Ohmmeters and is shown in Figure 3 as a white layer. The grey and black layers represent sands or gravel. Near the surface, the geoelectric profile corresponds well with the lithological borehole information. However, since resolution decreases with depth when using the geoelectric method, it was not possible to detect gravel layers below layer g1 due to rapid changes between thin gravel and clay layers.

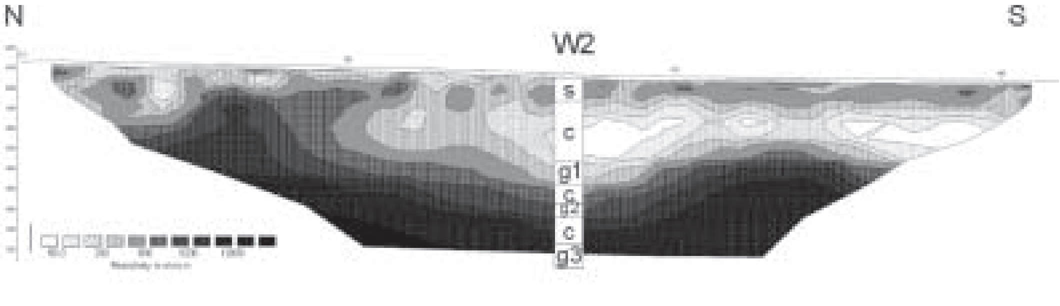

Figure 3. Resistivity section and the well W2 with lithology from cutting inspection. s=sand, c=clay, g1-g3=gravel 1-gravel 3. There is no vertical exaggeration.

The gravel layer g1 appears to have its catchment area at the surface near the borehole. For deeper aquifers, the distance from the borehole to the catchment location increases proportionally. The clay layer above g1 tapers out to the north of W2.

CONCLUSION

In response to the water suppliers' need to drill up to 250 m to obtain ground water in sufficient quality and quantity, high resolution seismic reflection surveys have been carried out in the Styrian Basin over the last 10 years. On the one hand, the seismic surveys give an overview of existing wells and their geological relation. On the other hand, seismic reflection surveys are helpful for forecasting the geological situation of planned wells, and to optimise their location in sandy layers. Recently, the catchment area of deep-water aquifers has been located using a combination of 2D-geoelectric studies together with seismic reflection surveys.

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