Utilization of Seismics for Geothermal Prospecting: Case Studies from the Carpathian Mts, Central Europe

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ABSTRACT

Geothermal energy in the Central European region is discussed most in scientific, industrial and political agenda, but the use of this resource for the electricity generation is still negligible due to lack of funding. The seismic method is one of the geophysical exploration methods for geothermal resources. In this paper we show the use of a less expensive seismic method and compare it with traditional "commercial" 2D and 3D seismics used for hydrocarbon prospection. The "light" seismic performed, for example, by Terraloc instrument provides good results where the depth of geothermal sources is about 1500m – 2000m with better visualization tool as compared to the "normal" seismic method.

1. INTRODUCTION

Prices of fossil fuels, potential instability of their production and an increase in environmental awareness has put renewable energy at the top of scientific, business and political agenda. There are numerous successful geothermal projects around the world, but funding for geothermal projects in the Central European region has not been forthcoming. The interest in these energy sources increased even more after an agreement of EU countries concerning each country's duty to produce 20% of the energy consumption from renewable energy sources. One of the clauses in this agreement is subsidizing the purchase of electricity coming from the renewable energy sources.

Geothermal energy is one of the renewable energy sources with several advantages as compared to the other types of renewable energy sources like wind and solar. Geothermal energy is reliable, stable, cheap, sustainable and environmentally friendly. However, the main challenge is in the exploration risk, uncertainty in production and initial financial investiment.

There are various surface geophysical exploration methods used in the evaluation of geothermal resources such as gravimetry, magnetometry, magnetotelluric and seismics. In this study we show two different seismic exploration methods used for the location of depth and geometry of geothermal reservoir. The first method is a "normal" commercial 2D seismics usually used for hydrocarbon exploration and the other one is "light" seismic instrument Terraloc usually used for shallow seismics.

GEOLOGICAL SETTING

Geothermal energy has a high potential in the countries of Central Europe. The reservoirs are located in the areas with thinned earth crust and Neogene to Quaternary volcanic rocks with increased geothermal heat. The geothermal potential areas in the Central areas are the Neogene / Quaternary sedimentary basins such as Vienna Basin in Austria, Vienna, Danube and East-Slovakian Basins in the Slovakia, Transcarpathian Basin in the Ukraine, Pannonian Basin in Hungary and South-Carpathian Basin in Romania (Figure 1).

Figure 1: Location map of the Carpathian Mts. and neighbouring countries. Red circles denote areas with high potential of geothermal energy. Black arrow shows position of the Slovakia geothermal reservoirs

The mean temperature of the reservoirs is 120°C at the depth 3000m suggesting low-temperature geothermal sources, which is however, still interesting from the viewpoint of utilization of this energy for electricity production. The hydrogeothermal reservoirs are mostly found within carbonate rocks with high degree of fissibility and karstification and in fewer cases, in coarse-grained Neogene rocks (sandstones and conglomerates), Neogene volcanic rocks, and fissured Paleozoic rocks.

The target of our study was the Mesozoic carbonates that form the basement of Paleogene Central-Carpathian Basin and Neogene East-Slovakian Basin in the Slovakia (Figure 2). The depth of the carbonates is about 1000m to 2200m as observed from wells drilled in the study area. The carbonates belonging to the Krizna Nappe Unit (Early Triassic to Late Cretaceous) are highly karstified and in both cases dip from the basin margins beneath the basin fill which is between 4 and 8km thick. The carbonates have the coefficient of permeability 8.16 x 10^{-5} to 2.089 x 10^{-4} m^2 s^{-1} and filtration coefficient of 9.44 x 10^{-8} to 8.50 x 10^{-6} m s^{-1}. The water discharge is up to 65 Ls^{-1}. The reservoir temperature at the depth of 3000m ranges from 105°C to 143°C.

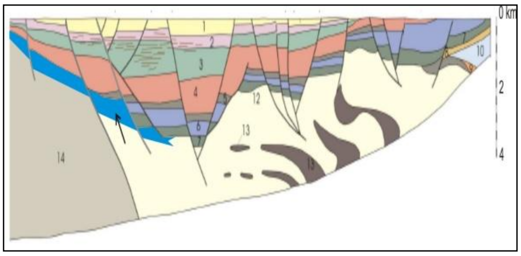

Figure 2: Geological profile across the East-Slovakian Neogene Basin showing Neogene basin fill (1 – 11) and the basement rocks (12-14). The geothermal reservoir (blue colour) is marked by an arrow.

2. MEASUREMENTS AND INTERPRETATION

3.1 Commercial 2D Seismics

The commercial 2D seismic method includes about 21km of seismic sections with the geometry of geophons and shot points in two parallel lines. The number of records in the first line was 184 with the length of the CDP line being 6950m, length of the receiver line being 6975m and CDP distance being 12.5m. The second line had 213 records with the length of the CDP line being 7000m, length of the receiver line being 6975m and CDP distance being 12.5m. After processing the seismics were interpreted by the software PETREL. The vertical resolution of the seismics was about 8m at the depth of 2000m providing very good data for definition of the geometry of geothermal reservoir (Figures 3 and 4).

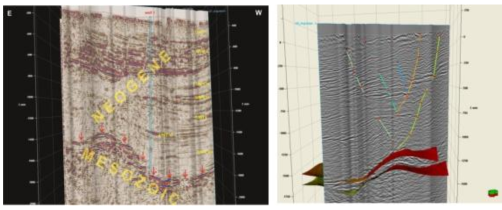

Figure 3: 2D seismics showing the position of the geothermal reservoir (marked as „Mesozoic“) beneath a thick cover of the Neogene sediments. The figure left shows normal faults in the studied profile as well as top and base of the reservoir

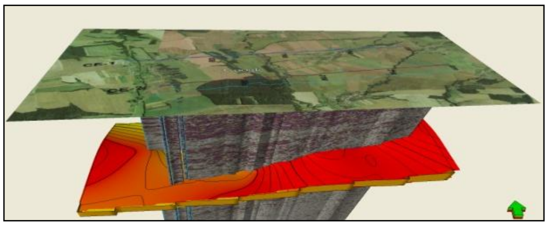

Figure 4: Visualization of the location of the seismics and position of the geothermal reservoir in the studied area.

3.2 “Light“ Seismics

The seismic measurements were performed using the instrument Terraloc Mk8 with 24 geophones SM-4B 10Hz. The seismic sampling interval was 500µs and the sampling step 8192. The distance among geophones was set to 12.5m. The shot source was 0.3 to 0.5 kg explosive Eurodyn 2 000 blasted from 3m deep wells. We realized two crossing seismic lines (Figure 5) using inline geometry with the shot in the middle of the geophones and 50m from the first geophone. The signal output was in the standard SEG-D format, which was subsequently processed by the software REFLEXW and exported in SEG-Y format. Finally, these files were imported to the softvare PETREL for interpretation of geological structure.

The resolution of the seismic method was satisfactory clearly showing the boundary between the shales and alternating shales and sandstones, belonging to the basin fill, and underlying mesozozoic dolomites. The mentioned lithological units differed by seismic wave amplitudes, frequency and lateral continuity. Based on the reflexes we were able to interpret main faults in the area and top of the assumed reservoir occurring in depth from 500m to 700 m.

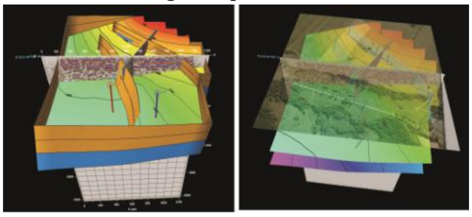

Fig. 5: Interpretation of geological structure from seismic record obtained by “light“ seismic instrument Terraloc Mk 8. The blue colour markes the position of the geothermal reservoir build up by the Mesozoic carbonates, red and blue sticks show the position of the proposed wells. The figure left showes the situation with overlain transparent map of the surface.

3. CONCLUSION

One of the most precise techniques used for prospection of the geothermal sources is seismic method. Besides the high resolution, the method has a great visualization potential if processed using a good software. The best results are usually obtained by commercial 3D and 2D seismics, which are commonly used for hydrocarbon prospection. However, in the Central European region there are the issues of financial restriction and reluctance to invest money to these types of the seismics. A substitution for the mentioned commercial seismics may be application of “light“ seismics, proved to be useful especially in areas where geothermal reservoir does not exceed 1500m. The described example from the Slovakia shows good results obtained by “light“ seismics performed by Terraloc instrument. The application of this method is also easier from the viewpoint of logistics and is essentially less expensive.

ACKNOWLEDGEMENT

This contribution was made in the framework of the project Centre for the research of the integrated combined systems of renewable energy sources efficiency ITMS code 26220220064 supported by the Research and Development Operational Programme funded by ERDF.