WS5-P03

Structural Characterization of a Geothermal Reservoir Using Seismic Depth Imaging Methods

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SUMMARY

Geothermal reservoirs can be characterized by the analysis of heat transport and fluid migration throughout the target rock volume. A hydrothermal simulation which provides insights into these processes, however, first requires detailed knowledge of the structural parameters of the reservoir. Those can be obtained from reflection seismic measurements. For this purpose, we apply two different prestack depth migration methods, namely the familiar Kirchhoff Prestack Depth Migration (KPSDM) and the recently developed Fresnel Volume Migration (FVM) on five seismic reflection profiles in a target region in Southern Tuscany, Italy. The resulting migrated images capture the important reflectors of the target region and provide a good insight in the potential extend of the geothermal reservoir. Moreover, we demonstrate that FVM produces cleaner images than KPSDM due to its “intelligent” aperture limitation. The obtained results provide the structural base on which a hydrothermal evaluation will be performed.

Introduction

The characterization of a geothermal reservoir can be accomplished by the analysis of heat transport and fluid migration throughout the target rock volume. Such data, which can be provided by hydrothermal modeling, minimizes the uncertainties in choosing appropriate locations for exploration wells. However, in order to set up a realistic and geologically reasonable model for hydraulic simulation, the structural framework of the target region first has to be known.

In our work, we compare two different seismic imaging techniques in order to determine the structural parameters of the target reservoir. The region of interest is an area of about 22 x 15 km size in Southern Tuscany, Italy. In this region, five seismic reflection profiles were carried out which recorded a total number of 1605 shots.

Our goal is to image the major seismic horizons on these profiles in order to provide a structural model for the hydrothermal analysis later on.

Methodology

For the seismic imaging we use two different migration techniques: the familiar Kirchhoff Prestack Depth Migration (KPSDM) and the recently developed Fresnel Volume Migration (FVM, Buske et al. 2009). Both methods are based on the integral formulation of migration, however FVM describes a methodological advancement of the KPSDM in that it uses an “intelligent” migration aperture.

For this purpose, the Fresnel volume corresponding to the dominant frequency content of the seismic data is back-propagated from the receiver to a target reflection or diffraction point. In this way, the migration operator is restricted to the area around the imaging point which physically contributes to the imaged reflection. As a consequence, migrated images that are computed by FVM show fewer artifacts and have less migration noise than those obtained by standard KPSDM.

In order to determine a suitable velocity model for our depth migration, we started with a 1D layered model which was derived from a nearby VSP measurement. This model was subsequently refined in the near-surface region by utilizing first-arrival turning ray tomography for each of the seismic lines individually.

Imaging results

Using the derived velocity models, we applied our depth migration techniques to the five reflection lines. The reflection profiles represent 2D seismic data. However, due to their severely crooked geometry we carried out the migrations in 3D using the real source and receiver coordinates. In this way, we ensure that no artifacts will be introduced into the image due to geometry.

The KPSDM and FVM results for a seismic line which crosses the reservoir are shown in figure 1 and 2, respectively. Both images show the major reflectors of the region whereas the FVM result exhibits less migration noise. Of particular interest is the broad reflective zone between 6000 and 8000 meters depth in both images. This reflector probably indicates the so-called “K-horizon” which is known from previous studies near this area (e.g. Brogi, 2008).

Conclusions

We applied two different prestack depth migration techniques to seismic reflection data in order gain insight into the structural features of a geothermal reservoir. Both techniques perform well on this challenging data set. However, we demonstrate that the FVM significantly reduces migration noise. These imaging results form the structural base on which a hydrothermal evaluation of the geothermal reservoir will be conducted.

Figure 1 KPSDM image of a seismic profile across the reservoir.

Figure 2 FVM image of a seismic profile across the reservoir.

Acknowledgements

We thank Enel Green Power for the permission to present this work. We also thank the German Federal Ministry for the Environment (BMU) for funding this research (FKZ: 032589D).

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