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Integrated 3D Structural Modeling – Different Data Sets to Characterize a Geothermal Reservoir in the Vienna Basin

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SUMMARY

In the Vienna Basin one of the main targets for geothermal exploration is the Leopoldsdorf fault system. The geothermal reservoir is in the prae-neogene calcareous alps. For description of the reservoir several old 2D seismic sections, well tops, structural maps and geological cross-sections exist. In the seismic sections in the deeper parts of the prae-neogene mostly chaotic reflections can be observed. Thus, it is not possible to do horizon interpretation in this depth. By combination of the different input data it is possible to enhance the modeling process and it is possible to build a detailed structural model. For geothermal projects it is often very important to simulate thermal and hydraulic flow along fault zones. For this purpose it is necessary to model faults as fault bodies. In the course of this project a workflow for fault body modeling within Petrel is developed. With the help of fault bodies it is possible to assign reservoir parameters not only to the formations but the fault itself too.

Introduction

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Project Overview

The Leopoldsdorf fault system is one of the main structural elements in the southern Vienna Basin. The fault system is developed in several en-echelon faults with a total throw of approximately 4000 m (Wessely, 1983). In the past the fault system was of interest for the oil and gas industry but with minor discoveries. In recent times the fault system becomes more important for geothermal purposes.
The focus of this study is on the description of the reservoir geometry as well as in the description of the flow paths of the hot water. In the project area several seismic 2D lines from oil and gas exploration are available (see figure 1). The aim of the seismic profiles for hydrocarbon exploration was in the neogene basin fill, whereas the target for geothermal exploration lies below in the prae-neogene calcareous alps. In addition to the seismic data wells with log information, structural maps and geological profiles are available. By combination of these different data sets it is possible to develop a detailed structural model of the subsurface with the focus on the prae-neogene formations.

Method

The 2D seismic profiles were recorded and processed in the late 80s. To get a clearer image of the subsurface on some of the seismic profiles a poststack signal enhancement was performed. With the help of the seismic sections it is possible to map faults. In the sense of horizon interpretation, good results can only be achieved for the neogene basin fill. In the deeper formations hardly any coherent reflections can be seen, only bits and pieces of horizons may be identified. To overcome the problem of horizon interpretation we decided to use a combination of seismic data, well formation tops, existing structural maps and available geological cross sections. All the data, except the seismic data, are in the depth domain. Therefore it is necessary to time-depth convert either the seismic interpretation or the whole seismic sections itself. For the time-depth conversion a robust velocity model, based on stacking velocities, checkshots and sonic logs is build (Eichkitz & Amtmann, 2010). Because we want to directly combine the interpretation of the seismic data with all the other input data we decided to directly time-depth convert the seismic data using the mentioned velocity model.
The geological cross-sections are based on information from well tops as well as on geological analogies (Wessely, 1993, Wessely, 2006). The cross-sections are scanned, loaded into Petrel as pictures and georeferenced at well locations. Interpretation of horizons is done by a combination of all available data, but input is ranked according to their reliability. The most secure data input is from well formation tops, followed by seismic data (where possible), cross-sections have secure depths at well positions, but in between they are assumptions based on existing geological models and on geological analogies. The structural maps are based on well data and old seismic data where time-depth conversion might be a hazy thing. Between these data sets structural maps are solely based on interpolation methods.
Horizon interpretation is done by combining the different input sets with regard to the ranking described above. Fault interpretation is directly taken from seismic interpretation. Structural modeling of the data is done by using the Structural Framework and the Corner Point Gridding approach incorporated within Petrel (Schlumberger Information Solutions).

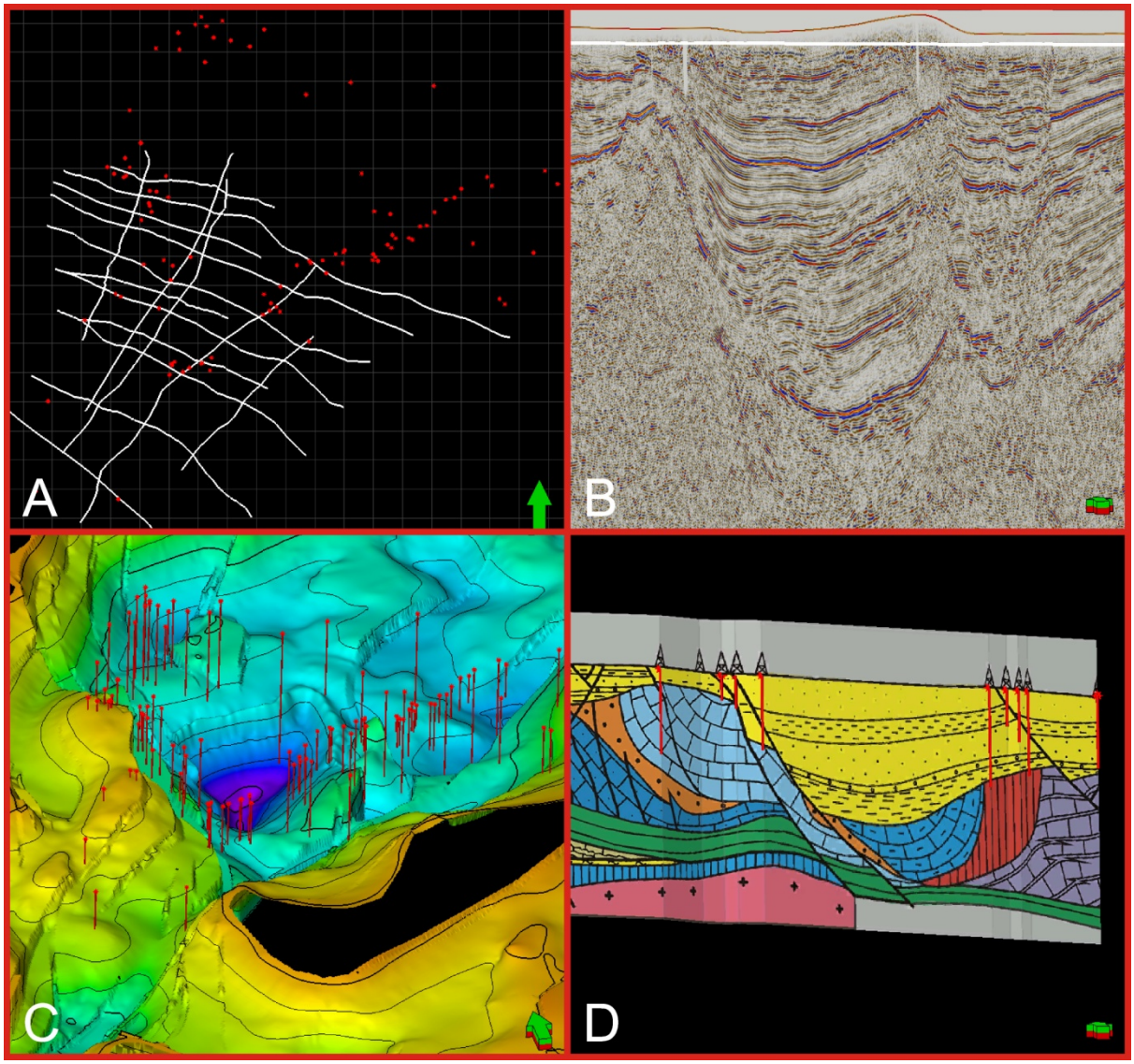

Figure 1 *Overview on available data. The upper left picture (A) shows the available 2D seismic sections (white) and wells (red) in the project area. Picture B illustrates one of the seismic sections after depth conversion. The lower left picture (C) shows one of the given structural maps (Top Prae-Neogene) together with the wells (red). In the lower right picture (D) is one example for the geological cross-sections. The yellow color in this picture indicates the neogene basin fill. Target for the geothermal project are indicated in bluish colors.*

For developing a geothermal site it is necessary to run a simulation case on the model. For this purpose the model cells are filled with reservoir parameters, which are derived from log interpretation, cores and from outcrop analogue studies. For a geothermal reservoir, flow along fault zones is very important. With the used software package it is at the moment not possible to directly model a fault zone as a three-dimensional body.
In the course of this project we try to develop a workflow for modeling fault bodies. The thickness of the faults needs either to be defined by outcrop analogies, by using seismic attributes if possible or in the worst case by simple assumption.

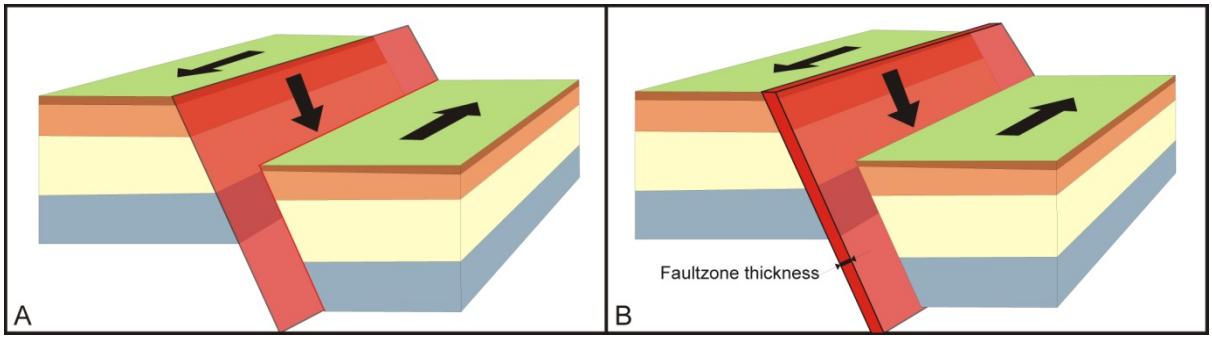

Figure 2 *Principles of modeling faults as plane surfaces (A) and as fault bodies (B)*

The fault body (figure 2) is described by two fault surfaces. In an initial step the interpreted fault surface is modeled to a fault plane. This new fault plane is subdivided into cells. On each corner point of the cells a perpendicular vector is calculated. The length of the vector is defined by the fault thickness. Afterwards the ends of the vectors are taken for generating a second fault surface. With these two fault surfaces (figure 3) a new model is build with the zone between the two surfaces defined as fault zones. This fault zone then has cells like a common formation zone and to the cells reservoir parameters can be assigned.

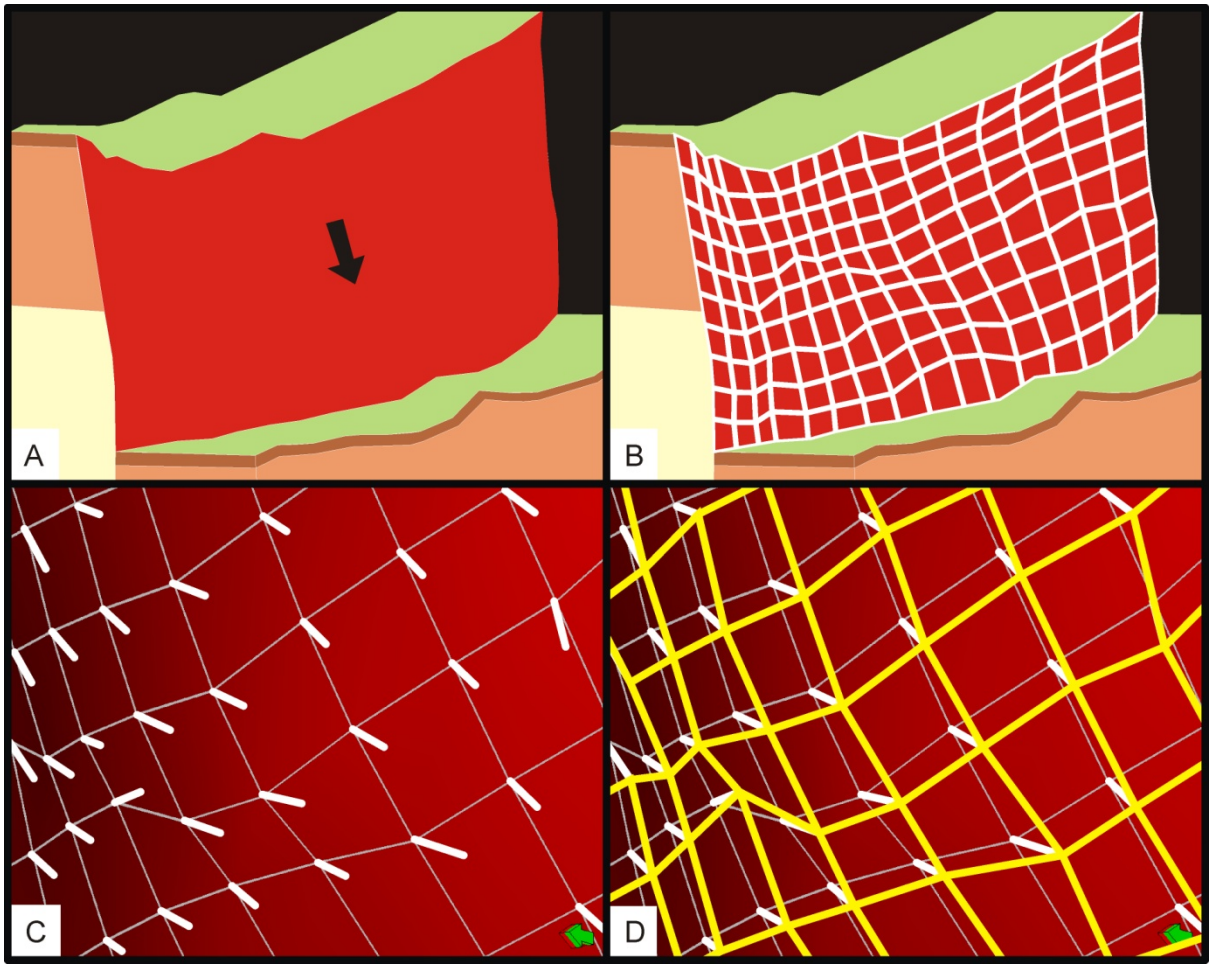

Figure 3 *Working steps for generation of a fault body. The initial fault surface (A) is divided into cells (B) and perpendicular vectors with given length (fault thickness) are generated (C). At the end of these vectors a new surface is generated (D). The newly created and the initial fault surface define the fault zone as fault body. The fault zone can be described with cells similar to formation cells and hydraulic-thermal flow in a fault zone can be simulated.*

Conclusion

Solely based on seismic profiles it is not possible to derive a robust structural model in such a complex area. With the help multiple input data (well tops, geological cross-sections, structural maps and seismic profiles) the modeling process can be enhanced and good structural model of the reservoir can be produced. For the hydraulic and thermal simulation it is essential that faults are modeled as fault bodies. With the here presented approach it is possible to do fault body modeling within Petrel and to assign the fault zone parameters.

Acknowledgement

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