

## SITE CHARACTERIZATION OF FLUVIAL, INCISED-VALLEY DEPOSITS

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### **INTRODUCTION**

The CO<sub>2</sub>SINK integrated project, supported under the FP/6 framework by the EU commission and industry, is part of a European research program that aims to investigate the potential of geological storage of CO<sub>2</sub>. The project is targeted at research on monitoring of CO<sub>2</sub> that will be injected into a saline aquifer near the town of Ketzin, about 25 km west of Berlin (Germany). Prior to this experimental injection a baseline survey of the site and the target reservoir is performed, and a detailed risk assessment is made to ensure that the experiment can be conducted safely.

One focus of the baseline study has been on the reservoir rocks in the Upper Triassic Stuttgart Formation, which are fluvial sandstone bodies whose dimensions and spatial extent remain a matter of exploration. The sedimentary setting is interpreted as being a system of incised-valley deposits, where channel belts have formed by amalgamation of individual fluvial channels. The channels are incised into floodplain-facies or playa-type facies sediments, possibly including some levee deposits and overbank crevasse splays.

Because data about the reservoir section are limited to few wells, geostatistical methods were used for the construction of a reservoir model and the evaluation of its uncertainty. Parameters from analogue sequences were used as an additional input into the conceptual model.

The reservoir model has been used to simulate the migration and fate of the injected CO<sub>2</sub> with a commercial flow simulator (ECLIPSE).

### **THE RESERVOIR SYSTEM AT KETZIN**

From exploration in the larger Ketzin area it is known that good quality sandstone reservoirs exist in the Upper Triassic section. The Ktzi 163/69 borehole has encountered the target reservoir and provides core and well-logging data. The Stuttgart Formation is lithologically heterogeneous: it is made up of muddy flood-plain-facies rocks of poor reservoir quality alternating with sandy string-facies rocks of good reservoir properties that may attain several tens of meters thick where subchannels are stacked. The sandstones consist of varying amounts of quartz, feldspar,

and rock fragments, classifying them as graywacke (Beutler and Häusser, 1982). They are fine-grained to medium-grained, well sorted, and often poorly cemented. Cements comprise silicates and clay as well as sometimes also anhydrite (Beutler et al., 1999). The sandstones have an average porosity of 23%. The permeability determined in hydraulic well tests ranges between 500 and 1000 mD. The temperature of the reservoir in the Ktzi 163/69 well is 33–36°C at a depth of 600–700m. This is also the depth interval in which the reservoir sandstones are expected at the CO<sub>2</sub>SINK injection drilling site. Formation pressure at 700 m depth is supposed to range between 70 and 75 bar.

### **GEOLOGICAL RESERVOIR MODEL**

The FLUVSIM program (Deutsch and Tran, 2002) has been used for the geostatistical modeling of the reservoir architecture between and beyond well control. It exploits the advantages of a hierarchical object-based modeling scheme. The geostatistical input to the stochastic modeling is derived from conceptual models of the sedimentological architecture of the Stuttgart Fm. (Beutler and Häusser, 1982, Beutler, pers. com.) as well as from regional facies maps of northeast Germany (Beutler, 2002).

The program operates with a background matrix of non-channel facies and generates objects of channel facies in the matrix (see Fig. 1).

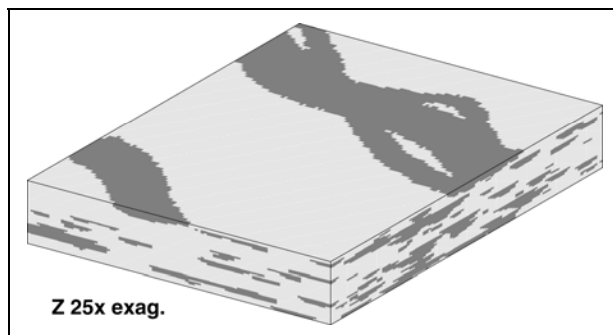


Figure 1. A realization of the geostatistical model of a fluvial system with channel belts in an area of 10x10 km. The total thickness of 80 m is exaggerated 25 x in this plot.

The program honors the primary borehole data with channel/non-channel facies supplemented by different types of secondary information, such as a vertical proportion curve to account for vertical trends in net/gross ratio (sand/clay ratio), and spatial variations in channel-sand frequency given as a spatial proportion map. The vertical proportion curve is mainly guided by the well data within the site area, but also accounting for general information about the sequence from other wells outside the area. The spatial proportion map is based on an interpretation of the structural evolution of the area indicating lateral bounds for the incised valley.

The modeling has not included the facies of levee deposits or crevasse-splay/overbank deposits.

The sand channel input parameters are derived from analogue outcrop data and conceptual models. The geometry parameters have been assigned to channel belts that can be considered to consist of amalgamated individual channels. The orientation of these channel belts ranges between 15° and 20°. The sinuosity is described by a channel amplitude of 100–500 m and a wavelength of 5,000–9,000 m; the channel belt widths range between 100 and 1,600 m combined with channel sand thickness between 1 and 8 m.

One example of a realization of the FLUVSIM modeling is given in Fig. 1. It shows the sinuosity of the wide channel belts and the partial amalgamation of the channel belt sands. The 3-D connectivity can be investigated and will show the vertical connectivity that is important for the CO<sub>2</sub> migration.

The spatial distribution of the channel sand and resulting net/gross ratio is shown in Fig. 2. The low net/gross ratio at the western and eastern margins is guided by the bounds set for the incised valley. An assemblage of this and other realizations can be used to investigate the expectations for net/gross ratio variability at planned well locations and thereby to establish a risk assessment for the future development of the injection facilities at the site.

To use the geological reservoir model for CO<sub>2</sub> propagation modeling, the channel sand has been assigned a permeability distribution with a mean of 500 mD (10–1000 mD), and the flood-plain rock has been assigned a permeability distribution with a mean of 20 mD (1–35 mD), see Fig. 3. The latter permeability is somewhat higher than that seen in measured data, but takes into account that clean mudstone might include some sand/silt stringers from levees or overbank sediments. The vertical-to-horizontal permeability ratio (kv/kh) is set to 0.33 everywhere to account for small-scale layering.

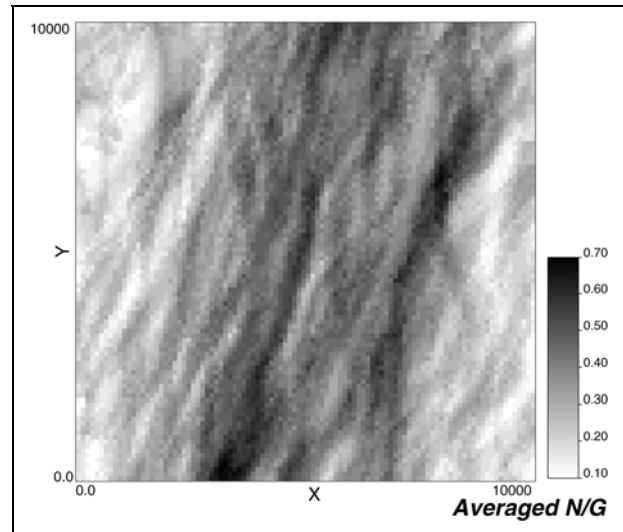


Figure 2. Map of the site area of 10x10 km showing the spatial variation of the net/gross ratio when the full model (80 m thick) is averaged. The main direction NNE-SSW for the channel belts is reflected, as well as the lateral bounds for the incised valley at the western and eastern margins.

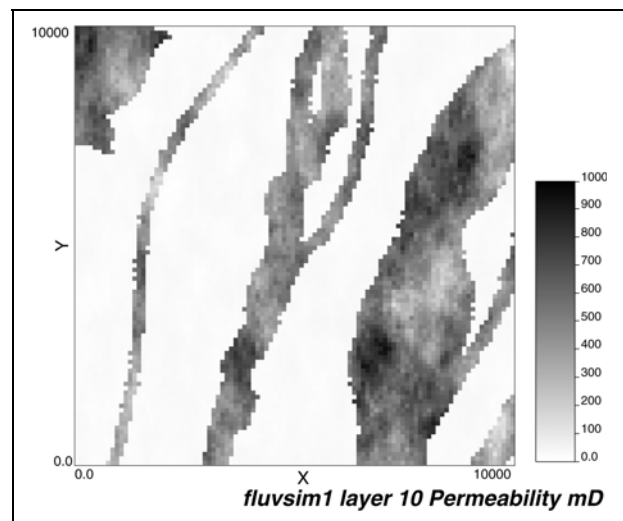


Figure 3. A single layer in the geostatistical model with permeability distribution incorporated. The patchy distribution of the permeability is obtained by merging the channel belt model with an unconditional sequential Gaussian simulation of a permeability field.

## DYNAMIC RESERVOIR MODEL

A major focus of this early modeling work was to evaluate the propagation and maximum extension of injected CO<sub>2</sub> in the subsurface and its migration path. For this purpose the ECLIPSE 100 reservoir simula-

tion program was employed by attributing brine and CO<sub>2</sub> properties to the simulator's oil and gas phases, respectively. The phase behavior is described by black-oil PVT (pressure-volume-temperature) tables. These describe the CO<sub>2</sub> density and viscosity as a function of pressure and temperature, CO<sub>2</sub> solubility in water and brine as a function of salinity, the density of brine, and its viscosity. The diffusion of CO<sub>2</sub> in water has been neglected in the present calculations, as its effect is negligible during the time span considered (20 years).

### **FUTURE WORK**

This initial site characterization is used to model probable reservoir conditions and thereby scenarios for the CO<sub>2</sub> migration in the reservoir section. As more data become available, the modeling scheme allows an easy update and gradual reduction of the uncertainty.

### **REFERENCES**

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