migration of the CO_2 plume. How heterogeneity impacts the injection operation will be studied in a separate work, in which we also discuss more realistic pressure constraints on the injection operation.

Our work is a continuation of an early study reported in [1], which focused on a few primary flow responses. Herein, we will also include flow responses that relate more directly to leakage risk. In addition, we evaluate how curvatures in the relative-permeability model influences plume migration; this as a complement to previous studies of endpoint and hysteresis effects, see e.g., [11, 7].

2 Model Setup

In this study, we will consider a storage operation in which supercritical CO_2 is injected into a shallow-marine reservoir underneath a sealing caprock that forms a type of structural trap that is often seen in petroleum reservoirs. To represent the aquifer geology, we use an ensemble of synthetic models developed in the SAIGUP study [8]. In this study, data were collected from many different sources to develop representative, parametrized models that span realistic parameter intervals for progradational shallow-marine depositional systems with limited tidal influence [6]. An ensemble of geostatistical realizations were then made from the parametrized model, each having a heterogeneity and geometrical complexity as seen in real-life models of petroleum reservoirs. In our study, we have selected the following five parameters that altogether give 160 realizations:

Lobosity – is defined by the plan-view shape of the shoreline. As a varying parameter, lobosity indicates the level at which the shallow-marine system is dominated by each of the main depositional processes. Two depositional processes are considered in the SAIGUP study: fluvial and wave processes. The higher the amount of sediment supply provided from rivers is relative to the available accommodation space in the shallow sea, the more fluvial dominant the process will be. As the river enters the mouth of the sea, it can divide into different lobes and branches. Wave processes from the sea-side smear this effect and flatten the shoreline shape. Less wave effect produces more pronounced lobe shapes around the river mouths. Very high permeability and porosity can be found in the channeling branches, while dense rock with low permeability fills the space between them. Reservoir quality decreases with distance from the shore-face. We expect that the level of lobosity can have a considerable effect on the CO_2 injection and plume size in the aquifer. In this study, models of three levels of lobosity are used: flat shoreline, one lobe and two lobes, as illustrated in the upper row of Figure 1.

Barriers – Periodic floods result in a sheet of sandstone that dips, thins, and fines in a seaward direction. In the lower front, thin sheets of sandstone are interbedded with mud-stones deposited from suspension. These mud-draped surfaces will potentially act as significant barriers to both horizontal and vertical flow, and are modeled by transmissibility multipliers corresponding to three levels of coverage for the barrier sheet: low (10%), medium (50%), and high (90%), as illustrated in the middle row of Figure 1.

Aggradation – In shallow-marine systems, two main factors control the shape of the transition zone between river and basin: amount of deposition supplied by the river and the accommodation space that the sea provides for these depositional masses. One can imagine a constant situation in which the river is entering the sea and the flow slows down until stagnation. The deposition happens in a spectrum from larger grains depositing at the river mouth to fine deposits in the deep basin. If the river flux or sea level fluctuates, the equilibrium changes into a new bedding shape based on the balance of these factors. The SAIGUP data models cases in which, for instance, the river flux increases and shifts the whole depositional system into the sea. The angle at which the transitional deposits are stacked on each-other because of this shifting, is called aggradation angle. Three levels of aggradation are modeled here: low, medium, and high angles. The three parameter choices are illustrated in the bottom row of Figure 1, where we in particular notice how a low aggradation angle gives continuous facies layering parallel to the dip direction of the model.

Progradation – denotes the direction of the depositional dip. Two types are considered here: up and down the dominant structural dip. Because the model is tilted a little, this corresponds to the lobe direction from flank to crest or vice versa.