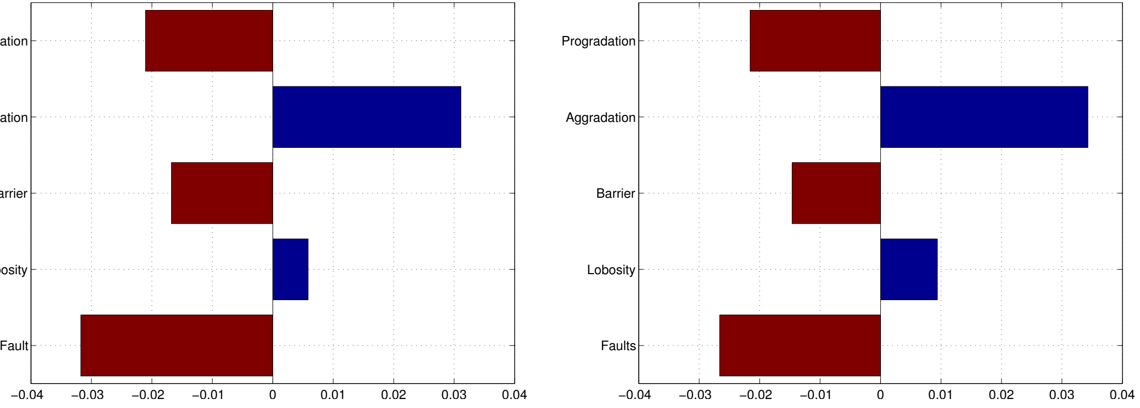

Figure 11: Sensitivity of the leakage risk with respect to the five geological parameters at the end of injection (left) and end of simulation (right).

respect to the chosen risk measure.

Figure 11 shows gradients for the leakage risk. Although less pronounced during injection time, the gravity force makes a major plume body attached to the crest both during the injection time and afterwards. Hence, we see that the leakage-risk sensitivity shows almost the same profile at end of injection and end of simulation. This can also be observed in Figure 10. The sensitivity is slightly less during injection compared to end of simulation, because more CO_2 will be below the caprock at end of simulation. This overtakes the effect of mobile volume reduction due to residual trapping process and the increase in the number of plumes at end of simulation, which both result in less risk of leakage.

Once again, aggradation angle and fault criteria are the two most influential features. Increasing the aggradation angle improves the vertical communication and contributes to increase the formation of CO_2 plumes below the caprock. Closed faults limit the movement of the plume and result in less accumulation below the caprock, whereas open faults generally increase the upward migration of plumes.

6 Conclusions

Herein, we have presented a study of how various geological parameters influence the injection and early-stage migration of CO_2 in progradational shallow-marine systems. One hundred and sixty equally probable realizations have been considered and several flow responses related to storage capacity and risk of point leakage have been calculated at the end of injection and after seventy years of gravity-dominated plume migration.

First of all, we have investigated the effect of relative permeability curvature by comparing the results of linear and quadratic relative permeability curves. The results show that linear relative permeabilities give significantly higher wave speeds that lead to earlier accumulation of CO_2 under the caprock, and will for this reason give conservative estimates of the plume migration and the risk associated with point leakage after a prescribed number of years.

Second, and more important, we have demonstrated and discussed how the heterogeneity induced by different geological parameters give large variations in flow responses. Each geological feature will influence the flow behavior and can result in local/global pressure build-up or pressure drop, enhance the flow direction, hinder the flow in the medium, or lead to loss of injected volumes over the open boundaries, and may induce different effects during the injection and plume migration. Specifically, we have demonstrated how variation in aggradation angle, fault criteria, and progradation direction significantly change the flow direction within the medium and hence impact the residual trapping and formation of movable CO_2 plumes under the caprock. Barriers are important during injection and must be modeled more carefully if the study focuses on injection operations.

Altogether, our study shows that geological heterogeneity has a major impact on the injection and formation of a CO_2 plume and the subsequent early-stage migration of this plume. A predictive study should therefore incorporate realistic estimates of geological uncertainty to provide reliable forecasts of operational risks and the long-term fate of injected CO_2.