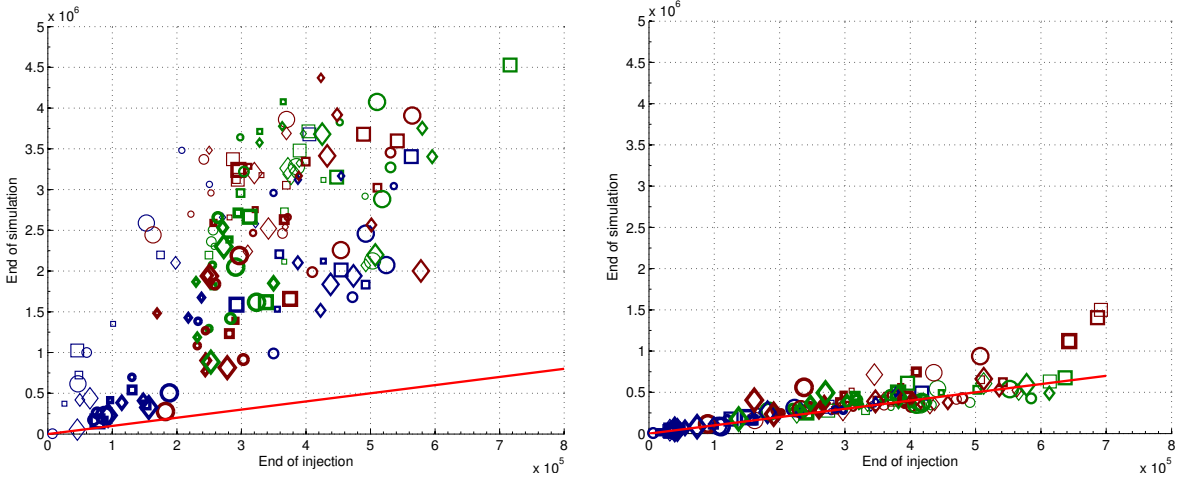

Figure 5: Residually trapped volumes for linear (left) and quadratic (right) relative permeabilities. Cases on the red lines have the same values at the end of injection and end of simulation.

flux for the linear relative permeability function. With nonlinear relative permeability function, some of the cases follow a linear trend (shown by the red line in the right-hand plot), in which the return flux is proportional to the outward flux.

3.3.2 Total mobile/residual CO_2

Residual trapping occurs when the CO_2 saturation is below the residual saturation value of 0.2. Although the residually trapped CO_2 is free to move in a molecular sense on the microscale, the corresponding bulk volume is considered immobile on the macro scale. To reduce the risk of leakage, it is therefore important to obtain an efficient volumetric sweep that will maximize the residual volumes and minimize the mobile volumes. Herein, we will define residually trapped volumes as volumes in which the CO_2 saturation is below the residual value of 0.2. Notice that with this definition, all mobile volumes (in which the saturation exceeds 0.2) will contain a residual portion of CO_2 that is not free to escape. This portion will eventually become residually trapped if the saturation of the mobile CO_2 decreases to the residual value.

Figure 5 shows cross-plots of the total residual volume at the end of injection and end of simulation. Drainage is the dominant flow process during injection. When injection ceases, the plume migration turns into a imbibition-dominated process which increases the residual trapping of CO_2. With linear relative permeability, the imbibition process takes place relatively fast, and the residual volume increases significantly from end of injection to end of simulation. Once again, low-aggradation cases form notable exception having small amounts of residual trapping. The reason is primarily that significant volumes have been lost over the down-dip boundary, and secondarily that the (vertical) sweep is limited because the CO_2 plume is confined to the lower layers of the reservoir during most of the simulation time.

With quadratic relative permeabilities, the migration process is significantly slower and many cases have almost the same residual volume at the end of injection and end of simulation. As already discussed, the curvature of the relative permeability function does not have a considerable influence on the flow paths (compare the streamline paths in Figure 2). Compared with the results in the left right plot of Figure 5, we therefore ultimately expect a significant increase in residual trapping before the plume settles; this prognostication has been confirmed for a few (arbitrary selected) cases by computing the plume migration for more than ten thousand years. We also observe that in some cases the residual volumes *decrease* after injection ceases. This is caused by mobile CO_2 invading zones of residual CO_2, thereby turning residual volumes into mobile volumes according to the definition of residual trapping used herein. These cases are therefore likely to be influenced by hysteresis effects, which for simplicity have been disregarded in this study.