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Time scales of relaxation dynamics during transient conditions in two-phase flow

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The relaxation dynamics towards a hydrostatic equilibrium after a change in phase saturation in porous media is governed by fluid reconfiguration at the pore scale. Little is known whether a hydrostatic equilibrium in which all interfaces come to rest is ever reached and which microscopic processes govern the time scales of relaxation. Here we apply fast synchrotron-based X-ray tomography to measure the relaxation dynamics of fluid interfaces in a glass bead pack after fast drainage of the sample. The relaxation of interfaces triggers internal redistribution of fluids, reduces the surface energy stored in the fluid interfaces and relaxes the contact angle towards the equilibrium value while the fluid topology remains unchanged. The equilibration of capillary pressures occurs in two stages: (i) a quick relaxation within seconds in which most of the pressure drop that built up during drainage is dissipated and (ii) a slow relaxation with characteristic time scales of 1-4h that is well described by the Washburn equation for capillary rise in porous media. The slow relaxation implies that a hydrostatic equilibrium is hardly ever attained in practice when conducting two-phase experiments.