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How secure is subsurface CO_2 storage? Controls on leakage in natural CO_2 reservoirs

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Carbon Capture and Storage (CCS) is the only industrial scale technology available to directly reduce carbon dioxide (CO_2) emissions from fossil fuelled power plants and large industrial point sources to the atmosphere. The technology includes the capture of CO_2 at the source and transport to subsurface storage sites, such as depleted hydrocarbon reservoirs or saline aquifers, where it is injected and stored for long periods of time. To have an impact on the greenhouse gas emissions it is crucial that there is no or only a very low amount of leakage of CO_2 from the storage sites to shallow aquifers or the surface.

CO_2 occurs naturally in reservoirs in the subsurface and has often been stored for millions of years without any leakage incidents. However, in some cases CO_2 migrates from the reservoir to the surface. Both leaking and non-leaking natural CO_2 reservoirs offer insights into the long-term behaviour of CO_2 in the subsurface and on the mechanisms that lead to either leakage or retention of CO_2.

Here we present the results of a study on leakage mechanisms of natural CO_2 reservoirs worldwide. We compiled a global dataset of 49 well described natural CO_2 reservoirs of which six are leaking CO_2 to the surface, 40 retain CO_2 in the subsurface and for three reservoirs the evidence is inconclusive. Likelihood of leakage of CO_2 from a reservoir to the surface is governed by the state of CO_2 (supercritical vs. gaseous) and the pressure in the reservoir and the direct overburden. Reservoirs with gaseous CO_2 is more prone to leak CO_2 than reservoirs with dense supercritical CO_2. If the reservoir pressure is close to or higher than the least principal stress leakage is likely to occur while reservoirs with pressures close to hydrostatic pressure and below 1200 m depth do not leak. Additionally, a positive pressure gradient from the reservoir into the caprock averts leakage of CO_2 into the caprock. Leakage of CO_2 occurs in all cases along a fault zone, indicating that faults play a major role when it comes to fluid migration from a reservoir. However, nearly 50% of the non-leaking studied reservoirs are also fault bound, demonstrating that faults are not always necessarily leakage pathways.