Gas pressure effects on salt – the large scale in-situ test Merkers

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Abstract:

Salt formations ensure safe isolation of disposed waste due to their impermeability for gases and fluids. However, significant gas quantities may be generated in the long-term (e.g. due to anaerobic corrosion, if humidity is present) resulting in a time dependent pressure build-up. For extension of the already existing knowledge (from lab and borehole tests), a large scale gas-injection test with a pressurized volume of 50m^3 was performed in the salt mine Merkers (Germany) to assess the effect of increasing gas pressures on the integrity of rock salt

The large-scale test site Merkers benefits from the unique mining situation in the bedded salt mass of the Werra salt formation (z1) where both potash seams were mined in a room-and-pillar system at 300 m (1st floor – Level 1) and 380 m depth (2nd floor – Level 2) respectively. From the second floor a nearly vertical 60 m high borehole was drilled by a special drilling machine with a diameter of 1.3 m upwards ending 20 m beneath the first floor. For access to the later sealed pressure volume an 85 mm pilot hole has been drilled from the upper 1st floor into the roof of the main bore hole, which was also used for the emplacement of a concrete seal at the bottom.

A highly sensitive AE-network consisting of twelve AE sensors was installed in four observation boreholes drilled parallel to the main borehole at a distance of approximately 15 m to the center line of the borehole, allowing a very precise localization of crack events (resolution is around one decimeter).

After equipping the borehole with pressure, stress and strain probes, the challenge was to install a gas tight seal plug. As appropriate material (with extremely low gas permeability, i.e. < 10^{-20}m^2) a special MgO-concrete was used, which was pumped into the borehole via the bore hole tube from the 1st floor resulting in 21 m height bore hole plug. Additionally, highly viscous brine acting as a capillary barrier was embedded at the top of the sealing element. The pilot borehole itself was sealed by a hydraulic dual circuit packer system. It has to be mentioned that all technical sealing measures were successful, i.e. we were able to realize a gas-tight shaft seal.

The pressurization took place over more than one year in several steps, i.e. to about 8 bar (Step 1), to about 35 bar (Step 2) and to about 56 bar (Step 3). During the 4th step of pressure increase a widespread AE cluster was observed three days before the maximal pressure of about 68 bars was reached. At this maximal pressure a gas and brine breakthrough occurred which prevented a further increase of pressure followed by a pressure decrease to ca. 56 bars (comparable to the 3rd step). The AE events are located in a cluster 5 to 15 meters (forming a more or less radial fluid zone) eastward the large borehole and in another cluster close by 5 to 15 meters northeast the large borehole, but slightly below the sealing plug.

The fluid breakthrough documents that the minimum principal stress in the surrounding rock salt has been reached and fluid-pressure driven percolation was initiated. It is important to note that the observed effects correspond qualitatively to the effects of small-bore hole tests but due to the large pressurized volume the effects are amplified, i.e. the gas flow could be directly monitored by the AE-measurements.

As main result, the experimental simulation of an increasing gas pressure demonstrated the generation of connectivity after a percolation threshold (i.e. given by the minimal stress) along already existing but primary not interconnected pathways. The observed acoustic emissions result from the evolution of temporary permeable discrete flow paths.

Based on the obtained experimental results conclusions will be given about the state of knowledge about gas-pressure induced integrity of salt formations obtained so far and remaining deficiencies.