Introduction to the salt solution mining process and cavern formation

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A brief simplified outline is given of the origin of the salt in the region of Twente, The Netherlands, the geomechanical characteristics of salt, the method of solution mining of salt, the stability of salt caverns, and the possibility to stabilize the salt caverns by back fill. The author is a member of the Committee for the Environmental Impact Assessment for the stabilization of the instable caverns in Twente. However, the committee has not yet assessed the final Environmental Impact Assessment report. Therefore, the Environmental Impact Assessment report and the data thereof are not part of this presentation nor of this abstract. The information provided is based on available information from the public domain and general geological and geomechanical knowledge.

(Slides 7-14) Salt was deposited in the region of The Netherlands and Twente during various geological periods in the past. The salt being exploited in Twente is from the Triassic period in the history of the Earth, some 200-250 million years ago.

(Slides 15-17) Salt has some remarkable geomechanical characteristics. The salt is deposited as crystals that are not compacted easily when the salt comes under pressure of overlying layers of material. However, other deposits (for example, sand and clay layers) can easily be compacted when under pressure. This implies that at larger depth under pressure of overlying deposits, the salt is relatively light-weighted as it could not be compacted, whereas the other deposits are relatively heavy-weighted because of compaction. A second remarkable geomechanical characteristic is the viscosity of salt. Under pressure salt easily deforms. Both characteristics, weight difference and viscosity, are responsible for the development of so-called “salt domes”.

(Slides 18-19) The salt is excavated by so-called “solution mining”. Fresh water is pumped via a borehole into the salt layer, the salt dissolves in the water, and the water with salt in solution (the so-called “brine”; in Dutch “pekel”) is pumped back to surface. After mining ceases, the result is an open space, a “cavern”, in the subsurface salt layer. The caverns are mostly not empty, but still filled with a residue of the water with salt solution.

(Slides 20-23) When an opening is made in the subsurface, the ground carries itself by “arching”. However, if the shape of the opening is such that the stresses around the opening become too high for the material forming the walls, roof, and floor of the opening, part of the walls, roof, or floor start breaking up. A second failure mode is possible when the shape allows for tensile stresses in the walls, roof, or floor. The ground is still arching, but at a larger distance from the circumference of the cavern, while the material inside the arch breaks up. This is a continuing process; the arch moves continuously further away from the opening while the material inside the arch breaks up. The opening is then denoted as “unstable”.

Stabilizing such an unstable opening does not need to be done by completely filling the opening with very strong material to carry the ground weight, but just some material which keeps the broken material in place adding to the radial stress inside the opening, and by that preventing the arch to move away from the circumference of the opening.

(Slides 24-28) In Twente the shape and position of some of the older caverns is (reported) to be such that the roof is collapsing. The material broken from the roof falls in the cavern and fills the cavern. It should be realized that the fallen material has a larger volume than when it was still part of the roof ("bulking" effect). This means that the cavern will extend in upward direction, but the new larger volume of broken material fills up the cavern and will prevent further failure. However, the broken material in the cavern will compact with time. Then the whole process of collapsing roof starts again with as result a slowly upward migrating cavern. Eventually this may form a subsidence depression or a sinkhole at surface.

(Slides 29-34) To prevent the breaking up of the walls, roof, and floor of the cavern, some other material (so-called "back fill") may be inserted in the cavern. This back-fill material does not need to be able to carry the full weight of the ground, but as long as it gives a (relatively small) radial stress on the walls, roof and floor it will be enough to stop the breaking, and prevent the cavern to further collapse and migrate to surface.

(Slides 35-36) The salt layers are in principle impermeable for oil and gas, shown throughout the world by numerous caprocks on top of oil or gas reservoirs preventing the leaking of oil and gas to surface for 10's to 100's of millions of years. It can be assumed the layers above the salt have been impermeable over the past 100's of millions of years, as if they would not have been impermeable the salt would have been dissolved by percolating ground water a long time ago. Hence the chance that back fill material would come into contact with water in the higher regions of the subsurface above the cavern is likely quite small.