Salty Matters

John Warren - Thursday, February 19, 2015

Solikamsk sinkholes and Uralkali's lower potash ore price

Solikamsk-2 Mine

The Solikamsk-2 mine output currently accounts for a fifth of the Uralkali's potash capacity. The mine is one of Uralkali's potash mines in the Kama district (western Urals) of Russia. The possible loss of the Solikamsk-2 mine in the near future may put upward pressure on the currently low world price of potash. Even if loss of production from the mine doesn't drive an increase in price, Uralkali as a company will continue to be profitable. All mines in Solikamsk basin benefit from low production costs, related to shallow ore depth. The collapse sinkhole is a classic example of what can happen if any salt or potash mine operates at a depth that is shallow enough to intersect the overlying zone of active phreatic water crossflow.

In November 2014 the most recent example of an evaporite-related ground collapse or sinkhole, daylighted to the east of the Solikamsk-2 potash production site. It seems likely that halite-undersaturated waters, sourced from above, now flow into an area of the Solikamsk-2 workings that were no longer mined, but were still connected to the active extraction areas of the Solikamsk mine. Worldwide experience shows that flooding is difficult to control once a salt mass is breached. Increasing volumes of inflow waters into the mine workings will likely lead to the ultimate loss of the Solikamsk 2 mine, as it has in what are other now abandoned salt mines and solution brinefields across the world.

Will collapse contine?

Recently the head of the Ural region's Mining Institute, Alexander Baryakh, was quoted as saying (Moscow Times Dec. 11 2014): ....."Based on our analysis and the world's experience in developing potassium mines, the risk of a negative scenario — the complete flooding on the mine — remains high. We are ready for this contingency, but we are doing everything possible to minimize related risks," adding that, "fortunately, the accident poses no danger to the residents of [the local town of] Solikamsk...."

When, in mid November, a stoping solution cavity above the abandoned section of the mine workings reached the surface, the resulting sinkhole diameter measured 30m by 40m. As of 6 February 2015, the at-surface sinkhole diameter had increased in size and measured 58 by 87 metres wide and was some 75 metres deep. Uralkali's ongoing measurements show levels of brine inflow into the Solikamsk-2 mine continuously varied over this time frame. Between 11 December 2014 and 21 January 2015, the average brine inflow was around 200 cubic metres per hour. Between 22 January and 06 February 2015, the average brine inflow increased substantially, reaching approximately 820 cubic metres per hour.

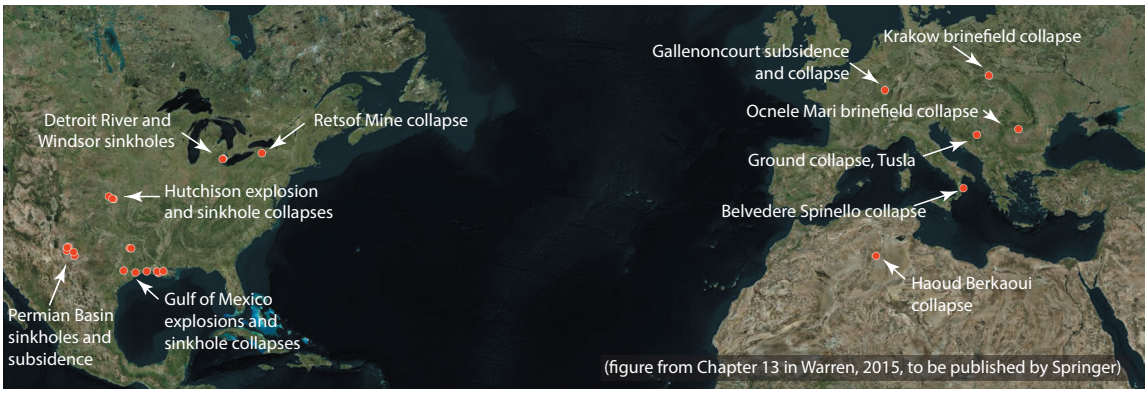
Accordingly, where underground equipment at Solikamsk 2 is not being used to mitigate the consequences of the collapse and water inflow, Uralkali has started to remove plant via the mine shaft. Three "Ural" continuous miners have already been dismantled and taken out. In line with their accident mitigation plan, Uralkali in a recent press release states: that the company continues to comprehensively monitor the situation both underground and at the surface; water inflows are monitored through brine level checks; groundwater levels are monitored by water monitoring wells and via the drilling of additional water monitoring wells currently in progress; gas levels are monitored around the sinkhole and in the mine; while the sinkhole is continuously monitored from a distance, using stationary cameras and air drones; and a seismologic network has been set up over the sinkhole area.

Salt collapse is a natural near surface evaporite solution doline forming process

Mining into "out of salt situations" can enhance the possibility of collapse

Is this usual?

This latest collapse is one of a series of evaporite collapse dolines or sinkholes that have daylighted atop the mined regions in this part of Russia. Collapse cavities typically reach the surface some years after extraction operations below the collapse have ceased. For example, in 1995, a collapse sinkhole formed atop the Solikamsk-2 potash mine's Verkhnekamsky deposit. The collapse on January 5th, 1995 resulted in a 4.7 magnitude seismic event on the Richter scale, with an associated initial 4.5 m of surface subsidence. Underground, the mine roof collapsed over an area measuring 600 m by 600 m. Across the period 1993 to 2005, several hundred earthquakes were recorded in the Berezniki-Solikamsk region with magnitudes varying from 2 to 5. These earthquakes were caused by collapsing underground tunnels of potash mines, mined out over the 70 continuous years of production. In October 2006, in order to prevent catastrophic outcomes of a sudden brine influx into the underground workings, Berezniki potash mine #1 was flooded by Uralkali. After that, three major sinkholes occurred in the region above the flooded workings.



On July 28th, 2007, a huge sinkhole appeared on the surface above the closed Berezniki mine #1, its creation likely aided by infiltration of undersaturated floodwaters water into the abandoned underground workings.

At the surface this sinkhole had an initial size of 50 by 70 meters and was 15 meters deep. By November, 2008, the sinkhole had expanded into a crater measuring 437m by 323m and some 100 m deep. The July 28th collapse released an estimated 900,000 cubic metres of gas (a mix of methane, hydrogen, carbon dioxide, carbon monoxide and other gases), which in turn led to gas explosions on the following day. Timely placement by the mine operators of a "significant volume" of backfill, prior to flooding, is credited with preventing further catastrophic collapses.

Berezniki 2008 sinkhole Source- ru wikipedia.ai

The mined potash ore level at both collapse sites (Solikamsk and Berezniki) is Middle Permian (Kungurian) in ag. The potash is halite-hosted and occurs in one of six evaporitic foreland sub-basins, extending from the Urals foreland to the Caspian basin. Sylvinite (potash) beneath the 1995 Verkhnekamsky collapse area was extracted from two to three halite-potash beds, with 10 to 16 metres of total extraction height. At that time the mine used a panel system of rooms and pillars under 200 to 400 m of overburden. Rooms were 13-16 m wide and pillars 11-14 m wide by 200 m long. Due to the relatively shallow nature of the Solikamsk and Berezniki potash ore levels, compared to other potash mines in the world, a "rule of thumb" used across the Upper Kama mining district is that surface subsidence typically reaches 50% of the subsurface excavation height around 48 months after excavation.

Freshwater entry must be prevented

Reliable maps of older solution wellls and cavities minimises the possibility of future collapse

The 1995 collapse event occurred 15 years after mining began, and 7 years after mining was completed in the area beneath the sinkhole. The delay before the main collapse doline surfaced implies there was a rigid bridging of overburden as a roof to the mine level. This is consistent with the uncommonly high release of seismic energy associated with the1995 collapse. The next largest collapses associated with published seismic measurements occurred in 1993 and 1997 with seismic magnitudes of 2.6 and 2.8, respectively.

An even earlier surface collapse occurred on July 25, 1986 atop a portion of the nearby 3rd Bereznki potash mine and is yet another case of a sinkhole forming atop a mine that was operating at relatively shallow depths. Potash extraction at Bereznki was active at depths of 235 and 425 m below surface. There, the targeted ore zone was overlain by a 100 m thick "salt complex" made up of halite and carnallite beds, overlain in turn by clays, carbonates, aquifers and sediments. Mining created "yield pillars," with 5.3 m wide rooms, 3.8 m wide pillars and a 5.5 m mining height. After mining, conditions in mined-out areas were described as, "pillars crushed and roofs sagged."

Observations of significant brine leakage into the 3rd Bereznki potash mine workings at a depth of 400m indicated a loss of hydraulic control as early as January of 1986. This was a prelude to the massive dissolution cavitation that was occurring in the 90 m interval of disturbed salt and clastics that overlay the potash level. Some 7 months later a large cavity formed in the sandstone/limestone overburden, which was nearly 200 m thick. In the mine it appeared the water inflow situation remained relatively stable, at least from Jan-

uary until July 1986. Failure of the mine head then occurred, the result of a cavity that had migrated vertically through more than 300m of limestones, mudstones and sandstones.

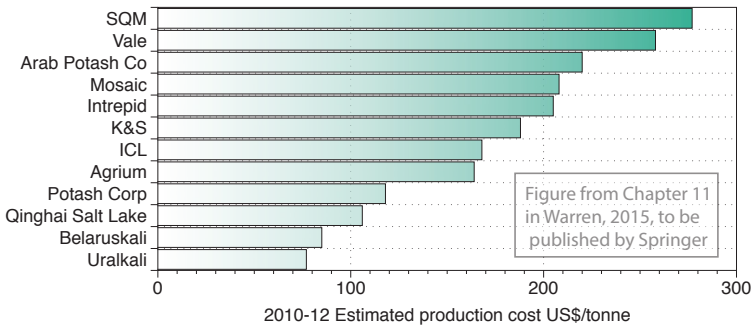
Berezniki 1986 sinkhole Source- ru wikipedia.org

Final cavity stoping was indicated by the near instantaneous appearance of a caprock sinkhole, which was 150 m deep and 40-80 m across and located at the top of a stoping breccia pipe or chimney of the same dimensions. Failure of this sequence began at 18:30 hours on July 25 with "clearly felt underground shocks" culminating with a final collapse at midnight, which was accompanied by an explosion with "flashes of light." In the final stages of stoping by the rising solution pipe, before the sinkhole daylighted, it took only 12 days to migrate through the last 100 metres of mudstone. This very high rate of stoping was likely aided by structural weakness in a fracture zone along a local fold axis.

In all these cases of rapid sinkhole creation, the collapse occurred above what was formerly an active area of the mine and took place some years after mining had ceased. In all cases, the ultimate cause of the size of the collapse was likely a combination of a significant cavity growth below what was a mechanically strong rock rock, likely a dolomite or a limestone bed. This unit had significant structural integrity and so allowed a solution cavity to expand prior to the ultimate brittle collapse of roof rock. Once collapse did occur, undersaturated groundwaters, sourced in the overburden, then reached the salt level in large volumes and further expanded the region of collapse. Likewise, once the upward stoping cavity reached the shallower unconsolidated sediment levels, the cavity's passage to the surface sped up so that it daylighted and expanded in a rapid fashion.

Shallow potash ore layers makes for low per tonne prduction costs

Solikamsk's shallow potash means future mine-centred collapses should be part of the risk assessment



Dissolving evaporites and solution dolines occur naturally in all parts of the world, wherever salt is within a few hundred metres of the landsurface, but mining of both salt and potash at depths shallower than 250-350 metres can exacerbate the speed and and intensity of what is an ongoing natural process of evaporite solution, surface collapse and sinkhole growth. While Uralkali's operations in the Solikamsk region continue to exploit a relatively shallow potash ore source, it will continue to supply the Company a relatively inexpensive product, but the company will have live with sinkholes breaking out above some areas of the mined region. That is, as long as Uralkali can continue to be a low cost supplier of potash, there will be likely be ongoing landsurface-stability problems. Some of the problems may not daylight until years after the extraction operation has ceased.

John Warren, Chief Technical Director
SaltWork Consultants Pte Ltd (ACN 068 889 127)
Kingston Park, Adelaide, South Australia 5049

www.saltworkconsultants.com