SOLUTION SALT MINING IN NEW YORK

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ABSTRACT: Bedded subsurface salt was first solution mined in New York in a well drilled for oil or gas in Wyoming County in 1878. The salt occurs in the Silurian Syracuse and Vernon formations at depths of 500 to 4000 feet, with a net aggregate salt thickness of up to 800 feet. There are currently five solution mining facilities in New York producing over two billion gallons of saturated brine, or over 2.4 million metric tons of salt, per year. Subsurface cavern development techniques used at these facilities include hydrofracturing, horizontal drilling, and roof padding. Chemical, pharmaceutical, and food-grade salt are all produced by the solution mining method in New York.

Solution mining wells in New York are regulated by both the United States Environmental Protection Agency and the New York State Department of Environmental Conservation. The primary goals of regulating subsurface operations at solution mining facilities are protection of aquifers and prevention of damaging or catastrophic subsidence. Modern methods of well construction and operation, cavern development, and well plugging ensure attainment of these environmental objectives.

INTRODUCTION

Although drilling rigs are not an uncommon sight in western and central New York, it is not generally known that the drilling target may be salt rather than oil or gas. The salt extraction process used in New York and other states that employs the drilling of deep wells is known as solution mining.

Solution mining is the process whereby wells are drilled to subsurface rock salt strata. Fresh or undersaturated water is injected to the salt strata, causing dissolution. Brine is created and pumped back to the surface. In New York, this brine is then either used as a raw material for chemical manufacturing at one of two plants in Niagara Falls, or processed at on-site evaporation plants for manufacture of products such as table salt, agricultural salt, water softener salt, and salt for pharmaceutical or chemical manufacturing.

Five solution mining facilities, listed in table 1, are currently active in New York. According to reports submitted by the operators to the state's Division of Mineral Resources, 2.3 billion gallons of brine were produced by the solution mining method in New York in 1994. Figure 1 shows that, based on statistics compiled by the U.S. Bureau of Mines for 1994, New York ranks third among the states in total salt production, and first in market value of salt produced. The solution mining method comprises about 45% of total salt produced in New York.

SUBSURFACE ROCK SALT IN NEW YORK

By 1820, a Syracuse salt manufacturer named Benajah Byington conceived the notion that beds of rock salt must directly underlie the area of springs in Onondaga County near Syracuse. He drilled many unsuccessful wells at his own expense between 1820 and 1835. According to Werner (1917), Byington's wells were "confined to the high ground east of Syracuse." No records are known to exist of the exact locations, depths, or total number of wells that Byington drilled.

The state of New York controlled salt rights surrounding Onondaga Lake between 1797 and 1908, and drilled its own rock salt exploratory well in Syracuse in 1839. The state's 600-foot well was unsuccessful, as was a 715-foot well drilled at Liverpool in 1867 by the Salt Company of Onondaga (Luther 1896).

Although an 1878 Wyoming County well is often cited as the discovery of subsurface rock salt in New York, Phalen (1919) notes that the existence of rock salt was recorded thirteen years earlier in an Ontario County well. The so-called "Muttonville" well was drilled for oil and gas, and encountered rock salt between 1,000 and 1,300 feet deep. The Ontario County rock salt discovery was apparently not widely publicized.
The 1878 Wyoming County well that is commonly regarded as the rock salt discovery well in New York was drilled by Vacuum Oil Company in search of hydrocarbons and is known as the "Pioneer" well. A total depth of 1,530 feet was attained without finding oil or gas. Thick beds of rock salt were encountered between 1,270 and 1,340 feet. The well was acquired by a newly formed company, called the Wyoming Valley Salt Company, which erected a small plant and sold the first solution mined salt in New York in 1881 (Werner 1917). Although the "Pioneer" well was only active for two years, solution mining has taken place continuously in Wyoming County ever since.

As the solution mining industry was getting underway in Wyoming County, quality of the shallow brine that supplied the salt industry in Syracuse was deteriorating. In addition, the Solvay Process Company began using brine as a raw material in its soda ash manufacturing plant in 1884 (Luther 1896). The discovery of subsurface rock salt in Wyoming County prompted a renewed search in Onondaga County, both to supply more highly saturated brine to the salt manufacturers and to meet the ever-increasing needs of Solvay Process Company. Salt manufacturer Thomas Gale and the State of New York drilled unsuccessful wells near Onondaga Lake in 1884 (Luther 1896). Meanwhile, the

Table 1. Status of solution salt mining in New York in 1994

<table>
<thead>
<tr>
<th>Operator</th>
<th>County</th>
<th>Town</th>
<th>Plugged Wells</th>
<th>Unplugged Wells</th>
<th>Year Started</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akzo Nobel</td>
<td>Schuyler</td>
<td>Reading</td>
<td>51</td>
<td>20</td>
<td>1893 (Glen Salt Co.)</td>
</tr>
<tr>
<td>Cargill</td>
<td>Schuyler</td>
<td>Dix</td>
<td>12</td>
<td>9</td>
<td>1899 (Watkins Salt Co.)</td>
</tr>
<tr>
<td>Morton International</td>
<td>Wyoming</td>
<td>Castille &amp; Gainesville</td>
<td>22</td>
<td>16</td>
<td>1884 (Duncan Salt Co.)</td>
</tr>
<tr>
<td>Texas Brine</td>
<td>Wyoming</td>
<td>Middlebury (Dale Field)</td>
<td>72</td>
<td>35</td>
<td>1970</td>
</tr>
<tr>
<td>Texas Brine</td>
<td>Wyoming</td>
<td>Middlebury (Wyoming Village Field)</td>
<td>4</td>
<td>33</td>
<td>1984</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>162</strong></td>
<td><strong>113</strong></td>
<td></td>
</tr>
</tbody>
</table>

NOTES:
1) Includes all methods of production
2) All data obtained from USDOI Bureau of Mines

Figure 1. Salt production and value top five U.S. States - 1994*.
Solvay Process Company had begun drilling a series of exploratory wells south of Syracuse which eventually led to the discovery of rock salt at a depth of 1,216 feet in Tully Valley in 1888 (Luther 1896; Phalen 1923).

**Salt Occurrence**

The bedded rock salts discovered in Wyoming and Onondaga Counties occur in the Vernon and Syracuse formations, respectively, of the upper Silurian Salina Group (Fig. 2). As shown on figure 3, salt underlies an estimated 8,500 square miles of New York State (Kreidler 1957). The salt strata dip to the south, ranging in depth from 500 feet at the northern edge of occurrence to 4,000 feet at the New York/Pennsylvania border. Net aggregate salt thickness attains over 500 feet in Chemung, Tioga, southern Tompkins and Schuyler and eastern Steuben counties.

**Figure 2. Salina salt units mined in New York State.**

**Figure 3. Occurrence of Silurian salt in New York State.**
Treesh and Friedman (1974) inferred that the Salina Group rocks were deposited in a sabkha environment. Earlier authors (e.g., Alling and Briggs [1961]; Rickard [1969]) attributed the salts to precipitation from seawater in restricted seas. Rickard (1969) correlated the salt beds mined by both conventional and solution mining methods in New York to the strata mined in Ohio, Ontario, and Michigan.


**The Early Years**

Werner (1917) considered 1893 the peak of the early solution mining industry in New York. Table 2 summarizes the status of solution mining in the state at that time, based primarily on information provided by Merrill (1893). The Tully Valley brine field in Onondaga County, where salt had been discovered only five years previously, was already the largest solution mining facility in the state, with 54 wells. In terms of production, Tully Valley was the top brine field in New York until 1985. Brine produced at Tully Valley was transported to the Solvay soda ash plant near Syracuse via a 20-mile long gravity pipeline. All the other facilities listed in table 2 were each associated with their own on-site plants where salt was derived from the brine using one of several evaporation methods.

According to Werner (1917), after 1893 the solution mining industry in New York suffered from overproduction. Industry reorganization and consolidation was the result, with many of the plants ultimately acquired and shut down by the International Salt Company shortly after the turn of the century.

Table 3 is the best estimate of the number of salt-related wells drilled in New York during the 175 years since the search for subsurface rock salt began. The total number of exploratory wells is undoubtedly higher, since the earliest wells are not tallied in the literature. For example, the total number of wells drilled by Byington is unknown. Some of the exploratory wells and “other” wells listed on table 3 are associated with rock salt mines rather than solution mining fields. “Other” wells associated with salt include former plant waste disposal wells, observation wells, and various types of wells associated with salt mines.

Table 4 summarizes all solution mining facilities known to have existed in New York since 1878.

**Table 2. Status of solution salt mining in New York in 1893.**

<table>
<thead>
<tr>
<th>COUNTY</th>
<th>NUMBER OF FACILITIES</th>
<th>NUMBER OF WELLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genesee</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Livingston</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>Onondaga</td>
<td>1</td>
<td>54</td>
</tr>
<tr>
<td>Tompkins</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wyoming</td>
<td>15</td>
<td>48</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>25</strong></td>
<td><strong>129</strong></td>
</tr>
</tbody>
</table>

Primary Reference: Merrill (1893)

**Table 3. Total number of salt-related wells drilled in New York, 1820-1993.**

<table>
<thead>
<tr>
<th>Well Type</th>
<th>Number Drilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration</td>
<td>69</td>
</tr>
<tr>
<td>Solution Mining</td>
<td>542</td>
</tr>
<tr>
<td>Other Wells Associated with Salt</td>
<td>39</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>650</strong></td>
</tr>
</tbody>
</table>

**Table 4. Solution salt mining in New York, 1878-1994.**

<table>
<thead>
<tr>
<th>County</th>
<th>Number of Active Fields</th>
<th>Number of Abandoned Fields</th>
<th>Number of Known Solution Mining Wells Drilled</th>
<th>Year First Well Drilled</th>
<th>Year Last Field Abandoned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genesee</td>
<td>0</td>
<td>2</td>
<td>11</td>
<td>1878</td>
<td>after 1917</td>
</tr>
<tr>
<td>Livingston</td>
<td>0</td>
<td>9</td>
<td>25</td>
<td>1883</td>
<td>after 1917</td>
</tr>
<tr>
<td>Onondaga</td>
<td>0</td>
<td>1</td>
<td>162</td>
<td>1888</td>
<td>1988</td>
</tr>
<tr>
<td>Ontario</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1884</td>
<td>unknown</td>
</tr>
<tr>
<td>Schuyler</td>
<td>2</td>
<td>1</td>
<td>88</td>
<td>1893</td>
<td>--</td>
</tr>
<tr>
<td>Tompkins</td>
<td>0</td>
<td>3</td>
<td>27</td>
<td>1891</td>
<td>1962</td>
</tr>
<tr>
<td>Wyoming</td>
<td>3</td>
<td>24</td>
<td>228</td>
<td>1978</td>
<td>--</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>5</strong></td>
<td><strong>41</strong></td>
<td><strong>542</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Solution Mining Methods and Technology

The earliest incidence of technology transfer between the salt and petroleum industries took place in 1859, when Colonel Edwin Drake installed surface casing in his famous oil well in Oil Creek, Pennsylvania. Drake had observed the shallow salt drillers in Syracuse using this technology to prevent water inflow, and applied it when shallow water was encountered at the Oil Creek well (Eskew 1948). Use of surface casing in salt, oil, and gas wells is now not only common practice, but required by regulations to ensure that shallow aquifers are protected from contamination by brine and hydrocarbons in the wellbore.

In recent decades, technologies developed in the petroleum industry have been adapted to solution mining operations. Examples include use of modern drilling equipment, casing and cementing materials and methods, wireline logging, perforating, hydrofracturing, and horizontal drilling.

Early solution mining methods.—Methods used during the first few years of New York's solution mining industry are recounted by Merrill (1893), among others. The earliest Wyoming and Livingston County solution mining operations consisted of single well caverns, where fresh water was introduced through the annulus and brine withdrawn by pumping through the tubing (Fig. 4). It was common practice, where water-bearing zones were present above the salt, to allow water from these zones to flow down the annulus to contact and dissolve the salt. Where there was not a sufficient downhole water source, operators pumped water from nearby creeks or springs down the annulus, thereby forcing brine up through the tubing. At multi-well fields, caverns often became interconnected. Operators then began using separate wells for injection and withdrawal.

Wells in Tully Valley connected very early in the field's history to form large multi-well galleries. It was not necessary to pump fresh water down the Tully Valley wells because the lakes that supplied water were located at a higher elevation than the wells. The natural hydrostatic head created by this difference in elevation was sufficient to force brine to the surface, where it flowed almost 20 miles via gravity pipeline to the Solvay Process Company's soda ash plant near Syracuse.

Roof padding.—Caverns created by the methods described above typically developed a “morning glory” or inverted cone shape, with the greatest diameter at the cavern roof or top of salt. Solutioning occurred preferentially at the top of the cavern, with insolubles falling to the floor, forming a blanket and reducing the surface area of salt available for solutioning (Pullen 1973). An ever-widening unsupported roof span was created that would eventually collapse. This caving would damage tubing in the wellbore, necessitating shutdown and costly repair procedures. Wells would ultimately be abandoned because of the difficulty of maintaining reliable production after repeated cavings and reworkings.

The first technology implemented by the industry to control cavern shape, prevent waste of salt at the cavern bottom, and minimize collapse is known as roof padding. Initially developed for use in Tully Valley by Trump (1936), roof padding consists of injecting a fluid such as air or oil along with the fresh water. The air or oil forms a cushion at the top of the cavern. This cushion, or pad, prohibits the fresh water from coming into contact with the cavern roof, thus confining solutioning to a controlled height at the bottom of the cavern. Once a desired cavern diameter is attained, thickness of the cushion is reduced to allow upward solutioning and formation of a cylindrical cavern. Theoretically, roof padding increases stability by controlling both height and diameter of the cavern. Roof padding also reduces waste by eliminating the blanketing effect that occurs when solutioning takes place only at the top of an inverted cone-shaped cavern.

Roof padding, using air as the cushion, was first used in Tully Valley in 1929 (Fig. 5). The goals of air-padding of solution caverns in Tully Valley were longer well life and greater ultimate salt recovery without cavern collapse. However, use of the technology in conjunction with close well spacing and pre-existing interconnected caverns resulted in lack of control of the location and direction of solutioning. Longer well life enabled removal of larger volumes of salt, thus contributing to the continued creation of large, unsupported roof spans. Inadequate roof support led to cavern collapse and eventual sinkhole formation.
Two New York operators used fuel oil for roof padding in the early and middle 1970's. Currently, the only fluid injected into solution mining caverns in New York for roof padding is food-grade mineral oil. A proposal for diesel oil injection as a facility where caverns are to be created for natural gas storage has been approved. Figure 6 is a schematic representation of oil-padding in a single-well cavern. Modern facilities maintain close control of the location and extent of solutioning, so that roof padding does not contribute to the type of problems associated with Tully Valley.

"Wild brining." --Pullen (1973) used the term "wild brining" to refer to withdrawal of brine created via solutioning of subsurface salt by naturally circulating groundwater, without the use of injection. The industry soon recognized that this practice could cause uncontrolled solutioning to occur remote from the withdrawal wells, ultimately resulting in subsidence problems. Because of this hazard, most operators discontinued their use of this method by 1921 (Solvay Process Company [Brussels] 1921).

The early New York practice of allowing aquifer water to flow down brine well annuli can be viewed as man-induced "wild brining," because brine was withdrawn without injection of fresh water. However, early "wild brining" at single-well caverns in Wyoming and Livingston Counties in New York is not known to have caused significant ground subsidence. Reasons probably include low production rates combined with relatively short well life, with most of the early facilities having been drilled between 1880 and 1893 and abandoned by the turn of the century. In addition, at single-well caverns aquifer water entered and brine was withdrawn through the same wellbore, so the location of solutioning was limited to beneath that well.

The only long-term "wild brining" to take place in New York occurred in Tully Valley and did contribute to significant subsidence and sinkhole formation. Starting in about 1930, casings were removed from closely spaced wells, allowing aquifer water to flow down wellbores and dissolve salt. Brine withdrawal from multi-well connected caverns led to large unsupported roof spans. Caverns collapsed, resulting in fracturing of overlying strata. Through this process, groundwater recharge to the deep salt strata was increased to the extent that by the late 1950's fresh water injection was no longer necessary for sufficient solutioning to occur (Tully 1985). A true "wild brining" scenario, as illustrated in figure 7, was thus created, whereby circulating groundwater rather than injected fresh water was the cause of solutioning. The point of fresh water entry to the salt cavern, which is the location of most solutioning, was unknown. Large volumes of brine were withdrawn without maintaining control of the location or extent of solutioning. Sinkholes and significant general ground subsidence were the ultimate result.

The practice of "wild brining" in Tully Valley, and therefore in New York State, ceased when the field was abandoned in 1988.

Figure 5. Tully Valley air-padding technology, 1929.
**Hydrofracturing**—Hydrofracturing methods first used by the petroleum industry have been adapted to the solution mining industry for establishing connections between wells to create multi-well caverns. The earliest hydrofracturing efforts at a solution mining field in New York were described by Jacoby (1961). Only one operator in New York is currently using the hydrofracture technique on a routine basis, but hydrofracturing has been used by all of New York’s active operators at their existing fields.

The hydrofracturing method now used in New York involves cementing casing through the salt bed to be mined, and then notching the casing and cement near the base of the salt (Fig. 8). Hydrofracturing operations commence at one well, with water injected under pressure until a fracture connection is established with a target well. Once two wells are successfully connected by hydrofracturing, they are alternated between withdrawal and injection to balance production and create a dog-bone shaped cavern near the base of the salt. When adequate spacing is maintained between caverns, this technique provides for efficient, well-controlled development of the salt resource.

Successful hydrofracturing requires knowledge of the preferred direction of fracture propagation, which is best gleaned from a thorough geologic investigation to understand the effects of features such as folds, faults, or stratigraphic discontinuities. Haimson (1974) recommended that experimental hydrofracturing be performed in newly developed fields.

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**Figure 6.** Typical NY single-well oil-pad development, 1995.

**Figure 7.** Schematic illustration of “wild brining” modified from Tully (1985). Brine cavity is recharged by water entry through open wellbores and annuli as well as fractures associated with subsidence features.
Horizontal drilling.--Since 1990, two solution mining operators in New York have adapted horizontal drilling to their routine cavern development operations. One well is drilled horizontally near the base of the salt, followed by development of up to three vertical wells. The vertical wells are operated as single-well caverns until they connect to the horizontal well. Once the vertical and horizontal wells are connected, the vertical wells are used for injection and the horizontal well for withdrawal. Solutioning occurs and caverns are thus created at the vertical wells, with the horizontal well acting as a pipeline to convey saturated brine from the bottoms of the caverns to the surface (Fig. 9). One operator uses roof padding, with food-grade mineral oil, to control growth of the caverns at the vertical wells. As with hydrofracturing, when adequate spacing is maintained between well groups, horizontal drilling for solution mining cavern development ensures efficient, well-controlled brine production.

Although new caverns will be created at existing fields, no new solution mining facilities to support salt manufacture are anticipated in New York at this time. Solution mining will be used to create caverns at new facilities for natural gas storage; one such facility, to be operated by Avoca Natural Gas Storage, Inc., has been permitted. This facility, located in Steuben County, will be developed in conjunction with brine disposal wells to re-inject the brine withdrawn from the salt strata into deeper rock formations. Economic considerations currently render alternatives to brine disposal, such as on-site evaporation or transportation to existing manufacturing plants, infeasible for a new facility.

Natural gas storage to be operated by New York State Electric and Gas in an existing cavern at Akzo Nobel Salt, Inc.'s active solution mining facility in Watkins Glen has also been permitted.

ENVIRONMENTAL ISSUES

Solution mining in New York is regulated from an environmental standpoint by both the United States Environmental Protection Agency (EPA) and the New York State Department of Environmental Conservation (DEC). Table 5 summarizes the roles of the EPA and DEC with respect to solution mining regulation. The primary goals of environmental regulation of solution mining are protection of aquifers and prevention of damaging or catastrophic subsidence.

Protection of Aquifers

Aquifers must be protected with respect to both quality and quantity of water. Well construction and operation requirements are designed to prohibit contact between brine and any subsurface fresh water source. All solution mining operators in New York cement all wellbore casing strings from the base of the casing to the surface, eliminating brine
Table 5. Regulation of solution salt mining in New York State.

<table>
<thead>
<tr>
<th>Agency</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York State Department of Environmental Conservation Division of Mineral Resources</td>
<td>- <strong>Issue Well Drilling Permits</strong> - Review and approval of well construction and completion methods; site specific environmental assessment and drilling permit conditions.</td>
</tr>
<tr>
<td>United States Environmental Protection Agency</td>
<td>- <strong>Track Well Status and Production</strong> - Ensure timely plugging of idle wells with no future utility.</td>
</tr>
<tr>
<td></td>
<td>- <strong>Site and Facility Inspections</strong> - Ensure compliance with environmental standards set in state rules, regulations, and guidelines.</td>
</tr>
<tr>
<td></td>
<td>- <strong>Issue Well Plugging Permits</strong> - Review and approve plugging plans, final site inspection and approval of site restoration.</td>
</tr>
</tbody>
</table>

well annuli as possible conduits for brine migration into fresh water aquifers. Furthermore, injection pressure limitations are set to prevent creation of fractures in the rock strata that lie between the salt strata and overlying aquifers. These intervening strata are referred to as “confining” zones, whose properties must be evaluated to ensure that they will indeed act to confine brine to the salt cavern. The EPA also requires periodic mechanical integrity testing of injection wells, to demonstrate soundness of downhole casing and cement. Finally, aquifers are protected by timely plugging of wells with no future utility, eliminating abandoned wellbores as possible means of communication between salt caverns and fresh water zones. All abandoned wells at the facilities listed in table 1 have been plugged, as have all wells at the abandoned Tully Valley brine field. In addition, 20 wells abandoned at a Tompkins County brine field in 1962 were plugged in 1988.

A potential impact to quantity of groundwater exists when operators propose use of aquifer water for injection and/or hydrofracturing. Hydrologic evaluations must be performed in order to set appropriate limits on rate of withdrawal from aquifers. None of the facilities listed in table 1 use aquifer water as the primary source for routine injection operations.

**Prevention of Damaging or Catastrophic Subsidence**

Damaging or catastrophic subsidence is prevented by controlled, limited extraction of salt and timely plugging of abandoned wells. Such subsidence has not occurred at any of the facilities listed in table 1, and is not known to have occurred associated with solution mining in New York outside of Tully Valley. As stated previously, the problems in Tully Valley were primarily caused by creation of large, unsupported roof spans and lack of control of the location or extent of solutioning. The many significant differences between Tully Valley and today’s active facilities are described in table 6.

**Other Environmental Concerns**

NYSDEC (1988) lists the following additional environmental resources potentially impacted by solution mining operations: wetlands, surface water bodies, agricultural areas, significant habitats, and areas of historic, cultural, or archaeological significance. Well/facility siting restrictions and site-specific environmental assessments and permit conditions are the primary means of protection of these resources.

Surface impacts during drilling of wells are prevented by environmentally sound site preparation, including lined pits for fluid containment and appropriate sedimentation and erosion control measures. Drilling fluids must be removed and sites restored shortly after cessation of drilling operations.

The potential for large brine spills at individual wellsites during production operations is minimized by the fact that brine is piped directly from the well to a pipeline or to plant storage tanks, with no wellsites storage. Nevertheless, some operators construct surface impoundment basins at wellsites.
Table 6. Differences between Tully Valley and today's active solution mining facilities.

<table>
<thead>
<tr>
<th></th>
<th>Tully Valley</th>
<th>Today's Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geology</td>
<td>Small ratio of overburden thickness to thickness of salt mined.</td>
<td>Larger ratio of overburden thickness to thickness of salt mined.</td>
</tr>
<tr>
<td>Well Construction</td>
<td>No cement behind casing for most of life of field.</td>
<td>All strings of casing cemented from the base of casing to the surface.</td>
</tr>
<tr>
<td>Cavern Development</td>
<td>Little or no control of lateral solutioning throughout the life of the field, creating interconnected caverns of up to one mile long without adequate roof support.</td>
<td>Controlled injection and solutioning using state-of-the-art practices such as horizontal drilling, notching and hydrofracturing, and roof padding.</td>
</tr>
<tr>
<td>Volume of Salt Removed</td>
<td>Estimated 65% of salt in place in most field areas.</td>
<td>Estimated 10 - 15% of salt in place.</td>
</tr>
<tr>
<td>Regulatory Oversight</td>
<td>None.</td>
<td>State and EPA.</td>
</tr>
<tr>
<td>Well Plugging</td>
<td>Many wells left unplugged for up to 100 years.</td>
<td>All abandoned wells plugged.</td>
</tr>
</tbody>
</table>

The Traditional Role of the Geologist

Log interpretation.—Wireline logs are run in every new solution mining well to determine salt thickness and to identify the base of the salt in order to plan effective hydrofracturing and horizontal drilling programs. At new facilities, thickness and strength characteristics of the confining zones are important for determining injection pressures that will not create vertical pathways between the salt zone and upper fresh water zones.

Core evaluation.—Geologists perform core evaluation, mostly at new facilities, to determine salt quality as well as the characteristics of the roof rock and confining zones. Analysis of both logs and cores on-site by the geologist promotes the most efficient final design of the wellbore completion program.

Mapping.—Continued mapping as new wells are drilled at existing facilities is important for identifying faults and stratigraphic or facies changes as well as for determining the distribution of overlying gas or water and confining zones. Faults must be identified because they affect the depth wells must be drilled in order to reach the salt. Faults can also interfere with hydrofracturing and horizontal drilling to create galleries. Jacoby and Dellwig (1974) described how hydrofracturing was affected by faulting at one of New York’s brine fields. Stratigraphic changes such as salt lens pinchouts can also interfere with gallery creation. The downhole location of gas and water zones must be known in order to plan effective well casing and cementing programs.

The Expanding Role of the Geologist

As the worldwide solution mining industry evolves, so do the functions of geologists employed in the industry. Today's solution mining industry is made up of a small group of intensely competitive companies, with the geologist playing a very diverse role (McCartney 1995). Furthermore, the typical geologist employed in the industry today, whether a company employee or consultant, is often responsible for a large geographic area that encompasses more than just one state. Additional duties of the geologist employed in the solution mining industry may consist of any of the following:

- environmental assessments and interfacing with regulators
- feasibility studies, cost evaluation and design aspects of new facilities, including hydrologic investigations to evaluate potential water sources
- involvement in underground natural gas and compressed air storage projects, including site selection, design of casing programs and cavern development methods and evaluation of brine disposal options
• facility maintenance, long-term planning and workover operations
• mapping of salt quality and structures in underground salt mines as well as at solution mining fields

SUMMARY

Since 1878, the solution salt mining industry in New York has evolved from one of many small facilities operating in a "boom" atmosphere to one of a handful of larger facilities developing New York's salt resource in a methodical and efficient manner. A total of 542 wells have been drilled in 41 fields, with significant subsidence and sinkholes known at only one facility, Tully Valley, which is no longer in operation.

While Tully Valley provides an educational example of poor solution mining practices, such as "wild brining," and the associated adverse impacts, New York's current facilities provide the contrasting example of state-of-the-art techniques combined with effective regulatory oversight. Wells are cased and cemented to prevent pollution of aquifers. Modern cavern development methods, including hydrofracturing, horizontal drilling, and roof padding, are used to prevent damaging or catastrophic subsidence. Subsurface operations are overseen by both the EPA and the DEC. The geologist, along with his or her fellow professionals in both the solution mining industry and the regulatory agencies, plays an important role in assuring that New York's salt resource is economically developed and utilized without adverse environmental impacts.

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