Prairie Formation Solution-Mining Activity on the Rise

By Ned W. Kruger

Introduction

The Prairie (Evaporite) Formation contains the world's largest potash resource. With two recent additions, there are currently 12 mines working the Prairie Formation potash deposits in Saskatchewan. Previous Geo News articles (Murphy, 2011) (Kruger, 2019) have described how the potassium-bearing salt deposits were formed over a broad area including Saskatchewan, southwestern Manitoba, northwestern North Dakota, and northeastern Montana. Theses potash deposits underlie an area of approximately 11,000 square miles (28,500 km^2) in northwestern North Dakota (Anderson and Swinehart, 1979). While there are multiple uses of potash, it's primary use is as a fertilizer. These mines support agricultural production in North America and throughout the world.

World potash production was down approximately 5 percent in 2019 from a record high production volume of 43.3 million metric tons in 2018 (fig. 1) (Jasinski, 2020). In the United States production has remained rather stable at around 500,000 metric tons per year from 2016 through 2019, after a reduction of approximately 50% in the preceding five-year period. New Mexico and Utah are currently the only U.S. states with potash production.

According to North American potash producers, the weather played a significant role in last year's loss of production, as early and late seasonal rainfall events and increased wetland extents caused reduced application rates by crop producers. Canadian potash mines also dealt with the effects of a rail strike and the loss of a potash production tax credit which they had benefited from since 1990. Still another factor was the stockpiling of some imports in China over the past several years, providing China greater price negotiation leverage in their new contracts. This resulted in a drag on pricing which led some producers to reduce their production output and idle mines in late 2019. Over the past decade, China and India have been viewed as the

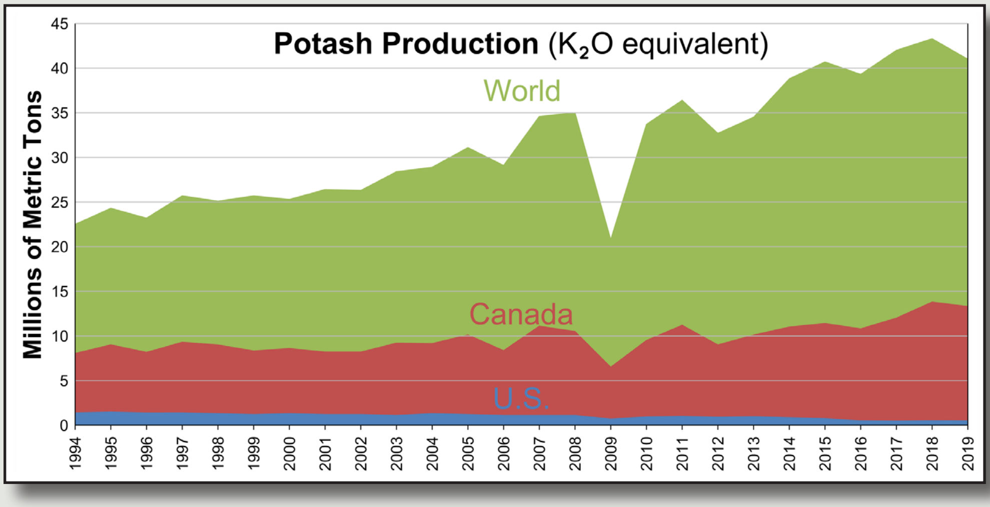
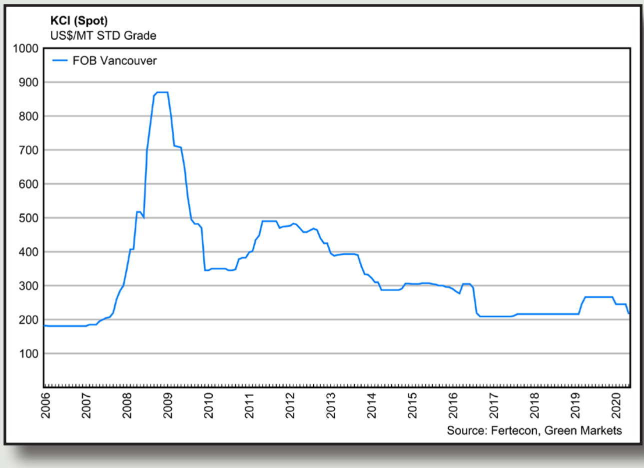


Figure 1. World, Canadian, and U.S. production of potash from 1994 through 2019. Source: U.S. Geological Survey Mineral Commodity Surveys.

Background photo credit: Arthur Ma, Western Potash Corp.



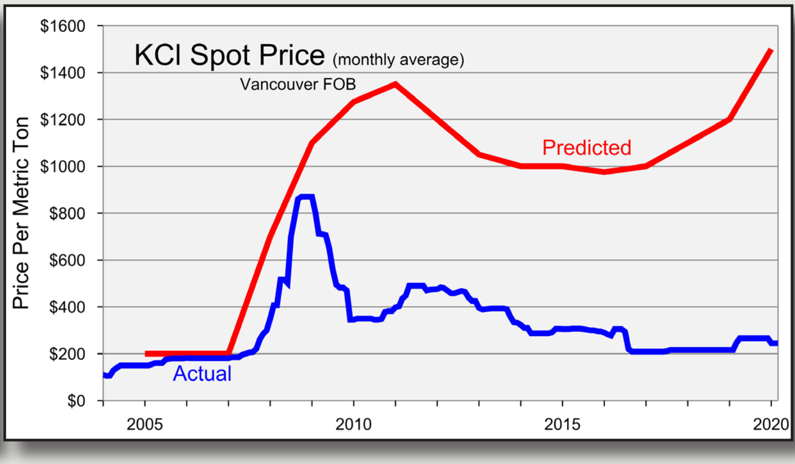


Figure 2a. Potash spot market prices from 2006 through May of 2020. Source: Fertecon, Green Markets.

Figure 2b. Comparison of a 2005 price forecast (Murphy, 2011) with actual prices.

greatest source of potash consumption growth. There was some growth in price support early in 2019, but all those gains were given back by May of 2020 (fig. 2a).

A 2011 Geo News article (Murphy) included a graph showing an industry-made prediction of prices over the time period of 2005 to 2020 (fig. 2b), which we may now view with hindsight. The projection rather accurately forecast the steep incline of prices over the first several years, but subsequent to the economic downturn of late 2008 and 2009 the predicted and actual trends were widely separated. Such a result is not surprising, as factors unknown at the time of the forecast compound over time. While projections are continually recalibrated as new market conditions and events warrant, they also show that taking a new mine operation from concept to production, a process which might take a decade or more, requires fortitude, adaptability, and innovation.

Solution Mining Momentum North of the Border

In 2017, K&S Potash Canada's Bethune Mine, formerly known as the Legacy Project, began production as Saskatchewan's first greenfield potash mine in over 40 years. Less than three years later, Western Potash became the next with production at its Milestone Mine beginning in the spring of 2020. The new mines were both built to produce via solution-mining methods, where water is injected to dissolve salts and the resulting brine pumped back up to the surface where the minerals are recrystallized. They join Mosiac's Belle Plaine Mine, built by Kalium Chemicals in 1964, as mines originally designed for solution-process mining in areas where the potash deposits are too deep for conventional underground mining. The Milestone Mine brings potash production ever closer to the North Dakota border (fig. 3). A fourth facility in Saskatchewan, Nutrien's Patience Lake Mine, also currently operates as a solution mine, however it was converted from conventional mining operations after water seeps into the mine shaft ultimately flooded the mine in 1987.

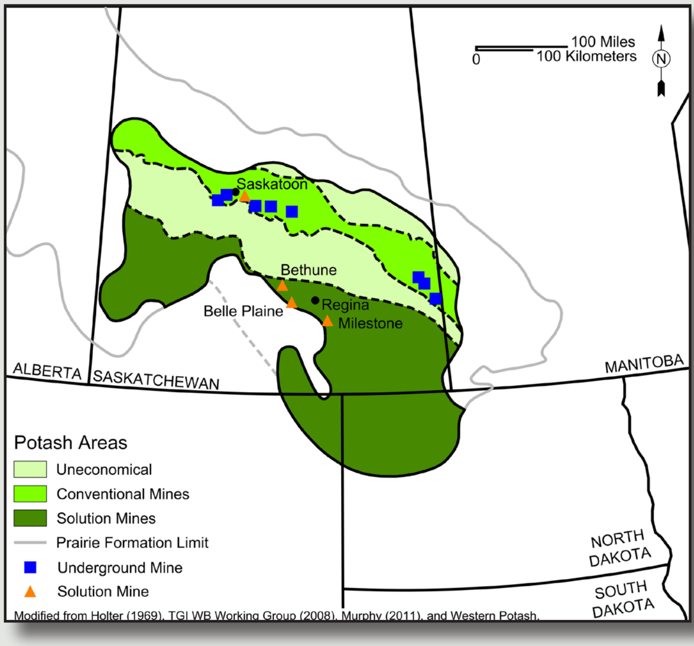


Figure 3. An outline of the Prairie Formation extent with shaded potash-containing areas and locations of operating potash mines.

A typical potash solution mine involves a process of injecting fresh water and recovering brine from a set of two vertical wells to form caverns in the salt below a potash deposit. The caverns are enlarged until open communication between the two wells exists and sumps are created below the wells where insoluble impurities can be held. Once the wells are connected, hot brine is injected into one well where it dissolves potash from the roof and walls before it is extracted through the other well. The process works its way up through the potash layer with an injected oil blanket used to prevent uncontrolled vertical migration (fig. 4). Back at the surface the potash-containing brine is recrystallized in ponds by natural or mechanical cooling, with both potash and salt (primarily NaCl) being brought to the surface.

The Milestone project is a particularly interesting case to look at as a possible template for a future solution-mined potash production facility in North Dakota. The project was designed

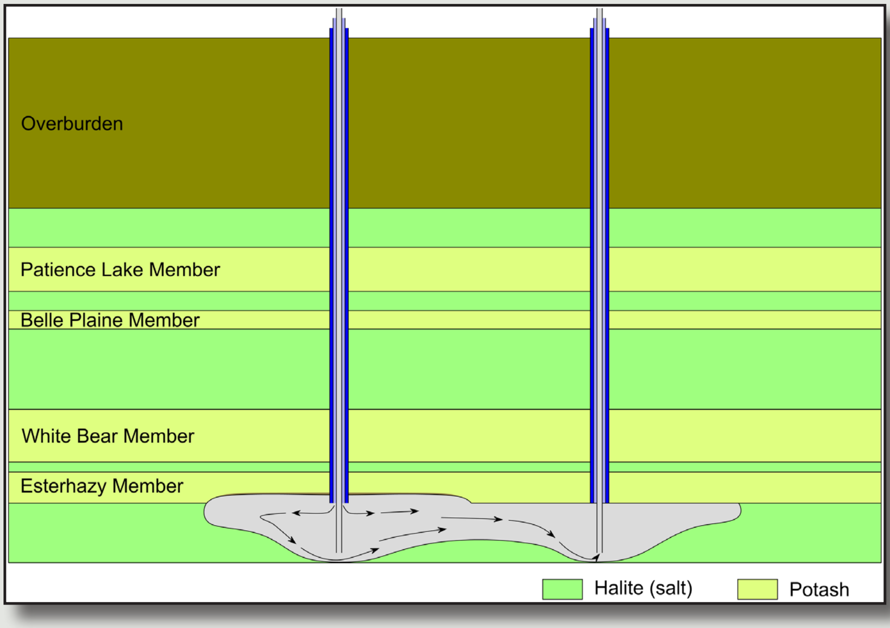


Figure 4. Illustration of a standard potash solution mine with vertical wells. Modified from Western Potash.

to be more environmentally friendly, with less use of fresh water and no surface tailings. Taking advantage of horizontal drilling technology, the injection and production wells are drilled to intersect at the bottom of the potash layer, from which point the injection well continues horizontally (fig. 5). Rather than using fresh water to create caverns beneath the potash target, brackish water is used as the injection solution and "hot" mining of the potash is able to proceed almost immediately. The nearly salt saturated brine selectively dissolves potash while flowing back toward the recovery well, leaving salt behind while gradually enlarging the horizontal cavern. This selectivity for potash also means an oil blanket is not required to control the cavity, as the upward progress stops at the top of potash bed where the overlying salt is encountered. Once the brine is back at the surface it is cooled in ponds, causing the potassium chloride to precipitate out and settle at the bottom of the pond. The remaining brine, still containing dissolved sodium chloride, is then pumped back down the well to recover more potash.

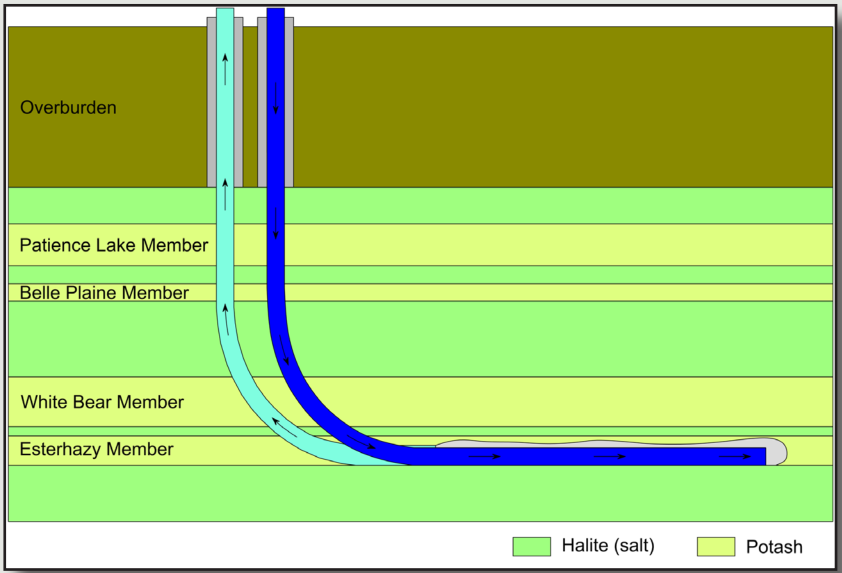


Figure 5. Illustration of a potash solution mine with horizontal drilled injection and production wells. Modified from Western Potash.

Milestone can also help us have a sense of the work and time involved to bring a greenfield project to production. This project was initially financed and permitted in the spring of 2008 at a time when potash prices were projecting, and in fact trending, upward. Western Potash was able to continue through the market downturn which began in the fall of 2008, and a year later had identified an exploration target based on 2D seismic data. A two-well drilling program was initiated as part of a feasibility study delivered in 2012. Several years later, a total of 11 potash exploration wells had been drilled and hundreds of line kilometers of 2D and 3D seismic data were purchased or acquired. A pilot study was completed in 2015 and an engineering report followed in 2016. All of these tasks culminated in a Phase 1 production project in the fall of 2018 when construction began on a six-well, three-cavern mine site capable of producing 146,000 tons of potash per year.

In anticipation of a future cycle of commodity prices renewing interest of potash production in North Dakota, the NDGS has been creating new maps of the Prairie Formation (fig. 7). A map series depicting potash member isopach thicknesses and log-based estimates of potassium oxide (K_2O) concentrations of various wells includes up to six maps per 100k sheet (figs. 7a & 7b), one for each of the potash members mapped within the sheet.

References

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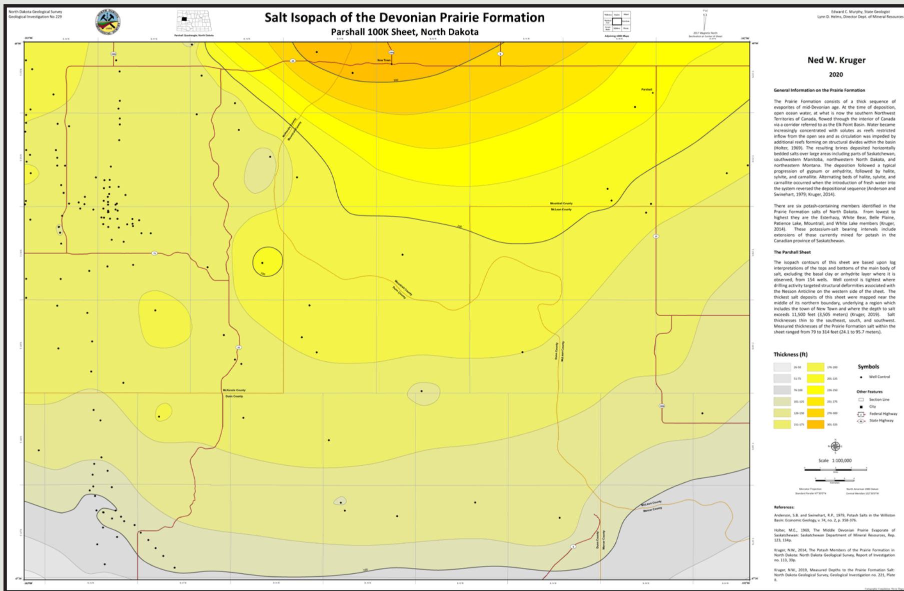

Figure 6. North Dakota Geological Survey, Geological Investigation No. 229.

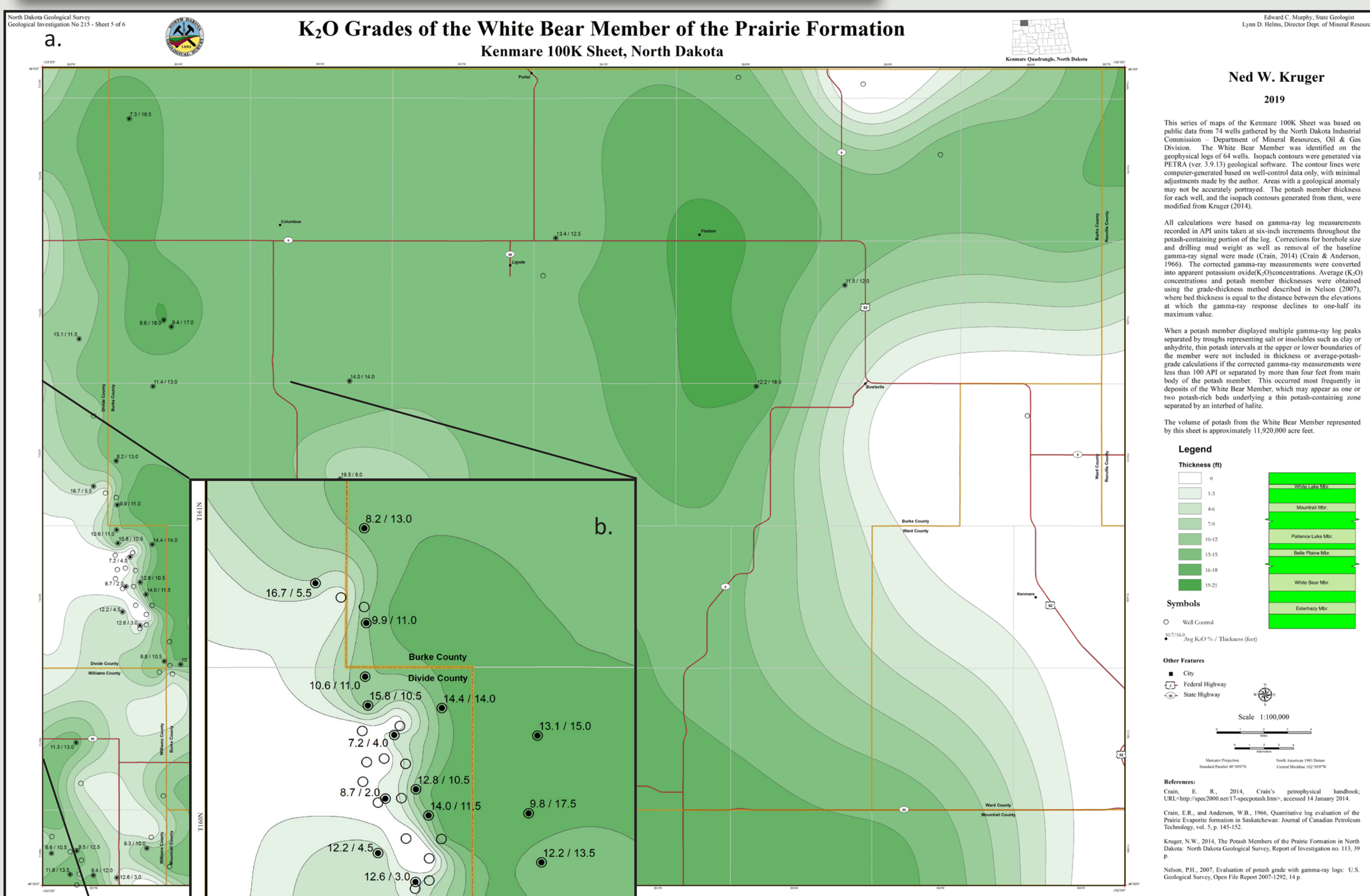

Figure 7a. North Dakota Geological Survey, Geological Investigation No. 215, sheet 5 of 6.

Figure 7b. Expanded view of GI-215, sheet 5, the two numbers given for selected wells represent the potassium oxide concentration percentage and the thickness of the potash interval in feet.