POTASH IN NORTH DAKOTA

ED MURPHY

Introduction

For the first time in 34 years, the North Dakota Geological Survey has issued a subsurface mineral permit for potash exploration. The permit was issued to Dakota Salts, LLC -- a wholly owned subsidiary of Sirius Exploration PLC. At least four earlier potash exploration wells have been drilled in northwestern North Dakota. In 1962, Texaco, Inc. drilled the TXL Storage no. 1 near the town of Lignite in Burke County. A cavern was created in the salt section of this well for propane storage. Three additional potash wells were drilled in 1976; two were drilled in Burke County and one in Bottineau County. Burlington Northern, Inc. drilled the Helming no. 4-11 in Bottineau County. Chandler & Associates, Inc. drilled the Ewing no. 3-3 and the Wilson no. 2-33 in Burke County, and farmed-out the potash section of these wells to Kalium Canada, Ltd.

Potash

The term potash originated in the early 16th century, referring to the salt that remained when a mixture of water and wood ashes were evaporated in an iron pot to form potassium carbonate (Wilton, 2009). Today, potash is the common name typically applied to a variety of potassium salts (fig. 1). In the Williston Basin, potash primarily consists of potassium chloride (mineral name sylvite) and hydrated potassium magnesium chloride (mineral name carnallite). Potash spot market prices or mining statistics are typically reported as either KCl (potassium chloride) or K_2O (potassium oxide) equivalent.

The Prairie Formation

North Dakota was covered, or partially covered, by seas throughout most of Paleozoic, Mesozoic, and early Cenozoic time (60 to 500 million years ago). The Williston Basin originated about 500 million years ago (Late Cambrian to Early Ordovician) becoming the primary receptacle for sediment deposition in an area that includes western North Dakota, northwestern South Dakota, eastern

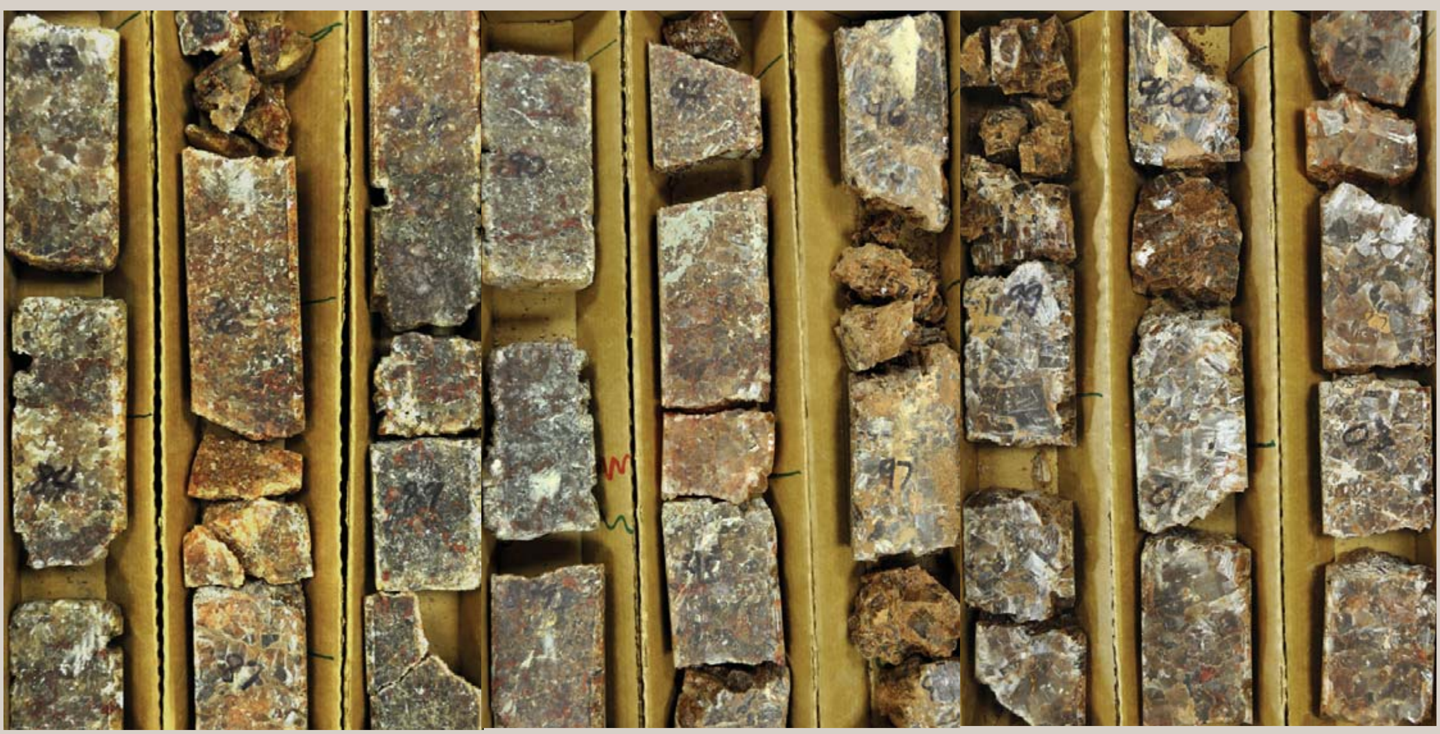
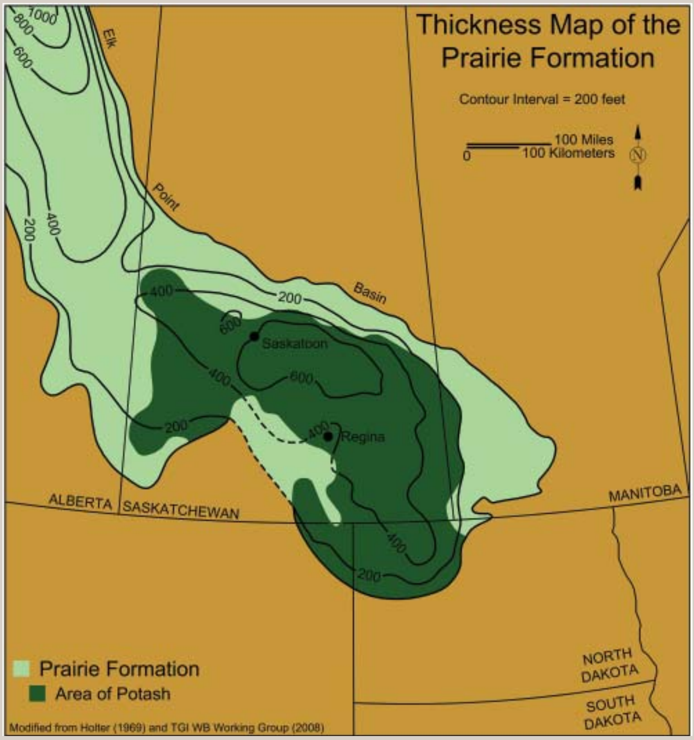


Figure 1. Twenty-one feet of salt core from a depth of 8,983 to 9,004 feet (going from 8,983 feet in the upper left to 9,004 feet in the lower right hand portion of the photograph) in the Texaco TXL storage well in central Burke County. Note the variable grain size, color, and clay content across this interval of the Esterhazy Member of the Prairie Formation.



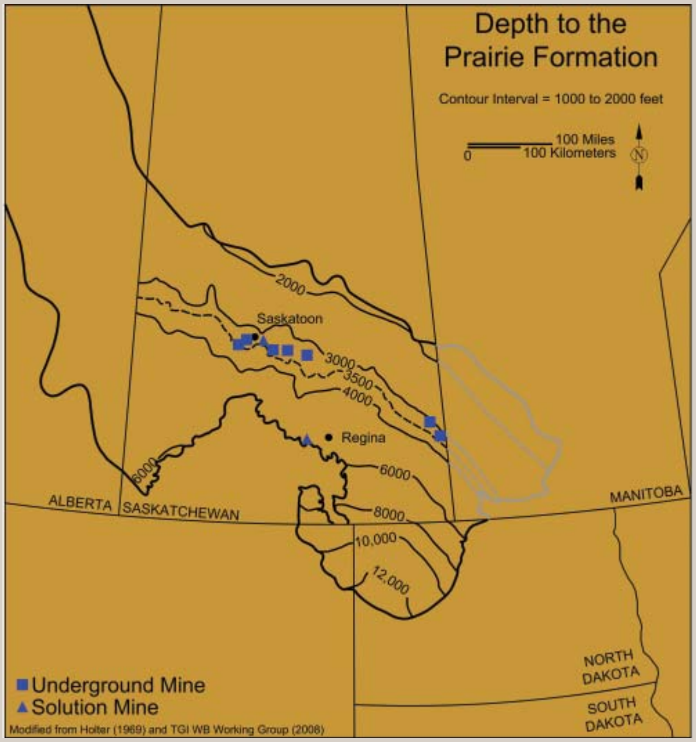


Figure 2a. An isopach map (thickness) of the Prairie Formation and the extent of potash zones within that formation. **2b.** Depth to the Prairie Formation and locations of operating potash mines. Mine locations taken from the Saskatchewan Ministry of Energy and Resources Operating Mines List published in March 2010.

Montana, southern Saskatchewan, and southwestern Manitoba. Periodically, these seas deposited evaporite minerals when they became isolated from the open oceans. Evaporites are deposited in waters confined within closed basins where circulation is impeded and the rate of evaporation exceeds the rate of recharge. As the volume of water is reduced the concentration of dissolved salts increases until eventually they begin to precipitate out of solution and are deposited on the basin floor. This scenario of evaporite deposition repeated itself at least two dozen times within the North Dakota portion of the Williston Basin. As a result, there are about 24 salt layers in the basin ranging in thickness from a few feet up to hundreds of feet (LeFever and LeFever, 2005). The thickest accumulation of salt in the basin occurs within the Prairie Formation (Devonian).

During the Middle Devonian, roughly 400 million years ago, the Williston Basin was some distance from the open ocean, but connected to it through an elongated northwest-southeast trending trough called the Elk Point Basin. The Elk Point Basin extended from northwestern North Dakota to northern Alberta (fig. 2a). Early in the Middle Devonian, two structural divides created three sub-basins within the Elk Point Basin, the southernmost sub-basin covered Saskatchewan, Manitoba, North Dakota, and Montana. The poorly circulating water within these sub-basins began to precipitate salt, creating the Prairie Formation, or the Prairie Evaporite as it is known in Canada. The Prairie Formation extends from northwestern North Dakota into northern Alberta. Throughout much of Saskatchewan and northwestern North Dakota the Prairie Formation is 300 to 500 feet thick (fig. 2a). While halite (sodium chloride, NaCl, typically known as table salt) and anhydrite (calcium sulfate, $CaSO_4$) are the dominant evaporites within the Elk Point Basin, potash was also deposited in the sub-basin that covered parts of Saskatchewan, Manitoba, North Dakota, and Montana creating the largest potash deposit in the world. This deposit extends over an area of 76,000 square miles, more than the total land area of North Dakota (71,000 square miles). Roughly 12,000 square miles of this potash deposit is situated in northwestern North Dakota.

Potash is concentrated into three zones within the Prairie Formation because minerals have different solubilities. Minerals typically precipitate from seawater in the following order: calcite and dolomite, gypsum and anhydrite, halite, sylvite and carnallite, etc. By the time the potassium salts began to precipitate in the Elk Point Basin, much of the seawater had evaporated. The presence of halite both above and between the potash zones indicates that water levels periodically rose in the basins and the evaporative cycle began all over again.

Complicating the stratigraphy of the Prairie Formation is the dissolution of some of the salt over time. This dissolution is especially evident along the edges of the deposit. Salt collapse within the Prairie Formation has affected overlying rocks and in some cases has been credited with creating traps or inducing faults and fractures into the overlying formations that are associated with oil production (LeFever and LeFever, 2005).

Most of the salt within the Prairie Formation, whether in Canada or in the United States, is halite. Potash makes up only about 10% of the formation by volume and is concentrated in three zones. The uppermost potash zone is discontinuous across the international border and is called the Mountrail Member in North Dakota and the Patience Lake Member in Saskatchewan. The other two members, the Belle Plaine and Esterhazy, are remarkably continuous and can be correlated from Saskatchewan into Manitoba, Montana, and North Dakota (Anderson and Swinehart, 1979) (fig. 3).

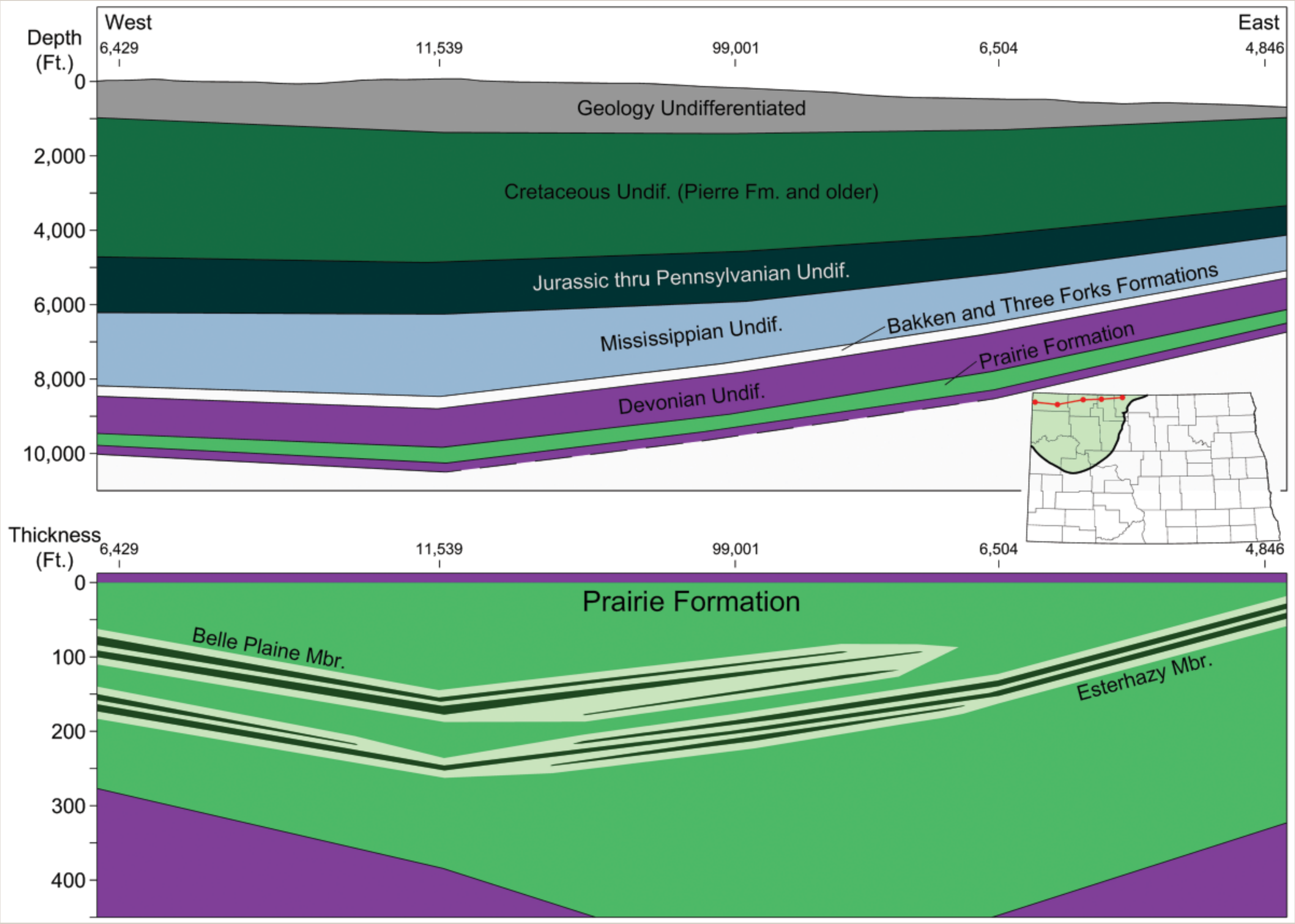


Figure 3. An east-west cross section (correlating to red line on inset map) to the base of Devonian rocks in northwestern North Dakota. The lower expanded cross section of the Prairie Formation demonstrates its variable thickness as well as the lenticular nature of the potash beds (dark green) within the Belle Plaine and Esterhazy Members. Most of the salt in the lime green and light green portion of the lower diagram is halite.

History of Potash Mining in the Prairie Formation

Potash mining began in Saskatchewan in 1959 and by 1971 the nine potash mines currently operating were all in production. Of these mines; seven are underground workings, one is a flooded underground mine now operated as a solution mine (Patience Lake), and another is a solution mine (Belle Plaine). It has been estimated that Saskatchewan contains 63.5 billion metric tons of recoverable potash reserves (reported as K_2O). This amount includes 4.5 billion metric tons of potash that could be mined by conventional underground methods and 59 billion metric tons by solution mining techniques (modified from Holter, 1969). The cut off between conventional underground mining and solution mining has been placed at about 3,600 feet, beyond which conventional underground salt mining is not considered safe (Halabura and Hardy, 2007) (fig. 2b).

Production and Uses of Potash

Canada is the leading producer of potash in the world. In 2008, Canada produced 10.5 million metric tons of potash (K_2O equivalent), accounting for approximately one third of the world's production of 35 million metric tons (fig. 4). Russia, Belarus, Germany, China, Israel, Jordan, and the United States are, in that order, the other leading potash producers (Jasinski, 2010a). Almost half (45%) of the potash mined in the province of Saskatchewan is consumed in the U.S. In contrast, only about five percent of Saskatchewan's potash is consumed within Canada. The remaining 50% or so of Saskatchewan's potash production goes to the Pacific Rim (China, Japan, Malaysia, Korea, and Indonesia) and Latin American countries (Fink and Berenyi, 2010).

In 2008, the United States mined about 1.1 million metric tons of potash (K_2O equivalent). In the meantime, the United States imported 5.7 million metric tons, 87% of these imports coming from Canada. Most of the potash produced within the U.S. in recent years has come from southeastern New Mexico, but there has also been domestic potash production in Michigan and Utah (Jasinski, 2010a). The potash deposits in northwestern North Dakota and northeastern Montana are recognized as the largest deposits in the United States. While Anderson and Swinehart (1979) placed the resource at 60 billion tons (50 billion in North Dakota and 10 billion tons in Montana) the U.S. Geological Survey estimates the total U.S. potash resource at roughly 7 billion metric tons, with the majority of that occuring in northwestern North Dakota and northeastern Montana (Jasinski, 2010a).

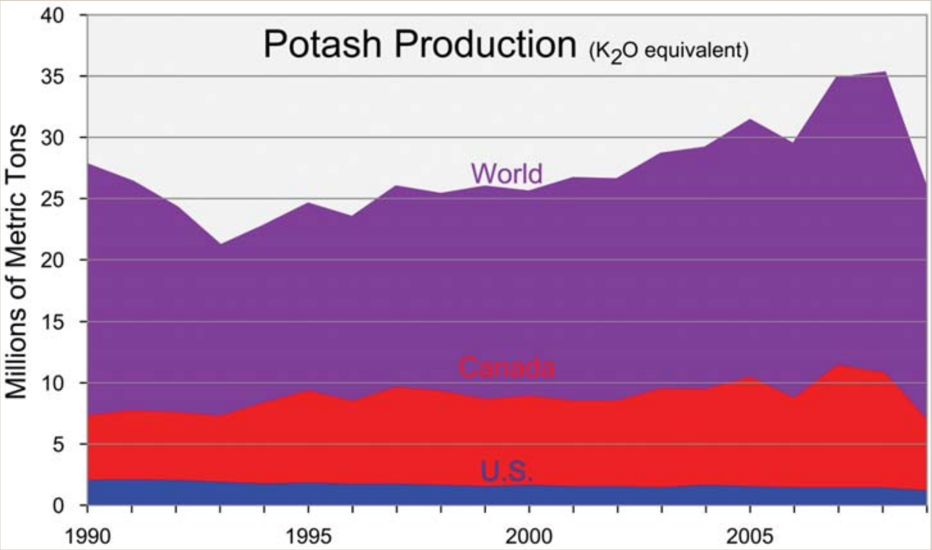


Figure 4. World, Canadian, and U.S. production of potash from 1990 through 2009. Source: U.S. Bureau of Mines and U.S. Geological Survey Mineral Commodity Surveys.

Worldwide, 93% of the potash mined is used as agricultural fertilizer (Jasinski, 2010b). Typically, the nitrogen, phosphorus, and potassium contents of fertilizer are labeled, in that order, on the fertilizer bag. In other words, a fertilizer bag labeled 22-2-14 contains 14% potassium by weight. Potash is used in a variety of other applications including aluminum recycling, metal electroplating, oil and gas drilling, mud, snow and ice melting, steel heat-treating, and water softening (Jasinski, 2010b).

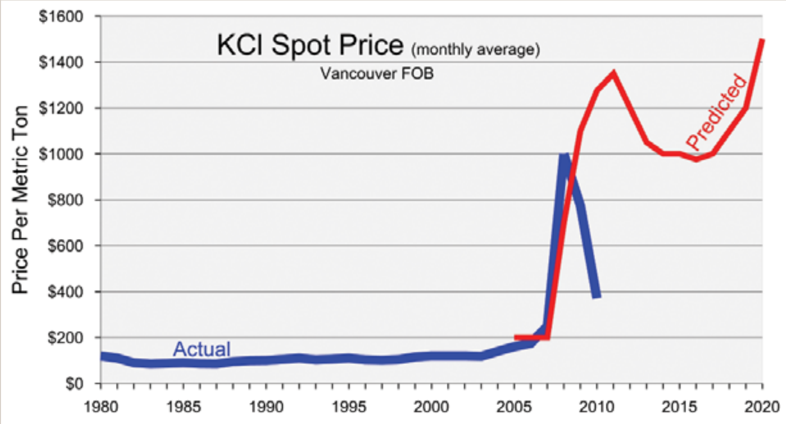


Figure 5. Potash spot market prices from 1980 thru 2010 and projected prices from 2005-2020. The projected prices were estimated in the mid 2000s and did not foresee the worldwide economic downturn that began in 2008. Source: Fertecon.

Price and Outlook of Potash

Throughout the 1980s and 1990s the spot price for potash was less than $200 per metric ton of KCl. As was the case with many mineral commodities, potash prices began increasing in the mid 2000s setting a record price in 2008 (fig. 5). A potash price projection in the mid 2000s predicted that the KCl spot price would begin dramatically increasing in 2007, peak at $1,375 in 2011, and would stay above $1,000 per metric ton through the year 2020. Much of this speculation was driven by projected increases in potash consumption within China and India.

The worldwide economic downturn has driven prices far below the record high, but they are still more than twice the average price of ten years ago (fig. 5).

In 2009, worldwide production of potash dropped 29% (down from 35 to 25 million metric tons of K_2O) as a result of the decrease in potash demand stemming from the economic downturn. Canadian potash production dropped 38%, going from 10.5 million metric tons in 2008 to 6.5 million in 2009. U.S. production decreased 24% to 840,000 metric tons in 2009 (fig. 4). Potash production has been recovering in 2010 to near pre-2009 levels. Going forward, as the world economy recovers, some in the industry are predicting potash will continue to increase at the past decade's rate of about 2.5% per year (Stone, 2009).

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