A SASKATCHEWAN POTASH REVIEW

Paul Labbe and Dave Kelly

Wardrop Engineering Inc. A Tetra Tech Company

Abstract

This paper will provide an update of the Saskatchewan Potash experience with some background on the last forty years of operational development, current technology and expansion interest in this area of Canada's potash reserves.

Discussion will focus on current operations, a current technology review and relate new technology options that have been tested but which are not yet generally exploited in the potash industry.

Some topics of discussion include dry processing, wet milling, underground mining machine and back-up equipment development, mill water handling reduction, brine injection and solution mining vs. traditional mining systems for Potash. Saskatchewan has a unique place in the current world supply of potash and operations in Saskatchewan have demonstrated a long and stable history.

These features can provide an interesting case study for other high volume miners and producers.

Keywords

Potash, potash mining, mineral processing, soft rock mines, Saskatchewan, underground milling, electrostatic separation, magnetic separation, wet milling, flotation, compaction, boring machines, road headers, conveyors, crystallization, potash supply, TEM/Total Extraction Mining, Mosaic Potash, Potash Corp. (PCS), Agrium, continuous miners, salt mining, entry driving, boom miner, drum miner, drifting

Introduction

The world has seen many changes in the mining and mineral processing industry from 2005 to the summer/fall of 2009. During 2005, 2006, 2007 we saw large price increases on all metals as the industrial expansion demand for these commodities in quickly growing economies like China outstripped the supply. Industrial minerals and fertilizers such as potash also experienced large growth during this period however the changes in potash and fertilizer priced generally lagged the growth in the metals market significantly. Large commodity price changes included at least a three-fold increase in potash from 2005 to mid 2009. Large worldwide price increases like these which are clearly tied to real demand growth over this many years have historically drive structural changes the industry affected.

1.0 Background

1.1.1Potash as Fertilizer – Potash is generally considered to be one of the three key nutrients or fertilizers required in large quantities to support agriculture around the world. The other two key fertilizers include nitrogen and phosphate. Key large cap western companies that are leaders in potash fertilizer often also carry strong portfolios in nitrogen and phosphate as part of their business model. Three large companies control potash production in Saskatchewan, Canada in 2009. They include: The Potash Corp.(PCS), Mosaic Potash and Agrium.

1.1.2 Population Growth – Earth has about 6.7 billion people. The population of humans continues to grow at a rate of about 80 million per year (1) and countries like China and India still represent the largest growth areas. This population growth may soon strain the ability of our agricultural systems to feed everyone. (2) Increased farm outputs through more efficient farm practices and increased fertilization are named as popular means to provide enough food for everyone. (3)

1.1.3 Market Trends Changing – It has been noted in the popular press and by food researchers around the world that the wealth generation of the middle class in Asian countries like China and India from the sustained strong economic activity in these countries from has resulted in dietary changes in Asian. The access to more disposable income for food has led to increased demand for meats, more variety and protein. (4) These foodstuffs require increased crop growth and the application of more fertilizers.

1.1.4 Satisfying a Need - With increasing world demand (5) and prices for fertilizers, including potash, the traditional suppliers have undertaken expansions (6) and there is very strong interest by prospective new suppliers to invest in the industry and perhaps develop new production capacity.

1.2 Is History Repeating Itself ?

The constant, steady growth of a domestic and export market for potash in the 1950's/60's (8) led first to new plants and plant expansions in the Carlsbad New Mexico, USA region and then to further 1960's production capacity development with 10 new mines in Saskatchewan. This era saw the largest US expansion and the creation of an entirely new industry in Saskatchewan, Canada.

2.0 Discussion

2.1 Framing the Discussion

The purpose of this paper is to: a) discuss some of the current technologies actively used in potash production; and b) to identify some of the potential innovations that have been considered and tested but not typically engaged and exploited yet by a majority of sites.

2.2 Geologic Setting

Much of Southern Saskatchewan is underlain by Prairie Evaporite formations. Potash beds occur as part of the halite in the upper portions which make up part of these formations. Four potash beds are usually present when drilling. They include: the Esterhazy; the White Bear; Belle Plaine; and Patience Lake. Each is generally consistent and continuous within the mineable portion of the potash zones except for local anomolies, washouts or identifiable high risk zones. Each of the four beds has characteristic bed depths, ore grades and mineralogy. Current commercial operations (2009) exist in three general areas of Southern Saskatchewan: the Saskatoon Area; the Esterhazy Area; West of Regina. The Mosaic Belle Plaine mine operates in the the Belle Plaine member and others in the area West of Regina. The Mosaic K1 and K2 mines as well as the Potash Corp.(PCS) Rocanville mine operate in the Esterhazy area and they mine the Esterhazy member. The Saskatoon area mines including : Agrium Vanscoy, PCS Cory, PCS Patience Lake, PCS Allan, PCS Lanigan and Mosaic Colonsay all mine portions of the Patience Lake members. It is common to see both an Upper Patience Lake (UPL) and Lower Patience Lake (LPL) member in the Saskatoon area and these may or may not both be mineable a any location.

The potash beds are overlain by a sequence of lateral beds or continuities called the Dawson Bay. The Dawson Bay is made up of a dolomitic mudstones and carbonates. It is common in some areas to see halite plugs and halite caps 9in the Dawson Bay. This Dawson Bay is generally 4-14m above the desirable potash mining horizon.

Water bearing regions of the Dawson Bay sometimes trend in a north-easterly direction between mines. Tapping into these reservoirs would be disasterous as there would be serious mine flooding so mines are designed to avoid these regions. There are also local washouts or anomalies into which Dawson Bay rocks have migrated. These are also undesireable features of high risk potential for potash miners.

The Dawson Bay is generally a constant blanket protecting the mining horizon as a protective structural plate. It is impervious to water bearing zones above when complete so it provides both structural support and a water barrier when competent. However grave danger and high risk exposure exist when it's structural integrity has been compromised locally, when it channels to aquifers or reservoirs in the area and local washouts can present other hidden risks. Modern 3D seismic can generally be relied on to identify local or regional concerns before mining into a problem area so operators need to ensure enough testing, rigour and analysis is performed in advance of underground mining.

Saskatchewan potash beds occur in the top 70 meters of the Prairie Formation. They are made up mostly of a mixture of halite and sylvanite but sometimes include portions of carnalite.

2.3 Industry Development

2.3.1 The Last Forty Years

2.3.1.1Pioneers

2.3.1.1.1 Traditional Mines - Potash was discovered in Saskatchewan in 1943 while crews were drilling for oil. Based on the earlier oil exploration drilling results potash exploration drilling began formally in 1951. This work led to more potash discoveries and the development of the first Canadian potash mine.

PCA, the Potash Company of America, opened the first Canadian potash operations at Patience Lake in 1958. Production from this mine was soon stopped in 1959 when they experienced severe water leakage in the shaft. Extended grouting and shaft rehabilitation work was performed over the next five years and then this traditional mine/mill operation was reopened in 1965. Unfortunately Patience Lake underground operations flooded in 1987, after 22 years of operations. It wasn't opened again until 1989 when it had been converted to a solution mine. Patience Lake still operates today as a solution mine with the Potash Corp.

2.3.1.2.1 Solution Mining - Kalium Chemicals opened the first potash solution mine in Saskatchewan in 1964. This mine incorporated a number of new, innovative and freshly patented processes at Belle Plaine mine in south western Saskatchewan. This mine is deeper than most of the other Saskatchewan potash mines at 1585 meters and this region is now the subject of considerable interest and exploration by juniors.

2.3.3 Rest of the First Wave

The remaining eight mines were also built throughout the 1960's at Vanscoy, Cory, Allan, Colonsay, Lanigan, Esterhazy and Rocanville. Saskatchewan is the world's largest potash exporter. Canadian potash exports account for about 43% of world potash trade into roughly 40 countries.

2.3.1.1 At the Face

Most of the existing mines developed small workings in the shaft bottom area with some combination of drill and blast and small roadheader systems. Space was cramped when first coming out of the shaft and contractor employees made up the workfor at this stage of mine development. Soon after small workings were opened up shop areas were designated in the workings and lifting/crane systems were set up there. The original planning in the traditional mining system based mines were generally intended to assemble and utilize continuous boring machines in the longer mainline and production panel workings. Most of the 9 new traditional mines utilized gathering arm loaders and some for of schuttle cars, ramcars or scopptrams as back-up systems to the boring machines. Boring machines were typically two rotor Goodmans, Wabcos or Mariettas in the Saskatoon area mines except for the PCA mine which had their own custom version of a ranging drum miner in place. Rocanville began operations with a four rotor Marietta miner but the mining height was much less there, at about six foot/six inches tall compared to the typical eleven foot/six inches tall cut height at most Saskatoon area mines.

Moving from the basic development operations with drill and blast to advanced development with roadheaders made a substantial difference in safety, cycle time and advance rates in the early days. Once contractors were replaced with regular owner production teams and roadheaders were replaced by much larger continuous bore machines these advance rates and mine integrity improved even more. The main travelways and conveyor runs outside of the shaft pillar were designed to last for very long periods (permanently) with minor rehabilitation needed only every half decade or so. They were generally designed on an advance system of traditional coal mining like room and pillar designs with the dimensions set very specifically to suit the local hydrostatic conditions and to hold the roof up over long periods. Once these main headings were complete a series of panel sub-mainlines were developed on a similar room and panel design which was also intended to provide for a long opening life. Multiple production panels could be run off of these panel sub mainlines that would be general room and pillar design but they were dimensiond to allow gradual closure and creep relaxation of the openings in a safe way so as to reduced roof failure and encourage safely abandoning these production openings. Over time the rock mechanics experts and mining engineers came to understand that a modified room and pillar or chevron design would provide the best combination of open structure infrastructure support and closed closure given the production panel sized desired, highest extraction ratios practical, ventilation and other necessary opening infrastructure times and suitably quick closure rates that would best provide for the necessary stress relief and closure rates for these ore.

Once the initial development work with continuous miners was completed and machine headings began to be set up in the production panel workings additional back-up equipment began to be added to provide borer panel back-up systems on a trial basis. This equipment was all being modified from coal based systems used previously in the UK and USA so it took some development time and effort to adapt them to potash mining this deep. For example at Allan potash mine the schuttle cars and gathering arm loaders continued in operation competitively until well into the early 70's on at least three of the five main production faces, This mine opened operations as APM Operators officially in 1966 so after almost two years of development work underground the schuttle cars carried production for almost 7 or eight years. Hewitt Robins Mineveyors were introduced to two of the mine faces and phased into a third later in the 60's and they eventually took over from the schuttle cars and loaders by the mid to late 1970's. The schuttlecar/loaders were not as mechanically or electrically reliable as the multi-bridge minveyors and their operation was much more sporadic/stop-start than mineveyors smooth continuous work. The original mineveyors at Allan were three bridge systems with central operator steering control and self drive capabilities at each transfer point of the bridges. Too many loose cuttings and variable ground conditions were the main threats and challenges to the mineveyors. The Allan had slightly higher ore grades than some of the other Saskatoon area mines but they also typically had rougher ground conditions so borers and backup systems worked hard in these conditions. As early as 1973/1974 record hourly cutting rates of 3300 tph were achieved on the odd shift on the bores with three bridge Hewitt Robins Mineveyors but the actual average advance rates over the 8 hour working shifts at the same time were only between 600-800 tph so it's clear that much work needed to be done to balance ou production activities/rates and maintenance, machine support at that time.

In those days the surge storage capacity between the mine and the mill were very limited and the mill maximum was much less than the mine/hoisting capacity so much work went into better matching operating philosophies between surface and underground over the next couple decades.

By the late 1970's through the 1980's All the Saskatoon area mines were developing and introducing home grown designs and versions of Mineveyor like systems that were much more robust, had larger conveyors/throughput, had better steering, had higher horsepower drives, and that had 5 then 7 then more bridges to provide greater time between setups, more flexibility in mine design and greater capacity. This development trend to change backup systems has slowed over the 1990's and since 2000 but with the latest round of expansions interest has been reknewed in how to drive improvements in this equipment. Once most people felt comfortable in the late 1990's or early 200's that almost everything had been done to optimize back-up equipment operator shifts were changed from eight hours to twelve to reduce the non-production time and one mine, PCS Rocanville even automated the cutting and back-up equipment to allow production faces to continue operating while operators travelled to complete the shift changes.

2.3.1.2 Collar to Collar

Given the higher underground production and hoisting rates possible than what the potash mills generally were able to process most Saskatchewan operations spent a fair bit of time and money in the 1980's and 1990's adding adequate surge bin capacity both before the hoist loading pocket underground and at the surface hoist dump stations but before the mill dry end to better balance and cancel these disparities. These physical changes and better labour management practices around these areas helped to smooth out the entire operations, better control costs, reduce energy requirements and to optimize the overall mill and mine operations at lower than peak tph but higher average overall throughput of mill, hoist and mine combined in a calendar year yielding a better return to the owners and more product tonnes out the loadout to rail and the customer each year. All this work in the late 1970's to the mid 2000's allowed the average operation to reduce their workforce from 535 ppl to 325ppl while increasing their tonnages by about 12.5 percent at the same time. Of course hoists, loading pockets, guidance systems, ropes, headframes and other needed to be increased and beefed up accordingly. This exercise is continuing at most Saskatchewan mine well into 2014 or 2015 to match the additional throughput targets they are working towards in 2009.

2.3.1.3 Dry Handling

Ore is cut in the mine at plus 30 cm and down then shipped via belt conveyor and loaded into hoists to surface holding bins. After the bins the ore enters the dry handling systems.

Size Reduction, wherever possible plants today will grind the ore to the liberation (from halite) size. Fines are separated next. Some plants in Germany use a dry electrostatic seperation.

Mines/plants use primary crushers to reduce the ore to -10 to -15 cm then secondary hammer mills or impact mills will further reduce this ROM ore to -5 cm. The next stage includes screening of the oversize for return to the mill and size reduction to -2 to -4 mesh. Finally ball mills, rod mills or cage mills are used to grind ore to – 5cm and then regrind to 20 to 32 mesh before it reaches liberation sizing.

2.3.1.4 Wet Milling

Ore ground to liberation size is hydrocycloned, deslimed to remove insoluables and any remaining fines. Coarser particles are then typically separated by flotation. Some plants in Germany also or alternatively use alternate wet heavy media separation. After benefication and sometimes a quick leach potash is compacted to a larger size. Fines and sometimes slimes can be leached and recrystalized.

2.3.1.5 Water/Brine Handling Reduction

More effort has been made to reduce brine and water handling requirements during the past two decades to improve plant efficiencies and reduce costs.

2.3.1.6 Brine Injection

Excess brine and flood water inflows are pumped into deep injection wells in increasing amounts with 2007-09 expansion efforts.

2.3.2 Recent History

2.3.2.1 Two Decades of Tight Money

From about 1985/6 to 2005 there was not much excess margin to support a lot of new process or product/equipment development. Most new developments can from manufacturers and very limited operations experimentation. Still PCS and Mosaic maintained small technical services groups who put effort into developing ore grade sensors, improved flotation cells, column leaching, more effective compaction units, product specialties, automation, crushing improvements, better centrifuges and screens.

2.3.2.2 The Three Year Run Up

Recent plant expansions include very few innovations other than the items mentioned above. They are targeted at getting higher volumes through at somewhat reduced costs but operators are risk averse when adopting new technology and known innovations. There are a number of prudent innovations available to these operators from development in other industries that these operators have not adopted.

2.3.2.3 2008/09 Commodity Market Crash

The worldwide market failure driven by the US housing market crash in the summer/fall of 2008 has slowed some Saskatchewan plant expansions and it will ensure that no technological leaps come from these expansions due to early adoption of innovations in the market. This may be a risk to existing operators if one or some of the new greenfields mines/mills planed turn out to be successful early adopters of any strong new innovations.

2.3.2.4 Settling In, 2009

2.3.3.Near Future

2.3.3.1 World Demographics/Population Continues to Explode

Given the expectation that the world's human population will reach 9 billion by 2050 which is a 50% increase over the 6 billion arrived at in 2008 the food supply chain will be even more reliant on fertilizers like potash. Even at the 6 billion population mark soil nutrient deficiencies were not even being met with farmers annual potash application rates and the improving disposable incomes of large Asian populations had not really yet fully realized the increasing demand for potash driven increases in meat protein and more variety. All these factors are projected to push the annual demand of potash well beyond the 30 Mtpy mark from around the current 20

Mtpy amount delivered. This is also a 50% increase requirement for the supply side from the industry which seems conservative given the actual historical rise of 50% from 2 Mtpy in 1951 to 3Mtpy in 1960 or a single decade.

2.3.3.2 Demand and Supply to Follow?

Saskatchewan operators are working hard to raise current production capacity about 25% from now to 2014 but this may not be enough. It's also likely that at least two or three new potash mines may be built in Saskatchewan over the next decade but tjis will also only increase production capacity by 25% in that period.

2.4 Current Operations

2.4.1 Operators Innovate on a Budget

Given the tight money from 1985 to 2005 operators introduce very little innovation and innovations they did adopt were based simply on the evolution of existing equipment and systems and do not involve any revolutionary concepts, techniques or strategies.

2.4.2 Run-up Opens Expansion Opportunities for Proven Technology

From 2005 to 2009 only the tried and true equipment and systems has been incorporated into large scale plant expansions in PCS, Mosaic and Agrium. Agrium did incorporate some particularly strong evolutionary themes particularly in their compaction circuits. Wardrop was the prime engineer on the job and they were invited to bring these concepts to the fore in pre 2006 expansion planning. Most of these concepts are being copied by the other operators now.

2.4.3 Does Greenfields Open the Door for Innovation

It is understandable that existing operators have chosen not to introduce new risk into their expansions by adding early adoption of innovations to the current round of plant expansions.

During the last large scale expansion of the industry during the 1960's design and construction of all 10 potash plants in Saskatchewan quite a number of new innovations were added i.e. solution mining, new vibrating screen configurations and equipment, crusher innovations, flotation cell innovations and testing and use of new and innovation flotation techniques and agents.

The new Saskatchewan plants gained a market significant advantage and operating cost advantage by doing this. As a result they not only created entire new markets for this additional product worldwide but they also captured and took over significant portions of the existing domestic mark in North America. As a result over 80% of the US producers shut down their operations over the next decade and they still haven't recovered from this blow.

Are there currently significant innovation opportunities that can offer similar benefits to new operators considering greenfields mines/mills in Saskatchewan? It appears that the answer to this question is clearly yes.

2.5 Opportunities for Innovation

2.5 Technologies Tested

There have generally been three phases to the advancement or potash operations. They are large scale greenfields mine/mill expansion driven by demand and price increases; short highly profit driven technology investigation and testing; long periods of oversupply, low margins, and maintenance without much innovation or investigation.

2.6 Scale-up and Prove-up

One of the biggest challenges today for potash mines is how to handle their waste tailings and brine disposal programs. With the increased sensitivity worldwide to environmental concerns these two issues and the availability of fresh water for processing are grave concerns to anyone considering a new operation and the serious burden of permiting their new operation.

What innovations are available to new operators?

PCS has proven with their tailings trial that placing tailings back underground is technically viable and probably economically viable. Eliminating the need for surface tailings piles at a new mine/mill will be truly innovative and welcomed by the public, government and customers.

Placing tailings underground can result in a competent capable of providing structural support for the mine roof in mined out areas. If done correctly this process can allow increased extraction rations in production panels, reduced operating costs and extended mine life.

Kali Und Saltz had proven that dry Electrostatic precipitation was technically viable in German milling. PCS had much less favorable results in earlier trials even though their work did show it could be done on a small scale. Dry processing would eliminate the brine disposal and fresh water needs of potash processing.

Large capital costs lie in developing a full size production shaft. Is there any way to save these costs or reduce the size of the shaft. Could dry processing be done underground so that only the 20-25% of finished product would need to be hoisted?

2.7 Ideas Not Yet Investigated

Wardrop has worked with a number of clients who are substantially expanding their existing potash operations and new clients who are considering advancing completely new greenfields mine/mill complexes. Many operators in these two classes do not want to be exposed to the risk of new technology adoption.

We have listed only a small number of the more significant innovations possible in the previous sections. Even this small number of innovations offer quite a range of possibilities to reduce cost, improve operating efficiencies and revolutionize the environment of a potash operation.

2.7.1 U/G Mills

Milling potash ore on the surface can be redundant if proper steps are taken to contain these operations underground. This change can reduce the amount of material that needs to be hoisted to surface by 75-80%. This change can also make the placement of waste or tailing back into the newly mined out areas that much more viable. Removal of this waste from surface will be revolutionary in Saskatchewan or most parts of the potash world.

Adopting large scale ES or total dry processing in a central underground mill location underground would simplify current milling practices and eleiminate the need for brine handling, brine injection and fresh water supply for mineral processing completely. All the handling and other issues related to these elements of a potash milling circuit then are eliminated as well.

2.7.2 Reducing Volumes Handled Beyond The Face

It also seems likely that smaller scale dry ES can be viably performed near the mining or mining machine face in the production panel. More rigorous crushing and size reduction would then be completed down to at least the liberations size at this location. Some or all of the ore could be dealt with in this manner. All waste could then be capture at this location and immediately passed back to the open mine face to provide support and ground control. Done effectively this backfill can replaced pillars and panel extraction ratios can be increased.

This process will reduce or eliminate waste handling systems back to the mill and then to disposal sites. Again since this is a dry process it would eliminate brine handling, brine disposal and fresh water handling/sourcing for the mill.

2.6 Interest in Expanding

2.6.1 Athabasca, BHP, Potash One and More

Athabasca Potash, Potash One and BHP have all spent a couple seasons advancing their Saskatchewan projects and they look to be in a good position to advance to the Environmental Assessment Stage (EIS) over the winter of 2009 to spring/summer of 2010. These three companies have the most advanced potash projects so far.

A number of other junior potash exploration companies are now either in their first or second season of work to identify a resource and reserve.

2.6.2 Solution Mining vs. Tradition U/G Systems

Most of the currently operating potash mine in Saskatchewan are traditional room and pillar underground mines. Two solution mines are in operation here. One, Belle Plaine was originally designed for solution mining and it has always been a solution mine. The second, Patience Lake was originally designed for traditional underground mining and it operated that way for over twenty years. However a serious flood at Patience lake caused the operators to convert it into a solution mine.

Traditional Saskatchewan potash mines have historically cost about 1.43 times the capital cost to build of a typical solution mine of about the same size in Saskatchewan. It is also historically correct that solution mines have significantly higher operating costs per tonne than the traditionally mined potash mines and that solution mines are much deeper in Saskatchewan.

There are now more exploration projects for a new solution mine in Saskatchewan than there are traditional mines.

2.6.3 Outside of Saskatchewan

There a number of developing potential potash projects in Brazil, Argentina and other in play as well now.

3.0 Conclusions

The potash industry has experienced unusually high growth in their product price and in world demand since 2005. This trend has convinced existing Saskatchewan producers and prospective potash miners alike to expand their operations in Saskatchewan.

3.1 Summary of Discussion

Growing market demand for potash and improved prices in the 1950s drove the creation of 10 new potash operations in Saskatchewan. These operations adopted new technological innovations as part of their inception and business strategy. This strategy captured them large shares of existing market share and allowed them to create and develop even bigger new markets for this newly created production capacity.

Innovation stagnated with low prices and decreased demand in from 1985 to 2005. These years were difficult for producers and cost cutting, maintenance were the order of the day during this cycle.

During the period from 2005 to 2009 worldwide prices and demand for potash grew strongly. This cycle encouraged existing operators to expand and new prospective operators to enter the market. More effort has been made to reduce brine and water handling requirements during the past two decades to improve plant efficiencies and reduce costs.

Innovations such as Total Extraction Mining (TEM), Electrostatic Seperation and Underground milling have not been engaged by the current Saskatchewan potash operations. They have been tested and demonstrated in the recent past.

3.2 Conclusions and Opportunities

The potash market seems to be driving expansion and production capacity growth. Owners expanding or developing new potash operations can choose to maintain the status quoe or adopt new technologies and innovations in expansions or greenfields projects.

Adopting new technological advances has allowed new and expanded operations to jump ahead of technologically lagging competitors in the past. Do innovations like TEM, dry ES, Underground potash Milling and others afford their early adopters a real chance to leap frog ahead of technologically lagging operators in 2010-2015?

Ackowledgements

The authors wish to express their thanks to Mark Kraft of Mosaic Potash, John Voight of SMRI, John Cairns of Wardrop Engineering and Tom Lu of the 9th International Salt Symposium, technical program, organizational committee for their help, understanding, information, editorial feedback and encouragement in the creation and presentation of this paper. We also wish to declare and thank Messrs. David Waugh, Lionel Regnier, Gerry Couture, Mike Meadows, Norm Bueg, Rob Plotsz, Jim Couch, Terry Heal, Garth Moore, Rob Bubnick, Jim Johnson, Robb Altman, Lewis Cluet from the existing Mosaic Potash and Potash Corp. operations and corporate management, engineering teams for their ongoing support and engagement of engineering and research professionals like Wardrop Engineering Inc. in their ongoing sustaining, development and expansion capital programs. Messrs. Labbe and Kelly also wish to notice and thank early technology pioneers like Blue Taylor, Dr. Dennis Storer and Dr. Graeme Strathee for the inspiration, mentoring and coaching they have provided to many of the early and current Saskatchewan potash practitioners by driving early research and tech. support innovation agendas and through providing us with their vision and fortitude while nourishing, encouraging and sustaining practical solutions and technological innovation in the Saskatchewan potash industry.

Footnotes

1 – Wikipedia, (2009). Population Growth/World Population.

2 – Pimentel, Huang, Cardova & Pimentel, (1996). Impact of Population Growth on Food Supplies & Environment, AAAS/AGM

3 - Cummer, C.H. (1997). World Potash Supply/Demand and Outlook, Canpotex

4 – Heilig, G.K. (1999). Can China Feed Itself, Policy Discussions, IIASA

5 – FAO Potash Demand Update

6 – Various Potash Corp, Mosaic Potash and Agrium press releases and announcement from 2007-2009

7 – Press releases, annual reports and updates from Athabasca Potash, Potash One, Taiji Resources,MJ Potash, BHP and others from 2007-2009

8 – Anon., (1955). Expansions at Carlsbad based on Potash Consumption Continuing Growth……, J. Agic. Food Chem, 3 (4) pp. 288-289, April

References

Dunn, C.E. (1982). Geology of the Middle Devonian Dawson Bay Formation in the Saskatoon Potash Mining District. Sask Energy and Mines, Report 194, pp. 117

Edwards, C. (2007). Underground Milling of Uranium Ores, CIM/CMP 39th Proceedings, pp. 331-337

Garrett, D.E. (1996). Potash Deposits, Processing, Properties and Uses, Chapman & Hall

Edited by Folinsbee, J. for CMP) (2007). 39th Annual Canadian Mineral Processors Meeting Proceedings, CIM/NRC, ISBN: 1-894475-62-3

Fuzesy, L.M. (1983). Petrology of Potash Ore in the Middle Devonian Prairie Evaporite, Saskatchewan.

Labbe, A.P. (1982). Development of a TEM Waste Tails Transport System for the Prefeasability Testing of TEM Flinger and Drop Pipe, PCS Mining

Laurens, J.F. (1982). Introduction of Continuous Miners at Mines De Potasse D'Alsace, Potash 83

LeBeque, M.K. & Karlovsky, J. (1982). The History and Evolution of Boring Machines into the Potash Industry, Potash 83

Edited by McKercher, R.M. (1983). Potash 83 Potash Technology: Mining, Processing, Maintenance, Transportation, Occupational Health & Safety, Environment. Pergamon Press

Pufahl, D.D., Yoshida, R.T., (1982). A Study of Potash Tailings: Properties and Behavior, University of Saskatchewan

Schwerdtner, W.M. (1964). Genesis of Potash Rocks in the Middle Devonian Prairie Evaporite Formation, Saskatchewan, Geol. Soc. Am. Bull., V. 79, pp. 1103-1115

Singewald, A. & Neitzel, U. (1982). Electrostatic Separations Procedures for Raw Ore Minerals, Potash 93/Kali Und Saltz

Taylor, W.E.G. & Sizitkey, G. (1972. Study of Economics and System Requirements for Stowing of Salt Tailings into the Mined Out Areas of the Sylvenite Potash Mines, Rocanville Sask.

Taylor, W.E.G. & Butcher, M.(!983). Total Extraction Mining, Potash 83

Torre, D.C., (1982). Continuous Haulage: Proven, Practical, Productive, Potash 83

Wardlaw, N.C. (1968). Carnallite-Sylvite Relationships in the Middle Devonian Prairie Evaporite Formation, Saskatchewan, Geol. Soc. Amer. Bull., V. 79, pp. 1273-1294

Wittrup, M.B. (1990). The Petrogenesis of Brines in Devonian Potash Deposits of vWestern Canada, Chemical Geo., V. 82, pp. 103-128

SALT CULTURE
HISTORY AND EDUCATION