The Observer’s Guide to Potash!

Mark Arundell
IMEx Consulting
Before we begin....

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- **Disclaimer**
  - Not definitive – “Potash 101”
  - Potash is not Phosphate
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Without a market, a deposit is merely a geological curiosity - Harben
Potash

- What’s Potash?
- Why Potash?
- Geology - setting & examples
- Mining - conventional & solution
- Exploration Criteria & Tools
Potash

Polish potash war elicits investor interest

SPINIFEX

Nick Sas

It is an odd time in the small resources sector, when commodities such as potash and mineral sands attract serious investor attention in WA.

With many gold and nickel investors hurt over the past six months, the lure of diversification is becoming more attractive.

The announcement by BHP Billiton last month that it was pumping in $2.6 billion to finish the Jansen Potash project in Canada — particularly in light of BHP shareholders’ push for spending restraint — is one factor pushing potash into the spotlight.

Another factor is the entertaining, albeit slightly worrying, so-called potash wars between Russia and Belarus, which have also helped put the fertiliser feed back on the map.

For the record, according to BHP's chief executive of the mining group Uralkali was destined for Minsk, Belarus, late last year.

Uralkali sparked a row when it quit a trading alliance with State potash producer Belaruskali in a move that analysts say could push potash prices down by as much as 25 per cent before the end of the year.

The halls of the Perth Convention Centre are a long way from the halls of Minsk but according to Potash West managing director Patrick McManus, the reverberations have been felt by his company.

Potash West is attempting to develop the Dandaragan Trough project located north of Perth, and Mr McManus said a number of curious investors came to find out more about the company during last week’s Association of Mining & Exploration Companies conference.

For Potash West, the immediate threat of decreased prices from the potash war does not have a huge impact but the lingering long-term food security threat does.

Analysts have tipped this issue will become more pervasive in the later half of this decade, if not sooner.

Mr McManus admitted Potash West liquidated and, indeed, its share price, were low but he said inquiries from fertiliser groups had increased.

In January, the company put a $160 million price tag on a 2.4 million-tonne a-year operation that aims to mine potassium-rich glauconite — an essential product in the creation of fertiliser — with an eventual plan to ship 50 per cent of the product to South East Asia and China.

He said the company’s next step was to start construction of a working trial plant.

On the mineral sands front, Welshpool-based Mineral Commodities Limited highlighted the relative confidence in the sector by announcing a fully-underwritten $5.5 million entitlement issue late last week.

The one-for-four issue is priced at 80 cents below the 84.1c closing price on Friday. The company said it would use the money to fund the commissioning of its Tormin mineral sands project on South African’s west coast, 460km north of Cape Town.

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The West Australian

Monday, September 9, 2013
Potash

Hunters Please Note

Geologists of the N. S. Department of Mines are working in this area

Exercise extreme caution when shooting

New Glasgow
Nova Scotia
What’s Potash?

- The mineral (K) is one of the three main macro nutrients required by plants, along with nitrogen (N) & phosphate (P).
- Potash helps:
  - improve a plant's disease resistance
  - crop quality
  - increases yields
- Only potassium fertilizer source:
  - No practical substitutes
Why Potash?

**World Fertilizer Consumption**

More than 20 Percent of Consumption Outside of Asia, North and Latin America

- China
- India
- Latin America
- North America
- Other Asia
- Other*

Based on a combination of calendar and fertilizer year data. 2012 refers to 2012 CY and 2012/13 FY.

Percent Share of Other* Market Category - 2012

- Europe 46%
- FSU & Central Asia 20%
- Africa 14%
- Middle East 12%
- Other 8%
Why Potash?

Grain Yields and Fertilizer Use
Yields in Sub-Saharan Africa Lag As Does Fertilizer Use

* Based on 2011-2013 average

Source: USDA, IFA, FAO, PotashCorp
Why Potash?

At 31 December 2013

US$ billion

- RHP Billiton
- Rio Tinto
- Vale
- Glencore Xstrata
- Shenhua
- Freeport
- Anglo American
- Potash Corp
- Norilsk
- Grupo Mexico
- Southern Copper Co
- Barrick Gold
- Goldcorp
- Fortescue
- Teck Resources
- Mosaic
- Antofagasta
- Alcoa
- Newmont Mining
- First Quantum

Rio Tinto 2014
Why Potash? Potash Corp

**Yearly Pot Stock Price Since Inception**

**Potashcorp Potash Gross Margin**
- 1990: $0.1 Billion
- 2013: US$2.8 Billion
- 2015 (potential): $8.0 Billion

**Potashcorp Potash Production**
- 1990: 3.5 MMT
- 2013: 7.8 MMT
- 2015 (potential): 18.1 MMT

Source: PotashCorp

May 14
US$36.32

2010:
BHP
US$43.33
Commodity Overview

➢ Only 12 countries produce potash.
  ❖ Canada, Russia & Belarus - +60%

➢ Seven companies control >80% of global supply:
  ❖ Potash Corp of Saskatchewan, Mosaic Co, Agrium Inc, K+S, Uralkali, Belaruskali & Israel Chemicals

➢ Two marketing conglomerates **did** control >70% exports.
  ❖ Canpotex - Potash Corp, Mosaic and Agrium
  ❖ Belarussian Potash Co - Uralkali and Belaruskali.
Commodity Overview

Potash Production - 2013

- Canada
- Russia
- Belarus
- China
- Germany
- Israel
- Jordan
- Chile
- United States
- United Kingdom

Million Tonnes

USGS 2014
Commodity Overview

Worldwide Potash Fertilizer Consumption

(Millions of K₂O Nutrient Tons) — 1 Product Ton = 0.61 K₂O Ton

Excludes potash used in industrial applications and animal feed.

China
U.S.
Brazil
India

North American Potash Developments website
Commodity Overview

![Potassium Chloride Monthly Price - US Dollars per Metric Ton](Index Mundi website)
Potash One – Legacy PFS

Legacy Project (Saskatchewan, Canada)

- **NPV**$_{10}$ US$4.47B
- **IRR** 30.1%
- **Cap. Cost** US$1.88B
- **Payback** ~3.3 years
- **Mine Life** 40 years
- **Resource** 29Mt (Measured) 220Mt (Indicated)

**Q**: Who was the Chairman?

- Robert Friedland
November 22, 2010

“Potash One Agrees to Friendly Takeover by K+S for CAD 4.50 Per Share in Cash”

31.3% premium over the 10-day weighted average trading price

CAD $434 million (€311 million).
K&S Potash Canada

The Legacy mine will be the second project and is scheduled to begin production well drilling in February 2013.

$4.1B, 1,500m; 2016
Saskatchewan

POTASH

Potash producers in Saskatchewan plan to invest $13.9 billion to upgrade and expand production capacity by more than 90% by 2023. Ten facilities in the province produce nearly one-third of the world’s potash.

POTASH PRODUCTION

<table>
<thead>
<tr>
<th>Year</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>14.7 million tonnes</td>
</tr>
<tr>
<td>2023 (est.)</td>
<td>47 million tonnes</td>
</tr>
</tbody>
</table>

MINES ON THE HORIZON

<table>
<thead>
<tr>
<th>Year</th>
<th>Mine</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>K+S Canada’s Legacy mine</td>
<td>2.8 million tonnes per year</td>
</tr>
<tr>
<td>2018</td>
<td>BHP Billiton’s Jansen mine</td>
<td>8 to 10 million tonnes per year</td>
</tr>
</tbody>
</table>
Highfield Resources

New drilling at Javier and high-grade intervals, 2km grid

- 3.9m @ 12.2% K₂O from 751m incl. 2.4m @ 15.2% K₂O
- 1.2m @ 15.7% K₂O from 532m
- 6.6m @ 12.8% K₂O from 921m incl. 1.8m @ 17.5% K₂O
- 5.1m @ 12.9% K₂O from 955m incl. 2.7m @ 17.0% K₂O
- 3.0m @ 14.7% K₂O from 1,011m
- 1.5m @ 9.8% K₂O from 791m

- 2.1m @ 12.1% K₂O from 475m
- 2.4m @ 12.1% K₂O from 462m
- 3.3m @ 10.1% K₂O from 299m
- 2.4m @ 13.1% K₂O from 459m
- 5.1m @ 14.3% K₂O from 316m

- 11.7m from 463m, never assayed
- 4.5m from 282m, assay pending

Source: Company data

GMP Securities & ASX 2014
Where Potash - Reserves

WORLD POTASH RESERVES*
Economically mineable deposits are geographically concentrated

* Share of world’s potash reserves; reserves as defined by the US Geological Survey
Other countries total 1 percent
Source: US Geological Survey

PCS 2014
Where Potash - Production

Current producing potash basin

Other known potash basins
How - Geological Setting

- Evaporite
- Barred basin – restricted infill
- Cycle – CO$_3$, SO$_4$, NaCl, Carnallite
  - dolomite, anhydrite, halite, sylvite
- Reflux – sea level
- Preservation – reduced shale (?cap)
- Stable tectonics – dissolution
- Deposits laterally continuous
  - +30km strike Carlsbad, NM
Basin Pattern Models

Closed Basin

Refluxing Basin

After Hsu, 1976
Basin Development

After Guilbert and Park, 1986
Barred Basin Model

A. BASIN-TYPE EVAPORITE MODEL
TRANSGRESSIVE PHASE

B. BASIN-TYPE EVAPORITE MODEL
REGRESSIVE PHASE

Hite, 1983
Canning Basin - SEEBASE

50km

Kimberly

Fitzroy

Leinward Shelf

Broome Platform

Willara

Gregory

Kidson

Crossland Platform

Inflow

Bar

Pilbara

50km
## Mineralogy

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Formula</th>
<th>% K$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chlorides</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sylvite</em></td>
<td>$KCl$</td>
<td>63</td>
</tr>
<tr>
<td>Carnallite</td>
<td>$MgCl_2.KCl.6H_2O$</td>
<td>17</td>
</tr>
<tr>
<td>Kainite</td>
<td>$MgSO_4.KCl.3H_2O$</td>
<td>19</td>
</tr>
<tr>
<td>“Sylvinite”</td>
<td>$KCl.NaCl$</td>
<td>~21</td>
</tr>
<tr>
<td><strong>Sulphates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyhalite</td>
<td>$2CaSO_4.K_2SO_4.MgSO_4.2H_2O$</td>
<td>16</td>
</tr>
<tr>
<td>Langbeinite</td>
<td>$MgSO_4.K_2SO_4$</td>
<td>23</td>
</tr>
<tr>
<td>Anhydrite</td>
<td>$CaSO_4$</td>
<td>0</td>
</tr>
</tbody>
</table>
Elk Point Basin, Canada

Current producing potash basin:
- Elk Point Basin, Canada
- Maritimes
- Nunavut
- Newfoundland
- Paradox Basin, USA
- Neuquen Basin, Argentina
- Paradox Basin, USA
- Atacama Basin, Chile
- Sergipe Basin, Brazil
- Dead Sea
- Gulf of Mexico

Other known potash basins:
- Congo Basin, Africa
- North Caspian Basin, Kazakhstan
- Cis-Uralian Basin, Russia
- Zechstein Basin, Germany
- Pripyat Basin, Belarus
- Danakil Depression, Ethiopia
- Udon Thani, Thailand
- Lop Basin, China
- Qaidan Basin, China
- Michigan Basin, USA
- North Sea Basin, UK
- Paradox Basin, USA
- Neuquen Basin, Argentina
- Paradox Basin, USA
- Atacama Basin, Chile
- Sergipe Basin, Brazil
- Dead Sea
- Gulf of Mexico

Global expertise to build your resource base.
Elk Point Basin Potash Distribution
Elk Point Basin

Geology

- Winnipegosis - dolomite
- Mid Dev – Prairie Evaporite
  - Lower Ha-An
  - Three main potash bearing units
    - PLM, BPM, EM (max +30m)
- Second Red Bed
  - Shales – dolomitic; R G A
Prairie Evaporite

1000m below surface

- Patience Lake Member
- Belle Plaine Member
- Esterhazy Member

Prairie Fm

- ±75m

Sylvinite

Halite
AN, cg HA, CY
CA MgCl$_2$.KCl.6H$_2$O
Zechstein Style

Shaft

Rock salt

Potash deposit

Shaft

Potash deposit

Rock salt
Potash Mining

- Solar: Dead Sea, Utah, Chile, China
- Underground: Conventional & Solution
  - Conventional: Room & Pillar <1200m
    - Saskatoon, SK, Canada
  - Solution: 300 - ~2,000m
    - Regina, SK, Canada
Southern Saskatchewan Potash Mines & Depth to Potash

Conventional

Saskatoon

Solution

Regina
Conventional Mining

- Depth: 300m - 1200m
- Thick: 120m - >150m
- Room & Pillar - 5-12m high; 10-20m wide;
- 70% recovery (30% pillar)
- Drill & Blast, road headers or continuous miners
- Salt: 30cm bottom; 1-2m roof
- Prairie Evaporite
  - Strong impermeable rock 10-15m above
  - Not shale, sand, etc.
Room & Pillar

Vanscoy, Sk
Conventional Mining

Plan view
- conveyor assembly
- ore gathering arms
- bracing jacks

Side view
- conveyor assembly
- operator
- ripper teeth
- auger head
- ore gathering apron

salt
potash
Delaware Basin, New Mexico

- Delaware Basin
- Current producing basin
- Other known potash basins:
  - Holle-Kouilou
  - Pripyat, Belarus
  - Cis-Uralian
  - North Caspian
  - Danakil
  - Dead Sea
  - Lop
  - Qaidan
  - Bukhara
  - Udon Thani

- Fundy
- Michigan
- Zechstein
- Khemiset
- Paradox Basin
- Atacama
- Elk Point
- Neuquen
- Sergipe-Alagoas
Waste Isolation Pilot Plant

Why WIPP?

Bedded salt is free of fresh flowing water, easily impermeable and geologically stable – an ideal site for permanently isolating long-lived radioactive waste from the environment.

Throughout the 1960s, government scientists searched for an appropriate site for radioactive waste disposal eventually testing a remote desert area of southern New Mexico where, 250 million years earlier, evaporating cycles of the ancient Permian Sea had created 2,000-foot-thick salt beds.

In 1979, Congress authorized the U.S. Department of Energy’s (DOE) Waste Isolation Pilot Plant (WIPP). The WIPP facility, located 26 miles southeast of Carlsbad, New Mexico, was constructed during the 1980s. Conceded WIPP to the disposal of defense-generated transuranic waste, prohibiting disposal of commercial, low-level or high-level radioactive wastes. In 1998, the U.S. Environmental Protection Agency (EPA) certified WIPP for safe, long-term disposal of TRU wastes.

TRU waste consists of clothing, tools, rags, residues, debris, or other items contaminated with radioactive elements, mostly plutonium.

There are two categories of TRU waste: Contact-handled (CH) TRU waste handled by workers under controlled conditions without any shielding other than the container itself. The CH-TRU waste will account for approximately 96 percent of the volume of waste to be disposed of at WIPP. The remaining four percent will be reprocessed and TRU waste, which emits more penetrating radiation than CH-TRU and must be handled and transported in lead-shielded casks.

Prime regulators at WIPP are the EPA and the New Mexico Environment Department. A number of agencies, committees, and panels monitor WIPP progress and contribute to project success.

The DOE Carlsbad Field Office, which leads the nation’s TRU waste disposal effort, has coordinated TRU waste cleanup at a number of generator sites around the country. Since 1999, WIPP has set the standard for safe, permanent disposal of long-lived radioactive defense wastes.

WIPP Chronology

1974 The U.S. Atomic Energy Commission (AEC) chooses an ancient salt bed 26 miles east of Carlsbad for exploratory work in the search for an underground radioactive waste repository site.

1979 Congress authorizes WIPP as a research and development facility to demonstrate the safe disposal of radioactive waste from defense activities not regulated by the U.S. Nuclear Regulatory Commission (NRC).

1981 The U.S. Department of Energy (DOE), formerly the AEC, issues a record of decision based on an environmental impact statement to proceed with WIPP construction, and the first exploratory shaft is drilled. New Mexico Attorney General Jeff Bingaman files a lawsuit in federal court against the U.S. Department of the Interior (DOI), which has jurisdiction over the land where WIPP is located, and DOI, alleging violations of federal and state law. The lawsuit is settled by an agreement for more study and communication with the state, as well as addressing concerns such as emergency response and highway improvements.

1985 The U.S. Environmental Protection Agency (EPA) establishes radioactive waste disposal regulations specifically addressing transuranic (TRU) waste and WIPP; after DOE and the state of New Mexico agree WIPP must comply with EPA regulations.

1989 NRC certifies DOE’s main contact-handled (CH) TRU waste shipping cask, the Transuranic Packaging Transporter Model 2 (TRUPAC-M2), DOE completes repository construction.

1990 DOE issues a record of decision based on a supplemental environmental impact statement to continue with phased development of WIPP. EPA authorizes the state of New Mexico to issue and enforce a hazardous waste facility permit under the federal Resource Conservation and Recovery Act (RCRA) for disposal of waste that includes hazardous materials such as solvents or metal hydride.

1991 New Mexico Attorney General Tom Udall files a federal lawsuit against DOE and DOI regarding the withdrawal of land from public use for a WIPP testing phase. The lawsuit is later combined with another brought by several environmental groups alleging WIPP lacks interim status under RCRA that would allow WIPP to be treated as a hazardous waste facility permit has been issued.

1992 U.S. District Judge John Garrett Penn imposes an injunction, ruling the Interior Secretary exceeded his authority by changing the purpose of the land withdrawal from construction to testing, which includes transporting waste to WIPP. President Bush signs into law the WIPP Land Withdrawal Act, which transfers
Solution Mining

- Steam or Hot water injected
- Salt saturate inc. Potash recovery
- Single well (concentric casing)
- 150-1500m deep (Barradeel, NL : 2800m)
- One well - 100,000 tonnes
Solution Mining

- **Major cost**
  - Evaporation Ponds
    - plastic liner
  - Drying Kilns - Canada

- **Production**
  - Sol : 4.5Mt, Belle Plaine, SK (Mosaic)
  - Con : 3.0Mt, Colonsay, SK (Mosaic)
Solution Mining

Primary Mining

- Overburden
- Interbed Salt
- Patience Lake
- Interbed Salt
- Belle Plaine
- Interbed Salt
- Esterhazy

- Diesel Blanket
- Cut

- 80.0m
- 70.0m

- ~1500m
- ~13m
- ~18m
- ~4m
- ~8m
- ~10m
- ~14m
- ~16% K₂O
- ~19% K₂O
- ~20% K₂O
Belle Plain - Mosaic

- Evap. Ponds
- Salt Tailings
- Cluster House
- Plant – Crystalliser, Compactor

3 km
Potash Milling
Exploration Criteria

- Geological Setting
  - Barred evaporite basin

- Stable tectonic regime
  - Basement blocks

- K (γ) presence indicates fertile (sonic, ρ)
  - Grade +15% K₂O

- Elevated Br (sometimes!)
  - Min. >150ppm Br
Figure 6. Cross Section A to A’ showing Correlation of Prairie Evaporite Formation Potash-Bearing Members and Gamma Curves for 2008-2009 Drill Holes and Lumsden Historic Hole within KP 289
Tools – Well Logs

American West Potash, 2012
Tools – 2D Seismic

Congo – MagMin, 2007
Tools – 3D Seismic

Milestone
Western Potash
Tools
Australia?
Halite

Halite/Carnallite

Halite/Sylvite

Halite

2.74m @ 18.9% K₂O from 542.5m