Michael S. (Mickey) Fulp
M.Sc., C.P.G.

MercenaryGeologist.com
contact@mercenarygeologist.com

The Changing World of Uranium Mining

A Monday Morning Musing from Mickey the Mercenary Geologist

Contact@MercenaryGeologist.com

January 25, 2016

In last week's offering, Brien Lundin and I posted a comprehensive report on uranium and listed a variety of North American-focused exploration, development, and mining companies that stand to prosper as the price of uranium increases (**Mercenary Musing January 18, 2016**). Today, I document significant changes over the past ten years in both where and how primary supplies of uranium have been mined.

Many of these changes can be directly attributed to the wild swings in the price of uranium from 2004-2014.

The uranium spot price soared from \$10/lb U_3O_8 in 2004 to a peak of \$135 in the spring of 2007 and then collapsed back to \$40. The exponential rise and fall was driven by hedge funds, utilities, and traders competing in a speculative frenzy for physical supplies of yellowcake over nearly two years. Uranium price volatility foreshadowed the parabolic rise and fall of oil, copper, gold, and all other world-traded hard commodities that culminated late in the global economic crisis of 2008-2009.

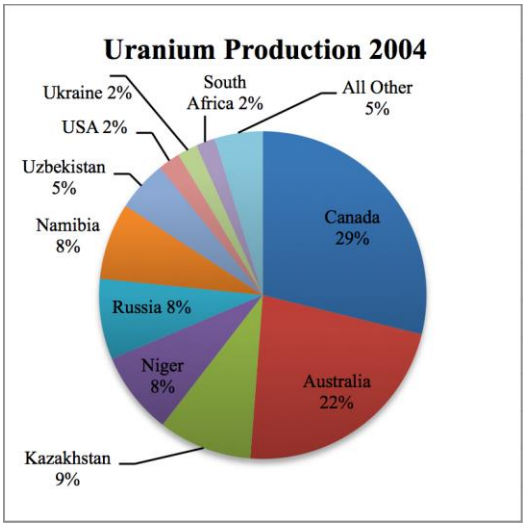
The spot price began moving up from \$40/lb in the summer of 2010 and briefly reached \$73 in February of 2011 immediately prior to the Fukushima incident. It fell to as low as \$28/lb in the summer of 2014 before settling in the \$35-\$38 range for most of 2015.

In the series of tables and charts below, I present the top ten uranium producing countries and ten largest mines in 2004, 2009, and 2014, document significant changes, and offer factors contributing to the rapidly changing world of uranium mining. Data sources are the World Nuclear Association and the International Atomic Energy Association.

First up are the top ten producing countries and the nine largest mines for 2004. Note that production figures for individual mines in Kazakhstan and Uzbekistan were not available until the late 2000s. Given Kazakhstan's position as the world's third largest producer in 2004, it is likely that one Kazak mine would make the list. Therefore, I only list nine large mines for the year.

Also note that only three mines made the list over the entire ten-year period; they are highlighted in the charts below:

Top 10 Producing Countries 2004		
Country	**Output (tU)**	**% of World**
Canada	11,597	29%
Australia	8982	22%
Kazakhstan	3719	9%
Niger	3282	8%
Russia	3200	8%
Namibia	3038	8%
Uzbekistan	2016	5%
USA	878	2%
Ukraine	800	2%
South Africa	755	2%
All Other		5%
Top 10 Total	**38,267**	**95%**



In 2004, Canada and Australia dominated world production with a combined 51% and five of its ten largest mines; Kazakhstan, Russia, Niger, and Namibia were also significant producers.

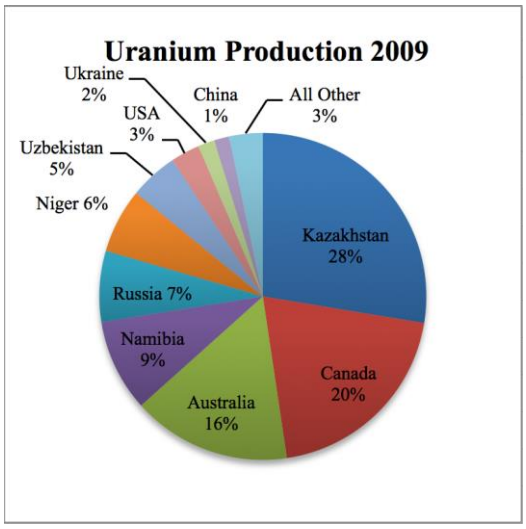
Top 9 Uranium Mines 2004				
Mine	**Country**	**Owner**	**Output (tU)**	**% of World**
McArthur River	Canada	Cameco	5965	15%
Ranger	Australia	Energy Resources Aus	3695	9%
Olympic Dam	Australia	BHP-Billiton	3143	8%
Rossing	Namibia	Rio Tinto	2577	6%
Krasnokamensk	Russia	ARMZ	2442	6%
Rabbit Lake	Canada	Cameco	1770	4%
Akouta	Niger	Areva	1683	4%
Somair	Niger	Areva	1068	3%
Beverley	Australia	General Atomics	780	2%
N/A	Kazak & Uzbek			

Top 9 Mines	**23,123**	**58%**
World Total	**40,178**	

Canada's Athabasca Basin had two of the world's largest mines, Australia had three mines of diverse geological types, and Niger had two giant sandstone uranium mines. If I were to include a tenth largest mine, they would account for about 60% of world production.

Next let's look at the top ten lists from 2009:

Top 10 Producing Countries 2009		
Country	**Output (tU)**	**% of World**
Kazakhstan	14,020	28%
Canada	10,173	20%
Australia	7982	16%
Namibia	4626	9%
Russia	3564	7%
Niger	3243	6%
Uzbekistan	2429	5%
USA	1453	3%
Ukraine	840	2%
China	750	1%
All Other		3%
Top 10 Total	**49,080**	**97%**



By 2009, world output had increased by a whopping 26% as the nuclear energy revival was in full swing with several hundred new reactors commissioned, under construction, planned, or proposed in many countries.

Kazakhstan had taken over as the leader in world production while Canada and Australia dropped to a combined 36%. US production was up 65% with most of that coming from small ISR operations.

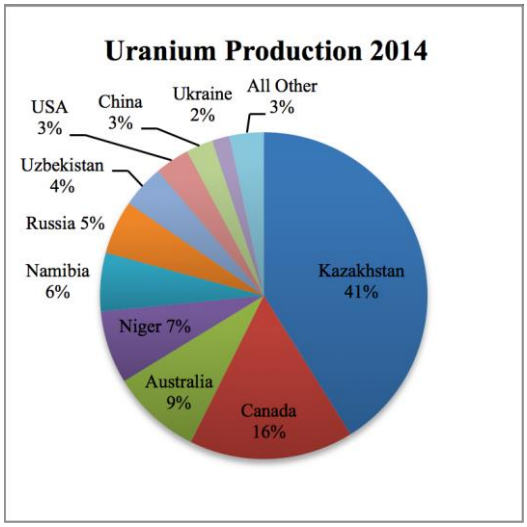
Top 10 Uranium Mines 2009				
Mine	**Country**	**Owner**	**Output (tU)**	**% of World**
McArthur River	Canada	Cameco	7377	15%
Ranger	Australia	Energy Resources Aus	4443	9%
Rossing	Namibia	Rio Tinto	3520	7%
Krasnokamensk	Russia	ARMZ	3003	6%
Olympic Dam	Australia	BHP Billiton	2981	6%
Tortkuduk	Kazakhstan	Areva / Kazatomprom	2272	4%
Somair	Niger	Areva	1807	4%
Rabbit Lake	Canada	Cameco	1463	3%
Akouta	Niger	Areva	1434	3%
Karatau	Kazakhstan	Karatau	1399	3%

Top 10 Mines	**29,699**	**58%**
World Total	**50,772**	

Eight of the nine largest mines in 2004 remained the same, most had significant production increases, and they accounted for about the same percentage of production despite the huge world increase. Canada, Australia, Kazakhstan, and Niger each had two of the world's giant uranium mines.

Lastly, here are the top ten lists from 2014. The changes over just five years are astounding:

Top 10 Producing Countries 2014		
Country	**Output (tU)**	**% of World**
Kazakhstan	23,127	41%
Canada	9134	16%
Australia	5001	9%
Niger	4057	7%
Namibia	3255	6%
Russia	2990	5%
Uzbekistan	2400	4%
USA	1919	3%
China	1500	3%
Ukraine	962	2%
All Other		3%
Top 10 Total	**54,345**	**97%**



Three years after the Fukushima incident in 2014, world uranium production still increased another 11%. Driving factors include the continuing nuclear build-out continued and the end of secondary supply from Russian weapons conversion. Production was increasingly dominated by ISR operations in Kazakhstan at 41% of world total and five of the ten largest mines.

Canada's production decreased 11% with most of its uranium coming from the world's largest and highest-grade mine at McArthur River, Australian production was down 37%, and US production increased by another 32% to reach its highest level since the late 1980s.

Top 10 Uranium Mines 2014				
Mine	**Country**	**Owner**	**Output (tU)**	**% of World**
McArthur River	Canada	Cameco	7335	13%
Katco	Kazakhstan	Areva / Kazatomprom	4322	8%
Olympic Dam	Australia	BHP Billiton	3351	6%
Somair	Niger	Areva / Kazat	2331	4%
Karatau	Kazakhstan	Kazatomprom / ARMZ	2084	4%
South Inkai	Kazakhstan	ARMZ / Kazatomprom	2001	4%
Priargunsky	Russia	ARMZ	1971	4%
Langer Heinrich	Namibia	Paladin Energy	1948	3%
Inkai	Kazakhstan	Cameco / Kazat	1908	3%
Central Mynkuduk	Kazakhstan	Ken Data JSC / Kazat	1790	3%

Top 10 Mines	**29,041**	**52%**
World Total	**56,252**	

High operating costs and low prices combined with weather issues, industrial accidents, and/or environmental opposition and permitting difficulties resulted in the world's second and third largest mines, Rossing in Namibia and Ranger in Australia, dropping completely off the top ten list. One large mine in the Athabasca and another in Niger are also missing. The other in Niger had recurring problems

with terrorism and resource nationalism. As a result, the world's large mine production dropped a bit but still contributed more than half of primary supply.

The way uranium has been mined over the past ten years has also undergone major changes. This table shows tonnages of uranium and percentages by type of mining method in 2004, 2009, and 2014:

	2004		2009		2014	
Mining Method	**(tU)**	**%**	**(tU)**	**%**	**(tU)**	**%**
Underground	15,790	39%	16,557	33%	*23,679	*42%
Open-Pit	11,089	28%	12,998	26%	*	*
In-Situ Leaching	7955	20%	17,166	34%	28,467	51%
Co-/By-Product	4460	11%	3681	7%	4107	7%
Heap Leaching	804	2%	360	1%		
Other Methods	80	0%	10	0%		

2004 and 2009 data from IAEA; 2014 data from WNA

* Open-Pit and Underground production grouped in source data

In-situ leaching and recovery increased by over 250% in just ten years. The vast majority of that increase was from new mines in Kazakhstan. With exception of the Athabasca Basin, Niger, Russia, and small high-grade mines in the Arizona Strip of the United States, underground mining has become largely uneconomic because of its high cost and the current low price of uranium.

The relative decline of open-pit mining can be attributed largely to much lower production from Ranger and Rossing, but that was offset somewhat by production from Langer Heinrich in Namibia. Co-product uranium comes mostly from the copper-gold-uranium operations at the unique Olympic Dam deposit in South Australia and is largely dependent on the price and demand for copper.

The major changes in mined sources of uranium and mining methods employed from 2004 to 2014 can be attributed to four factors:

- The ongoing worldwide nuclear build-out.
- Wild and unpredictable swings in the spot price.
- Financing difficulties for large capital expenditure underground projects.
- The phenomenal increase in low-cost ISR production from Kazakhstan.

Over the past ten years, annual world mine production has increased by over 16,000 tonnes, a gain of nearly 40%. All this growth and more has been has been attributable to Kazakhstan, which produced over 19,000 tonnes more in 2014 than in 2004. Besides having large sandstone uranium deposits ideally suited for in-situ mining, operations in that country have benefitted from a command economy, simple environmental regulations and permitting, the use of sulfuric acid as a lixiviant (a reagent that is banned for ISR in most other places) and a weak currency that was significantly devalued in 2015.

With 66 nuclear reactors under construction and another 158 in the planning stages across the world, the demand for uranium will continue to grow. And with its low cost and environmentally-benign footprint, ISR mining will continue to gain in market share.

That said, Kazakhstan's production has leveled off for the past four years, and it is equivocal whether that country can continue to satisfy the world's growing demand for yellowcake.

And that folks, is one of the many reasons "**Why I Remain a Uranium Bull**".

Ciao for now,

Mickey Fulp
Mercenary Geologist

Acknowledgment: Steve Sweeney is the research assistant for **MercenaryGeologist.com.**

The **Mercenary Geologist Michael S. "Mickey" Fulp** is a Certified Professional Geologist with a B.Sc. Earth Sciences with honor from the University of Tulsa, and M.Sc. Geology from the University of New Mexico. Mickey has 35 years experience as an exploration geologist and analyst searching for economic deposits of base and precious metals, industrial minerals, uranium, coal, oil and gas, and water in North and South America, Europe, and Asia.

Mickey worked for junior explorers, major mining companies, private companies, and investors as a consulting economic geologist for over 20 years, specializing in geological mapping, property evaluation, and business development. In addition to Mickey's professional credentials and experience, he is high-altitude proficient, and is bilingual in English and Spanish. From 2003 to 2006, he made four outcrop ore discoveries in Peru, Nevada, Chile, and British Columbia.

Mickey is well-known and highly respected throughout the mining and exploration community due to his ongoing work as an analyst, writer, and speaker.

Contact: **Contact@MercenaryGeologist.com**