

50 Years and C\$3 Billion
in Exploration Expenditures
for Uranium
in the Athabasca Basin
of northern Saskatchewan:

"An" Analysis

Roger Wallis

50 Years and C\$3 Billion

Why the Athabasca Basin is an IDEAL situation to make "An" Exploration Expenditure Analysis

- It is a well defined and constrained GEOGRAPHIC area
- Involves only ONE Commodity
- There is a specific START DATE to Exploration Expenditures
- Virtually all the relevant DATA is in the Public Domain

50 Years and C\$3 Billion

This "ANALYSIS" covers:

- WHAT was found
- WHAT it is worth
- WHEN it was found
- HOW MUCH was spent through time
- WHY the "Boom/Bust" Exploration Cycles
- WHO spent these \$'s

50 Years and C\$3 Billion

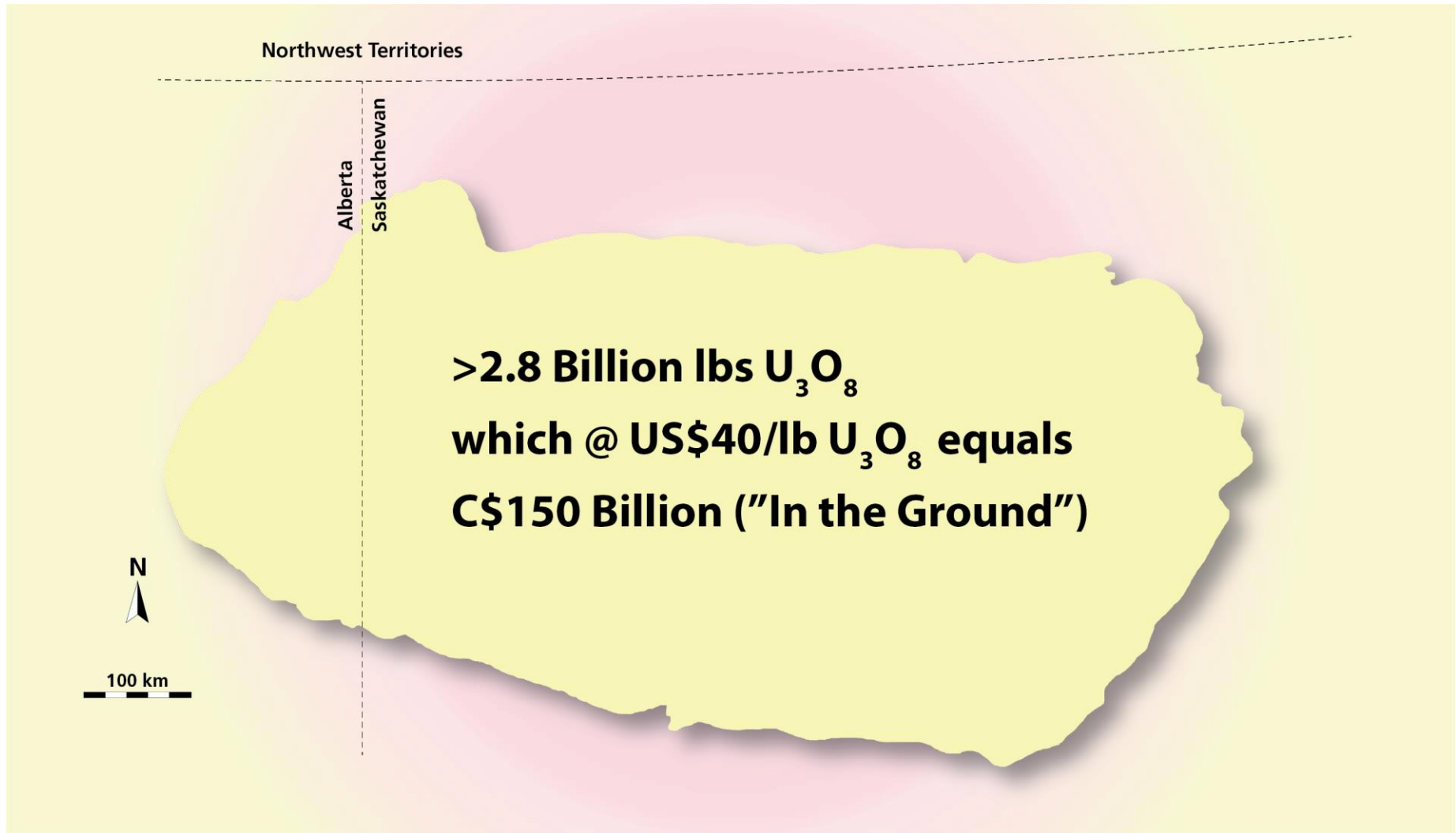
"ANALYSIS" topics continued:

- WHICH Companies were successful
- HOW successful were they
- WHAT was the cost to discover a "Deposit"
- WHAT was the cost to discover M's lbs U_3O_8
- "Brownfield" versus "Greenfield" success
- Cost effectiveness of Exploration versus Buying M's lbs U_3O_8

WHAT was FOUND and WHAT'S it WORTH

October 1968 – March 2018 Total Basin "Resources"

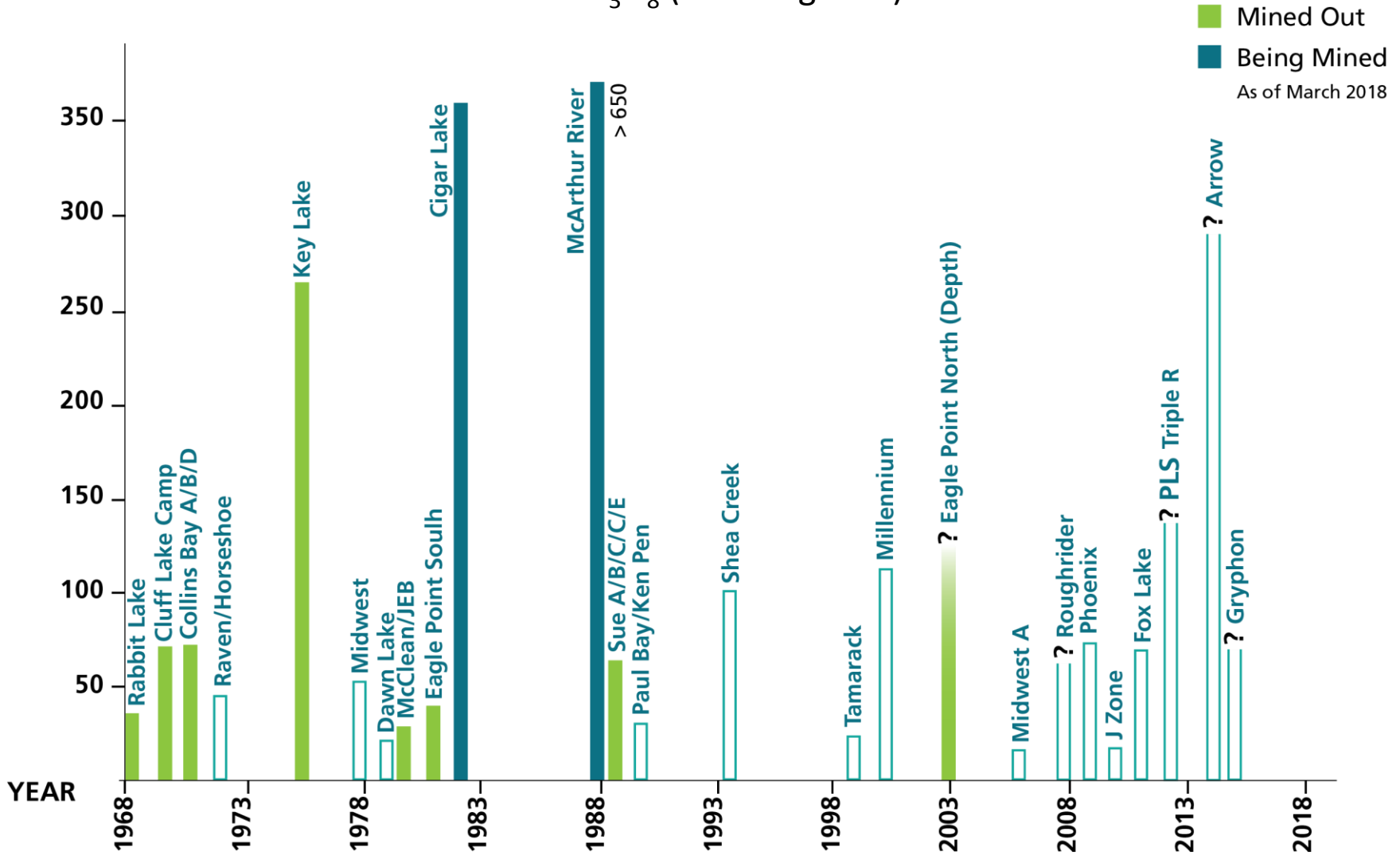
All Resource Categories/"In the Ground"



Athabasca Basin Uranium Deposits

Sequence and Size of Discoveries Mined Out or Being Mined

M lbs U₃O₈ (All Categories)



50 Years and C\$3 Billion

Athabasca Basin Uranium Deposits

- WHAT was SPENT to find the Deposits?
- WHAT Costs are included?
- WHAT were the "DRIVERS" of Exploration?
- WHY the "Boom/Bust" cycles?

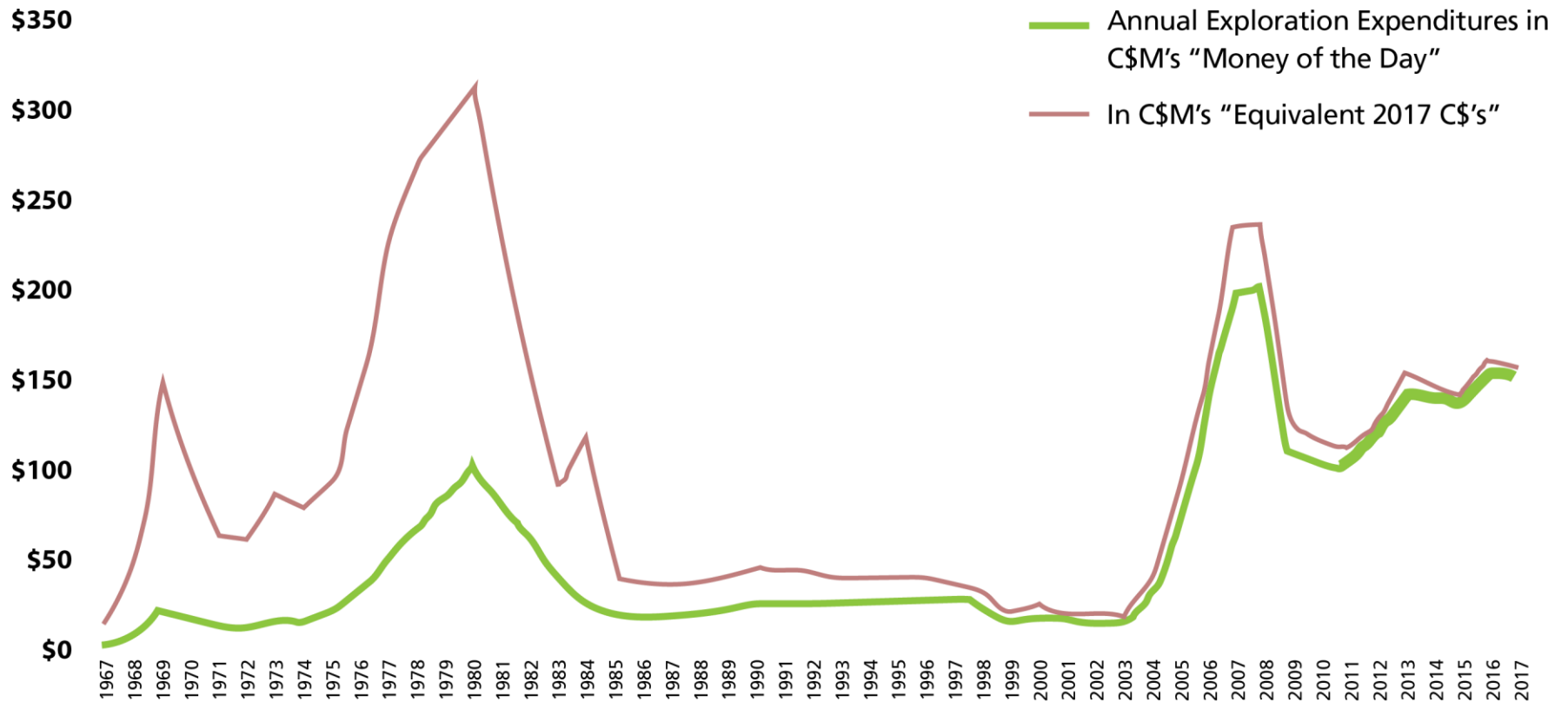
Athabasca Basin Uranium

Exploration Expenditures 1967 – 2017

In “Money of the Day” and in “Equivalent 2017 C\$’s

Total Expenditure 1967 – 2017 C\$2.87 Billion (MOD)

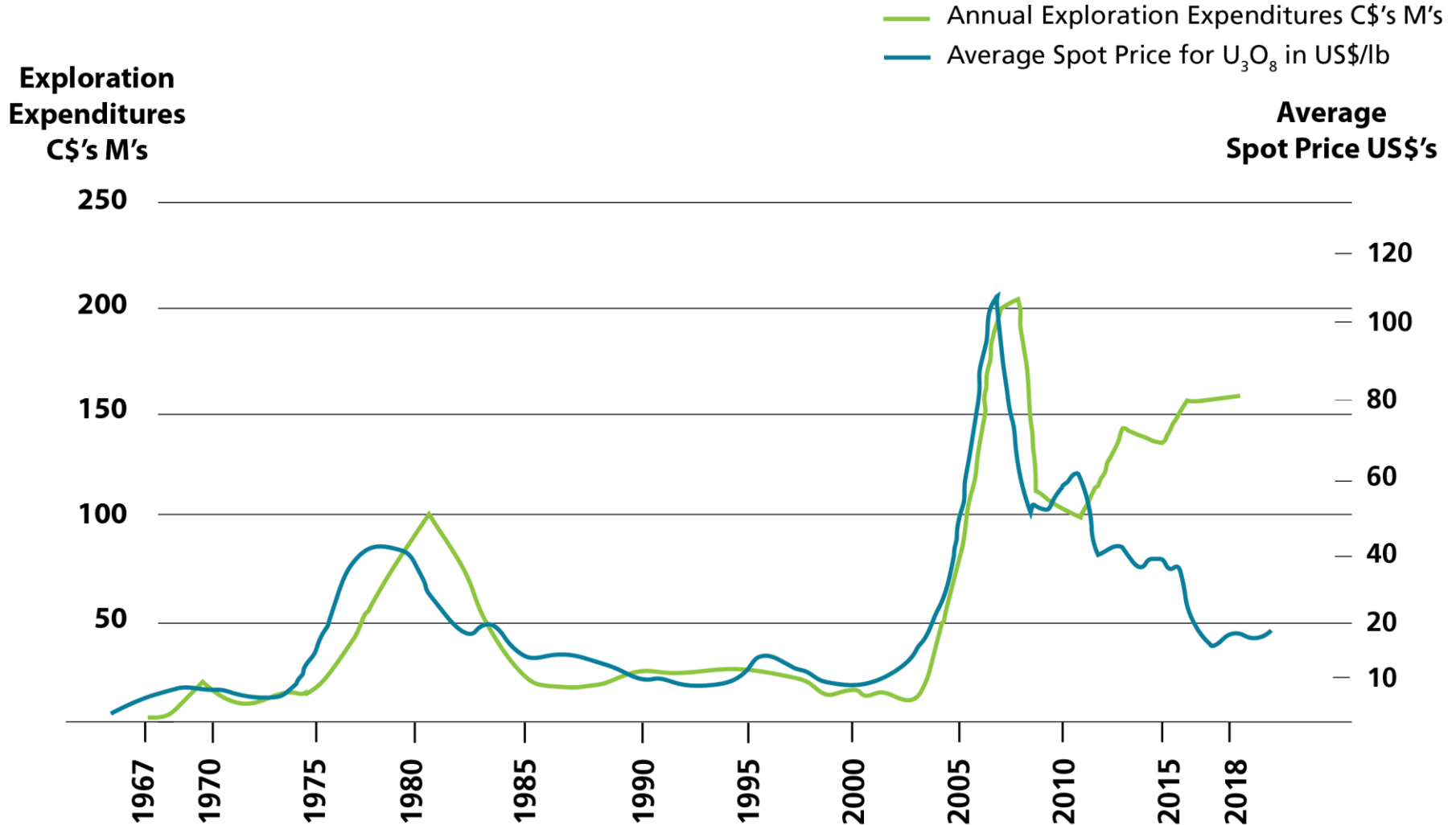
C\$’s M’s



Athabasca Basin Uranium

Annual Exploration Expenditures

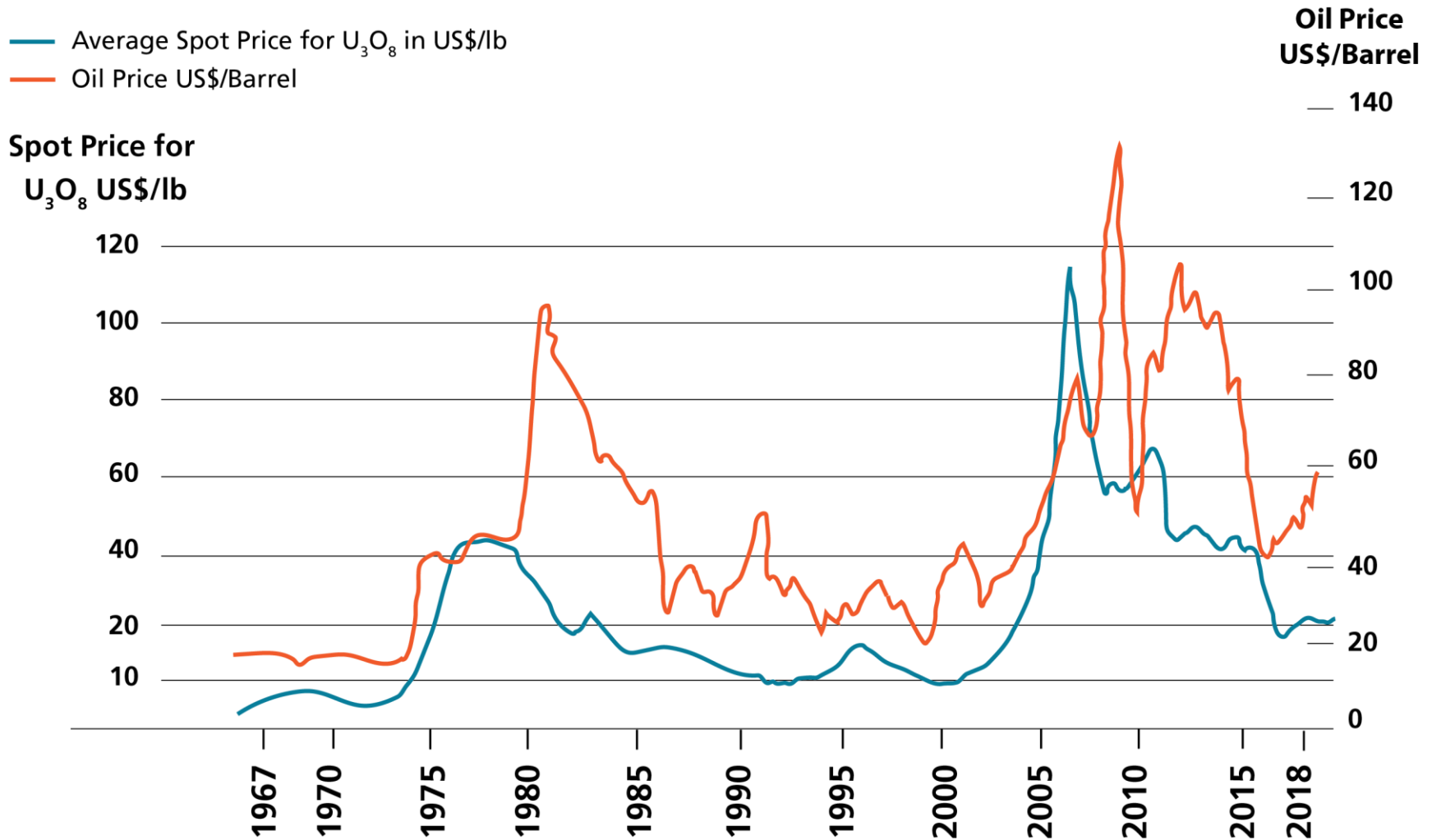
C\$'s Millions "Money of the Day" versus Spot Price of U₃O₈ (US\$'s)



Average Oil Price US\$/Barrel

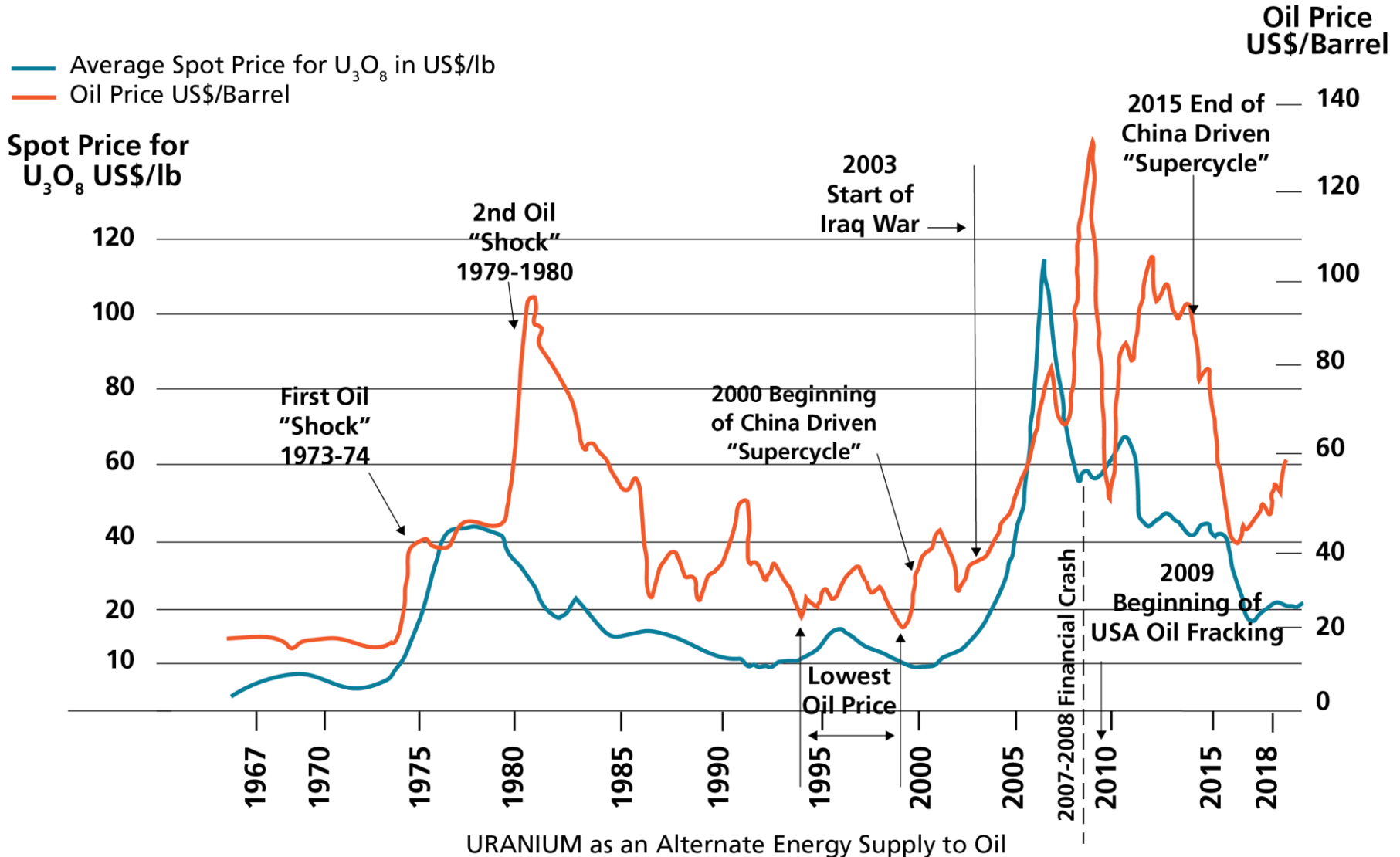
and Average Spot Price of U₃O₈ in US\$/lb

(both in "Money of the Day")



Average Oil Price US\$/Barrel and Average Spot Price of U₃O₈ in US\$/lb (both in "Money of the Day")

Significant Events and Price Consequences

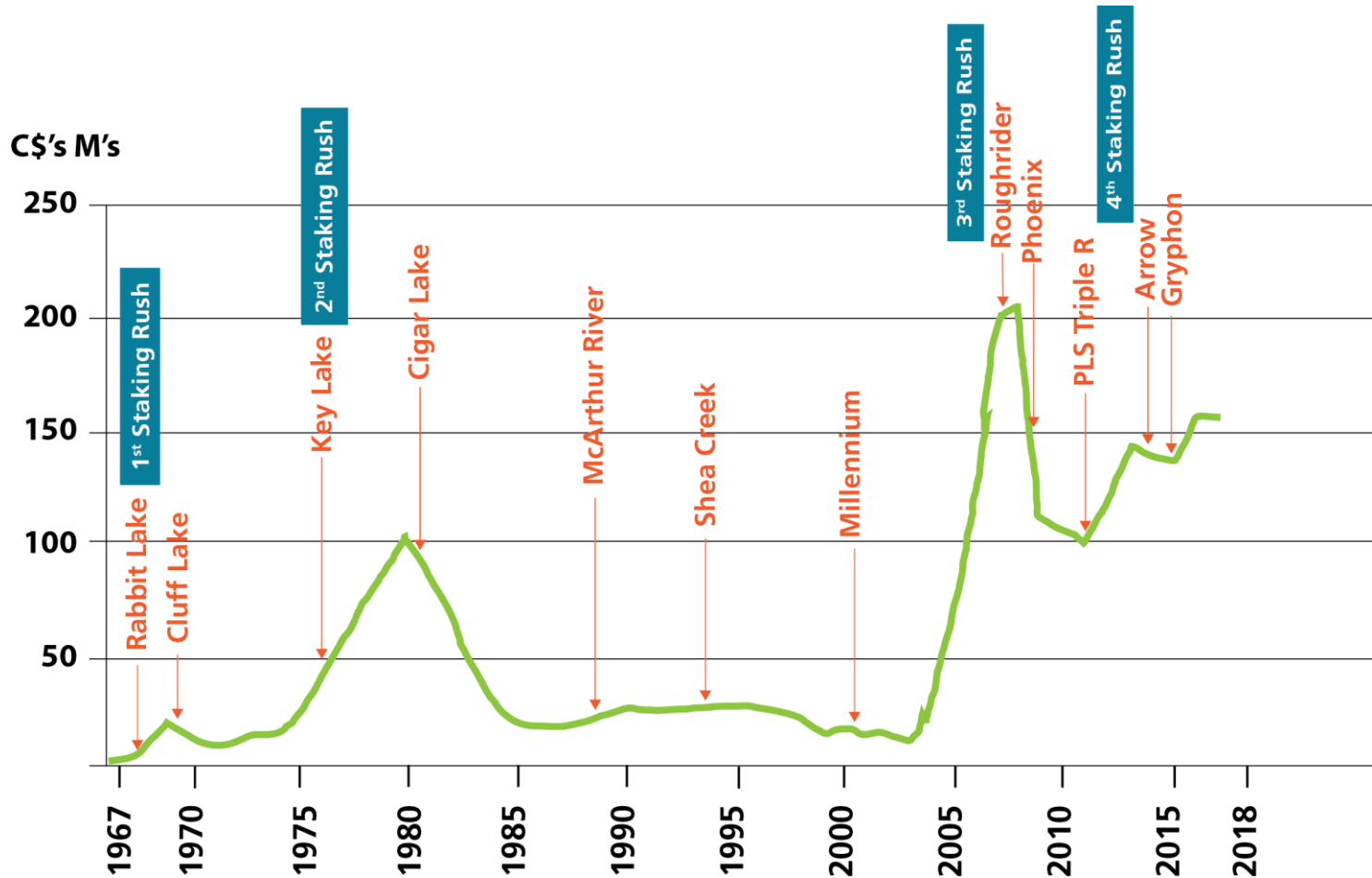


Athabasca Basin Uranium

Annual Exploration Expenditures C\$'s Millions "Money of the Day"

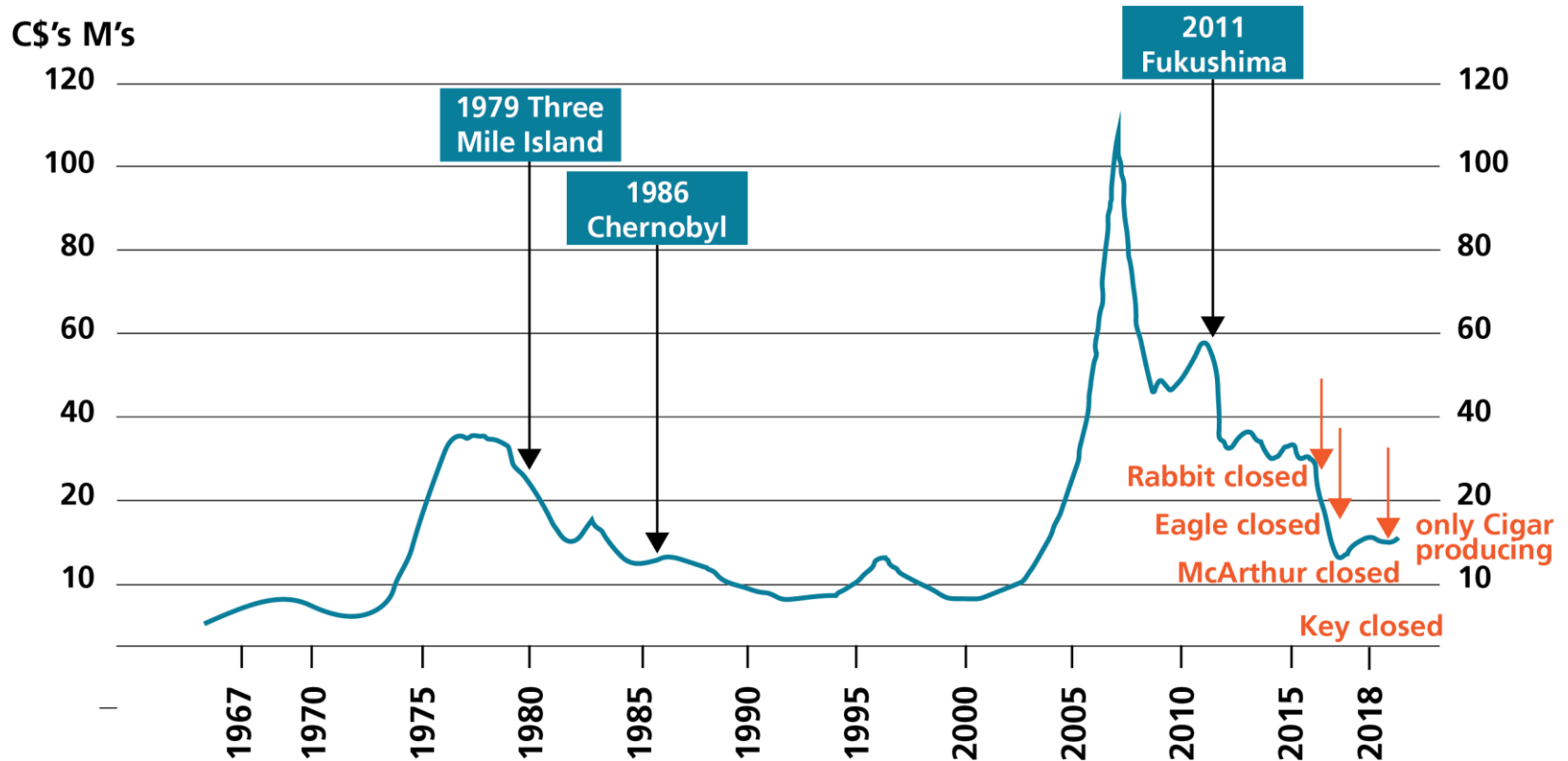
"EVENT" Sequence and Significant Discoveries

Does increased Expenditure result in increased Discoveries?



Average Spot Price for U_3O_8 in US\$/lb (in "Money of the Day")

Nuclear Reactor Events and their Consequences



50 Years and C\$3 Billion

The "BOOM/BUST" Cycles WHAT were some of the "Drivers"?

- Stop/Start growth of Nuclear Power Generation
- Supply/Demand of Uranium – nearly always out of "sync"
- With the 1973-74 and 1979-80 Oil "Shocks"
- And, the 2003 – Iraq War
- With new discoveries: Australia, Canada, Kazakhstan, Niger, etc.
- With Nuclear Reactor "Set Backs" e.g. Three Mile Island (1979), Chernobyl (1986), Fukushima (2011)
- Euphoria during "Metal Supercycles" China 2000-2015
- And, the converse – the world-wide Financial "Crisis" in 2007/2008

50 Years and C\$3 Billion

WHO spent the Exploration \$'s? WHAT TYPE of Company was involved?

Arbitrarily one can divide them into FIVE Different Groups
with different Interests and Focus:

- "Integrated" Uranium Co's
- "Utilities" = Electrical Power Co's
- Oil Co's
- Major Metal Mining Co's
- "Junior" Mining Co's

50 Years and C\$3 Billion

The "Integrated" Uranium Co's
(involved in pre-Basin exploration to present)
These Companies Mine, Mill and Process Uranium
and some own Nuclear Reactors

- Eldorado/SMDC/Cameco (Cdn.)
- Orano (previously AREVA, Famok, Mokta, Amok, Minatco, Cogema, SERU) (French)
- Uranerz/Urangesellschaft/Umetco (German)
- Denison (Cdn.)
- RTZ (UK)

ALL are Basin Exploration Operators

50 Years and C\$3 Billion

"Utilities" Electrical Power Co's (from 1970's to present)

- JCU/Idemitsu/OURD/PNC (Japan)
- KEPCO (South Korea)
- UK Nuclear Energy Corp./C.E.G.B.
- Ontario Power
- Elekrowatt (Swiss)
- ENUSA (Spain)
- CGN (China)
- CEF (Hong Kong)

Own Minority %'s in JV's

Rarely BASIN Exploration Operators

50 Years and C\$3 Billion

Oil Companies (1967-1992)

- Gulf
- Asamera
- Esso
- Agip
- Numac
- Bow Valley
- Getty
- Chevron
- Inexco
- Cdn. Occidental
- And MANY others

MANY were Exploration Operators and most owned % interest in JV's

50 Years and C\$3 Billion

Major Metal Mining Companies (1969-1984)

- Conwest
- Noranda
- Imperial Metals
- Exall Mining
- Kennecott
- INCO
- Etc.

Some were Exploration Operators.
Some owned % interest in JV's

50 Years and C\$3 Billion

"Junior " Mining Companies (1968-Present)

- There have been literally hundreds
- Mainly staked ground and sold it
- Some retained a Minority % in a JV
- 1968-2000 were rarely Exploration Operators
- 2000-present some became significant operators
 - (JNR)
 - (Hathor)
 - UEX
 - Canalaska
 - Purepoint
 - Forum
 - Pitchstone
 - Alpha
 - Fission Energy
 - Fission Uranium
 - NexGen
 - and many others

50 Years and C\$3 Billion

HOW Successful were the Various Company Types?

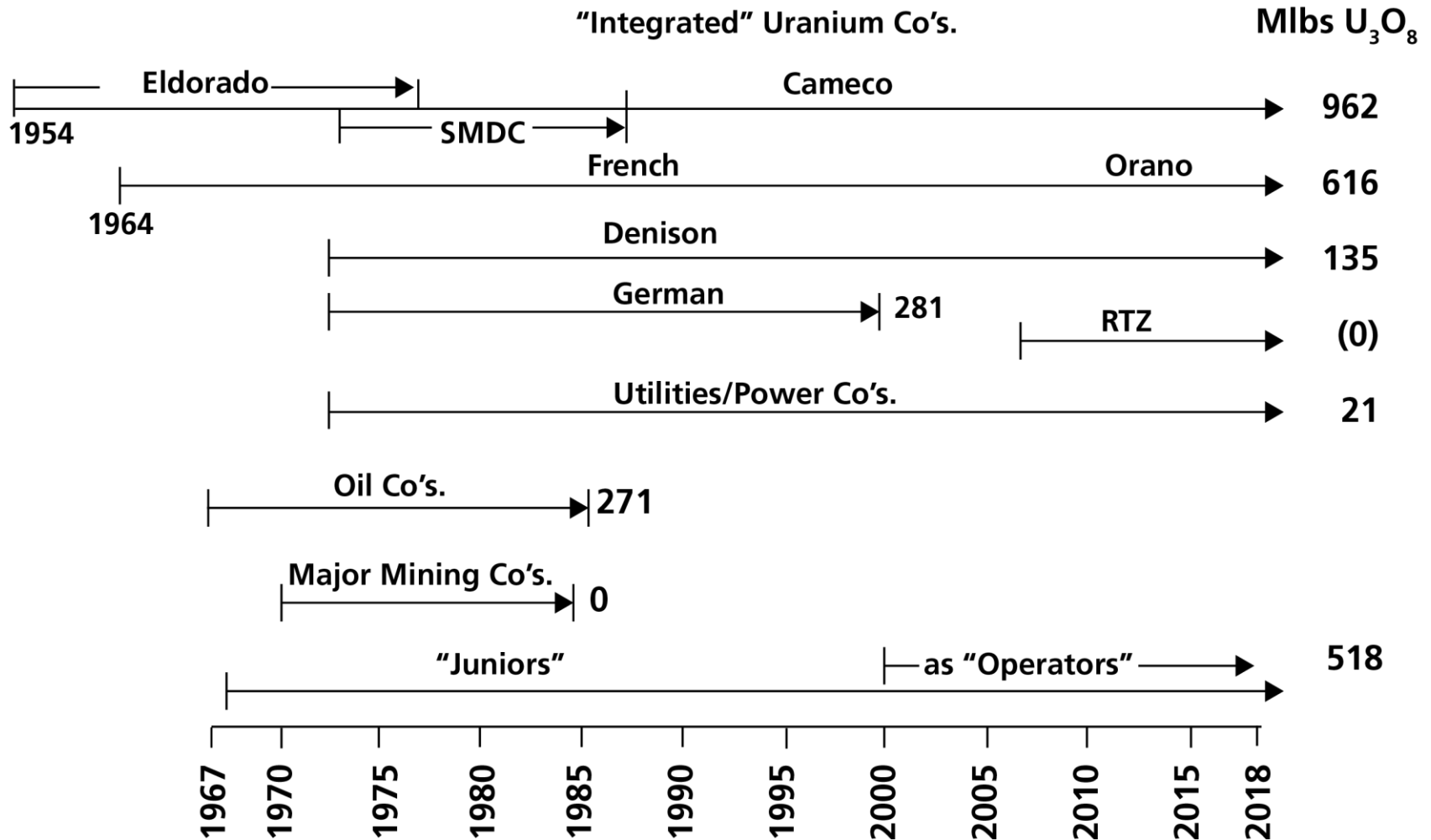
As THE Operating Co.	By "Deposits" and "significant Intercepts"	By M lbs U ₃ O ₈ ("in the ground")
"Integrated" U Co's	73	1994
"Utilities"	2	21
Oil Co's	25	271
Major Mining Co's	1	0
"Junior" Mining Co's and Prospectors	20	518
	121	2804

50 Years and C\$3 Billion

HOW Successful were Individual Companies?

As Operators	By "Deposits" and "Significant Intercepts"	By Mlbs U3O8 ("In the Ground")
Cameco (and predecessors)	27	962
Orano (and predecessors)	30	616
NexGen	5	301
Uranerz	7	281
Gulf Oil	11	186
Fission Uranium	4	141
Denison	8	135
Hathor	2	58
Esso	1	51
CanOxy	6	21
JCU	2	21
Asamera	6	13
Fission Energy	1	13
JNR	1	4
	111	2803

WHAT TYPE of COMPANY was INVOLVED and HOW Successful were they?



50 Years and C\$3 Billion

WHAT is involved in the COST of a Discovery?

In "this" Analysis the COST includes

ALL EXPLORATION Costs:

- Both pre-drilling
- And all drilling up to the "discovery" ddh

And ALL the DELINEATION Costs:

- Up to the published Tonnage/Grade

This can be a very variable cost e.g.

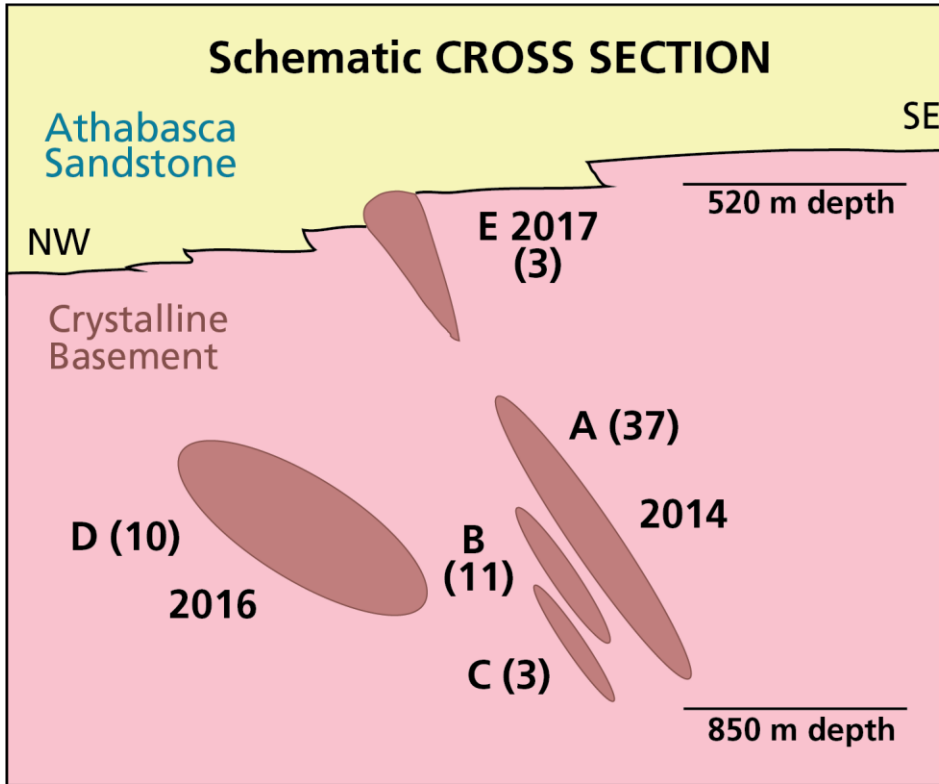
- Does the deposit have simple/complex geometry?
- Is there a simple/complex grade distribution?
- Is the Deposit deep/shallow?

WHAT does it COST to discover a "Deposit"?

- A "simple" question with both a simple and complex answer.
- The "simple" answer:
 - Take the Total \$'s spent and divide by the number of "Deposits" found.
- Equals C\$2.869B (MOD) \div 75 = \$38M/Deposit
- BUT - What is a "Deposit"? How is it defined?
- Are all "Deposits" equal?
 - e.g. Fond du Lac 1Mlbs U3O8 versus McArthur River >600Mlbs U3O8

WHAT is a “DEPOSIT”?

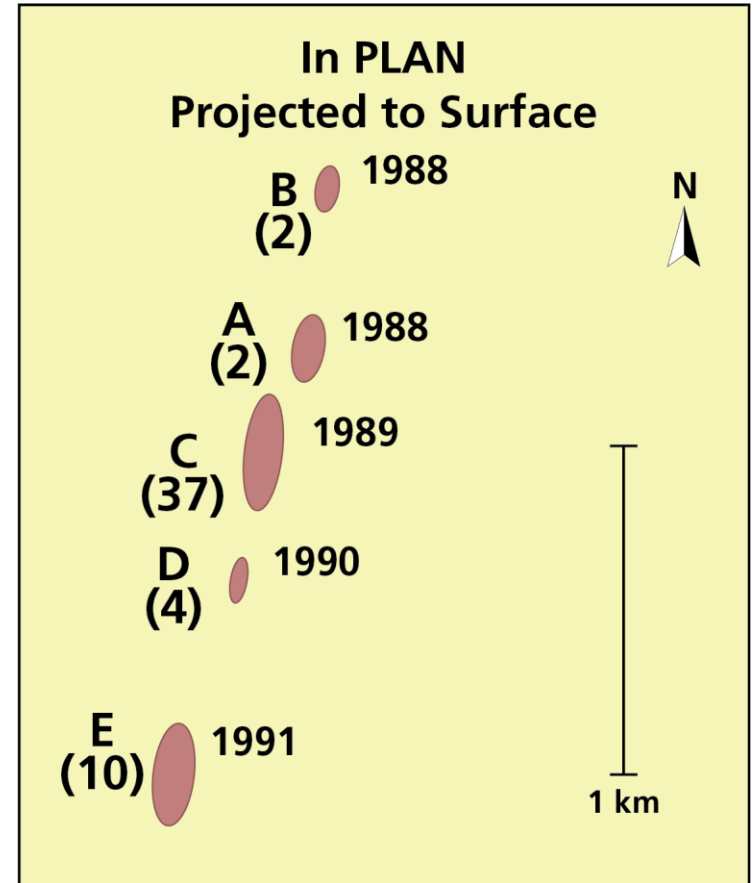
Example — are these **TWO** “deposits” or **TEN** “deposits”?



The GRYPHON Deposits

LEGEND

- D Lens/Deposit Name
- 2016 Discovery Year
- (10) M lbs U₃O₈



The SUE Deposits

50 Years and C\$3 Billion

WHAT does it COST to discover a "Deposit" ?

(i) WHAT is a "Deposit"?

One can take at least three approaches:

Case 1: The "No Discrimination" approach – a "deposit is a deposit". As long as there is a published tonnage/grade.

Case 2: The "Conservative" approach, combine all "zones" in a closely defined 3D space which are likely mined as ONE "deposit".

Case 3: The "Reality" approach, only include deposits which have actually been mined.

Case 1 $C\$2.869B \div 75 = C\$38M/\text{deposit}$

Case 2 $C\$2.869B \div 61 = C\$47M/\text{deposit}$

Case 3 $C\$2.869B \div 25 = C\$114M/\text{deposit}$

BUT these are ALL AVERAGE costs. Many individual deposits were vastly less expensive to discover.

50 Years and C\$3 Billion

WHAT does it COST to discover a "Deposit" ?

(ii) By SIZE in Mlbs U₃O₈

- >10M lbs U₃O₈ 62 deposits = C\$46M/deposit
- >50M lbs U₃O₈ 19 deposits = C\$150M/deposit
- >100M lbs U₃O₈ 8 deposits = C\$360M/deposit*

❖ BUT in fact ALL of these 8 deposits cost
<<C\$100M to discover/delineate.

So does "Average" cost mean anything?

50 Years and C\$3 Billion

WHAT is the COST to discover a lb of U₃O₈?

For interest, THREE previous estimates:

- 1980 - Lloyd Clark - SMDC <C\$0.70/lb U₃O₈
- 1981 - Gerry Pollock - SMDC C\$0.75/lb U₃O₈
- 1987 - Don Cranstone/Bob Whillans - Fed. Gov. EMR

Including Cigar Lake C\$0.59/lb U₃O₈

Not including Cigar Lake C\$0.97/lb U₃O₈

- This "Analysis": C\$2.869B ÷ 2.804B lb U₃O₈ = C\$1.02/lb
- but, as with Deposit cost, this "Average" obscures the reality.

50 Years and C\$3 Billion

WHAT is the COST to discover a lb of U₃O₈?

Some EARLY Discoveries (C\$'s MOD)

Year(s) of Discovery ddh	Name	Cost per lb U ₃ O ₈ (MOD)
1968	Rabbit Lake	C\$0.16
1969-71	Cluff Lake	C\$0.33
1972-74	Raven/Horseshoe	C\$0.87
1975-76	Key Lake	C\$0.38
1978	Midwest Lake	C\$0.49
1978	Dawn Lake	C\$1.9
1979-80	McClellan N/S	C\$0.26
1980	Eagle Point South	C\$0.28
1981	Cigar Lake	C\$0.11
1982	JEB	C\$0.41
AVERAGE COST	weighted by contained lbs	C\$0.30

50 Years and C\$3 Billion

WHAT is the COST to discover a lb of U₃O₈?

Some LATER Discoveries C\$'s MOD

Year(s) of Discovery ddh	Name	Cost per lb U ₃ O ₈ (MOD)
2000	Maverick (Moore Lake)	C\$8.75
2008	Roughrider	C\$0.55
2008-2017	Wheeler River (Phoenix/Gryphon)	C\$0.63
2009	J Zone	C\$0.38
2012-2017	PLS Triple R	C\$0.64
2014 -	Arrow	C\$0.25
AVERAGE COST	weighted by contained lbs	C\$0.49

- If a "Junior" is the Operator or a JV Partner almost all the information is in the Public Domain.
- Note: No Cameco/Orano discoveries are listed because there is little useful data in the Public domain even in SEDAR. So NO McArthur, Centennial, Eagle Pt. North, Millennium, Fox or Shea Creek.

50 Years and C\$3 Billion

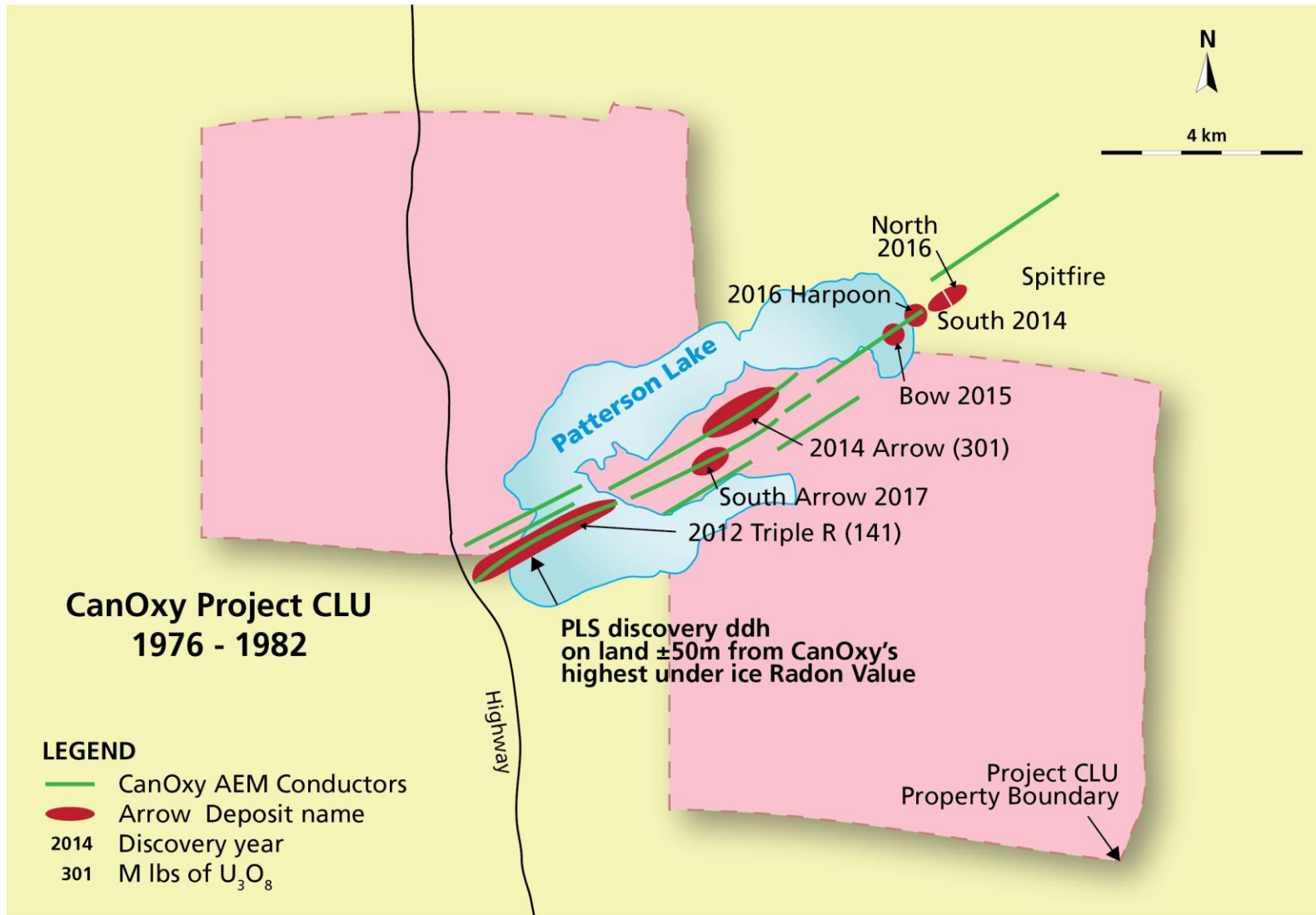
Athabasca Basin Uranium Deposits

DISCOVERY Time Frames Incredibly Variable

SOME EXAMPLES with Discovery Cost C\$'s lb U₃O₈:

- | | | |
|----------------|-----------|------|
| • Rabbit Lake | 18 months | 0.16 |
| • Arrow | 2 years | 0.25 |
| • Cluff Lake | 3 years | 0.33 |
| • Key Lake | 7 years | 0.38 |
| • Cigar Lake | 7 years | 0.11 |
| • Sue Deposits | 14 years | 0.58 |
| • Phoenix | 31 years | 0.63 |
| • PLS Triple R | 36 years | 0.64 |

Exploration Techniques – Assessment Data an Example



50 Years and C\$3 Billion

Athabasca Basin Uranium Deposits

"Brownfield" versus "Greenfield"

- o Successes and Costs through time

50 Years and C\$3 Billion

"BROWNFIELD" Successes – U₃O₈ (Date of Initial Discovery and Date of Final Discovery)

- CLUFF LAKE (Mill on site)
 - 1970 Discovery 18M lbs
 - 2000 Total Cumulative 64M lbs
- McCLEAN (Mill on site)
 - 1979-1980 Discovery 15M lbs
 - 2002 Total Cumulative 78M lbs
- RABBIT (Mill on site)
 - 1968 Discovery 41M lbs
 - 2005 Total Cumulative 303M lbs

50 Years and C\$3 Billion

WHAT does it COST to discover a lb of U₃O₈ through TIME?

Property	Deposits	Time	Cost per lb U ₃ O ₈ (MOD)
McClellan	N/S	1974-80	C\$0.26
	JEB	1981-84	C\$0.41
	Sue A/B/C/D/E	1985-92	C\$0.58
	Caribou	1992-2017	C\$1.15
Cluff Lake	D/N/OP/Claude	1964-74	C\$0.33
	DP/DJN/DJS	1975-86	C\$0.7
	DJW/DJWW	1987-2000	C\$1.6
Midwest	Main	1971-78	C\$0.49
	Midwest A	1979-2012	C\$1.45

- Though "Brownfield" equals lower operating costs these are offset by discoveries being ever more difficult.
- The exception is Gulf 1968-1980 Rabbit to H/R to Collins A/B/D to Eagle Pt. South basically no increase in cost but no idea of exploration costs to define Eagle Pt. North deposits.

50 Years and C\$3 Billion

Athabasca Basin Uranium Deposits

Is it "Better" to BUY
or to EXPLORE for lbs of U₃O₈?

50 Years and C\$3 Billion

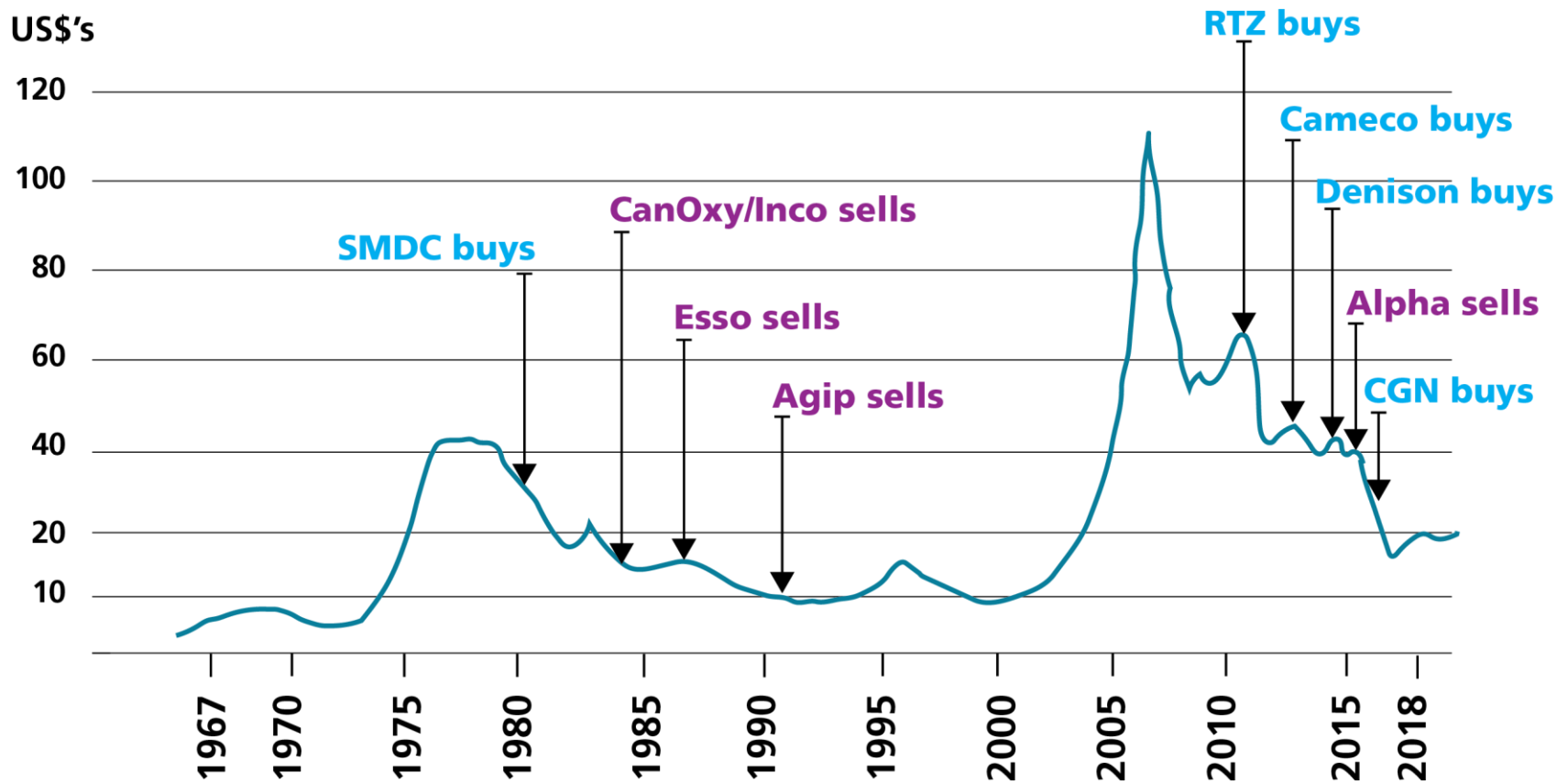
BUYING versus DISCOVERING lbs U₃O₈

Some examples through time (C\$'s MOD)

Year	Property	Seller	Buyer	%	C \$M	M lbs U3O8	Purchase Price (C\$'s per lb U3O8)	Discovery Cost (C\$'s per lb U3O8)
1980	Cluff	Mokta	SMDC	20	67	40	8.4	0.33
1984	McClellan	CanOxy/INCO	Minatco	100	24	21	1.1	0.26
1987	Midwest	Esso	Denison	50	12	40	0.6	0.49
1992	McArthur	Agip	SMDC	10	50	200 (?)	0.25	0.5(?)
2011	Roughrider	Hathor	RTZ	100	654	58	11.3	0.55
2012	Millennium	AREVA	Cameco	27.9	150	67.6	7.94	0.6(?)
2012	Maverick	JNR	Denison	50	10	4(?)	5.0	8.75
2013	J Zone	Fission Energy	Denison	60	70	13	9.0	0.38
2013	PLS	Alpha	Fission Uranium	50	185	108	3.4	0.64
2013	PLS	Fission Uranium	CGN	19.99	82	108	3.78	0.64

BUYING and SELLING lbs of U_3O_8

Average Spot Price for U_3O_8 in US\$/lb
(in "Money of the Day")



50 Years and C\$3 Billion

Why BUY when you can EXPLORE for so much less?

VERY DIFFERENT MOTIVATIONS, e.g.

1980 SMDC BUYS 20% of Cluff Lake = instant learning curve of mining/milling/exporting uranium

Mokta SELLS = Cash to build mine/mill and "legitimacy" operating in foreign country

1984/1987/1992 CanOxy/INCO; Esso; Agip SELL all their assets for cash. They want OUT of uranium.

Minatco; Denison; SMDC BUY "lbs in the ground" because uranium is their business

2011/2012/2013 Hathor; JNR; Fission Energy SELL and make huge cash gains on their investments

2011 RTZ BUYS 58M lbs U₃O₈ for C\$654M = C\$11.3/lb presumably to gain a "foot hold" in the Basin

50 Years and C\$3 Billion

Athabasca Basin Uranium Deposits

So ENDS Part 1!

PART 2 covers – HOW the MONEY was SPENT

The Exploration Story:

- The various TECHNIQUES used
- Their success/failure rates
- Their cost per lb U₃O₈ found
- "Genetic" versus "Pragmatic" Models
- The "missing" C\$2 Billion
- (some) Lessons Learned