

Long-term global trends for uranium exploration

Richard Schodde

Managing Director, MinEx Consulting

Adjunct Professor, Centre for Exploration Targeting , UWA

URAM 2018 (Uranium Raw Material for the Nuclear Fuel Cycle)

Organized by the International Atomic Energy Agency (IAEA)

27th June 2018, Vienna

Overview

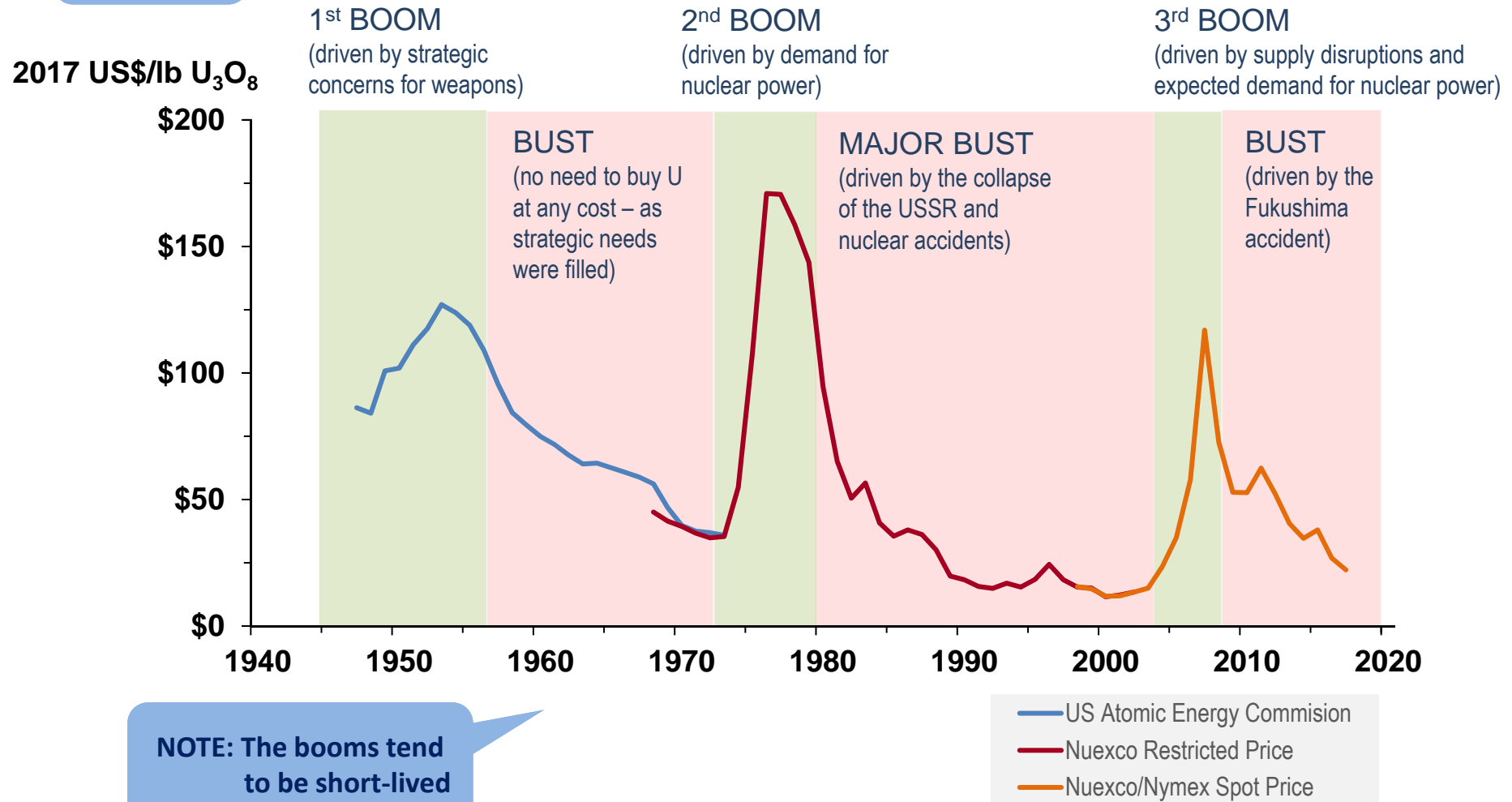
1. Long term trend in the uranium price
2. Long term trend in exploration expenditure
3. Location of discoveries
4. Trend in the number of discoveries over time
5. Trend in the amount of metal discovered over time
6. Discovery performance and unit discovery costs
7. Trend in the discovery rate versus mine production
i.e. Is the industry sustainable? What needs to happen to restore the balance ?
8. Conclusions/Summary

Since 1945 the industry has gone through three major booms and busts

1. LONG TERM TREND IN THE URANIUM PRICE

Uranium Price : 1947-2017

Three Major business cycles



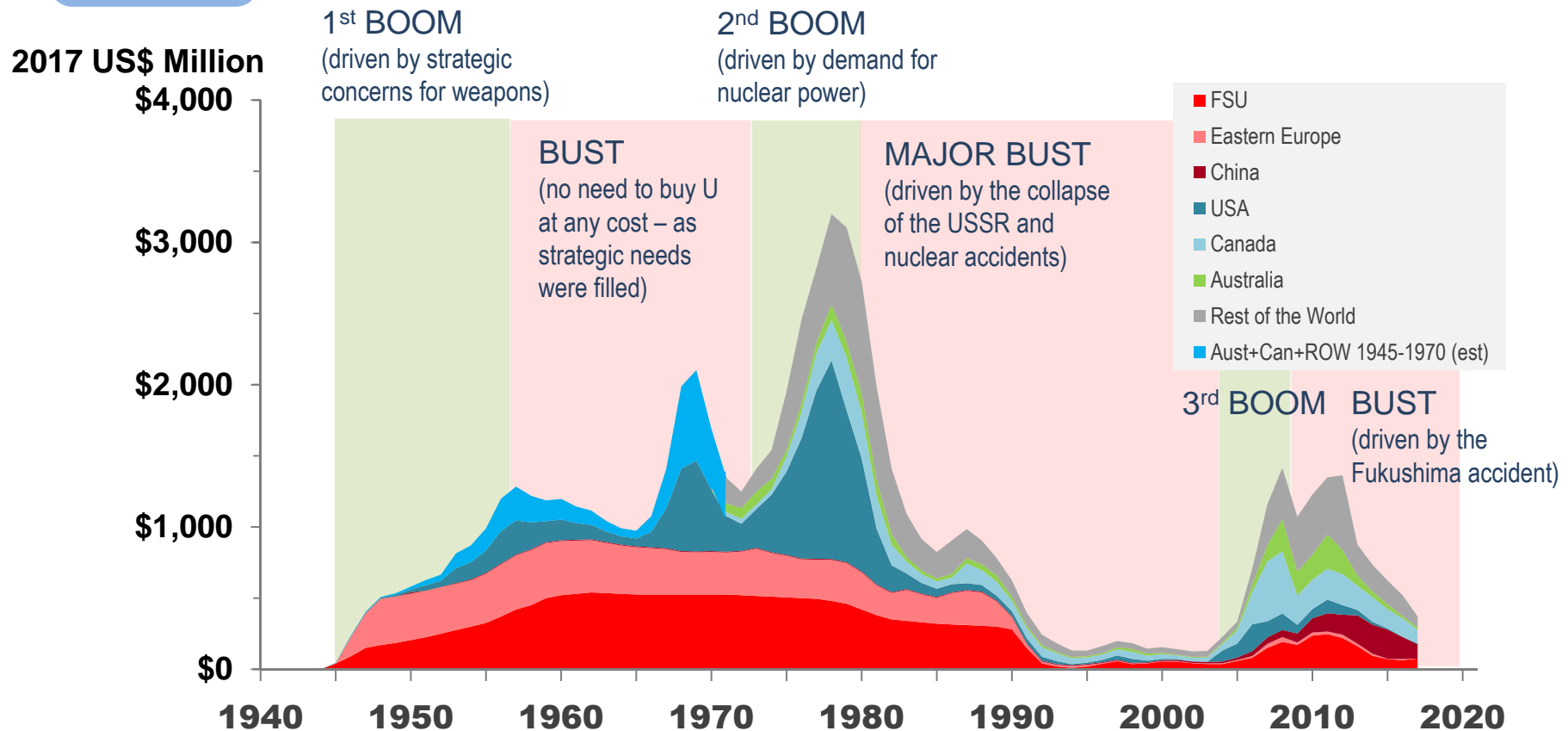
Sources: US DOE and AEC, Nuexco, Nymex

Since 1970 exploration expenditures have moved closely in-line with the price of uranium

2. LONG TERM TREND IN EXPLORATION EXPENDITURE

Uranium Exploration Spend: 1945-2017

Three Major business cycles

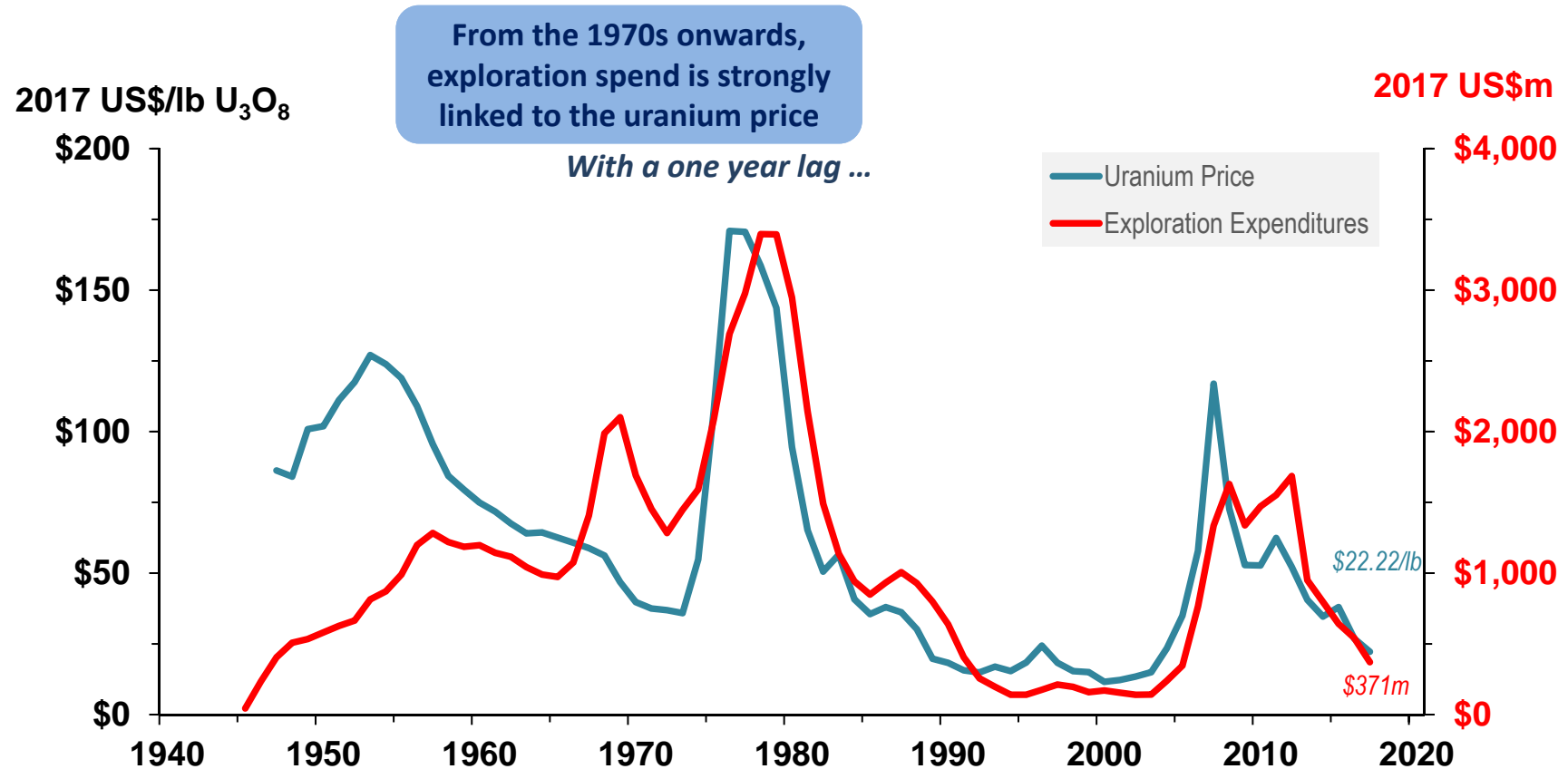


All-up over the last 7 decades \$76 Billion
has been spent exploring for uranium

Sources: MinEx Consulting estimates based on data from IAEA Red Book, ABS (Australia) and NRCAN (Canada)

Exploration Expenditures versus Uranium Price

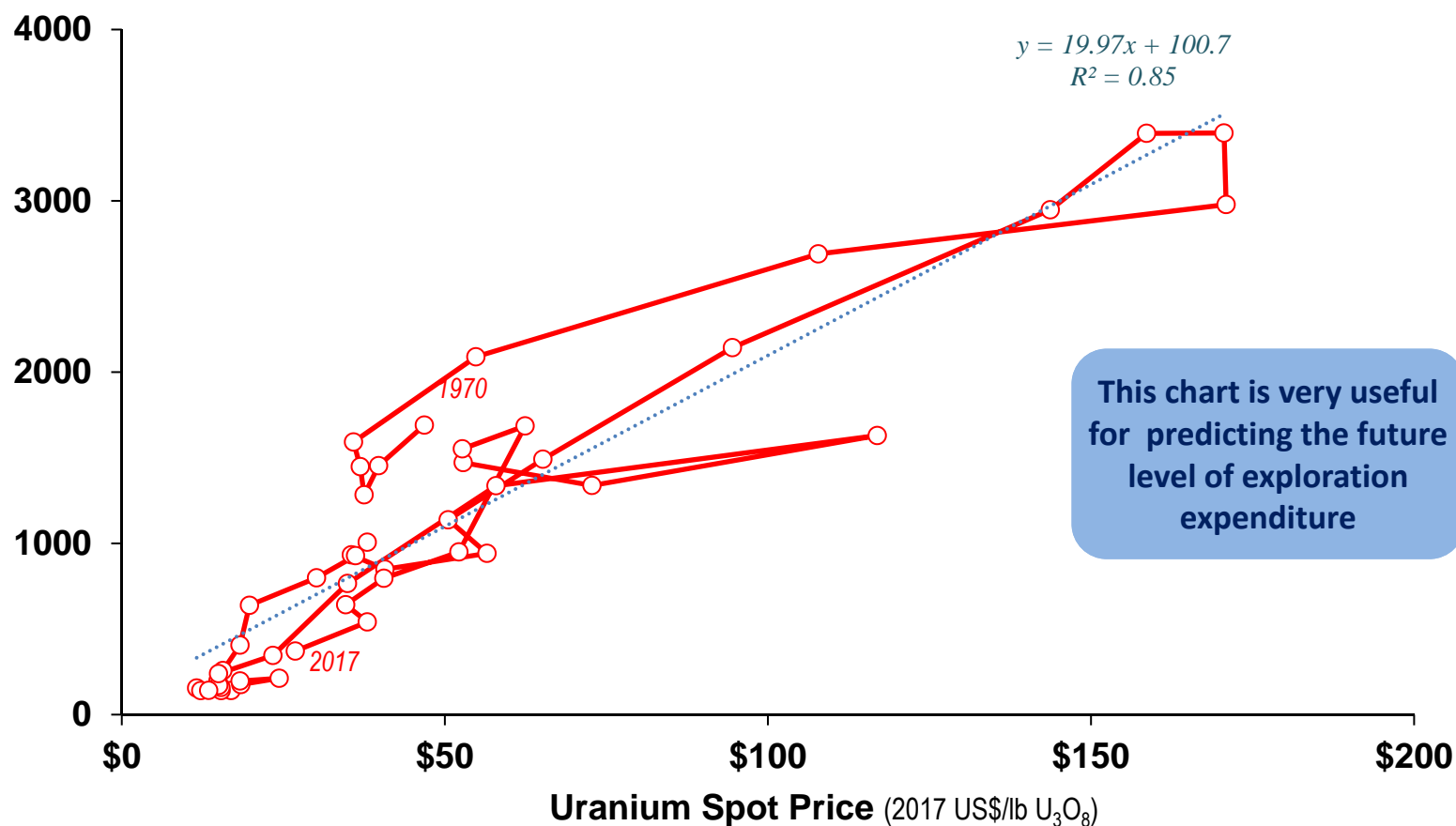
World: 1947-2017



Sources: MinEx Consulting estimates based on data from IAEA Red Book, ABS (Australia), NRCan (Canada), US DOE and AEC, Nuexco and Nymex

Relationship between the Uranium Price and World Exploration Expenditures: 1970-2017

Exploration Spend
(2017 US\$ Million)



Note: Includes a **one-year lag** between commodity price and exploration expenditure

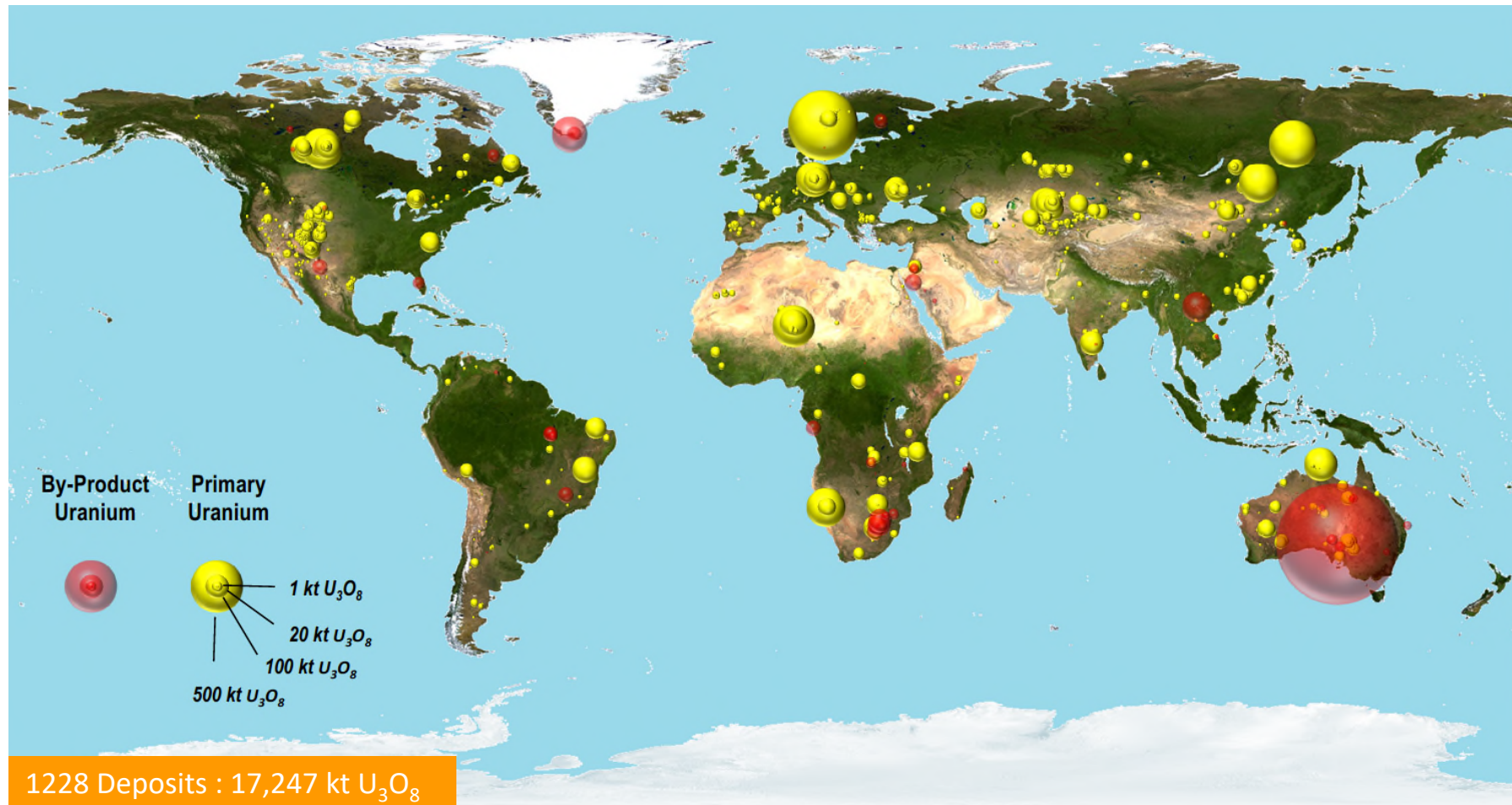
Source: MinEx Consulting © June 2018

Have identified over 1228 uranium deposits in the World (containing >0.5 kt U_3O_8). Only a handful of these are giant

3. LOCATION OF DISCOVERIES

Location of Uranium Deposits in the World: All Years

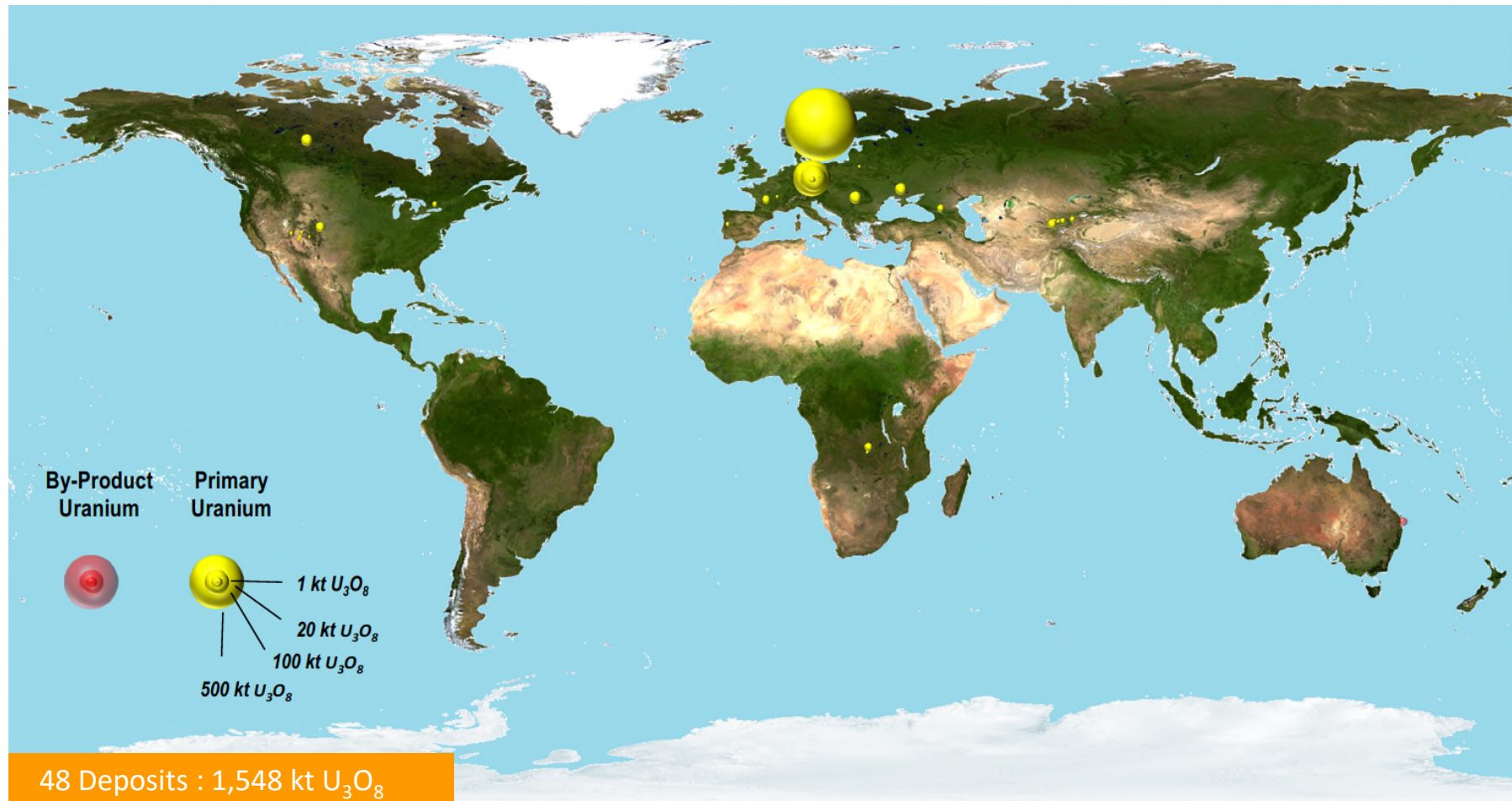
Primary and By-Product $>0.5\text{kt U}_3\text{O}_8$



Source: MinEx Consulting © June 2018

Uranium Discoveries : 1940-49

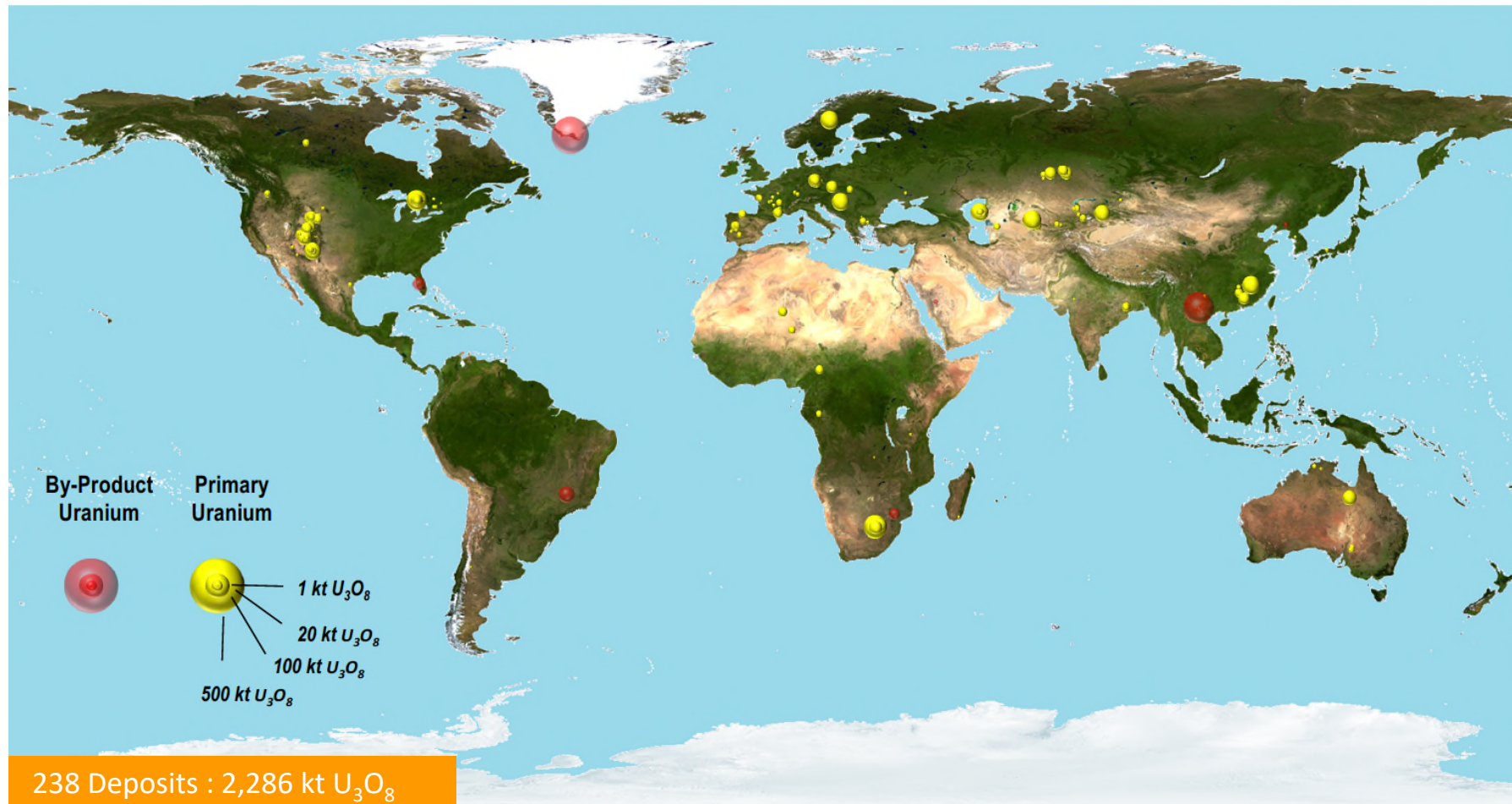
Primary and By-Product $>0.5\text{kt U}_3\text{O}_8$



Source: MinEx Consulting © June 2018

Uranium Discoveries : 1950-59

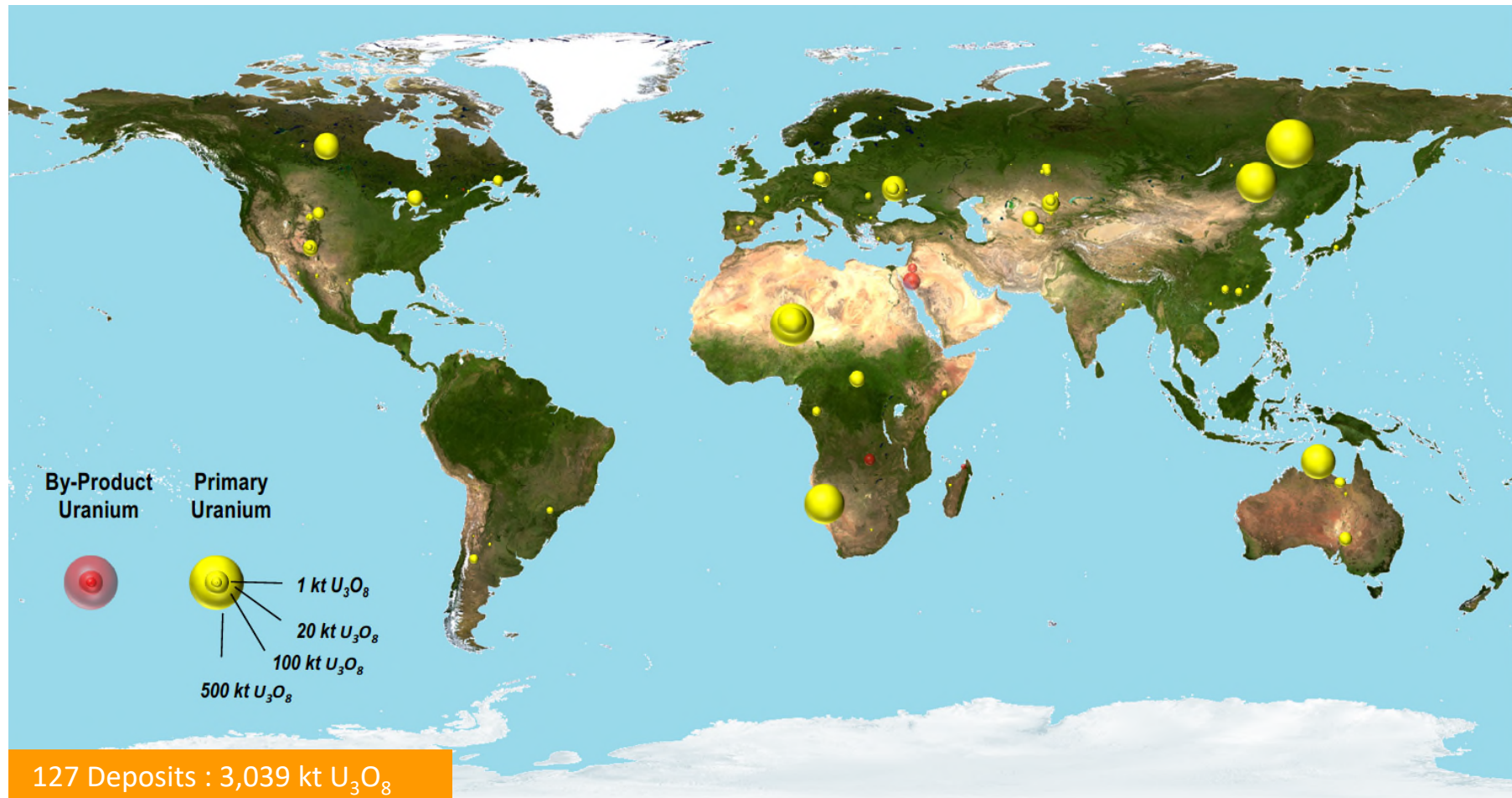
Primary and By-Product $>0.5\text{kt U}_3\text{O}_8$



Source: MinEx Consulting © June 2018

Uranium Discoveries : 1960-69

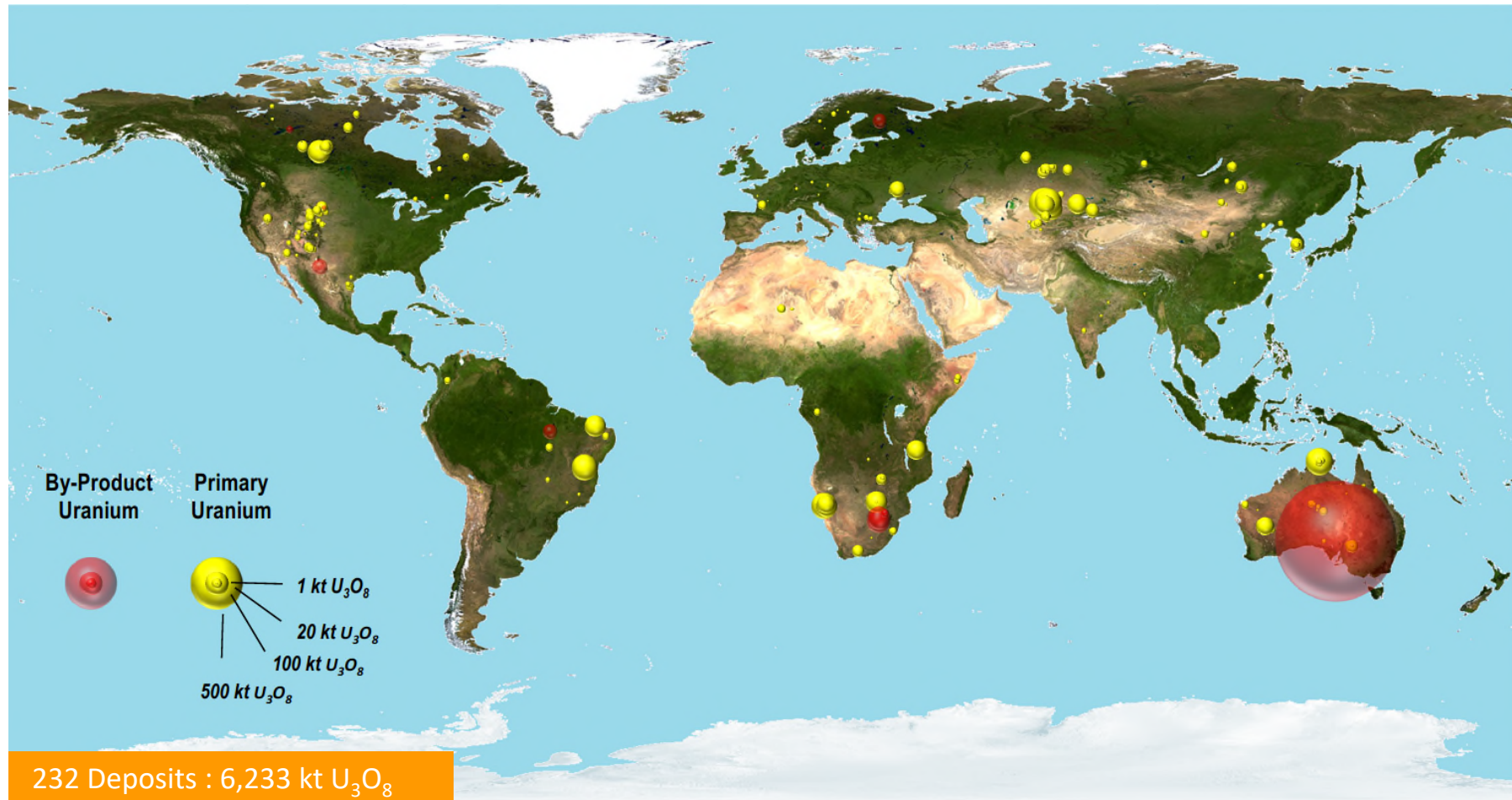
Primary and By-Product >0.5kt U₃O₈



Source: MinEx Consulting © June 2018

Uranium Discoveries : 1970-79

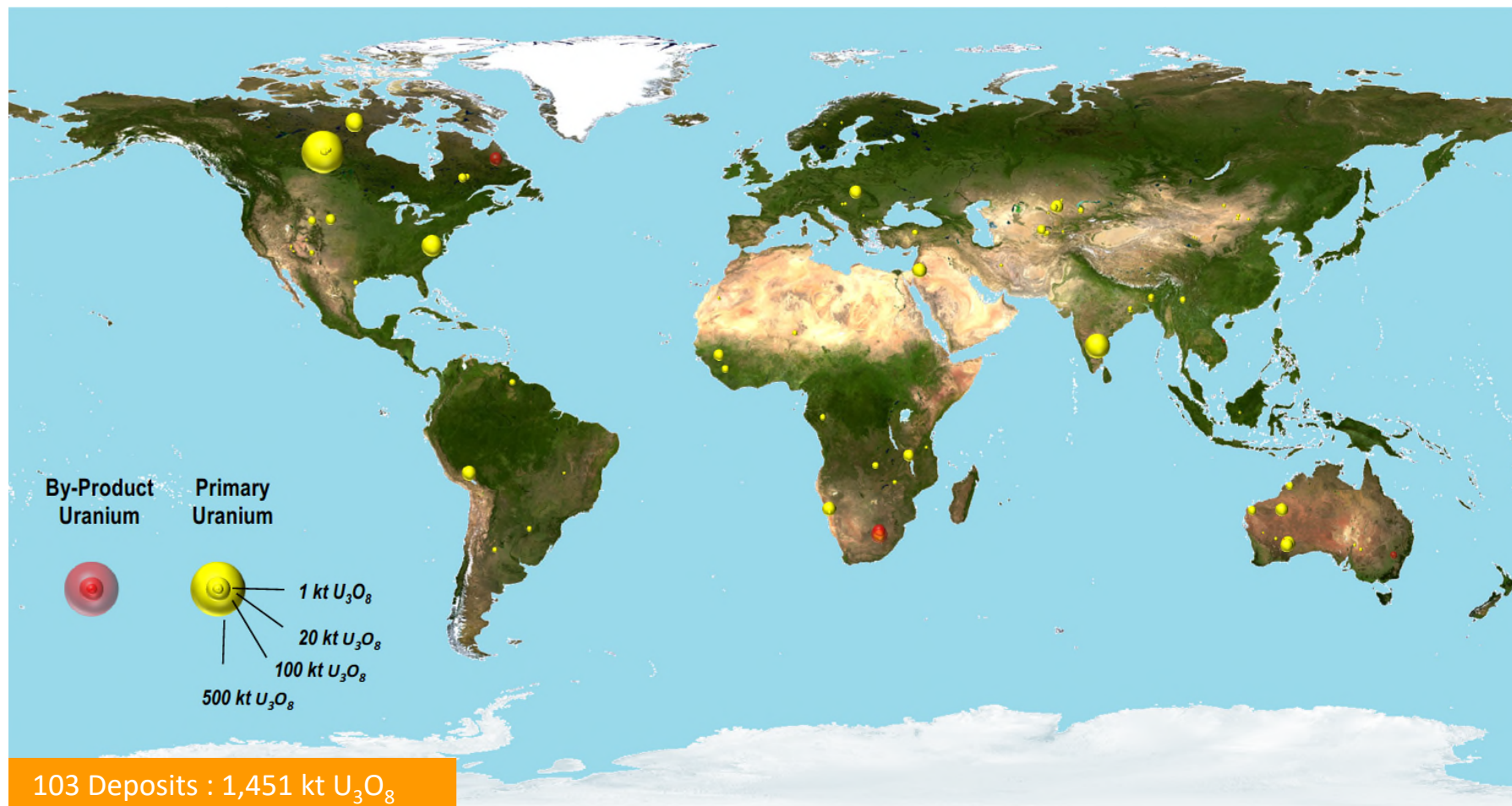
Primary and By-Product $>0.5\text{kt U}_3\text{O}_8$



Source: MinEx Consulting © June 2018

Uranium Discoveries : 1980-89

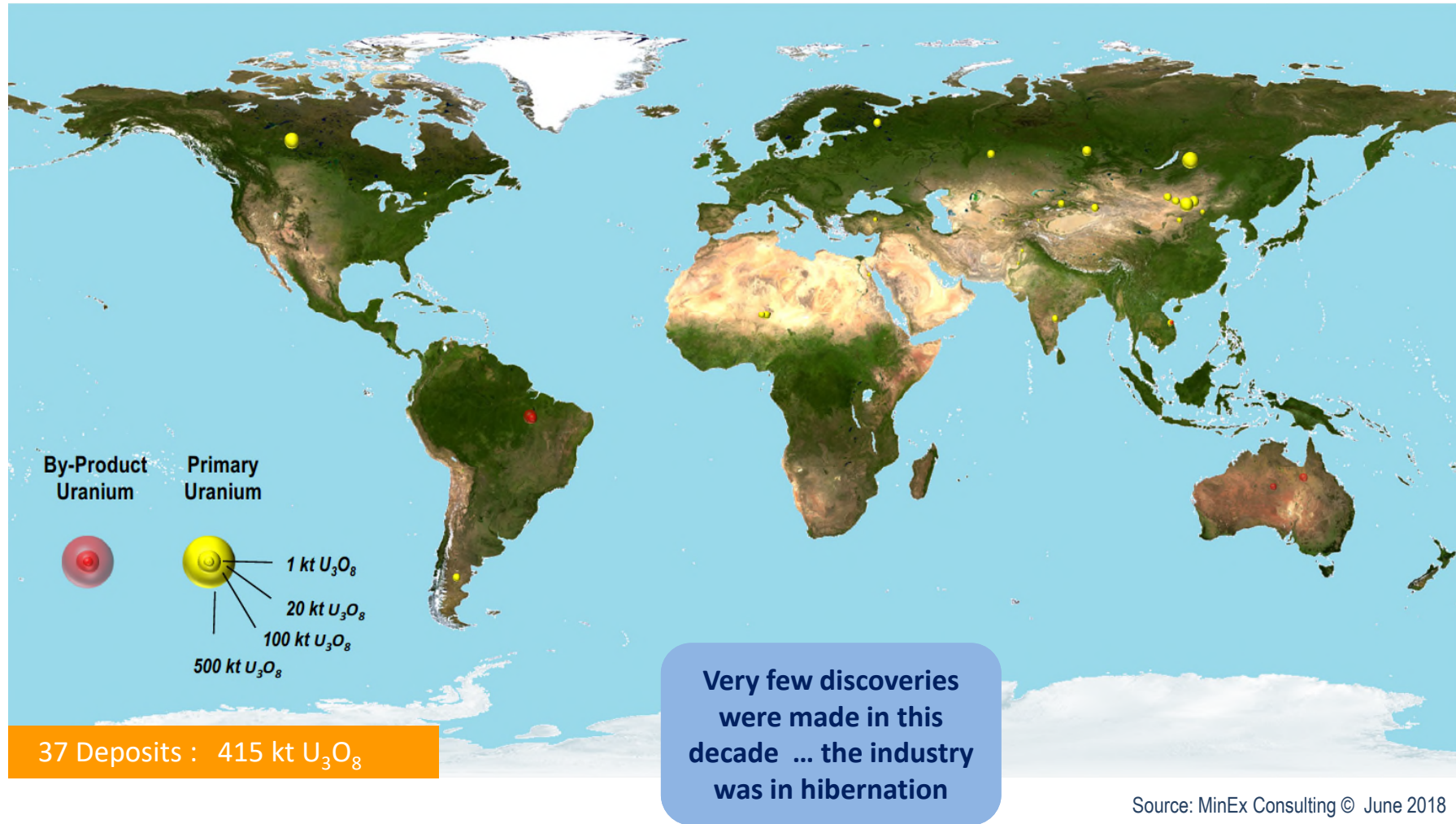
Primary and By-Product $>0.5\text{kt U}_3\text{O}_8$



Source: MinEx Consulting © June 2018

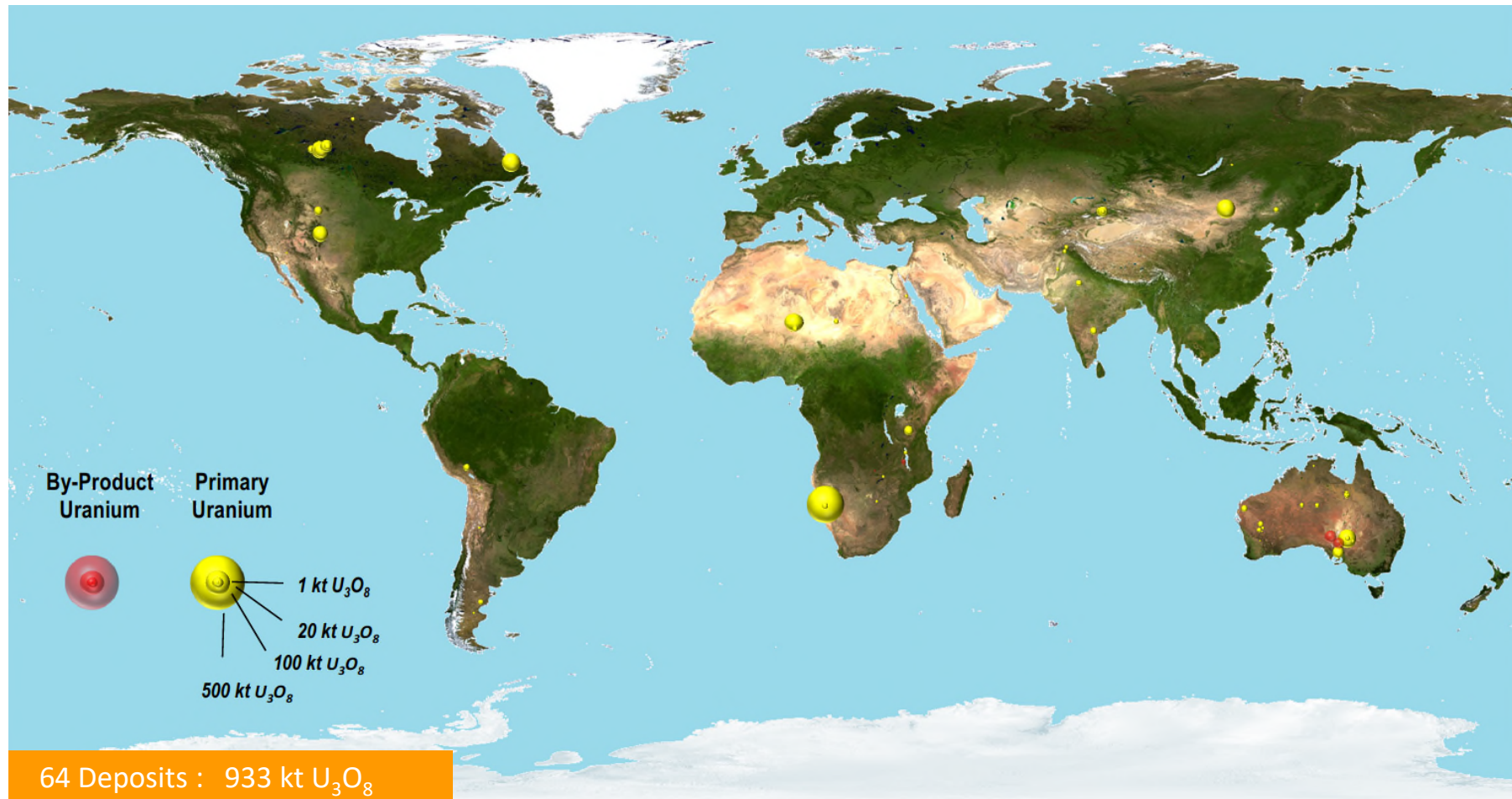
Uranium Discoveries : 1990-99

Primary and By-Product $>0.5\text{kt U}_3\text{O}_8$



Uranium Discoveries : 2000-09

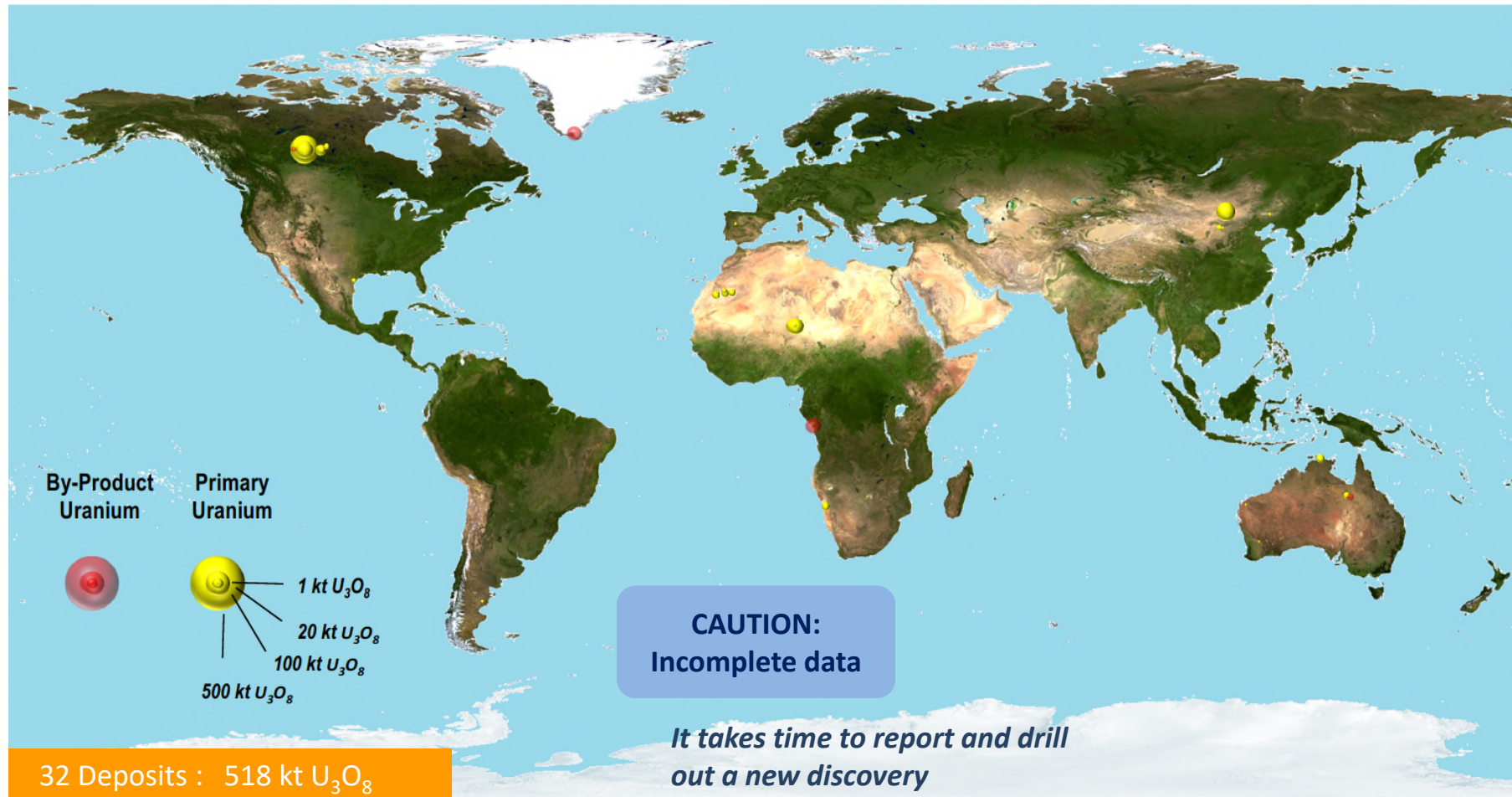
Primary and By-Product >0.5kt U₃O₈



Source: MinEx Consulting © June 2018

Uranium Discoveries : 2010-17

Primary and By-Product >0.5kt U₃O₈



Source: MinEx Consulting © June 2018

Primary versus By-Product Uranium

Deposits containing > 0.5 kt U_3O_8 : **All Years**

	Primary	By-Product
Total Number (#)	1172	56
Contained Metal (kt U_3O_8) (on a pre-mined Resource basis)	13,130 kt	4,120 kt
Deposits Mined to date		
Total Number (#)	516	6
Contained Metal (kt U_3O_8)	6,940 kt	2,950 kt
Historic Production (kt U_3O_8)	$>2,820$ kt	>110 kt

Actual cumulative production
for 1940-2015 is 3,174 kt U_3O_8
excluding losses

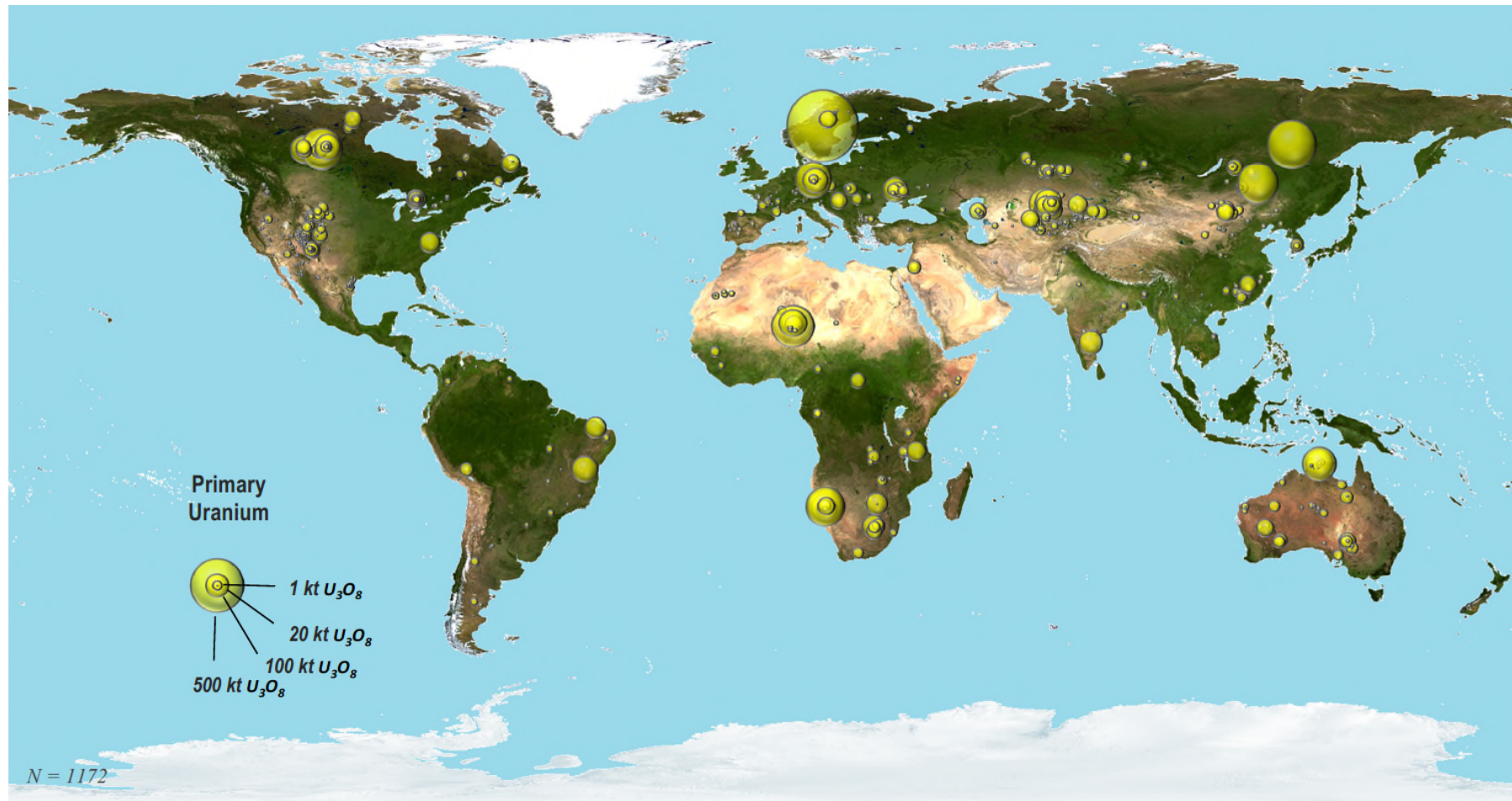
Given the very small level of historic by-product
material ... the author has excluded these
deposits from the current analysis

Sources: WNA and IAEA

Source: MinEx Consulting © June 2018

Location of Uranium Deposits in the World: All Years

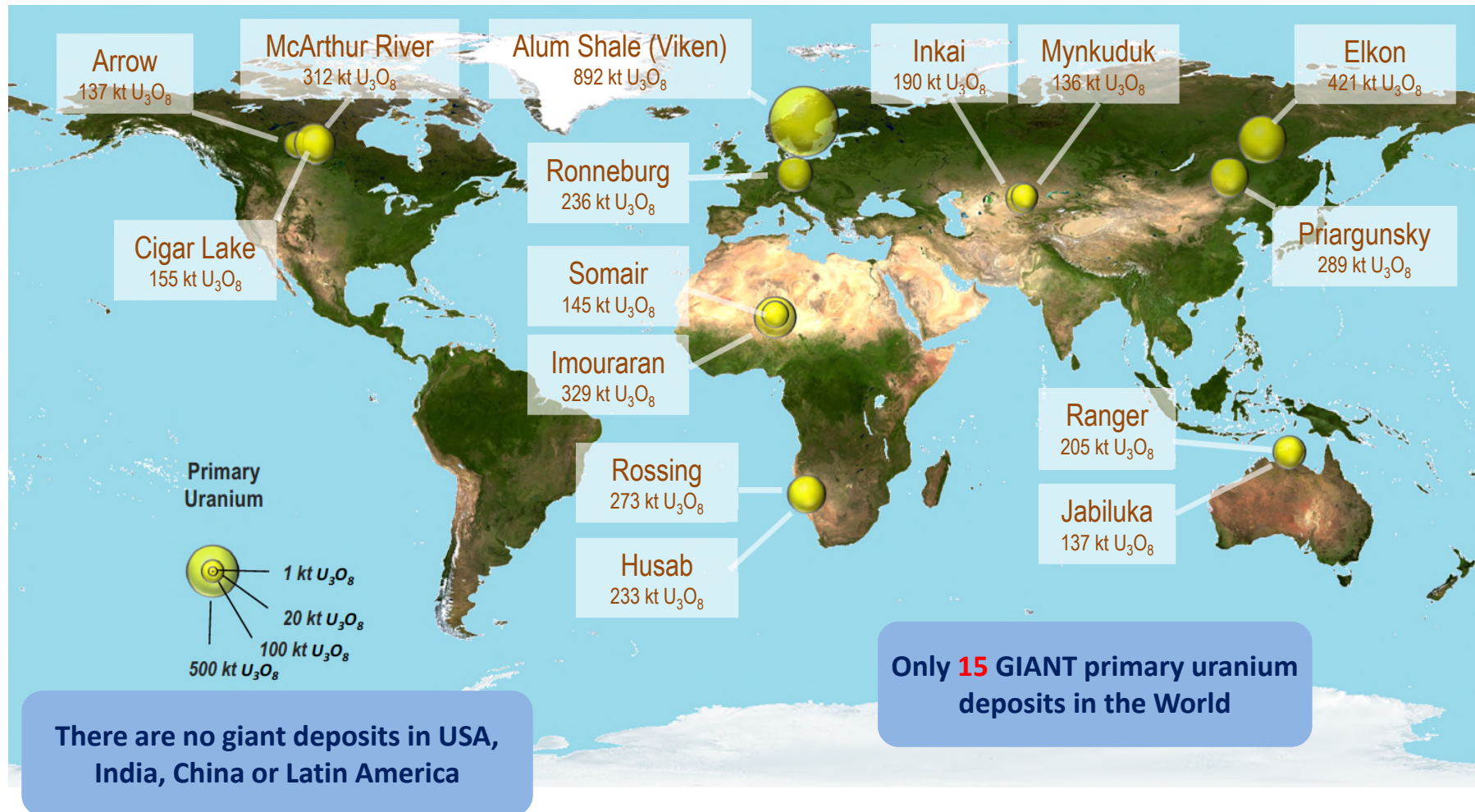
Primary only $>0.5\text{kt U}_3\text{O}_8$



Source: MinEx Consulting © June 2018

Location of Uranium Deposits in the World: All Years

Primary only >125kt U_3O_8



Note: Excludes by-product deposits – such as Olympic Dam (with 2717 kt U_3O_8)

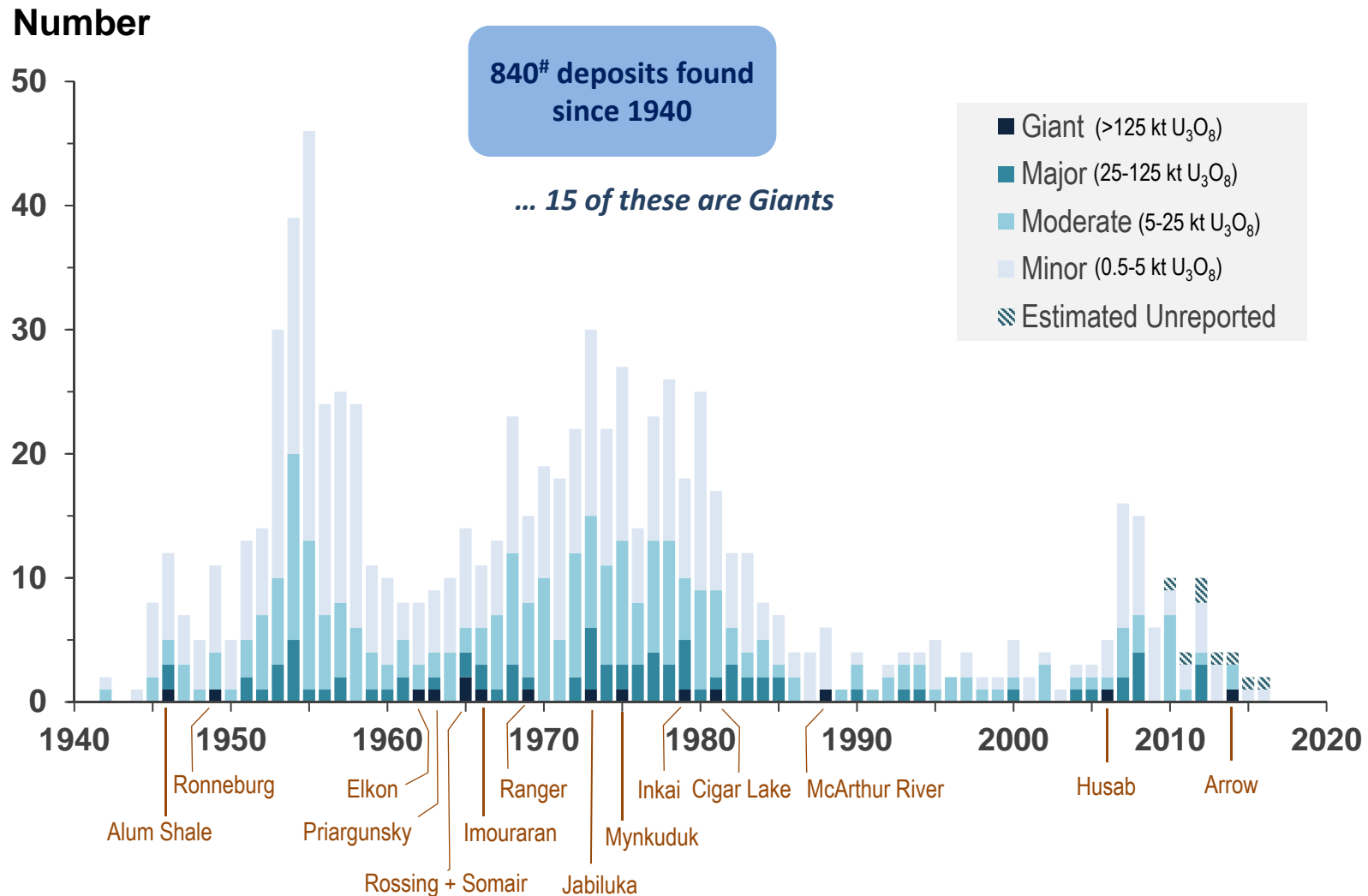
Source: MinEx Consulting © June 2018

Half of all of the World's uranium deposits were found between 1950 and 1980

4. TREND IN THE NUMBER OF DISCOVERIES OVER TIME

Number of Uranium Deposits found in World: 1940-2016

Primary uranium deposits only



Note: Excludes 329 deposits with no reported discovery date (318 Minor + 11 Moderate-sized deposits)

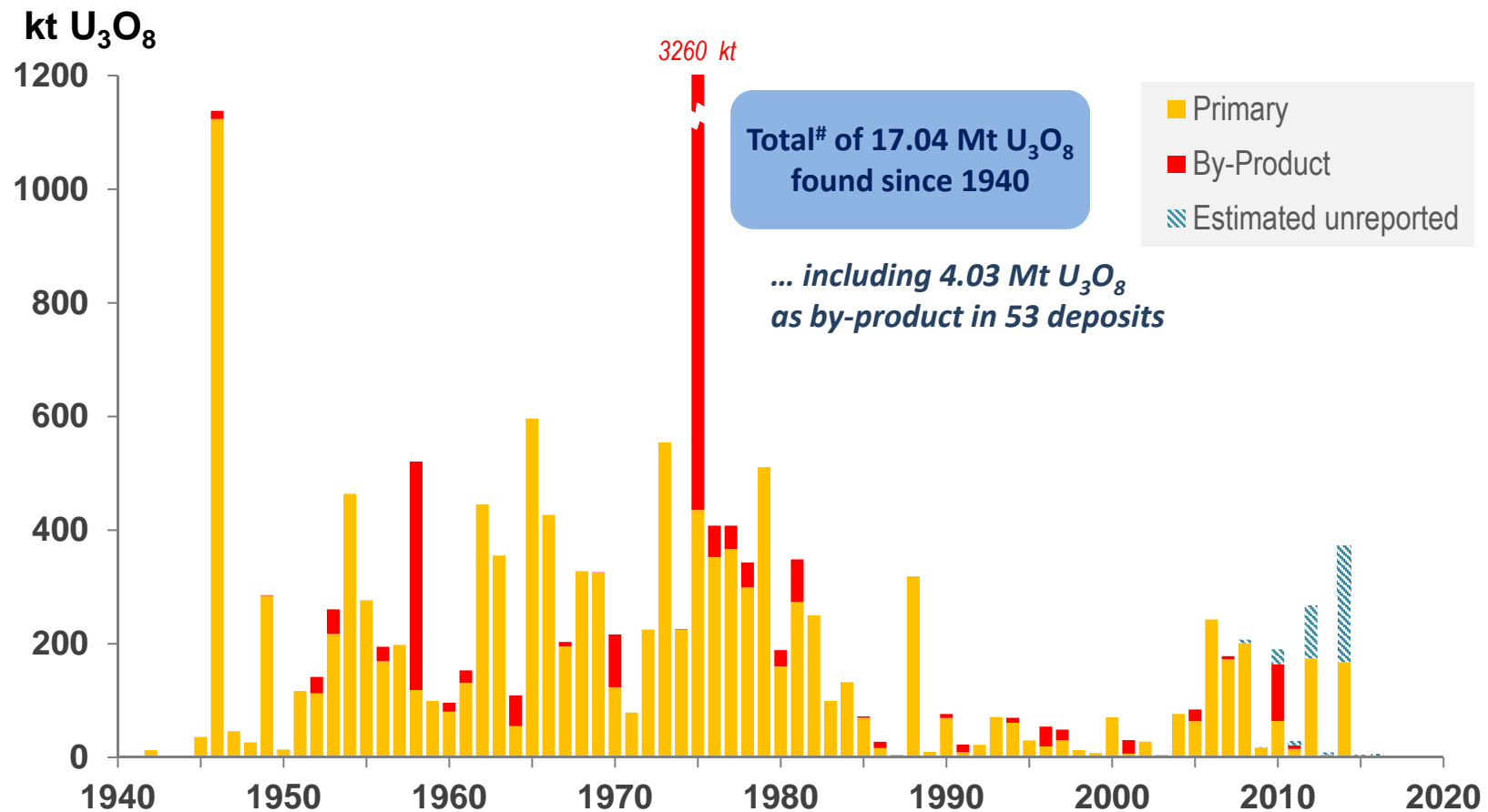
Source: MinEx Consulting © June 2018

The 1970s were the most fruitful decade – with over 6,200kt U_3O_8 being discovered. That is 15x what was found in the 1990s

5. TREND IN THE AMOUNT OF METAL DISCOVERED OVER TIME

Total amount of Uranium found in the World: 1940-2016

Primary & By-Product >0.5 kt U₃O₈

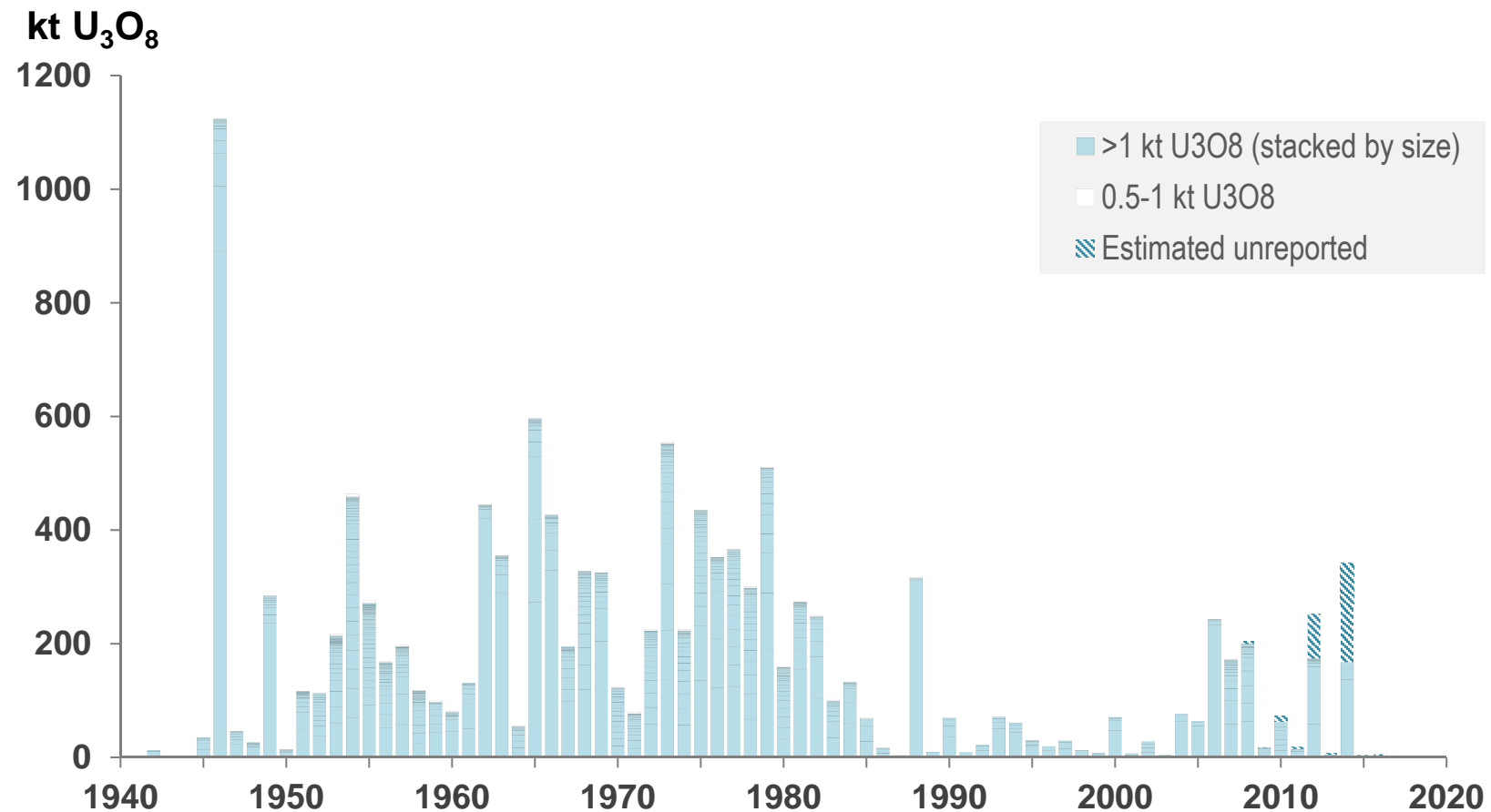


Note: Includes 0.61 Mt U₃O₈ in deposits with no reported discovery date

Source: MinEx Consulting © June 2018

Total amount of Uranium found in the World: 1940-2016

Primary deposits only >0.5 kt U_3O_8

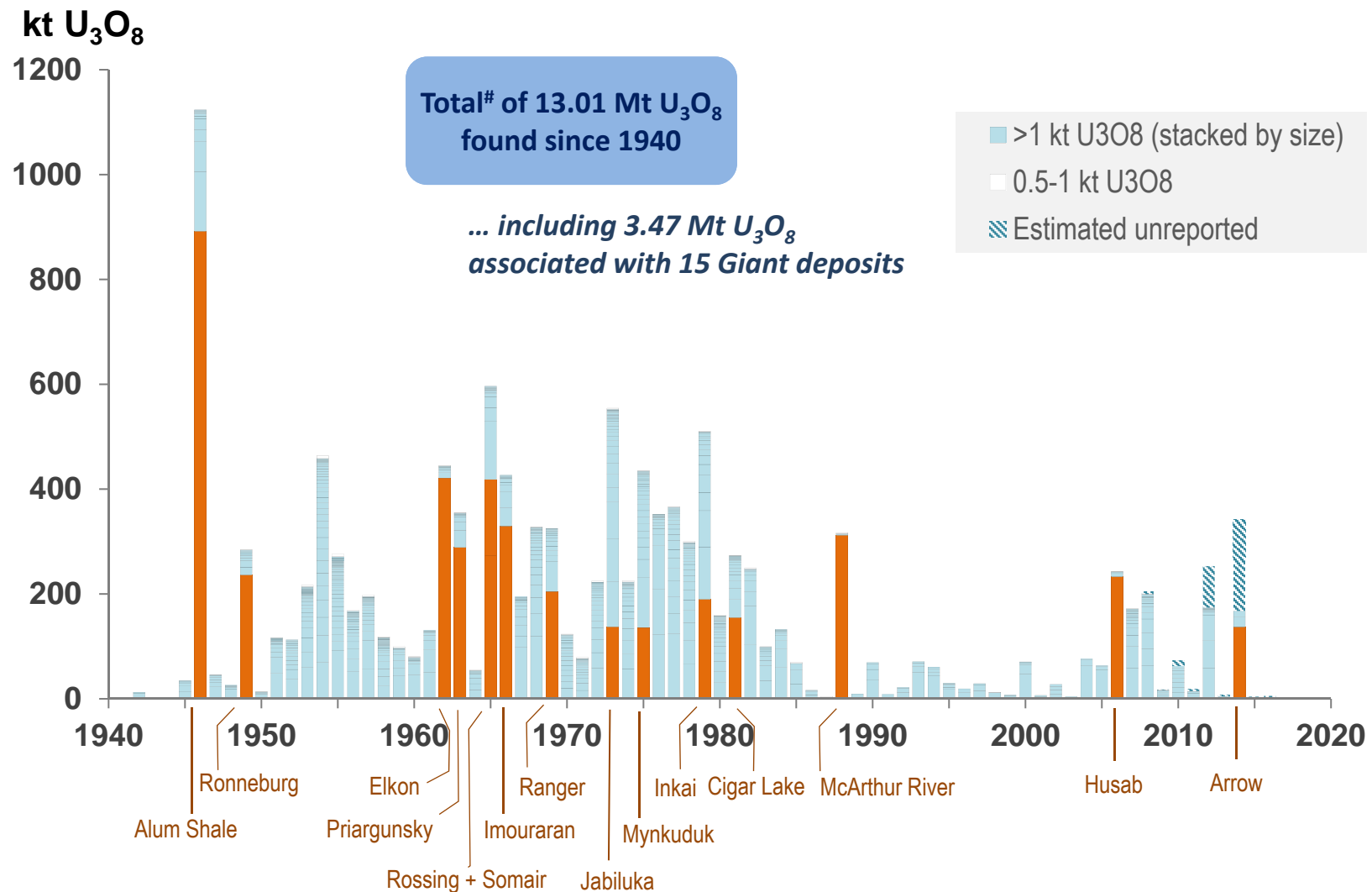


Note: Excludes by-product deposits

Source: MinEx Consulting © June 2018

Total amount of Uranium found in the World: 1940-2016

Primary deposits only >0.5 kt U₃O₈



Note: Includes 0.61 Mt U₃O₈ in 329 deposits with no reported discovery date

Source: MinEx Consulting © June 2018

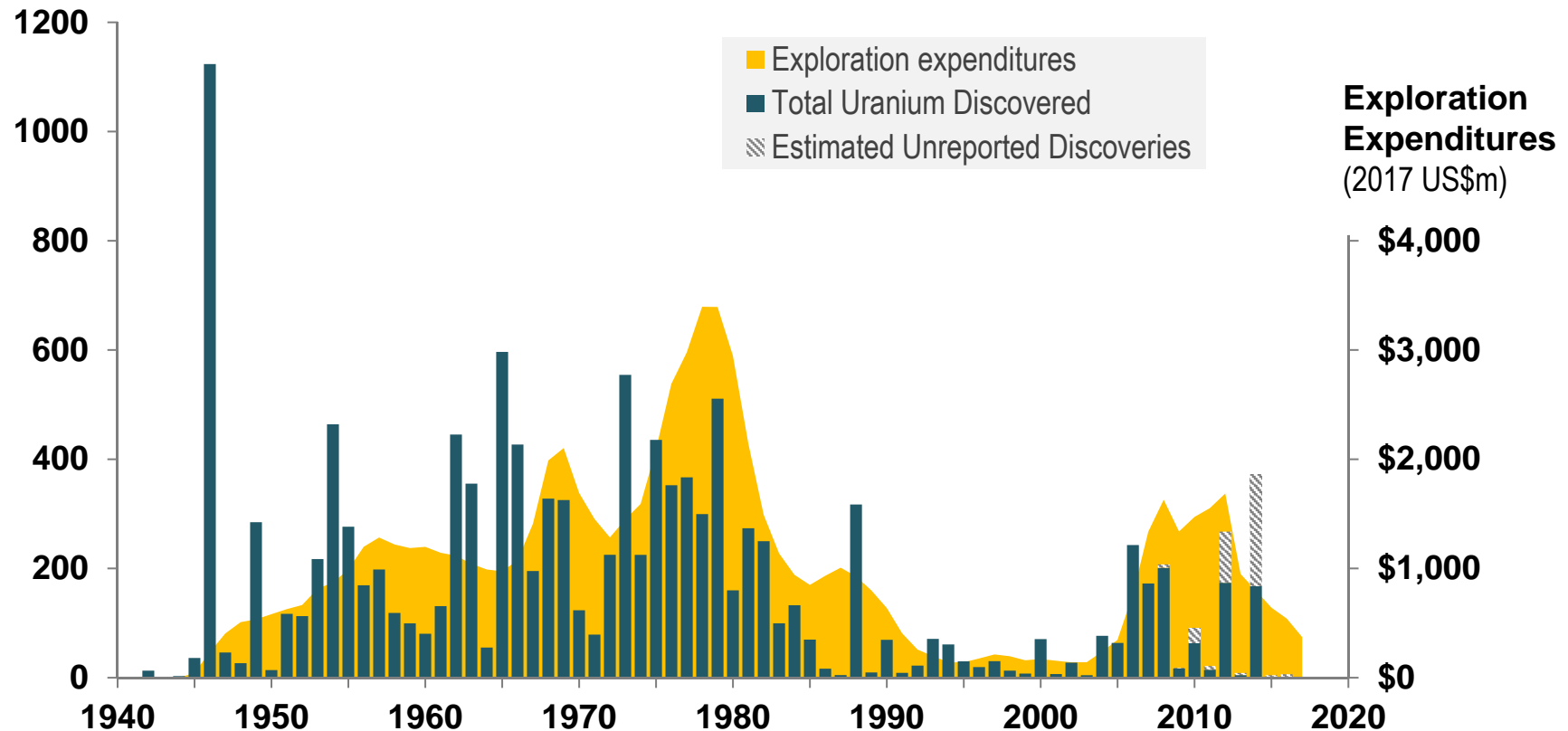
Surprisingly, the average unit discovery cost has remained relatively constant (at \$2-4/lb U_3O_8) over the last 3 decades

6. DISCOVERY PERFORMANCE AND UNIT DISCOVERY COSTS

Exploration expenditures versus Uranium Discovered

World: 1940-2016

Uranium Discovered
(kt U₃O₈)



Note: Excludes by-product deposits.

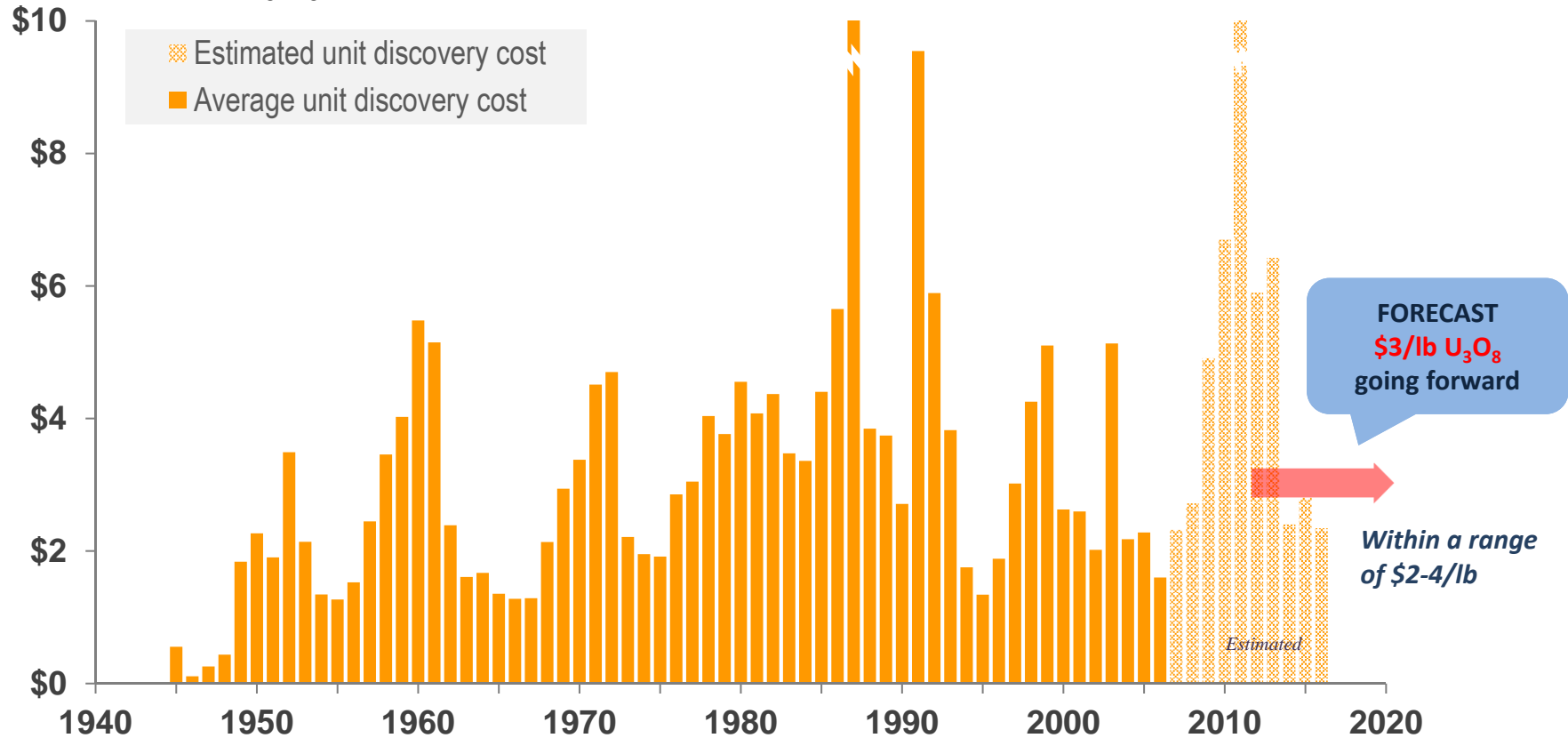
Estimated costs for 2007-2016 include adjustment for likely resource growth and unreported discoveries.

Source: MinEx Consulting © June 2018

Trend in Unit Discovery Cost for Uranium

World : 1945-2017

2017 US\$/lb U₃O₈



Note: Discovery cost is calculated on a 3-year rolling average.
Estimated costs for 2007-2016 include adjustment for likely
resource growth and unreported discoveries.

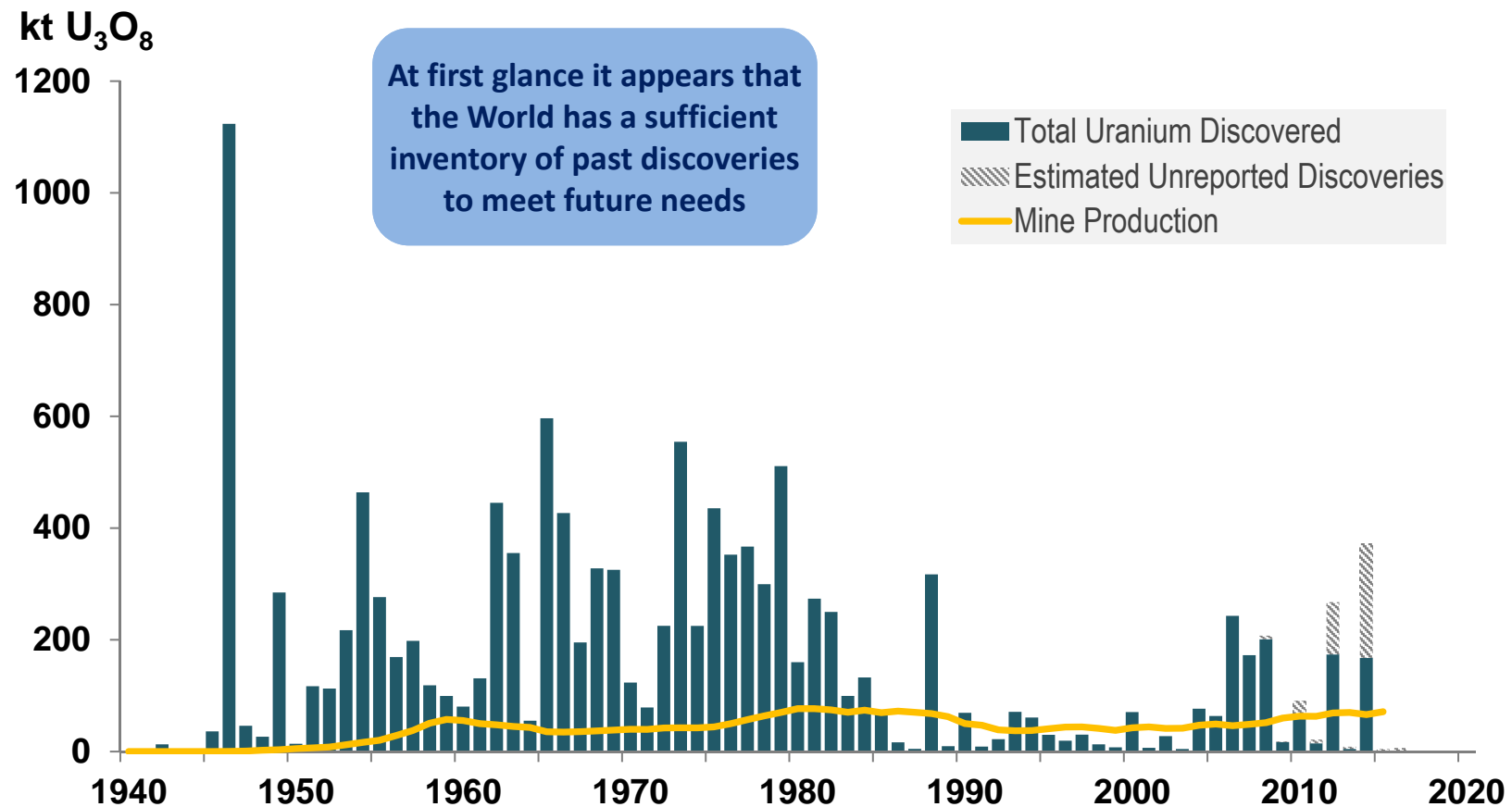
Source: MinEx Consulting © June 2018

The key question is ... are we finding enough new metal to replace what is mined. How sustainable is the industry ?

7. TRENDS IN THE DISCOVERY RATE VERSUS MINE PRODUCTION

Exploration expenditures versus Uranium Mine Production

World: 1940-2016

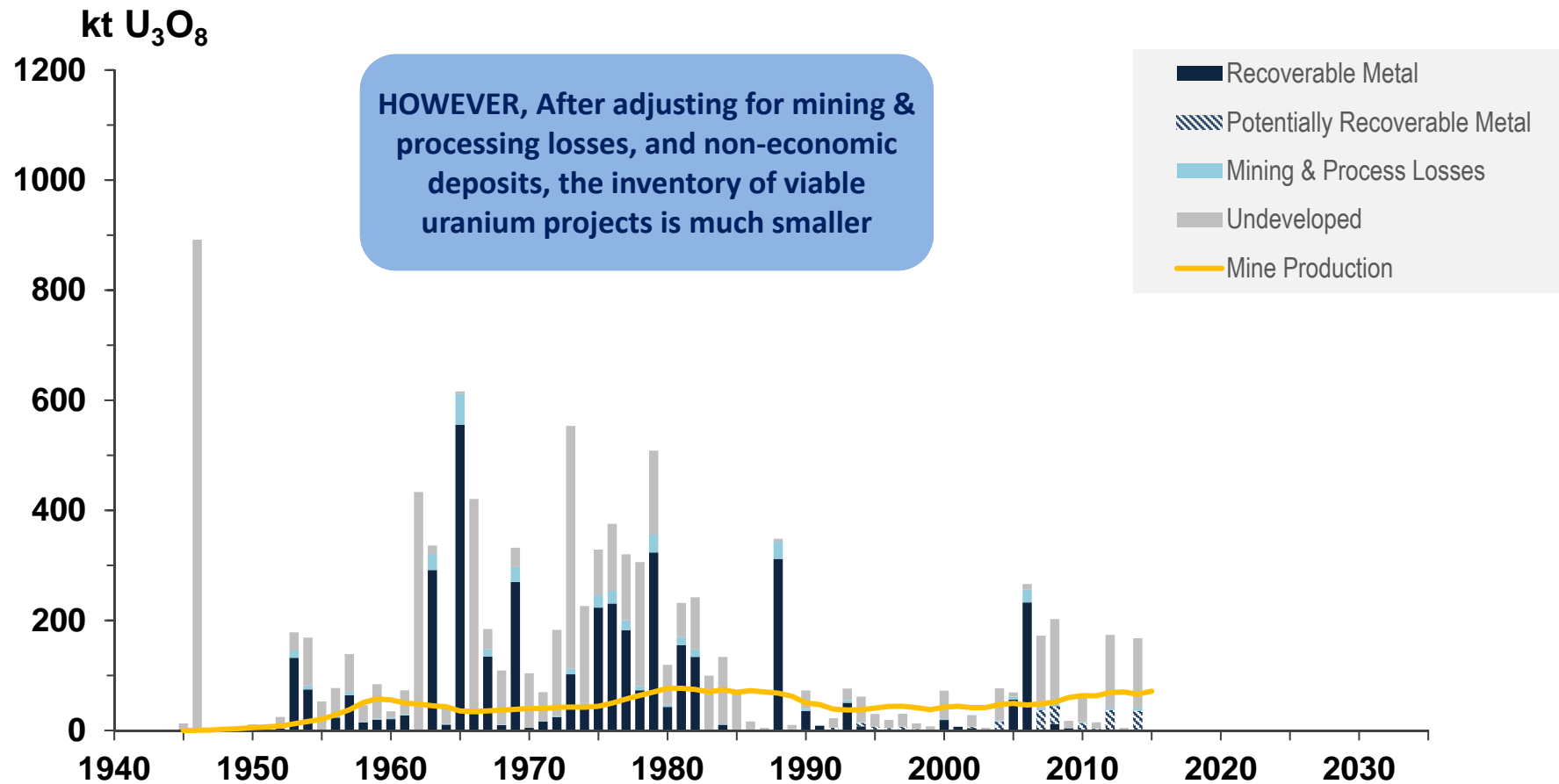


Note: Excludes by-product deposits.

Estimated costs for 2007-2016 include adjustment for likely resource growth and unreported discoveries.

Source: MinEx Consulting © June 2018

Recoverable Resources versus Production



Note: Excludes discoveries and future production from by-product uranium

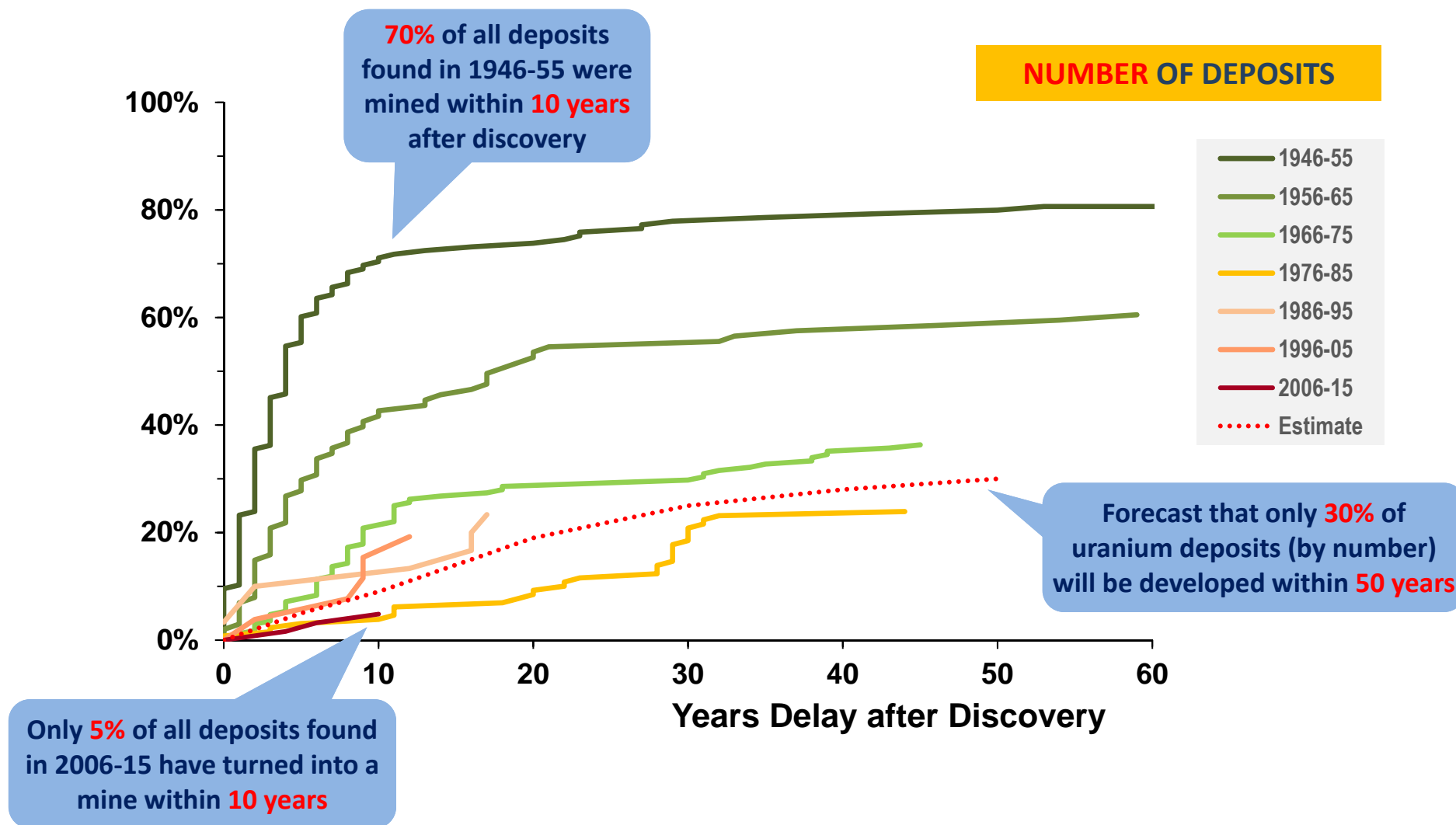
Potentially recovered metal (from 1997 onwards) assumes that 50% of the discovered resource is developed.

Assumes mining & processing losses of 10%

Source: MinEx Consulting © June 2018

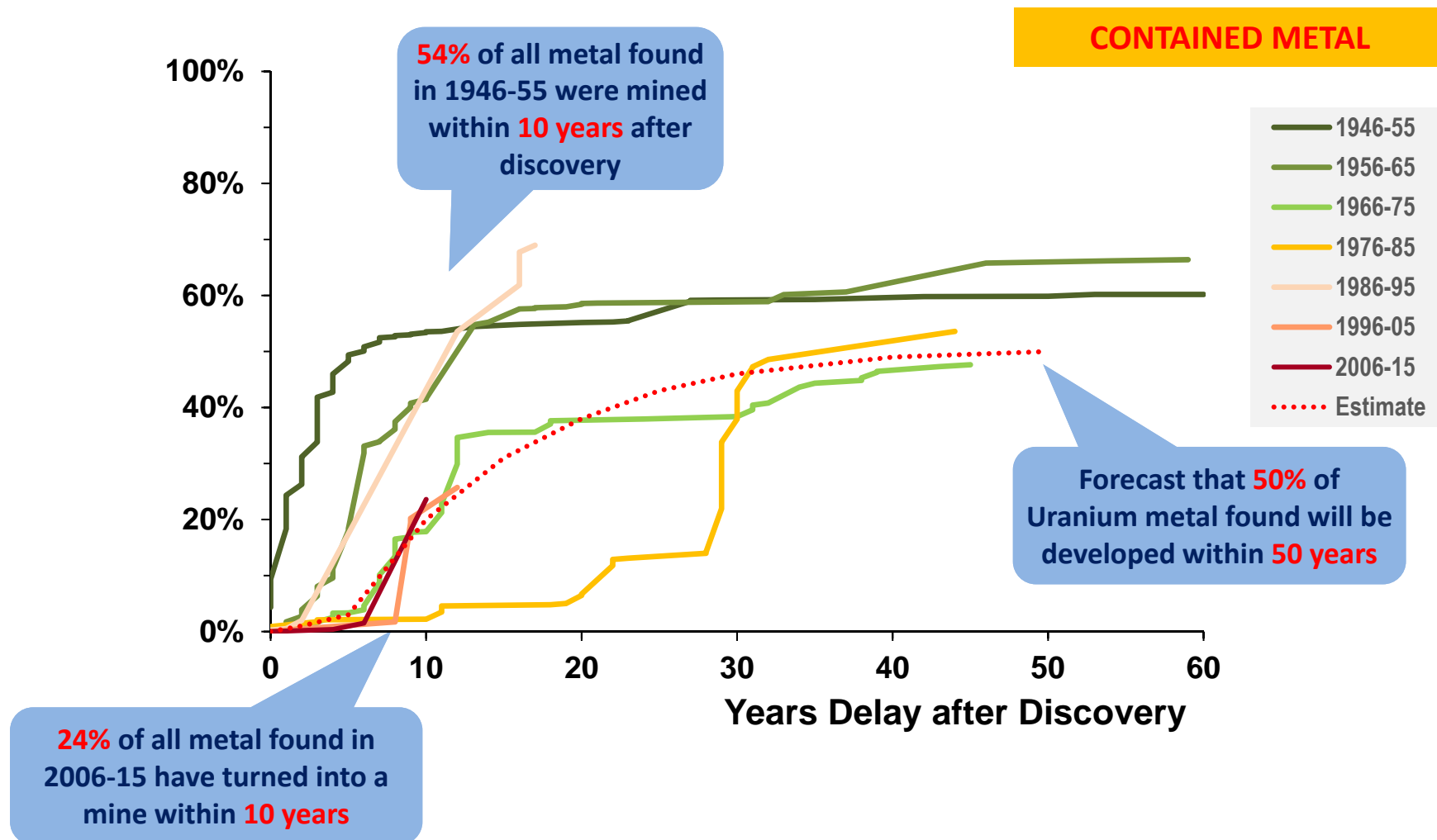
Time delay between discovery and development

Percentage of Primary Uranium Deposits that become Mines : World : 1946-2016

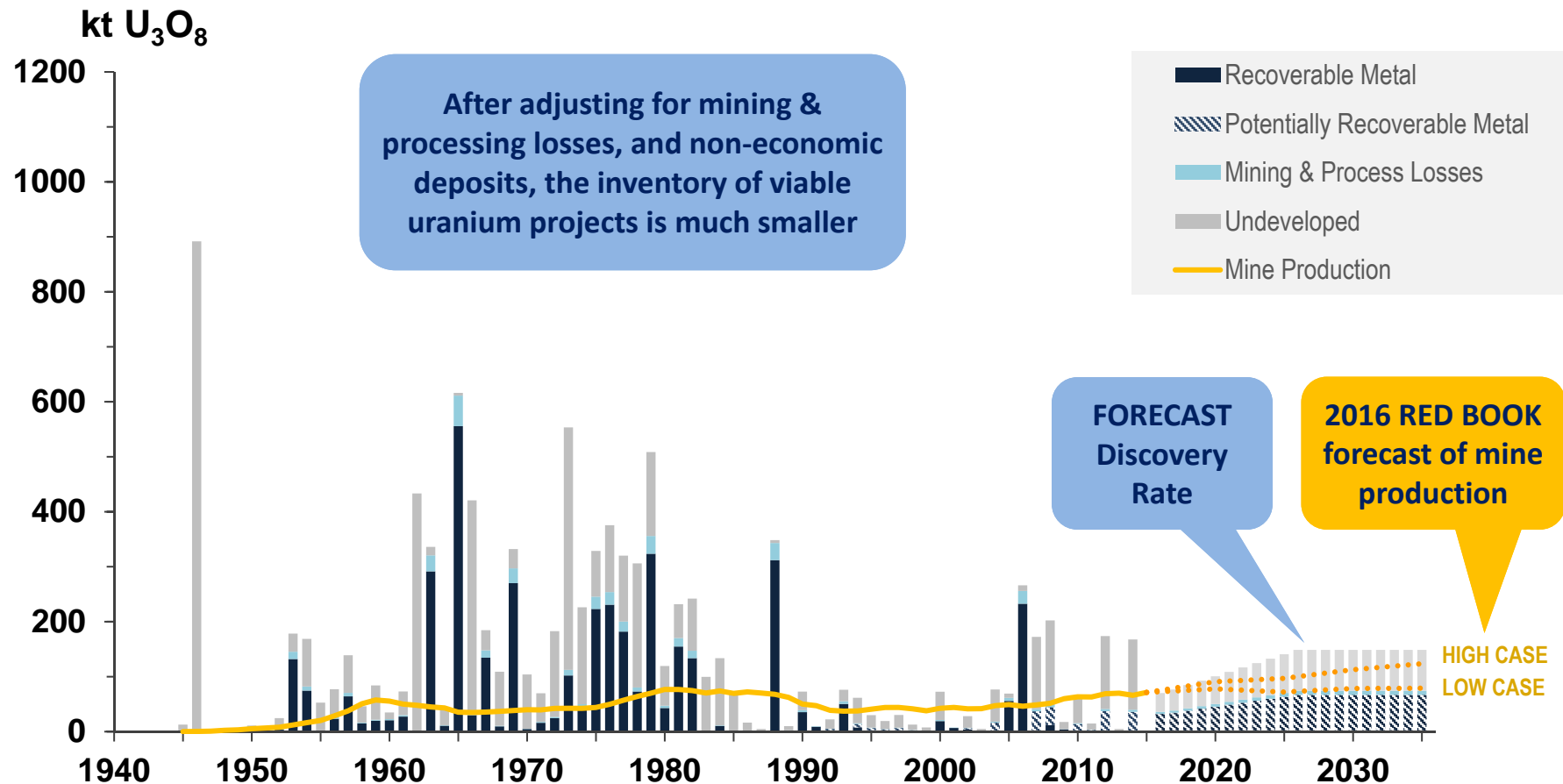


Time delay between discovery and development

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Recoverable Resources versus Production



Note: Excludes discoveries and future production from by-product uranium

Potentially recovered metal (from 1997 onwards) assumes that 50% of the discovered resource is developed.

Assumes mining & processing losses of 10%

Forecast discovery rate is indicative only, and assumes a unit discovery cost of \$3/lb U_3O_8 .

Forecast also assumes that the uranium price rises from \$23 to \$50/lb U_3O_8 over the next decade

Source: MinEx Consulting © June 2018

Scale of the Sustainability Challenge

Future uranium demand in 2020 is (say) 70 ktpa U = 82 ktpa U_3O_8 = **182 Million lb** U_3O_8

However only 50% of all metal discovered will (eventually) be developed into a mine. And 10% of the metal will be lost during mining & processing. So ...

*... we need to find $(182/50\% \times 1.1 =)$ **400 Million lb** pa of U_3O_8*

Assuming a Unit Discovery cost of (say) \$3/lb U_3O_8 , industry will need to spend ...

*$404 \times \$3 =$ **\$1200 million pa** on uranium exploration*

This analysis ignores the long lead-times associated with exploration.

Need to find today what the market needs in 25 years time. Highly likely to be >80 kt U

The challenge is that Industry only spent **\$371m** in 2017

*To stimulate this amount of spend, the uranium price needs to rise to **\$55/lb** U_3O_8 [see Chart 8 for details]*

For the industry to be sustainable in the longer term ...

We either need to *double the effectiveness* of our current exploration efforts (i.e. find metal for <\$2/lb U_3O_8),

or

The price of uranium needs to double (if not triple) over the current price... so as to stimulate increased exploration efforts and improve the economics of existing undeveloped projects.

Summary / Conclusions

1. Exploration spend is driven by the uranium price
2. The rate of discovery has slowed down in recent decades
3. Over the last 20 years the average unit discovery cost was \$3.87/lb U_3O_8 (in constant 2017 US Dollars). The author forecasts that, going forward, the future discovery cost will be in the range of \$2-4 /lb U_3O_8
4. The industry has a large inventory of undeveloped projects – most of which will never be developed (or certainly not quickly)
5. Unconventional resources are unlikely to deliver low cost metal. Very few of those will be developed.
6. Looking forward, only 30% of all discoveries (by number) and 50% of all metal found will ultimately be developed into a mine. For those that do get developed the average delay between discovery and development is 25 years (and getting longer). Some will take twice as long.
7. For the industry to replace what it mines (i.e. be sustainable), the industry needs to find uranium for <\$1.50/lb U_3O_8 (ie half the current rate) or the price of uranium needs to rise to \$50-75/lb U_3O_8 (ie 2-3x the current price)

Contact details

Richard Schodde
Managing Director
MinEx Consulting
Melbourne, Australia

Email: Richard@MinExConsulting.com
Website: MinExConsulting.com

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