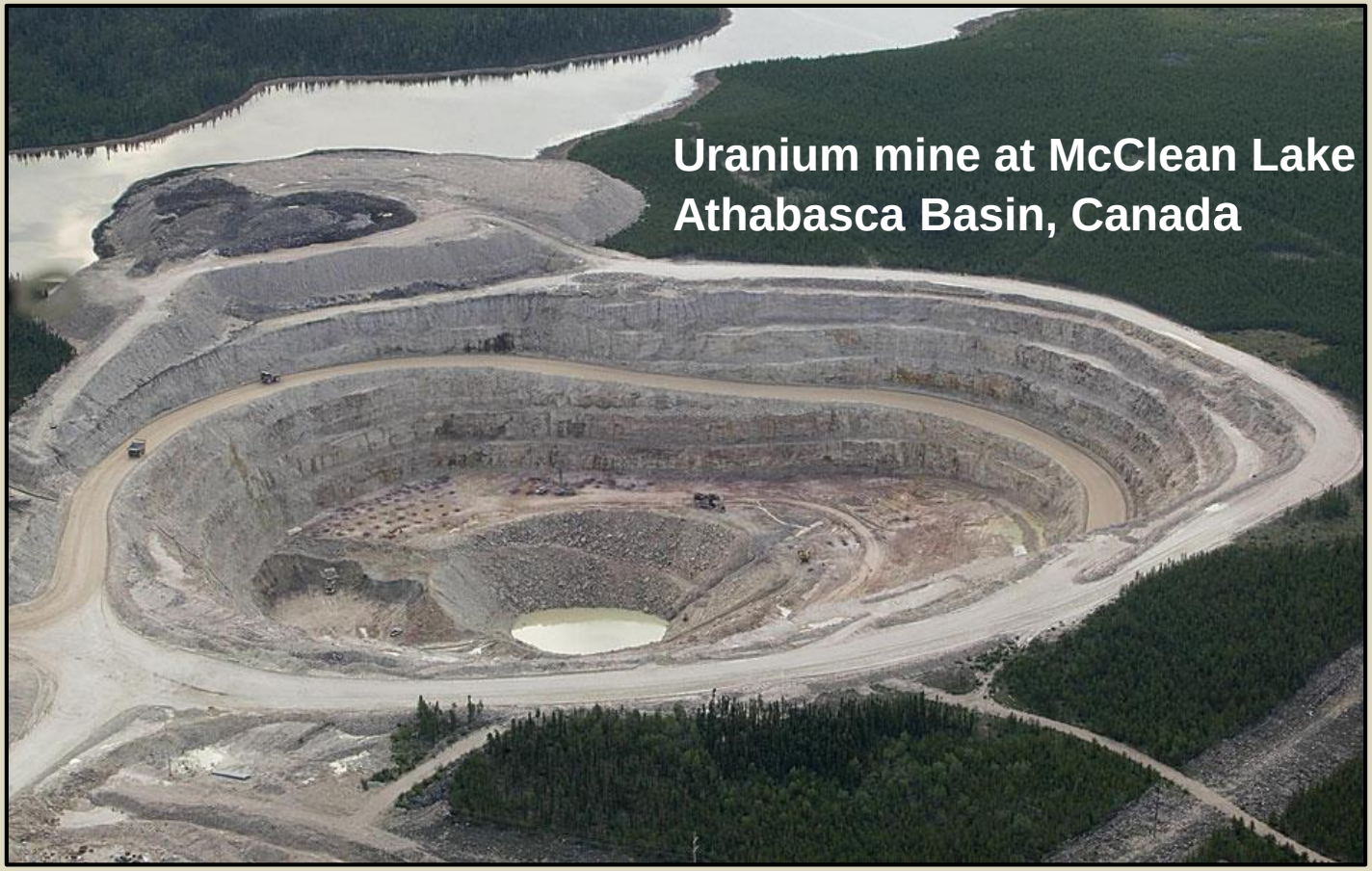
Application of UNFC-2009 to uranium and thorium projects: Guidelines



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Guidelines for Application of United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 for Uranium and Thorium Resources

- The easy application of UNFC-2009 to uranium and thorium resource projects,

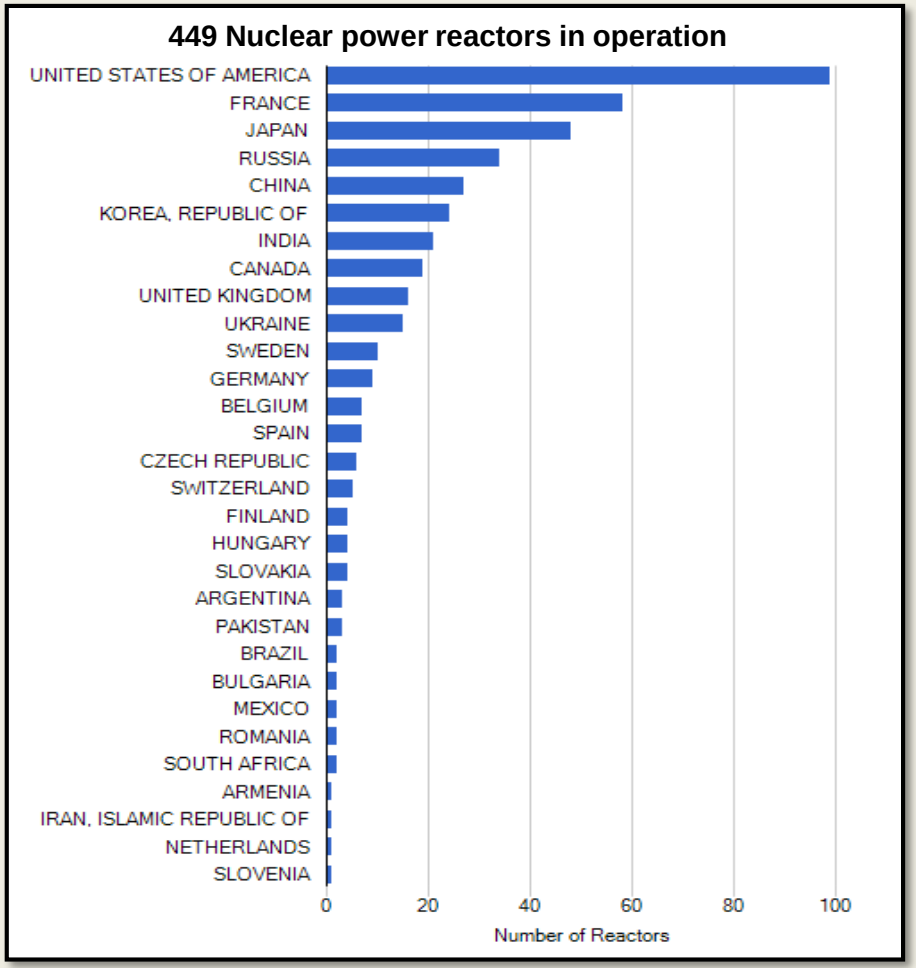
or

- The transfer of resource data from other resource classification schemes into UNFC-2009

An overview of global nuclear fuel resources and production, plus sources of information

- Background information — Especially useful to those not familiar with the global usage and production of nuclear fuels as an energy source

- Predictions of future nuclear energy needs and nuclear fuel requirements



Brief description of UNFC-2009

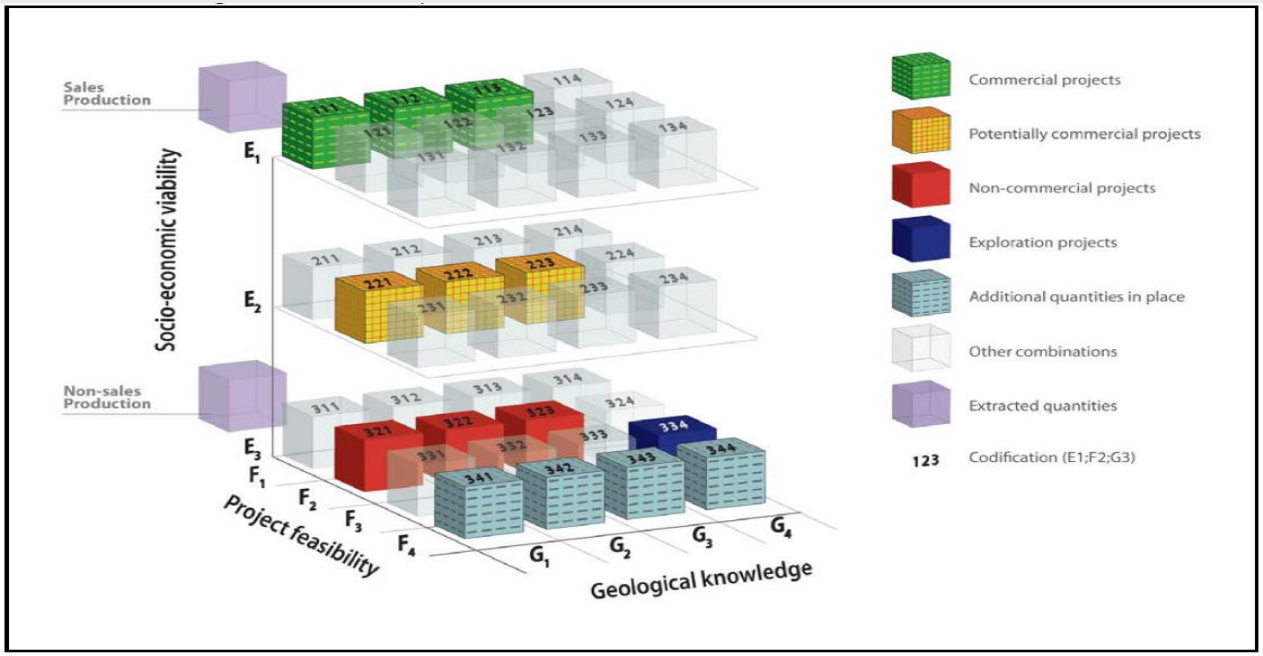
- Principles — basics of the UNFC-2009 classification framework

- Specifications – the application rules, which provide consistency

  Commodity-specific specifications (Bridging Documents)

  - Solid minerals — CRIRSCO template
  - Petroleum — PRMS system
  - Nuclear Fuel Resources — NEA/IAEA system and CRIRSCO

- **Guidelines —** non-mandatory guidance for application of UNFC-2009

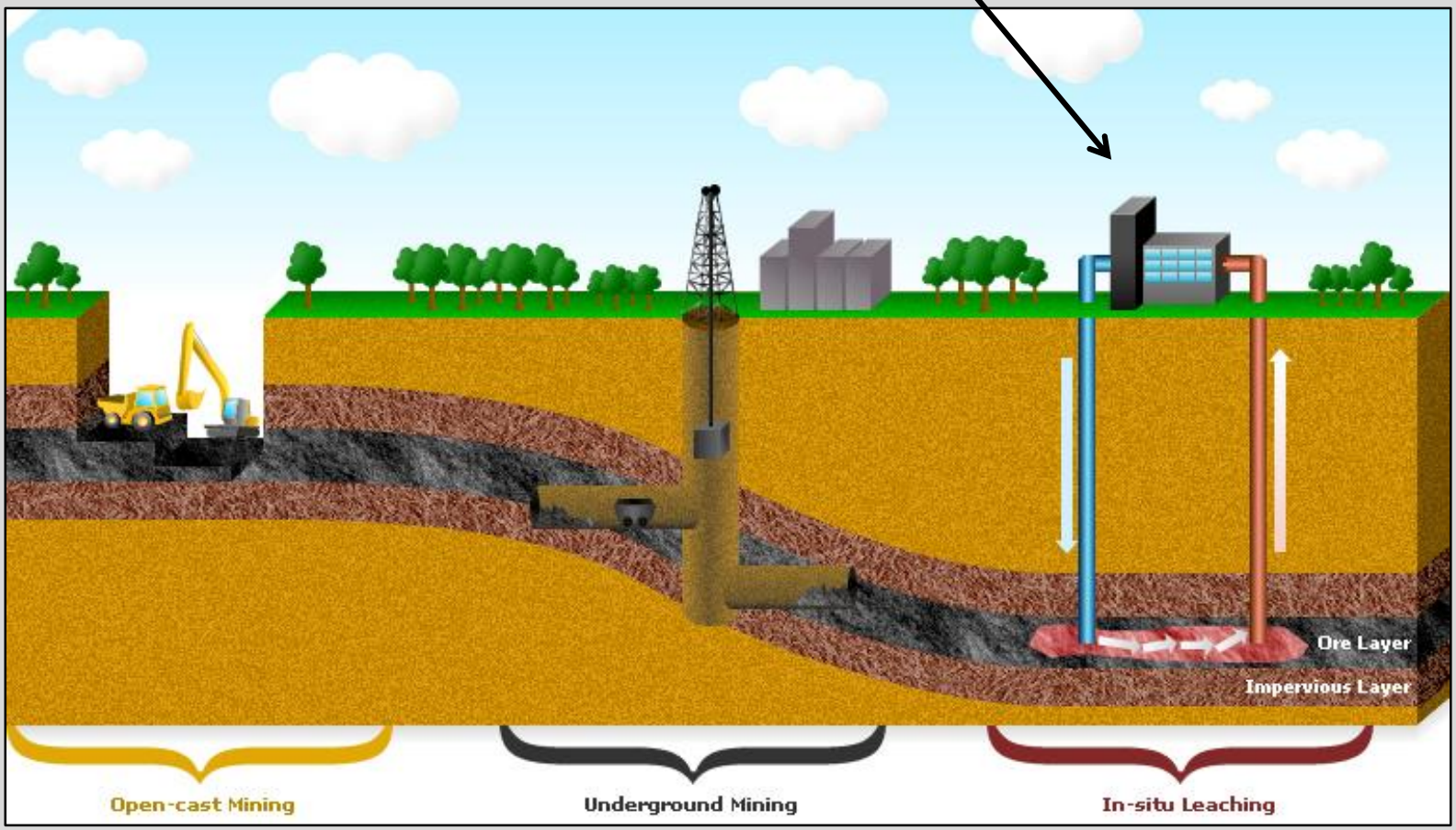


UNFC-2009 Classification					CRIRSCO Template		NEA/IAEA Classification		
UNFC Classes and Sub-classes		UNFC Categories			CRIRSCO Classes and Sub-classes				
Class	Sub-Class	E	F	G	Class	Sub-Class	IAEA-NEA Categories		Status
Commercial Projects	On Production	1	1.1	1	Mineral Reserves	Proved	Reasonably Assured Resources (RAR)		Existing
				2		Probable			
	Approved for Development	1	1.2	1		Proved			Committed
				2		Probable			
	Justified for Development	1	1.3	1		Proved			Planned
				2		Probable			
Potentially Commercial Projects	Development Pending	2	2.1	1	Mineral Resources	Measured	Identified Resources	RAR	Prospective
				2		Indicated			
				3		Inferred		IR*	
	Development On Hold	2	2.2	1		Measured		RAR	
				2		Indicated			
				3		Inferred		IR*	
Non-commercial Projects	Development Unclarified	3.2	2.2	1,2,3	Inventory (not defined in Template)	Development Unclarified (not defined in Template)	Identified Resources RAR IR*		Unclarified
	Development Not Viable	3.3	2.3	1,2,3		Not Viable (not defined in Template)			Not Viable
Exploration Projects		3.2	3.1	4	Exploration Results		Undiscovered Resources	Prognosticated Resources	
		3.2	3.2, 3.3	4				Speculative Resources	

Issues for consideration in application of UNFC-2009 to nuclear fuel resources

- Socio-economic viability issues (E-axis)
- Known environmental or social impediments or barriers to projects (E-axis)
- Project viability issues (F-axis)
- Geological knowledge challenges (G-axis)
- In-situ leach production (solution mining of underground uranium deposits)

In-situ leach mining of uranium (ISL)



COMPREHENSIVE EXTRACTION PROJECTS

"Comprehensive Extraction" — Methods that maximize returns from mining and processing, especially from low-grade, depleted and other non-commercial ore bodies

Conventional resources — Uranium is recovered as a primary product, a co-product, or as a significant by-product

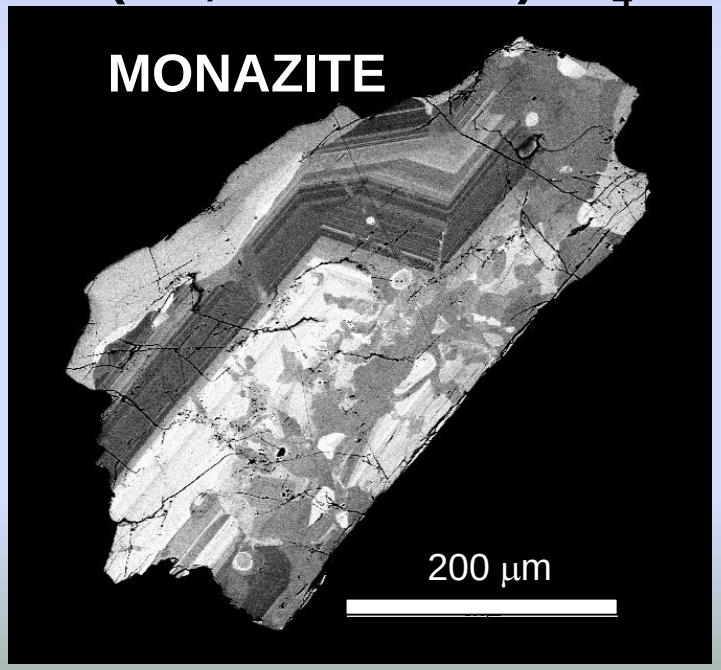
Unconventional Resources — Uranium is recovered as a minor by-product (example – phosphate deposits)

Comprehensive Extraction benefits:

- **Support principles of sustainability and resource conservation**
- **Optimizing returns from all resources in an ore body**
- **Reuse, recycle (tailings or residues)**

Case Study — A thorium source in the Mountain Pass rare earth elements deposit, California, and the application of UNFC-2009

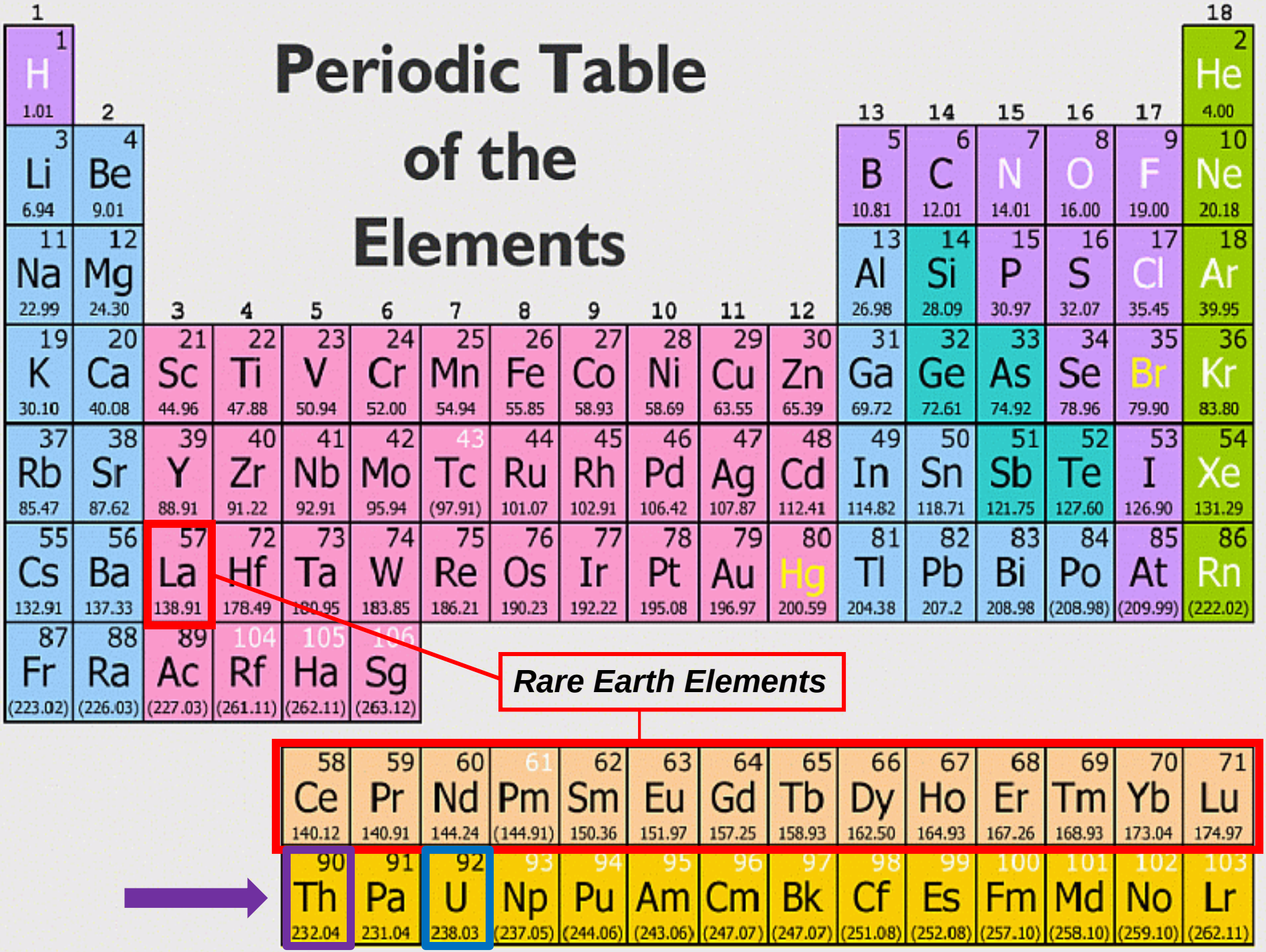
$(Th,Rare\ Earths)PO_4$

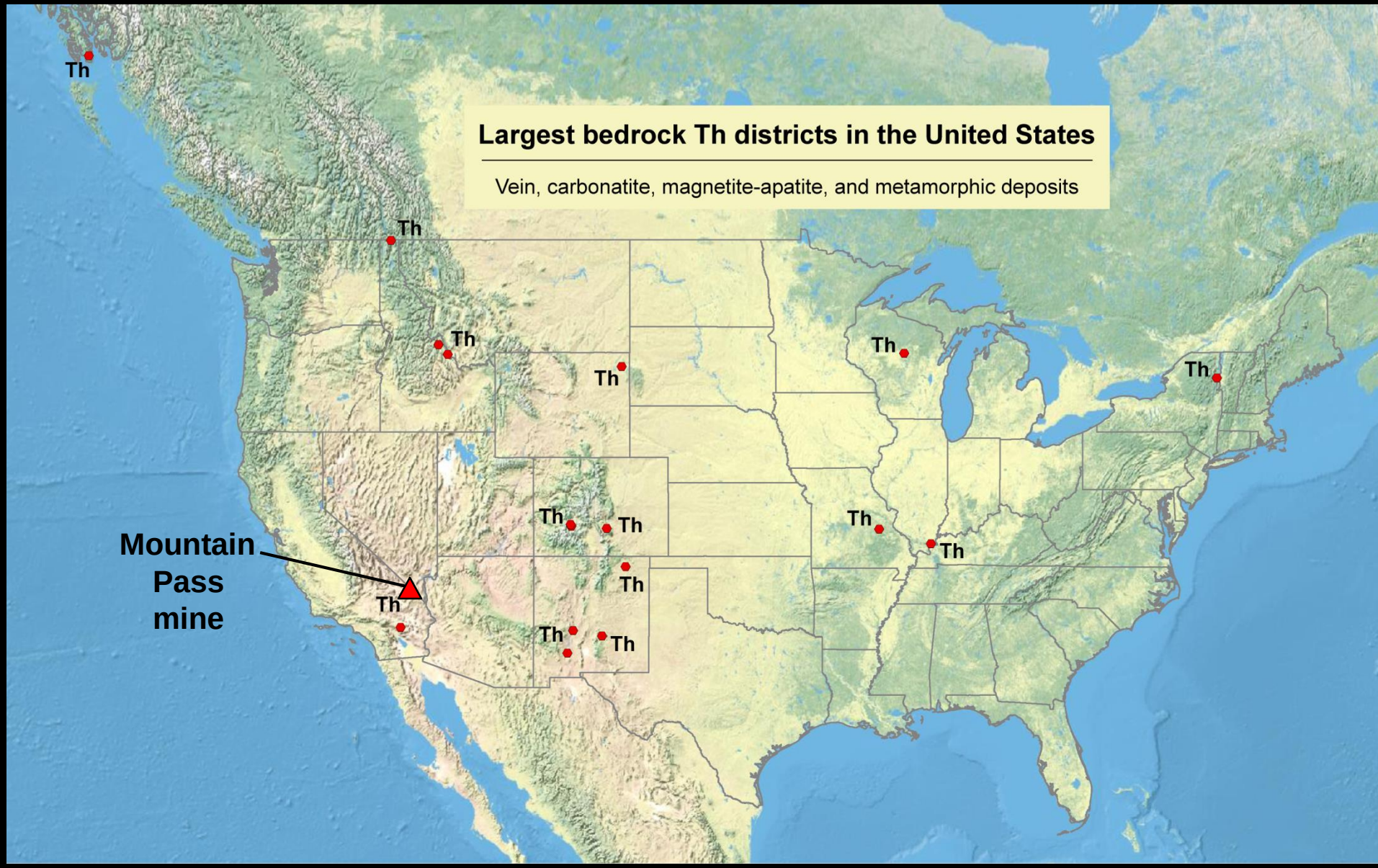


Brad Van Gosen

USGS
science for a changing world

Periodic Table of the Elements




Largest bedrock Th districts in the United States
Vein, carbonatite, magnetite-apatite, and metamorphic deposits
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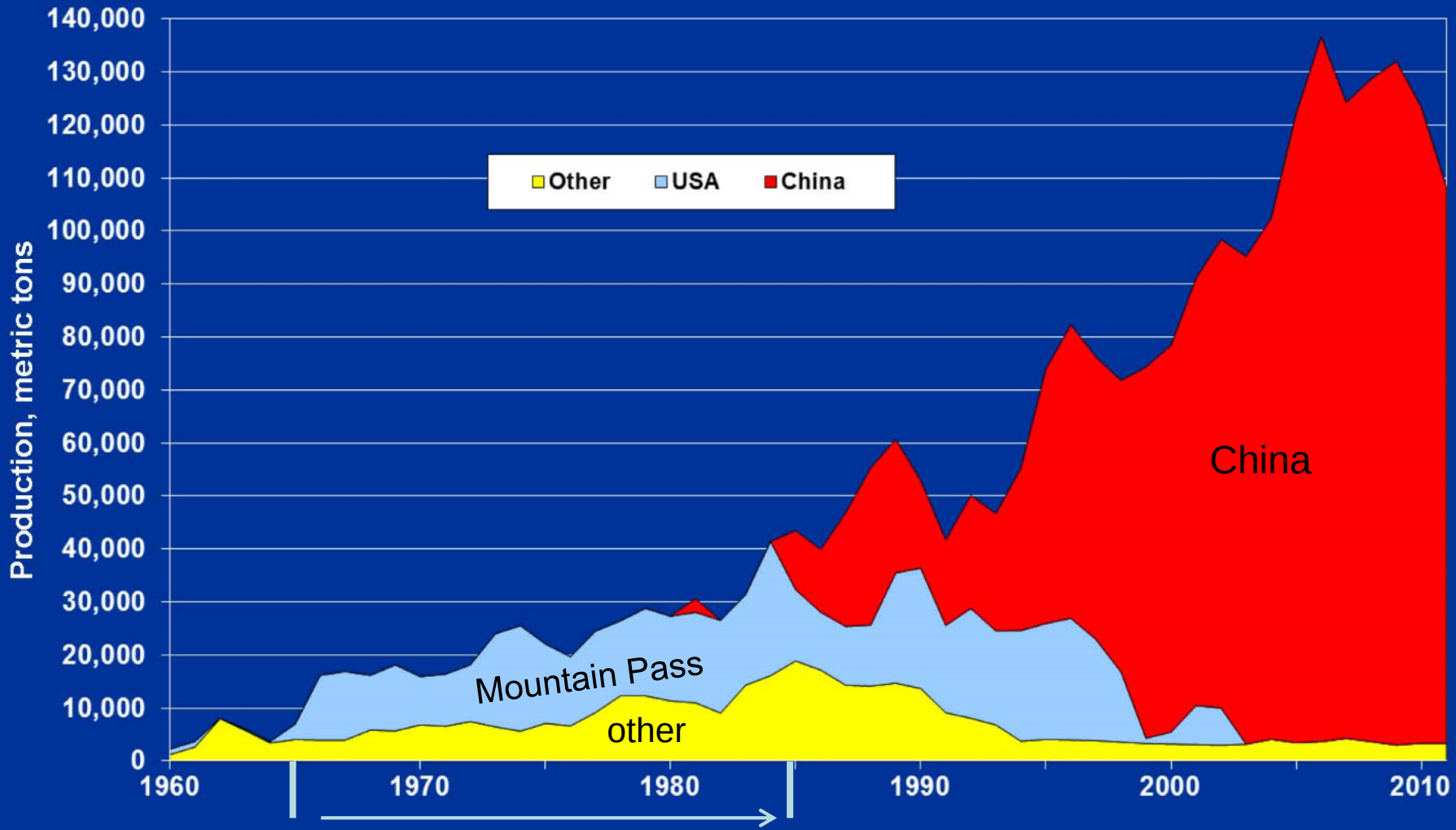
Mountain Pass mine

Global Rare Earth Oxide Mine Production



USGS

Mountain Pass mine of Molycorp, Inc.

Proved and Probable Reserves

16.7 million metric tons of ore, avg. grade of 7.98 % REE oxides, using cut-off grade of 5 %

Proved and Probable Reserves = **16.7 million metric tons of ore**

Ore averages about **0.025 % Thorium**, thus….

Thus, the deposit may contain approximately
4,200 metric tons of Thorium

Mountain Pass processing facilities of Molycorp (on-site)

Mountain Pass mine tailings (average **0.03 % Th**)

(the ore body = 0.025 % Th)

From 2010 until 2015, the Mountain Pass mine could be classified as:

E1.1 "Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions."

F1.1 "Extraction is currently taking place."

G1+G2 "Quantities associated with a known deposit that can be estimated with a high level of confidence" (Proven Reserves)
and
"with moderate level of confidence" (Probable Reserves).

However, since 2016, following mine closure,
the Mountain Pass deposit (resource) can be classified as:

E2 "Extraction and sale is expected to become economically viable in the foreseeable future."

F2.2 "Project activities are on hold and/or where justification as a commercial development may be subject to significant delay."

G1+G2 "Quantities associated with a known deposit that can be estimated with a high level of confidence" (Measured Resources)
and
"with moderate level of confidence" (Indicated Resources).

- As a potential producer of **Thorium** (as by-product of the production for rare earth elements), and
- Sampled for **Thorium** content at a reconnaissance level:

E3.3	"On the basis of realistic assumptions of future market conditions, it is currently considered that there are not reasonable prospects for economic extraction and sale [of thorium] in the foreseeable future."
F2.3	"There are no current plans to develop or to acquire additional data at the time due to limited potential."
G3	"Quantities [of thorium] associated with a known deposit that can be estimated with a low level of confidence."

Mountain Pass deposit

Mountain Pass deposit	**Quantities (metric tons)**	**Average Grade (%)**	**CRIRSCO Classification**	**UNFC-2009 Categories**			**UNFC-2009 Class**	**UNFC-2009 Sub-Class**
				E	**F**	**G**		
Total rare earth element oxides	1,333,000	7.98 (as oxide)	Measured + Indicated Resources	1.1 ↓ 2	1.1 ↓ 2.2	1,2	**Potentially** Commercial Project	(On Production) Development on Hold
Thorium	4,200	0.025 (elemental weight %)	"Inventory" (not used in CRIRSCO)	3.3	2.3	3	Non-Commercial Project	Development Not Viable

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Nuclear Fuels working group products thus far

92 U 238.03

- **Bridging Document between the Organisation of Economic Co-operation and Development Nuclear Energy Agency/International Atomic Energy Agency Uranium Classification and UNFC-2009**

- **Guidelines for Application of United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 for Uranium and Thorium Resources**

- ***13 Case studies so far:***

Yili Basin, China
Azelik deposit, Niger
Uranium resources of Argentina
Thorium resources of Brazil
Uranium deposits of India
Uranium in Malawi
Mountain Pass deposit (Th), USA
Coles Hill uranium deposit, USA
Paraguay
Egypt
Mongolia
Jordan
Rare earth/thorium in Argentina
more coming soon