Nuclear Waste Governance in Canada

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Nuclear Waste Governance in Canada

1. A Quick Overview

Nuclear Activities in Canada

URANIUM – one of the world's largest producers & exporters

world's largest uranium hexafluoride conversion plant at Port Hope;
> 85 percent of Canadian uranium is exported as uranium hexafluoride

REACTORS – heavy water moderated, natural uranium fuelled

25 domestic power reactors – 19 still operating, 18 of them in Ontario;
sales to India, Pakistan, Argentina, South Korea, Romania and China.

RESEARCH – Chalk River Nuclear Laboratories in Ontario

created through a WWII military decision made in Washington DC in 1944;
run by Atomic Energy of Canada Ltd (AECL), a government-owned company.

ISOTOPES – one of the world's largest suppliers

NRU reactor (Chalk River) produces most of world's medical isotopes; in 2016
Canada will stop producing isotopes from reactors, using accelerators instead.

Radioactive Wastes in Canada

1. Irradiated Nuclear Fuel (> 50 thousand tonnes)
2. Uranium Mill Tailings (> 250 million tonnes)
3. "Low & Intermediate Level" Wastes from reactors
4. Legacy radioactive wastes (prior to 1985)
5. Medical, Industrial, Research Radioactive Wastes

Radioactive Waste Programs

Nuclear Fuel Waste Act (NFWA)

currently searching for a "willing host community" to bury all of Canada's irradiated nuclear fuel in a DGR

~ estimated cost $26 billion ~

Nuclear Legacy Liabilities Program

AECL's solid and liquid HLW, including tanks, trenches, ponds and soil, plus dismantling of research reactors, 3 prototype power reactors, many contaminated buildings,

~ estimated cost $7-8 billion ~

Port Hope Area Initiative

consolidating 800,000 tonnes of radium-bearing wastes

~ includes dredging harbour, extensive excavations

~ estimated cost $2 billion ~

Recent Developments

URANIUM – two provinces have banned uranium mining

British Columbia & Nova Scotia have banned uranium exploration & mining;
Quebec hearings are underway to see if uranium mining will be banned there.

REACTORS – one province has phased out of nuclear power

Quebec has banned new reactors and has retired its only power reactor;
six operating reactors at Pickering will be retired by 2020 (2 are down already)

WASTE DISPOSAL – two provinces have opted out of process

Manitoba enacted a law against importing of nuclear waste for disposal;
Quebec's National Assembly passed a unanimous resolution to similar effect.

ISOTOPES – no isotope production using reactors after 2016

23,000 litres of HLW containing weapons-grade uranium will be disposed of;
isotope production using cyclotrons or other accelerators will be the new norm.

Nuclear Waste Governance in Canada

2. Historical Background

Military Links

1941-1943

1941 – Canada is asked to supply uranium for US and UK war efforts

the only available source of uranium not in German hands

– recovered from the residues of 1930s radium mining.

1943 – Quebec Accord on WWII A-bomb Project (US-UK-Canada)

Canada to supply uranium from Northwest Territories

Canada to refine uranium at Port Hope Ontario

Canada to host a secret laboratory in Montreal to study plutonium production using heavy water reactors


The Quebec Accord
CANADA – USA - UK
Quebec City
1943
Prime
Minister
of Canada
President
of the U.S.A.
Prime
Minister
of Britain

Military Links

1945

August 1945 – Hiroshima (Aug 6) + Nagasaki (Aug 9) A-bombings

unanimous consent required from US, UK, and Canada
because of the 1943 Quebec Accord

September 1945 – Canada's First Nuclear Reactor starts up

ZEEP = Zero Energy Experimental Pile [wartime decision]
heavy water from Denmark => France => UK => Canada

September 1945 – spy ring revealed by Soviet cipher clerk in Ottawa

activities at the Montreal lab and at Chalk River Ontario
helped the French, British and Russian A-bomb programs

Bronze Plaque at
Chalk River Visitors' Centre

Photo: Robert Del Tredici

THE ZEEP REACTOR

A nuclear chain reaction was first initiated in Canada on September 5, 1945, when the ZEEP reactor went into operation here at Chalk River. Originally part of an effort to produce plutonium for nuclear weapons, the reactor was designed by a team of Canadian, British and French scientists and engineers assembled in Montreal and in Ottawa in 1942-43 under the administration of the National Research Council. Named Zero Energy Experimental Pile because it was developed to produce only one watt of heat, the ZEEP reactor was used to provide data for the design of the powerful NRX (National Research Experimental) reactor. In 1952 the project was transferred from NRC to Atomic Energy of Canada Limited.

Military Links

1941-1972

The Uranium Connection

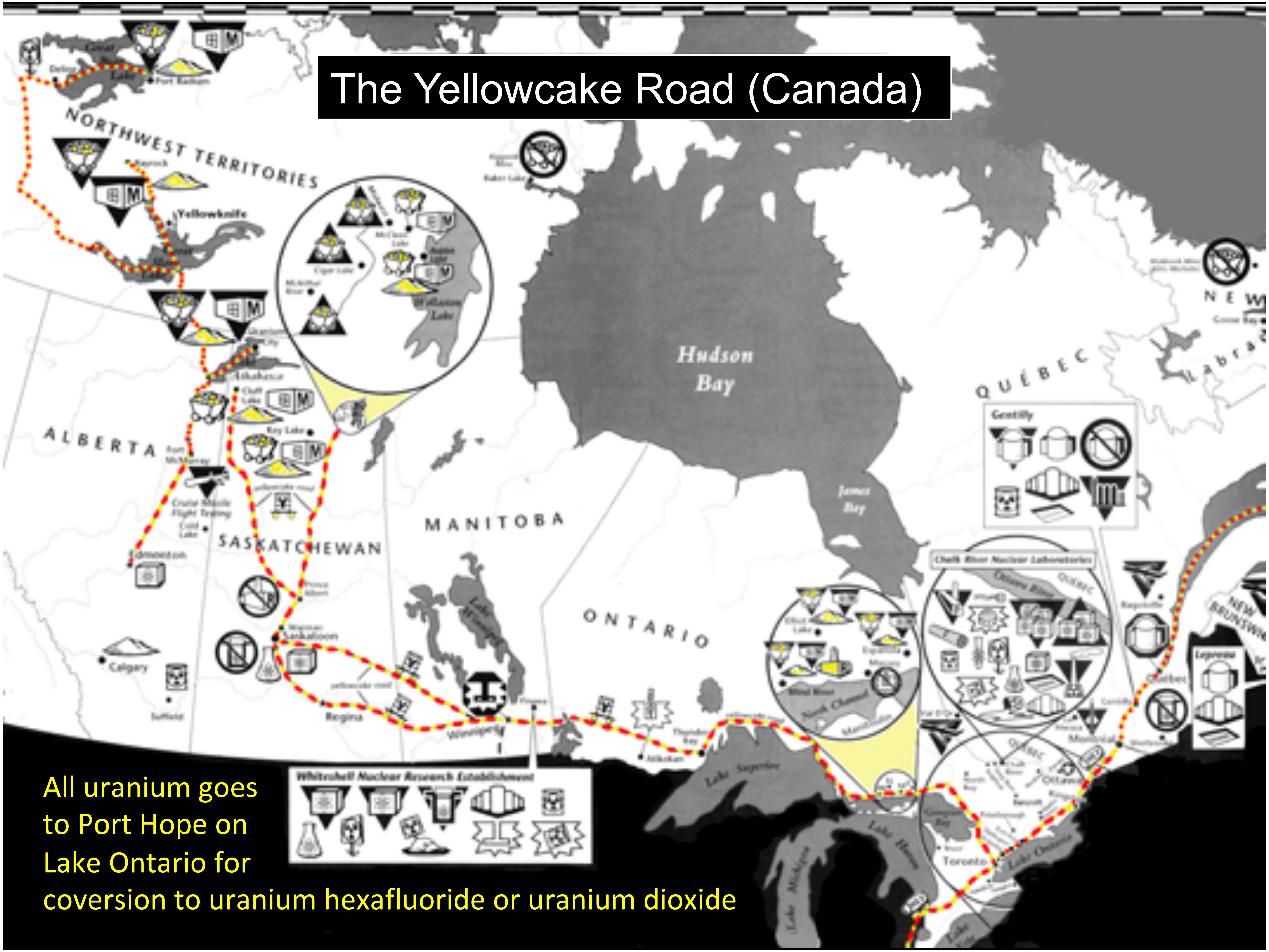
PORT HOPE: uranium-bearing ore concentrates from NWT and the Congo are refined at Port Hope for the WWII Atomic Bomb Project.

PORT RADIUM: World's first dedicated uranium mine opens in 1942 at Port Radium, NWT (originally a radium mine from 1931 to 1940).

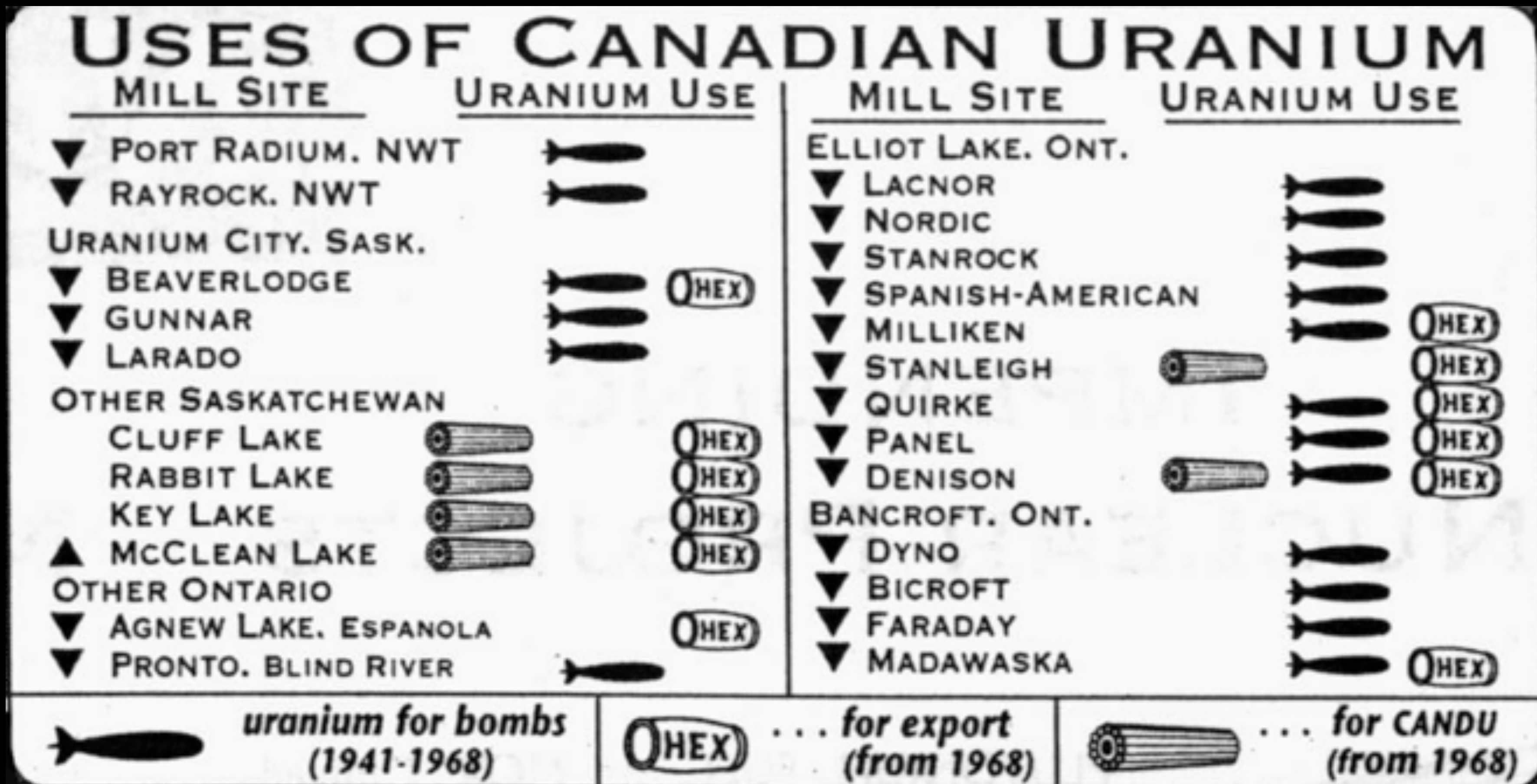
URANIUM BOOM: Dozens of post-war uranium mines open in NWT, Saskatchewan and Ontario to sell uranium to the US military.

PEAK MILITARY EXPORTS: In 1959 uranium is Canada's fourth most important export after lumber, pulp and paper, and wheat; all of the uranium exported at that time is destined for military use.

The Yellowcake Road (Canada)



All uranium goes to Port Hope on Lake Ontario for coversion to uranium hexafluoride or uranium dioxide



Until 1945, all Canadian uranium was sold to the US military for Bombs.
Although military sales ended in 1965, deliveries continued for a few more years.

Over 85% of Canada's uranium is sold to other countries.

Military Links

1941-1974

The Plutonium Connection

MONTREAL LAB: atomic scientists from UK, France, and Canada work on techniques for producing and separating plutonium 1943-45

BRITISH RESEARCH: pilot plant work for Sellafield takes place at Chalk River – involves reprocessing spent fuel to get plutonium metal.

CANADIAN RESEARCH: Canada sells plutonium to US military to help finance Canadian non-military nuclear research & development.

INDIA'S FIRST A-BOMB: In 1974 India detonates an A-bomb using plutonium produced in a research reactor given by Canada as a gift.

This glass paperweight is the exact size of the plutonium ball that was used as a nuclear explosive in the Nagasaki bomb.

Photo: Robert Del Tredici

Howard Morland with a model of a hydrogen bomb

Photo: Robert Del Tredici

H-bombs use a plutonium “trigger” (at the top) to raise the temperature to 50 million degrees.

When an H-bomb is dismantled, the plutonium is removed – thus making the bomb harmless.

Atoms For Peace

IAEA (1956): Canada assists in creating the IAEA, mandated to promote nuclear technology world-wide while not contributing to any military use

URANIUM POLICY (1965): US military contracts end and Prime Minister Pearson declares Canada's uranium will now be sold for peaceful uses only

NPT (1968):The Non-Proliferation Treaty divides the world into nuclear "haves" and nuclear "have-nots"; the "have-nots" promise not to develop nuclear weapons and the "haves" promise to get rid of theirs – eventually!

India refuses to sign, along with Pakistan, Israel, and South Sudan.

BILATERAL AGREEMENTS: a series of agreements with client countries promising not to use Canadian nuclear materials to build nuclear weapons

LOOPHOLE: India claims 1974 A-test was a "Peaceful Nuclear Explosive" (allowed by NPT); but Canada suspends nuclear cooperation with India

Nuclear Power Plants

PRECURSORS: NRX (1946, 24 MWth) “highest neutron flux in the world”; partial meltdown in 1952; NRU (1957, 200 MWth) versatile, still operating

PROTOTYPES: NPD reactor (1962, 22 MWe); Douglas Point reactor (1968, 200 MWe), Gentilly-1 reactor (1966, 250 MWe) – all permanently shut down.

PICKERING: Pickering A (1971-73, 4 x 540 MWe) and Pickering B (1983-86, 4 x 540 MWe) just outside Tortonto; all 8 to be retired by 2020.

BRUCE: Bruce A (1977-79, 4 x 750 MWe) & Bruce B (1985-87, 4 x 750 Mwe) largest nuclear station in North America; reactors to be refurbished.

DARLINGTON: 4 reactors (1991-93, 850 MWe) to be refurbished, 2-4 new reactors to be built – but go-ahead has been indefinitely postponed.

CANDU-6: Two reactors (675 MWe) outside Ontario, Gentilly-2 in Quebec (closed in 2012) ; Point Lepreau in New Brunswick (refurbished 2008-12).

Reactor Exports

INDIA & TAIWAN: copies of the Chalk River NRX reactor are used by both countries for nuclear research and for plutonium production

PAKISTAN & INDIA: KANNUP reactor (1959, 150 MWe) in Pakistan; RAPP-1 & RAPP-2 reactors (1963 & 67, 2 x 200 MWe) in India. After Canada broke off nuclear cooperation, India built a dozen CANDU clones.

ARGENTINA & SOUTH KOREA: Embalse reactor (1974, 650 MWe) in Argentina; Wolsung reactor (1975, 650 MWe) in South Korea. S. Korea has since built 3 more CANDU-6 reactors (1997-99) at the Wolsung site.

ROMANIA: Cernavoda (1978, 1 x 650 MWe) followed by a second CANDU-6 reactor at Cernavoda sold in 2000, with plans for up to 2 more.

CHINA: Quinshan reactors (1991-93, 2 x 725 Mwe) to be converted to burn “recycled enriched uranium spent fuel” from LWRs.

Nuclear Waste Governance in Canada

3. Irradiated Nuclear Fuel

The nuclear power industry in Canada has produced 3 million bundles of nuclear fuel waste to date, weighing over 50,000 tonnes.

They expect to double this volume over the next 30 years.

CANDU Fuel Bundle

Wet Storage (10 yrs)

Dry Storage (decades)

More is produced every day

Three categories of nuclear waste materials:

1. Fission Products (e.g. cesium-137, iodine-131)
   ~ the broken bits of uranium atoms

2. Activation Products (e.g. cobalt-60, carbon-14)
   ~ transmuted versions of non-radioactive atoms "activated" by absorbing stray neutrons

3. Transuranics (Actinides) (e.g. plutonium, americium)
   ~ heavier-than-uranium elements that are created when U-238 absorbs neutrons

These three categories are differentiated in the following table of radionuclides.

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
H (T)	Hydrogen (Tritium)	3	¥¥¥	¥	¥	
Be	Beryllium	10		¥	¥	
C	Carbon	14		¥¥¥	¥¥¥	
Si	Silicon	32		¥	¥	
P	Phosphorus	32		¥	¥	
S	Sulphur	35		¥		
Cl	Chlorine	36		¥		
Ar	Argon	39		¥	¥	
Ar	Argon	42		¥	¥	
K	Potassium	40		¥		
K	Potassium	42			¥	
Ca	Calcium	41		¥		
Ca	Calcium	45			¥	
Sc	Scandium	46		¥		
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
V	Vanadium	50			¥	
Mn	Manganese	54		¥	¥¥¥	
Fe	Iron	55		¥¥¥	¥¥¥	
Fe	Iron	59			¥	
Co	Cobalt	58		¥	¥	
Co	Cobalt	60		¥¥¥	¥¥¥	
Ni	Nickel	59		¥	¥¥¥	
Ni	Nickel	63		¥¥¥	¥¥¥	
Zn	Zinc	65		¥	¥	
Se	Selenium	79	¥¥¥			
Kr	Krypton	81	¥			
Kr	Krypton	85	¥¥¥			
Rb	Rubidium	87	¥			
Sr	Strontium	89	¥		¥	
Sr	Strontium	90	¥¥¥	¥	¥	
Y	Yttrium	90	¥¥¥	¥	¥	

Y	Yttrium	91	¥		¥	
Zr	Zirconium	93	¥¥¥	¥	¥¥¥	
Zr	Zirconium	95	¥	¥	¥	
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Nb	Niobium	92			¥	
Nb	Niobium	93m	¥¥¥	¥	¥¥¥	
Nb	Niobium	94	¥	¥	¥¥¥	
Nb	Niobium	95	¥	¥	¥	
Nb	Niobium	95m	¥		¥	
Mo	Molybdenum	93		¥	¥	
Tc	Technetium	99	¥¥¥	¥	¥	
Ru	Ruthenium	103	¥			
Ru	Ruthenium	106	¥¥¥			
Rh	Rhodium	103m	¥			
Rh	Rhodium	106	¥¥¥			
Pd	Palladium	107	¥¥¥			
Ag	Silver	108	¥	¥	¥	
Ag	Silver	108m	¥	¥¥¥	¥	
Ag	Silver	109m	¥	¥	¥	
Ag	Silver	110	¥	¥	¥	
Ag	Silver	110m	¥	¥	¥	
Cd	Cadmium	109	¥	¥	¥	
Cd	Cadmium	113	¥		¥	
Cd	Cadmium	113m	¥¥¥		¥	
Cd	Cadmium	115	¥			
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
In	Indium	113m			¥	
In	Indium	114	¥	¥	¥	
In	Indium	114m			¥	
In	Indium	115			¥	
Sn	Tin	113			¥	
Sn	Tin	117m	¥	¥	¥	
Sn	Tin	119m	¥¥¥		¥¥¥	
Sn	Tin	121m	¥		¥¥¥	
Sn	Tin	123	¥		¥	

Sn	Tin	125	¥¥¥		¥	
Sn	Tin	126				
Sb	Antimony	124	¥		¥	
Sb	Antimony	125	¥¥¥		¥¥¥	
Sb	Antimony	126	¥		¥	
Sb	Antimony	126m	¥¥¥			
Te	Tellurium	123	¥		¥	
Te	Tellurium	123m	¥		¥	
Te	Tellurium	125m	¥¥¥		¥¥¥	
Te	Tellurium	127	¥		¥	
Te	Tellurium	127m	¥		¥	
I	Iodine	129	¥		¥	
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	**F.P.** Fission Product	**F.I.A.P.** Activation Product	**Z.A.P.** Activation Product	**Actinide** (includes progeny)
Cs	Cesium	134	¥			
Cs	Cesium	135	¥¥¥			
Cs	Cesium	137	¥¥¥			
Ba	Barium	137m	¥¥¥			
La	Lanthanum	138	¥			
Ce	Cerium	142	¥			
Ce	Cerium	144	¥¥¥			
Pr	Praseodymium	144	¥¥¥			
Pr	Praseodymium	144m	¥¥¥			
Nd	Neodymium	144	¥			
Pm	Promethium	147	¥¥¥			
Sm	Samarium	147	¥			
Sm	Samarium	148	¥	¥		
Sm	Samarium	149	¥			
Sm	Samarium	151	¥¥¥			
Eu	Europium	152	¥¥¥	¥		
Eu	Europium	154	¥¥¥	¥		
Eu	Europium	155	¥¥¥	¥		
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	**F.P.** Fission Product	**F.I.A.P.** Activation Product	**Z.A.P.** Activation Product	**Actinide** (includes progeny)
Gd	Gadolinium	152	¥	¥		
Gd	Gadolinium	153	¥	¥		
Tb	Terbium	157		¥		

Tb	Terbium	160		¥		
Dy	Dysprosium	159		¥		
Ho	Holmium	166m	¥	¥		
Tm	Thulium	170		¥		
Tm	Thulium	171		¥		
Lu	Lutetium	176			¥	
Lu	Lutetium	176			¥	
Lu	Lutetium	176			¥	
Hf	Hafnium	175			¥	
Hf	Hafnium	181			¥	
Hf	Hafnium	182			¥	
Ta	Tantalum	180			¥	
Ta	Tantalum	182			¥	
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
W	Tungsten	181			¥	
W	Tungsten	185			¥	
W	Tungsten	188			¥	
Re	Rhenium	187			¥	
Re	Rhenium	188			¥	
Os	Osmium	194			¥	
Ir	Iridium	192			¥	
Ir	Iridium	192m			¥	
Ir	Iridium	194			¥	
Ir	Iridium	194m			¥	
Pt	Platinum	193			¥	
Tl	Thallium	206			¥	
Tl	Thallium	207				¥
Tl	Thallium	208				¥
Tl	Thallium	209				¥
Pb	Lead	204			¥	
Pb	Lead	205			¥	
Pb	Lead	209				¥
Pb	Lead	210				¥
Pb	Lead	211				¥
Pb	Lead	212				¥
Pb	Lead	214				¥
Standard	Common Name of	Atomic Mass	F.P.	F.I.A.P.	Z.A.P.	Actinide

Chemical Symbol	element	Number	Fission Product	Activation Product	Activation Product	(includes progeny)
Bi	Bismuth	208			¥	
Bi	Bismuth	210			¥	¥
Bi	Bismuth	210m				¥
Bi	Bismuth	211				¥
Bi	Bismuth	212				¥
Bi	Bismuth	213				¥
Bi	Bismuth	214				
Po	Polonium	210			¥	¥
Po	Polonium	211				¥
Po	Polonium	212				¥
Po	Polonium	213				¥
Po	Polonium	214				¥
Po	Polonium	215				¥
Po	Polonium	216				¥
Po	Polonium	218				¥
At	Astatine	217				¥
Standard Chemical Symbol	**Common Name of element**	**Atomic Mass Number**	**F.P.** Fission Product	**F.I.A.P.** Activation Product	**Z.A.P.** Activation Product	**Actinide** (includes progeny)
Rn	Radon	219				¥
Rn	Radon	220				¥
Rn	Radon	222				¥
Fr	Francium	221				¥
Fr	Francium	221				¥
Ra	Radium	223				¥
Ra	Radium	224				¥
Ra	Radium	225				¥
Ra	Radium	226				¥
Ra	Radium	228				¥
Ac	Actinium	225				¥
Ac	Actinium	227				¥
Ac	Actinium	228				¥
Th	Thorium	227				¥
Th	Thorium	228				¥
Th	Thorium	229				¥
Th	Thorium	230				¥
Th	Thorium	231				¥
Th	Thorium	232				¥

Th	Thorium	234				¥¥¥
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Pa	Protactinium	231				¥
Pa	Protactinium	233				¥¥¥
Pa	Protactinium	234				¥
Pa	Protactinium	234m				¥¥¥
U	Uranium	232				¥
U	Uranium	233				¥
U	Uranium	234				¥¥¥
U	Uranium	235				¥
U	Uranium	236				¥¥¥
U	Uranium	237				¥¥¥
U	Uranium	238				¥¥¥
U	Uranium	240				¥
Np	Neptunium	237				¥¥¥
Np	Neptunium	238				¥
Np	Neptunium	239				¥¥¥
Np	Neptunium	240				¥
Np	Neptunium	240m				¥
Pu	Plutonium	236				¥
Pu	Plutonium	238				¥¥¥
Pu	Plutonium	239				¥¥¥
Pu	Plutonium	240				¥¥¥
Pu	Plutonium	241				¥¥¥
Pu	Plutonium	242				¥¥¥
Pu	Plutonium	243				¥
Pu	Plutonium	244				¥
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Am	Americium	241				¥¥¥
Am	Americium	242				¥¥¥
Am	Americium	242m				¥¥¥
Am	Americium	243				¥¥¥
Am	Americium	245				¥
Cm	Curium	242				¥¥¥
Cm	Curium	243				¥¥¥

Cm Cm Cm Cm Cm Cm	Curium Curium Curium Curium Curium Curium	244 245 246 247 248 250				¥¥¥ ¥ ¥ ¥ ¥ ¥
Bk Bk	Berkelium Berkelium	249 250				¥ ¥
Cf Cf Cf Cf	Californium Californium Californium Californium	249 250 251 252				¥ ¥ ¥ ¥
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	**F.P.** Fission Product	**F.I.A.P.** Activation Product	**Z.A.P.** Activation Product	**Actinide** (includes progeny)

¥ indicates that the radionuclide is present in the designated category
¥¥¥ indicates an activity level of more than a million becquerels per kilogram

This list of 211 man-made radionuclides contained in irradiated nuclear fuel is by no means complete. (AECL)

Irradiated Fuel: The first 30 years

1945-62 – research reactors produce irradiated fuel: ZEEP, NRX, NRU
irradiated fuel and liquid HLW stored at Chalk River ~ no debate

1962-78 – power reactors begin producing irradiated nuclear fuel
irradiated fuel stored on site in pools ~ no public debate

1975 – Canadian Coalition for Nuclear Responsibility (CCNR) formed
CCNR highlights lack of a plan for safe long-term management

1977 – Federal Hare Report "Managing Canada's Nuclear Waste"
recommends "deep geologic repository" (DGR) in granite

1978 – Provincial Porter Commission Report : "A Race Against Time"
recommends nuclear moratorium if problem not solved by 1985

Irradiated Fuel: Another 30 years

1978 – Canada/Ontario Agreement involving AECL and Ontario Hydro
$750 million 15-year research effort to "verify" geologic disposal; construction of Underground Research Laboratory in Manitoba

1988-98 – 10 year Environmental Assessment Begins (Seaborn Panel)
forbidden to consider the option of stopping waste production; public hearings are held in five provinces on the DGR Concept

1998 – Report of the Seaborn Panel: Independent Waste Agency Needed
DGR Concept not ready to be adopted as Canada's approach; Agency is needed that is at arm's length from industry and gov't

2002 – Government passes Nuclear Fuel Waste Act and creates NWMO
Instead of an independent agency, waste producers are put in charge; Nuclear Waste Management Organization (NWMO) to advise gov't

Irradiated Fuel: 10 years more

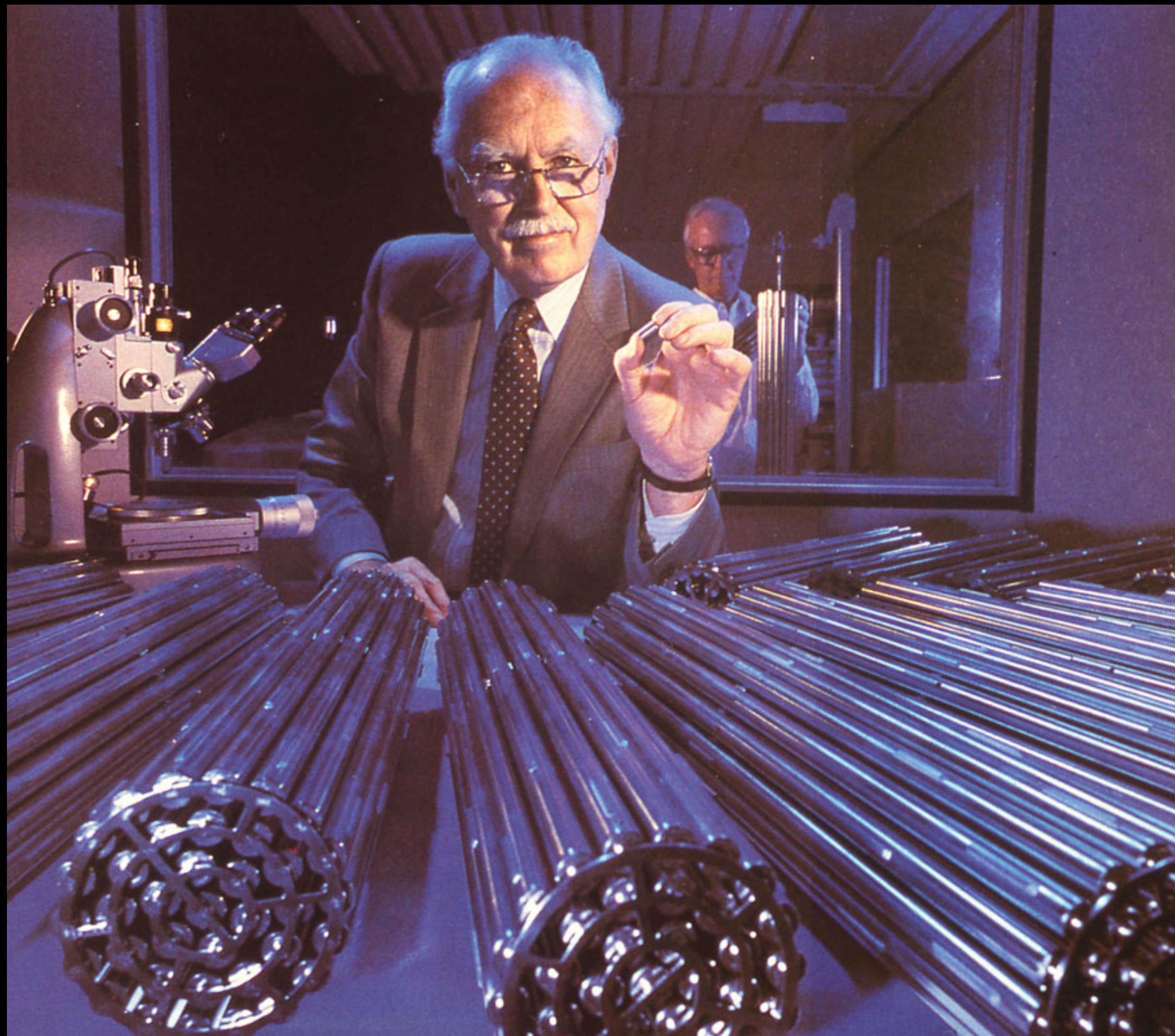
2005 – NWMO proposes a policy of "***Adaptive Phased Management"***
a multistage process leading to a Deep Geologic Repository (DGR)

2007 – NWMO's proposal is accepted by government without debate
NWMO is given authorization to implement its 300-year plan

2010 – *Site selection process begins with financial incentives ~ no debate*
NWMO works with town councils in search for a "willing host community"

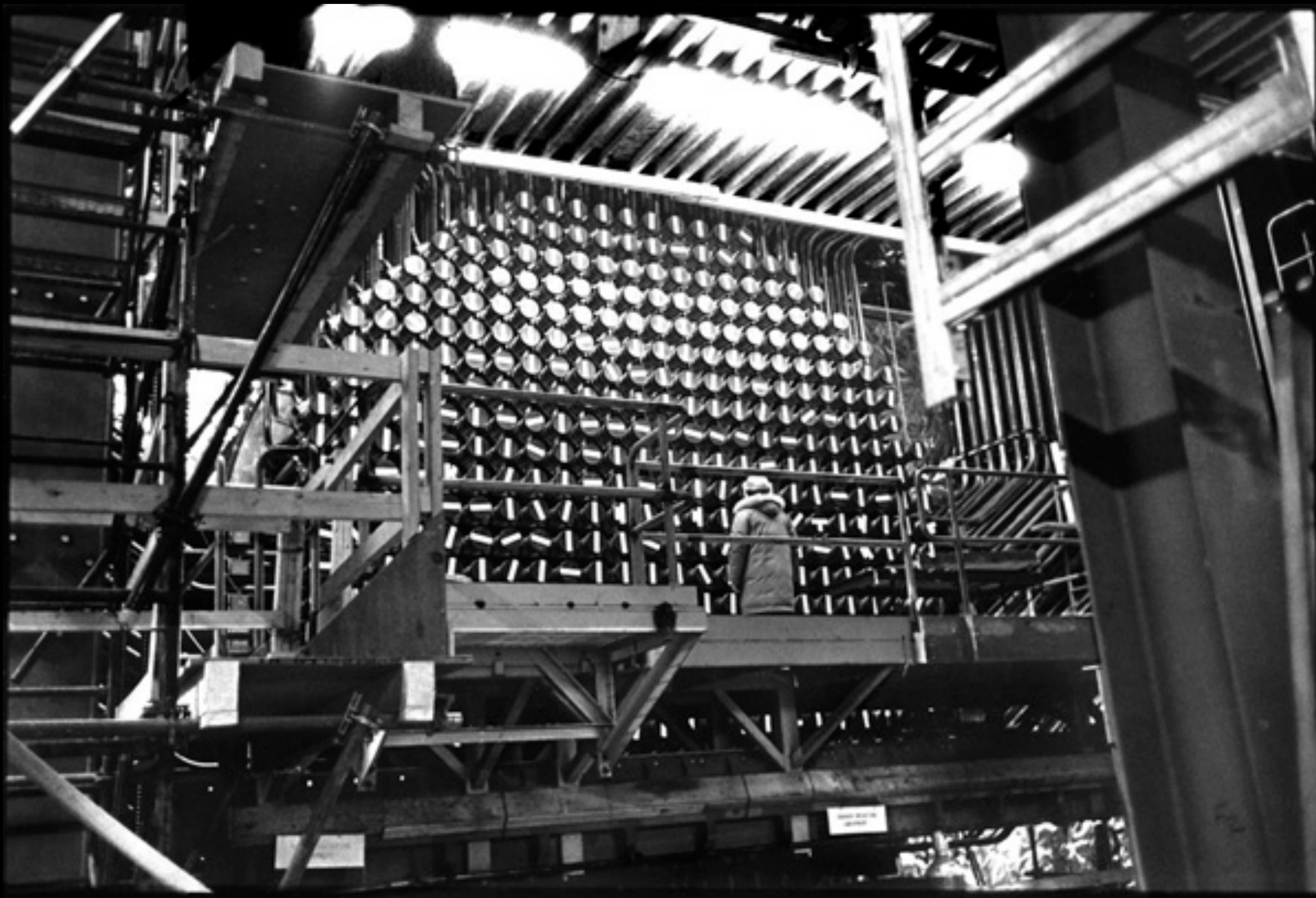
2012 – 21 town councils enlist in a learning process as potential candidates
these communities are located in Ontario (18) and Saskatchewan (3)

2014 – NWMO meetings with councils found contrary to Ontario Municipal Act
by law all town council meetings must be open to the public



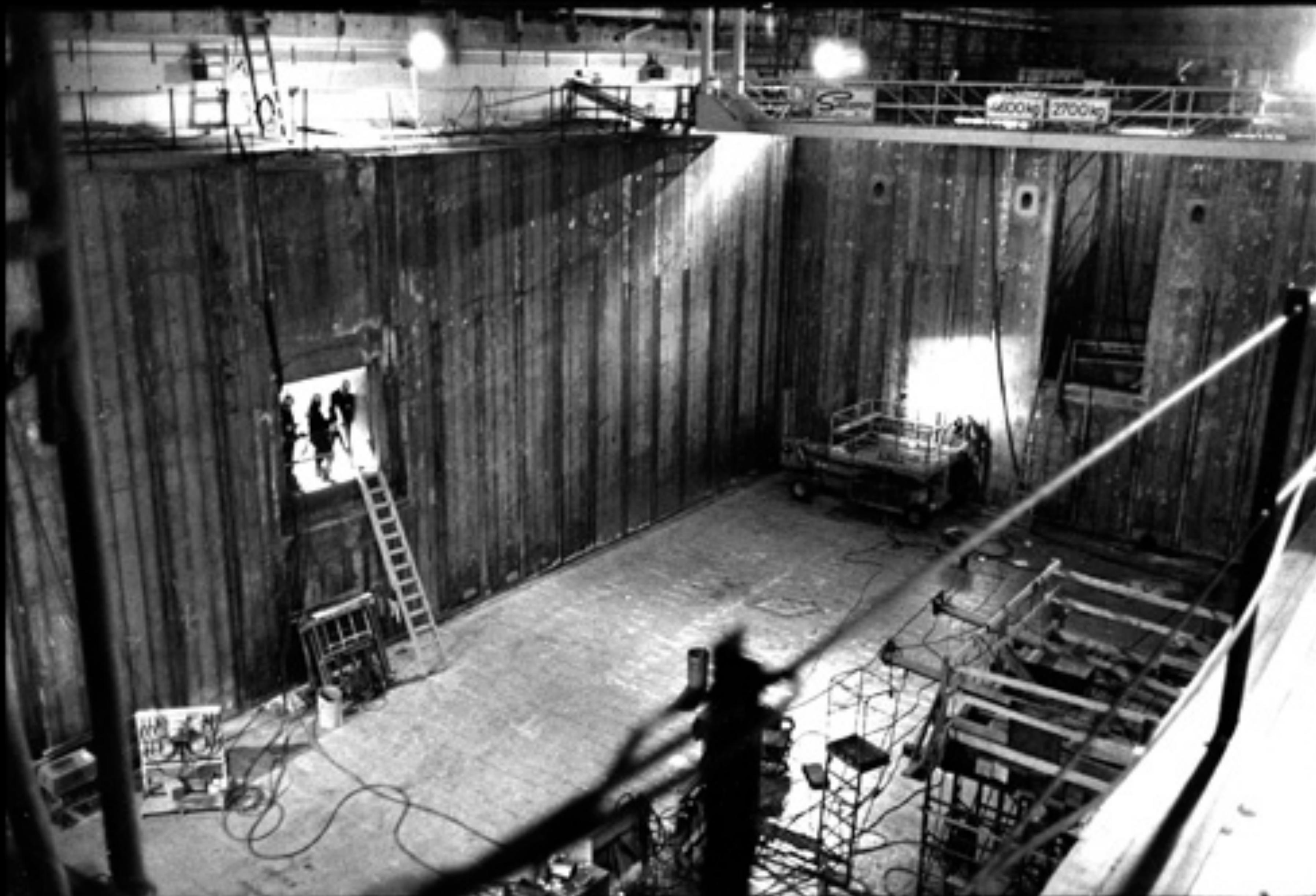
A CANDU fuel bundle like one of these can be handled safely before it is used, but after use in a reactor it delivers a lethal radiation dose in a few seconds.

"Small Wonder" : Canadian Nuclear Association Ad



The face of a CANDU reactor loaded with fresh (unused) fuel bundles

Photo: Robert Del Tredici



Irradiated fuel must be cooled for several years by circulating water in a spent fuel pool.

Photo: Robert Del Tredici

After 10 years in the pool, CANDU spent fuel is put into air-cooled “dry storage” containers.

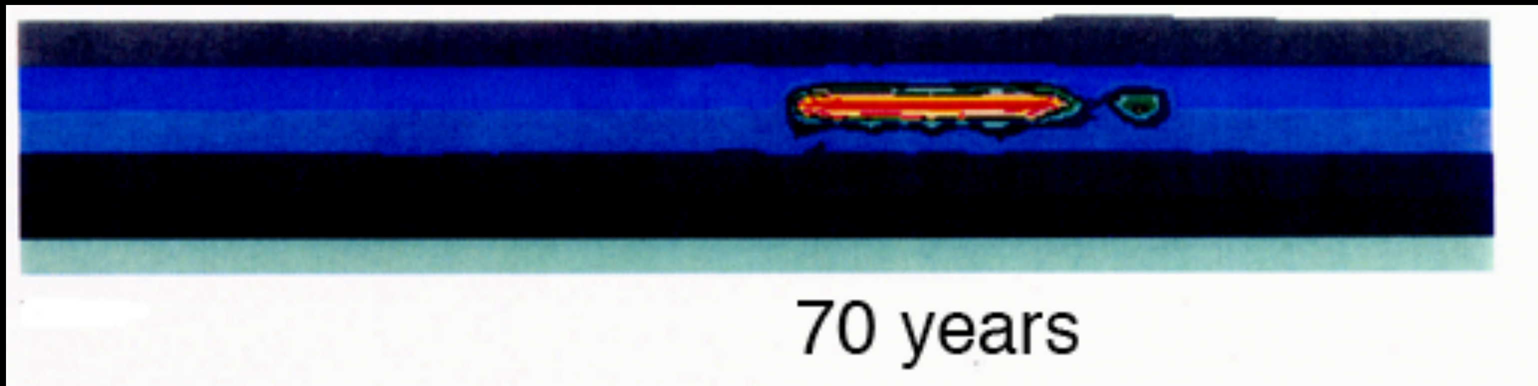
Photo: Robert Del Tredici

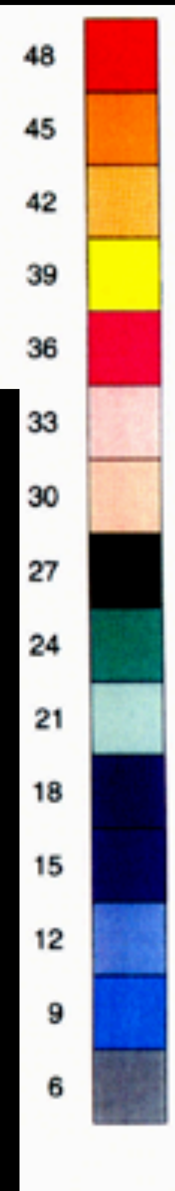
The Nuclear Waste Management Organization will wait 30 years before putting irradiated fuel underground to prevent it from spontaneously overheating due to radioactive disintegration.

Photo: Robert Del Tredici

"Thermal Pulse"

(about 50,000 years)





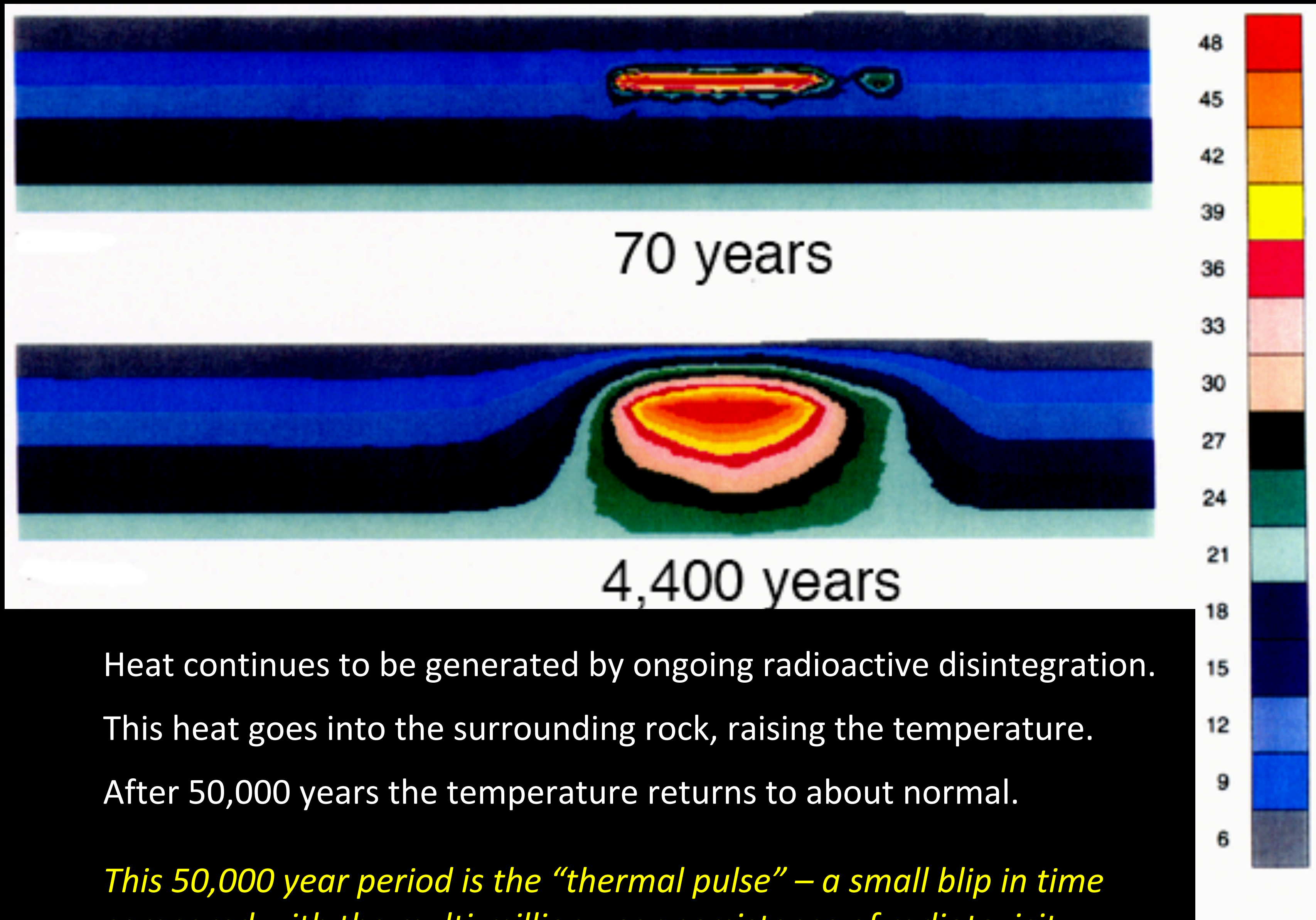
This series of graphics is from AECL's EIS on the DGR Concept.

The horizontal lines represent underground rock layers.

The colors indicate temperatures (in degrees Celsius).

Heat from the buried irradiated nuclear fuel warms up the rocks.

from AECL's EIS on the Geologic Disposal Concept, 1994.



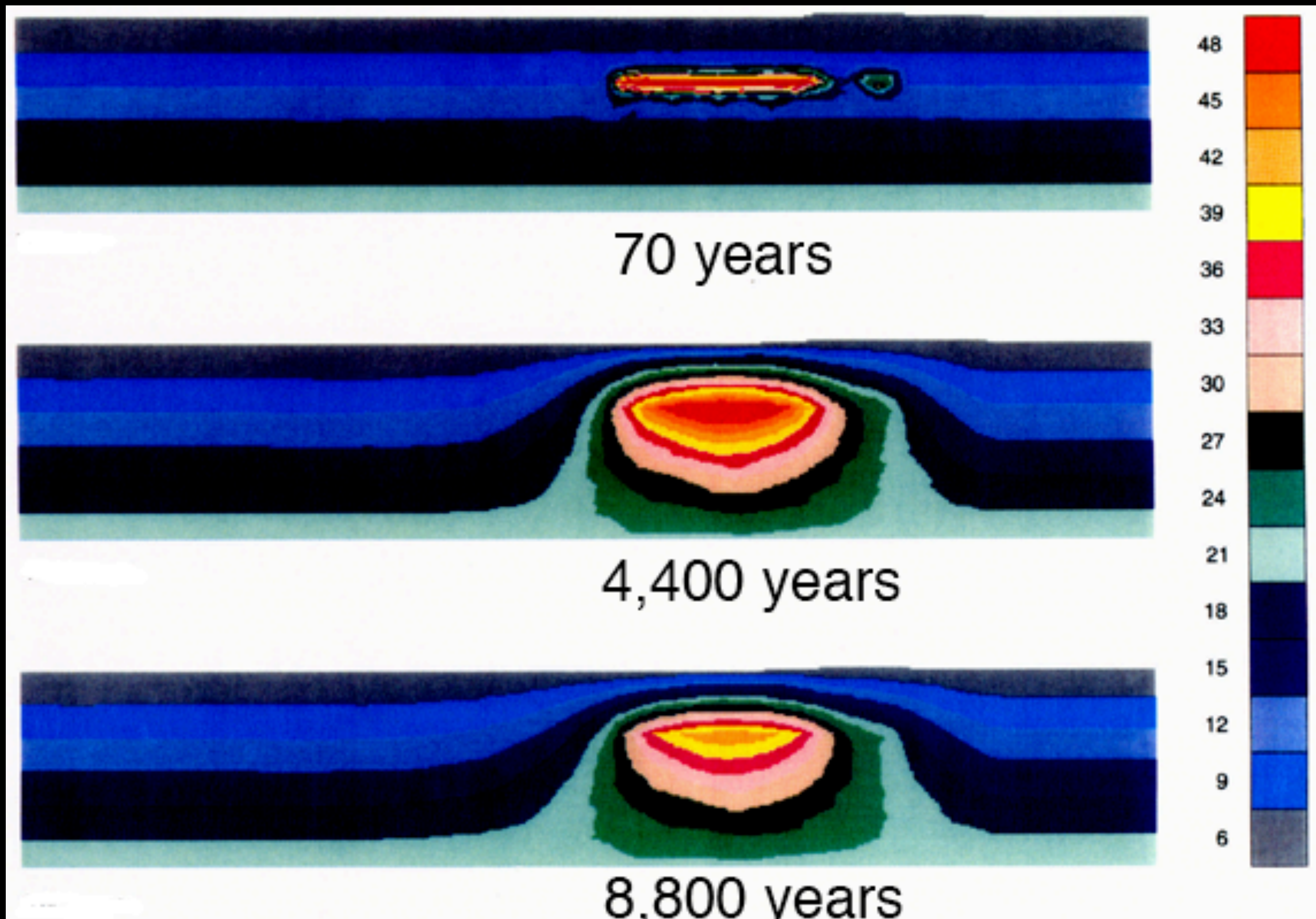
Heat continues to be generated by ongoing radioactive disintegration.

This heat goes into the surrounding rock, raising the temperature.

After 50,000 years the temperature returns to about normal.

This 50,000 year period is the "thermal pulse" – a small blip in time compared with the multi-million-year persistence of radiotoxicity.

from AECL's EIS on the Geologic Disposal Concept, 1994.

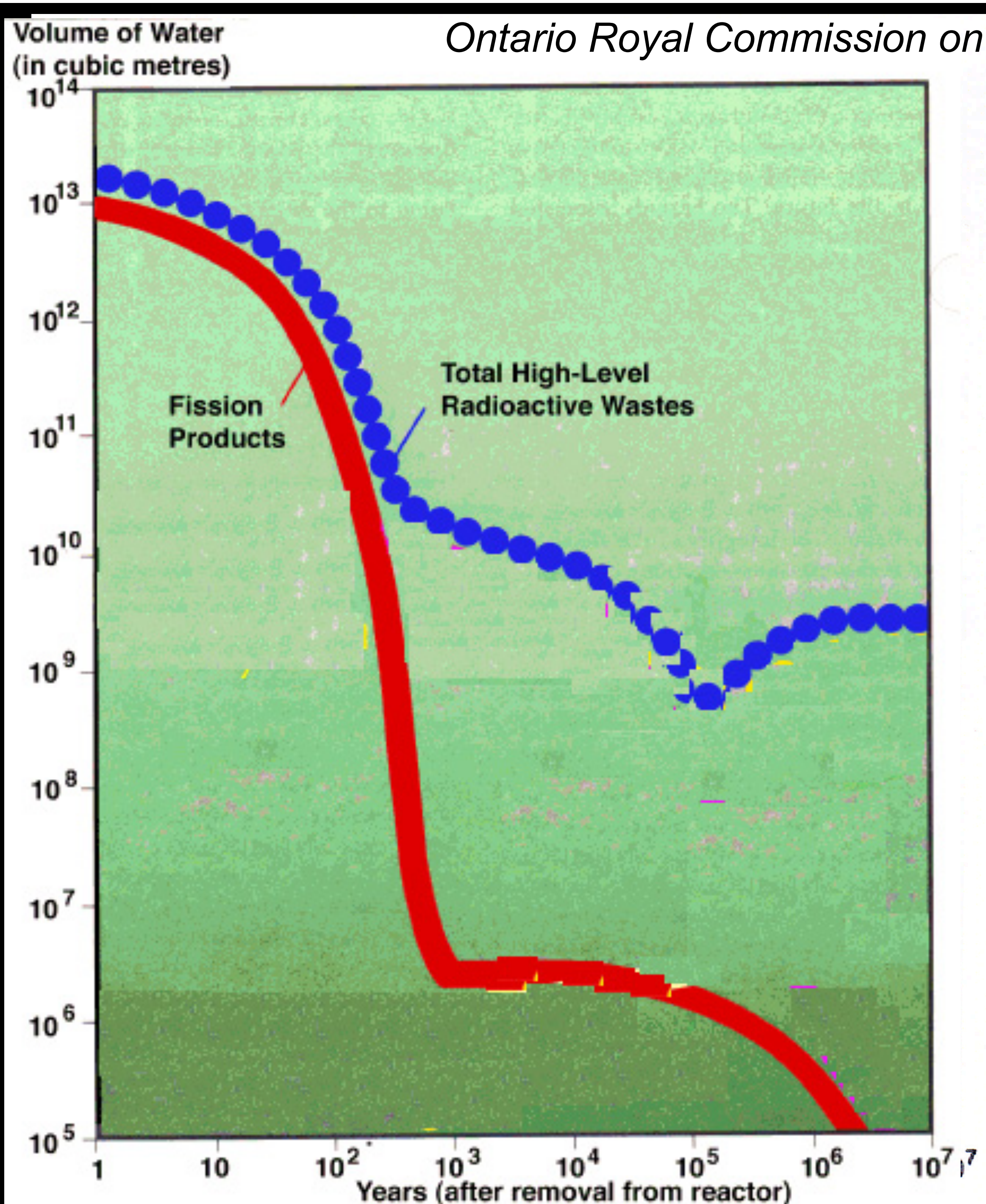


from AECL's EIS on the Geologic Disposal Concept, 1994.

Radiotoxicity

(10 million years and counting)

Ontario Royal Commission on Electric Power Planning (1978)



This graph shows the radiotoxicity of one year's worth of spent CANDU fuel from one reactor over a period of ten million years

The minimum amount of water needed to dilute one year of "fresh" spent fuel just out of a CANDU reactor is approximately the size of Lake Superior.

Royal Commission Report, 1978

NWMO

The **Seaborn Panel** recommended (1998) a Nuclear Fuel Waste Management Agency (NFWMA) that would

- *be at arm's length from the nuclear industry,*
- *have stakeholders on the Board of Directors, and*
- *report regularly to the Parliament of Canada.*

Instead, the **Government** created (2002) an industry-owned Nuclear Waste Management Organization (NWMO)

- *whose Board Members are representatives of the nuclear waste producers, and*
- *which reports to the Minister of Natural Resources, – the one responsible for promoting nuclear power.*

NWMO is seeking for a “willing host community” to accept all of Canada’s irradiated nuclear fuel. Candidate sites are in Ontario and Saskatchewan

November 2012

Problems facing NWMO

MANITOBA: Site of the Underground Research Laboratory where AECL did all its field work for a DGR, the province enacted a law prohibiting the import of nuclear waste for permanent storage.

QUEBEC: The province closed its only operating nuclear reactor in 2012, and the National Assembly (legislature) passed a unanimous resolution against import of nuclear waste from other jurisdictions.

ONTARIO: NWMO was recently found to be in violation of the Law governing municipalities by holding closed-door meetings with town councillors without public participation or even transcripts.

SASKATCHEWAN: In a series of government-sponsored public hearings held in 2009, 88 percent of participants voted against expanding the nuclear agenda, including hosting spent reactor fuel.

Aboriginal Peoples Positions

After meeting with NWMO representatives, **Band Council Resolutions (BCR's) by several First Nations and Metis organizations** have been passed opposing the continued production of nuclear waste (irradiated fuel) and/or the hosting of high level nuclear waste on aboriginal lands.

Examples:

- *Métis Nation of Saskatchewan, 2011*
- *Saskatchewan Aboriginal Women's Circle Corporation, 2012*
- *Native Women's Association of Canada, 2012*
- *Canoe Lake First Nation, 2013*
- *Peter Ballantyne Cree Nation, 2014*
- *Opaskwayak Cree Nation, 2014*

Nuclear Waste Governance in Canada

4. Rolling Stewardship

Nuclear Waste Governance in Canada

Recently in Canada an alternative to the abandonment of reactor wastes has been proposed, based on the concept of “Rolling Stewardship”.

FACTS:

There are 100s of radioactive poisons with distinct biological pathways.

We do not know how to destroy or neutralize these wastes.

Nuclear wastes are dangerous for millennia, even millions of years.

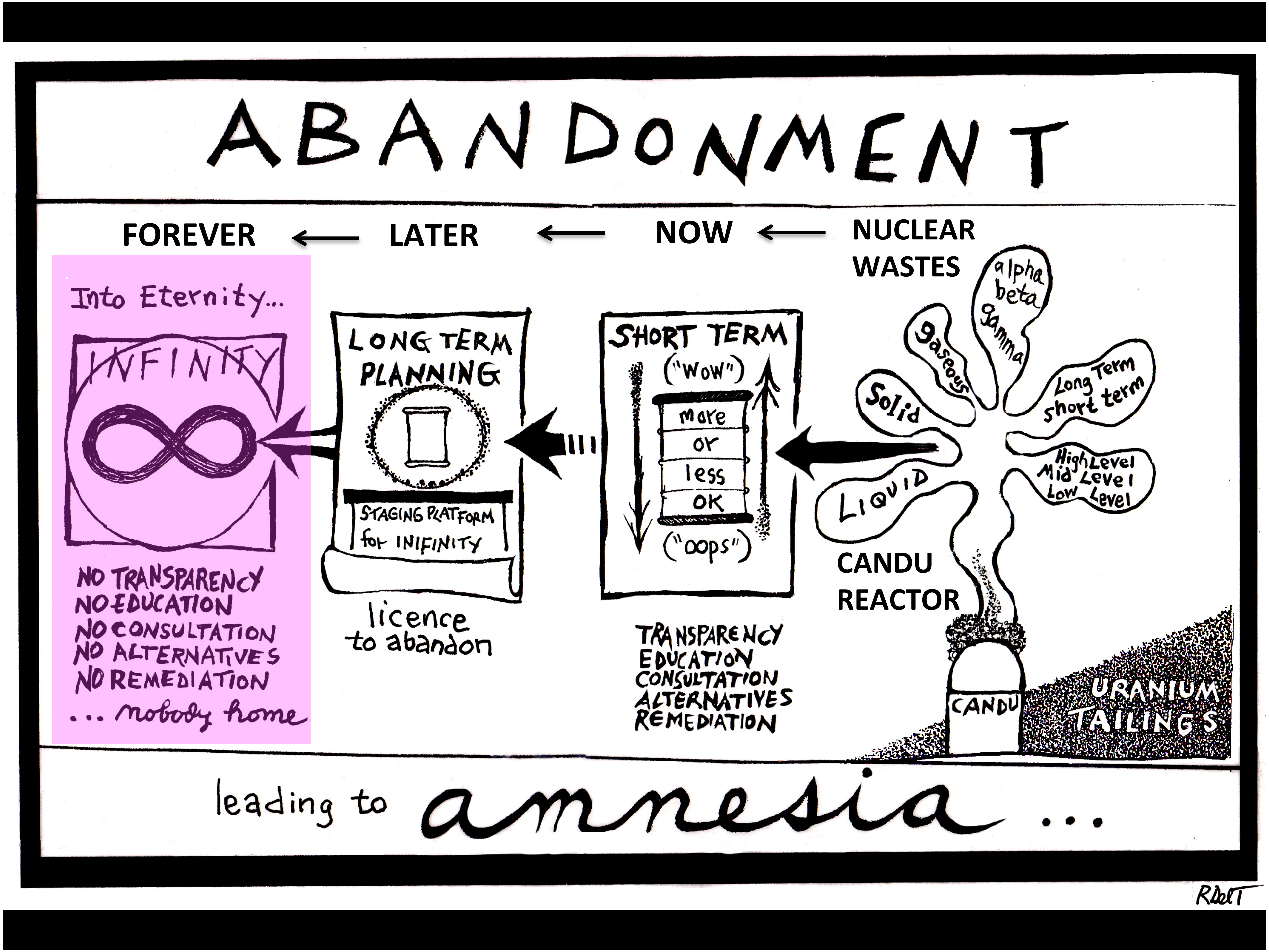
Disposal = abandonment: this approach is not scientifically certain.

Lack of precedent: humans have never safely “disposed” of anything.

USA has tried 8 times to locate a disposal site and failed all 8 times.

Germany has two failed underground repositories: Asse II, Morsleben.

WIPP, the only Deep Geologic Repository in USA, recently failed.


ABANDONMENT
FOREVER
LATER
NOW
NUCLEAR WASTES
Into Eternity...
INFINITY
LONG TERM PLANNING
STAGING PLATFORM for INFINITY
SHORT TERM
("WOW")
more or less OK
("oops")
alpha beta gamma
gaseous
Solid
LIQUID
Long Term short term
High Level Mid Level Low Level
CANDU REACTOR
CANDU
URANIUM TAILINGS
NO TRANSPARENCY
NO EDUCATION
NO CONSULTATION
NO ALTERNATIVES
NO REMEDIATION
... nobody home
licence to abandon
TRANSPARENCY
EDUCATION
CONSULTATION
ALTERNATIVES
REMEDIATION
leading to amnesia ...
RDeT

PROPOSAL:

A new nuclear waste policy based on frankness.

We begin by admitting we have at present no proven solution.

One alternative to abandonment is Rolling Stewardship.

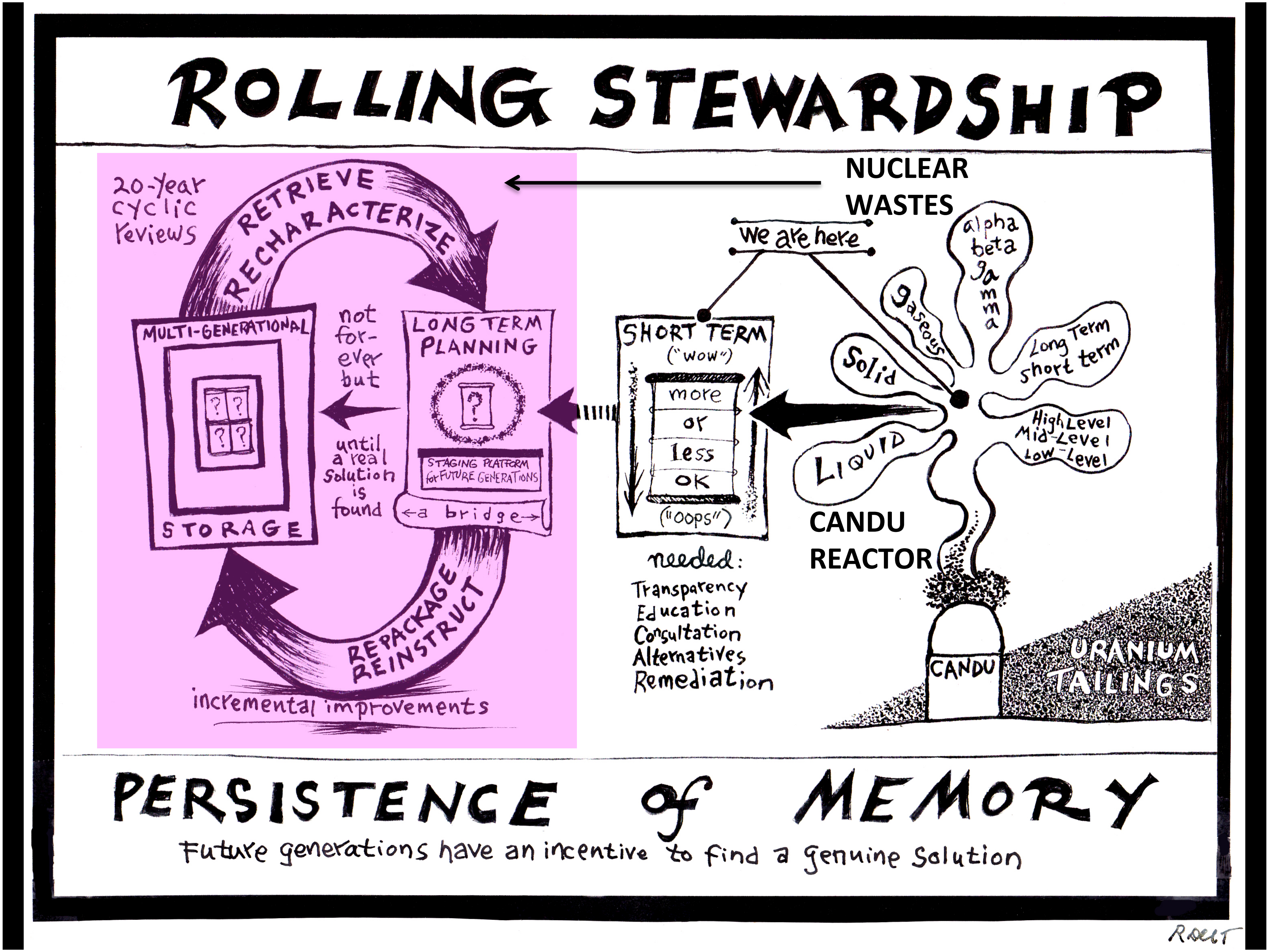
Wastes are monitored and retrievable for the foreseeable future.

Wastes are packaged safely for extended periods & repackaged later.

This is not a solution – it is only an ethical waste management scheme.

Rolling Stewardship is needed until a “genuine solution” is found.

The production of additional wastes can/should be phased out.


ROLLING STEWARDSHIP
NUCLEAR WASTES
20-Year cyclic reviews
RETRIEVE
RECHARACTERIZE
MULTI-GENERATIONAL
STORAGE
not for-ever but
until a real Solution is found
LONG TERM PLANNING
STAGING PLATFORM for FUTURE GENERATIONS
a bridge
REPACKAGE
REINSTRUCT
incremental improvements
We are here
SHORT TERM
("WOW")
more
or
less
OK
("oops")
needed:
Transparency
Education
Consultation
Alternatives
Remediation
alpha
beta
gamma
gaseous
Solid
Long Term
short term
High Level
Mid-Level
Low-Level
LIQUID
CANDU REACTOR
CANDU
URANIUM TAILINGS
PERSISTENCE of MEMORY
Future generations have an incentive to find a genuine Solution
RDELT

POINTS TO PONDER:

Abandonment is based on the concept of amnesia: forget it!

Rolling Stewardship is based on persistence of memory: look after it!

Rolling Stewardship allows timely corrective action to be taken.

Rolling Stewardship imparts all information to the next generation.

A 20-year "changing of the guard" would officially transfer resources.

Ongoing monitoring, robust packaging, and retrievability at all times.

Recharacterization of the wastes and repackaging when necessary.

This is not a solution – it is a responsible waste management scheme.

Rolling Stewardship is needed until a genuine solution can be found.

A solution might involve destruction or neutralization of the wastes.

Nuclear Waste Governance in Canada

5. Uranium Mill Tailings

Uranium Shovel: the radioactive ore is brought to the surface and ground to a fine sand.

Photo: Robert Del Tredici

This 10-metre high wall is part of a deposit of 70 million tonnes of U tailings in Elliot Lake area.
Photo: Robert Del Tredici

Uranium Tailings
in Canada

250 million tonnes
of radioactive sand

with a 76,000
year half-life

Note: uranium-bearing ores contains several of the most deadly radionuclides known to science

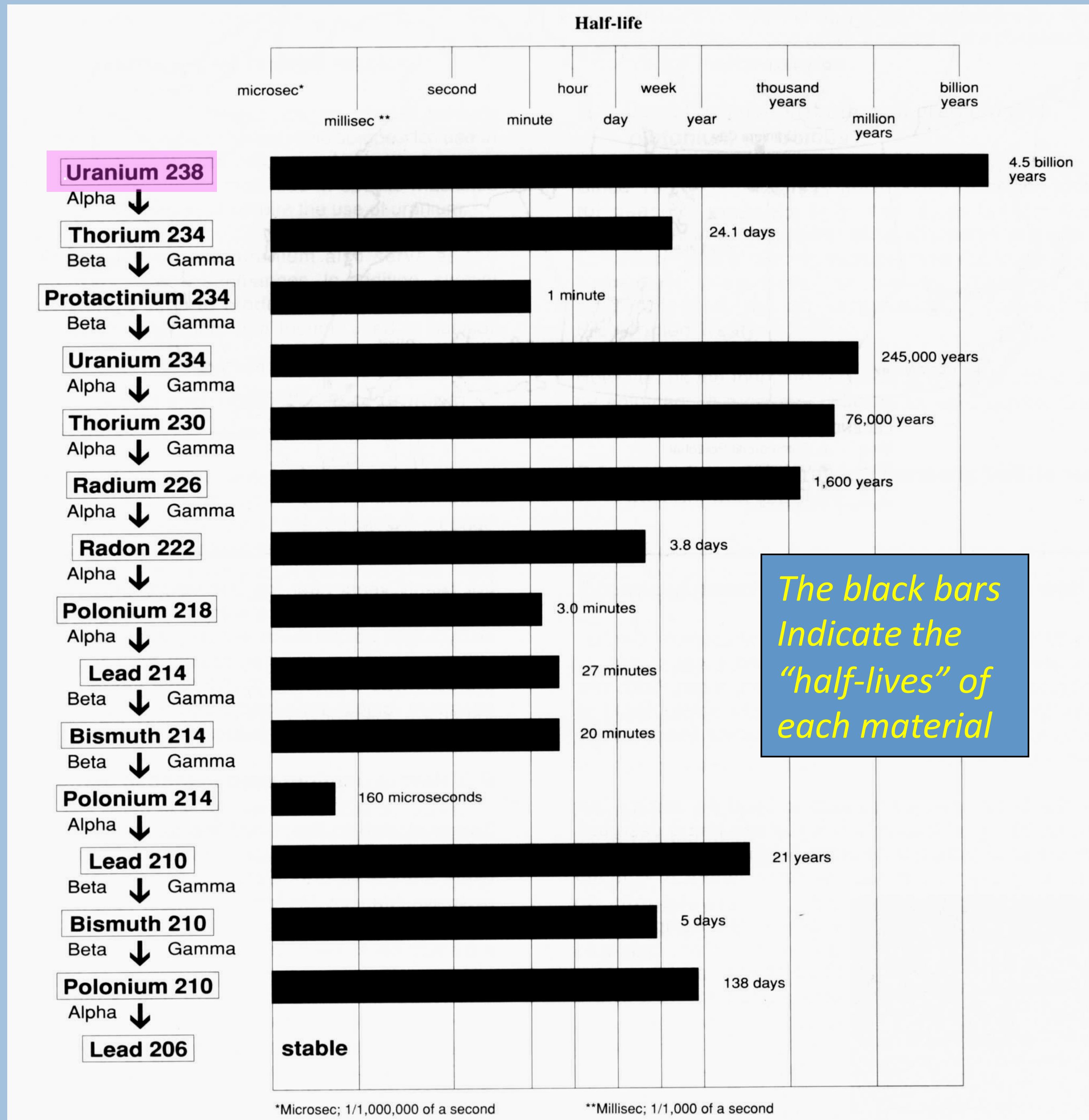
e.g. Radium, Radon, Thorium, Polonium

85 percent of the radioactivity in the ore is left behind in the tailings as waste.

URANIUM

When uranium atoms disintegrate they change into more dangerous radioactive elements.

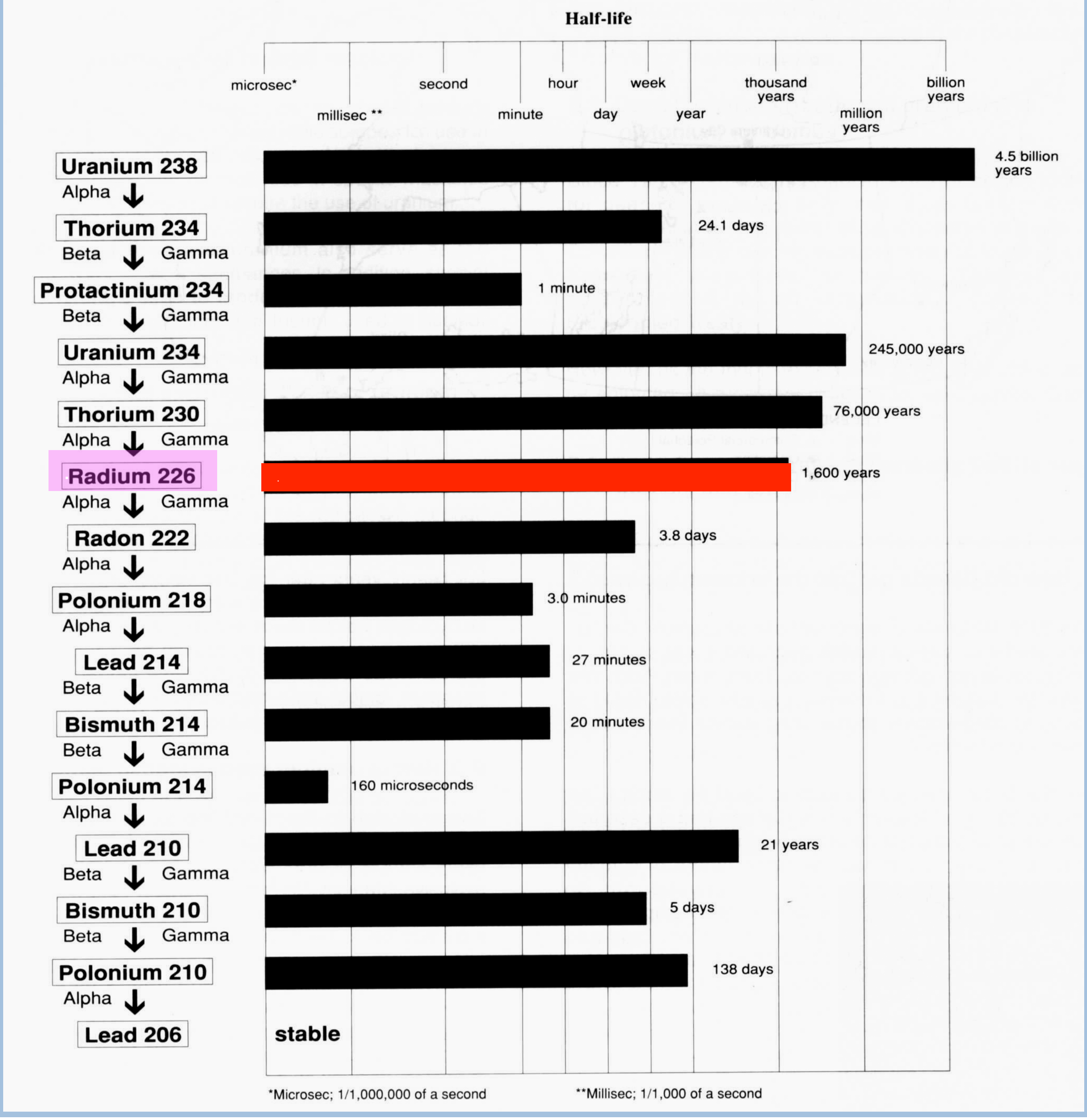
This is the "decay chain" of U-238. There is a similar decay chain for U-235.



RADIUM

In the first half of The 20th century, Radium-226 killed thousands with fatal anemia, bone cancer, and head cancer.

Radium is called a "superb carcinogen" by British Columbia Medical Association.

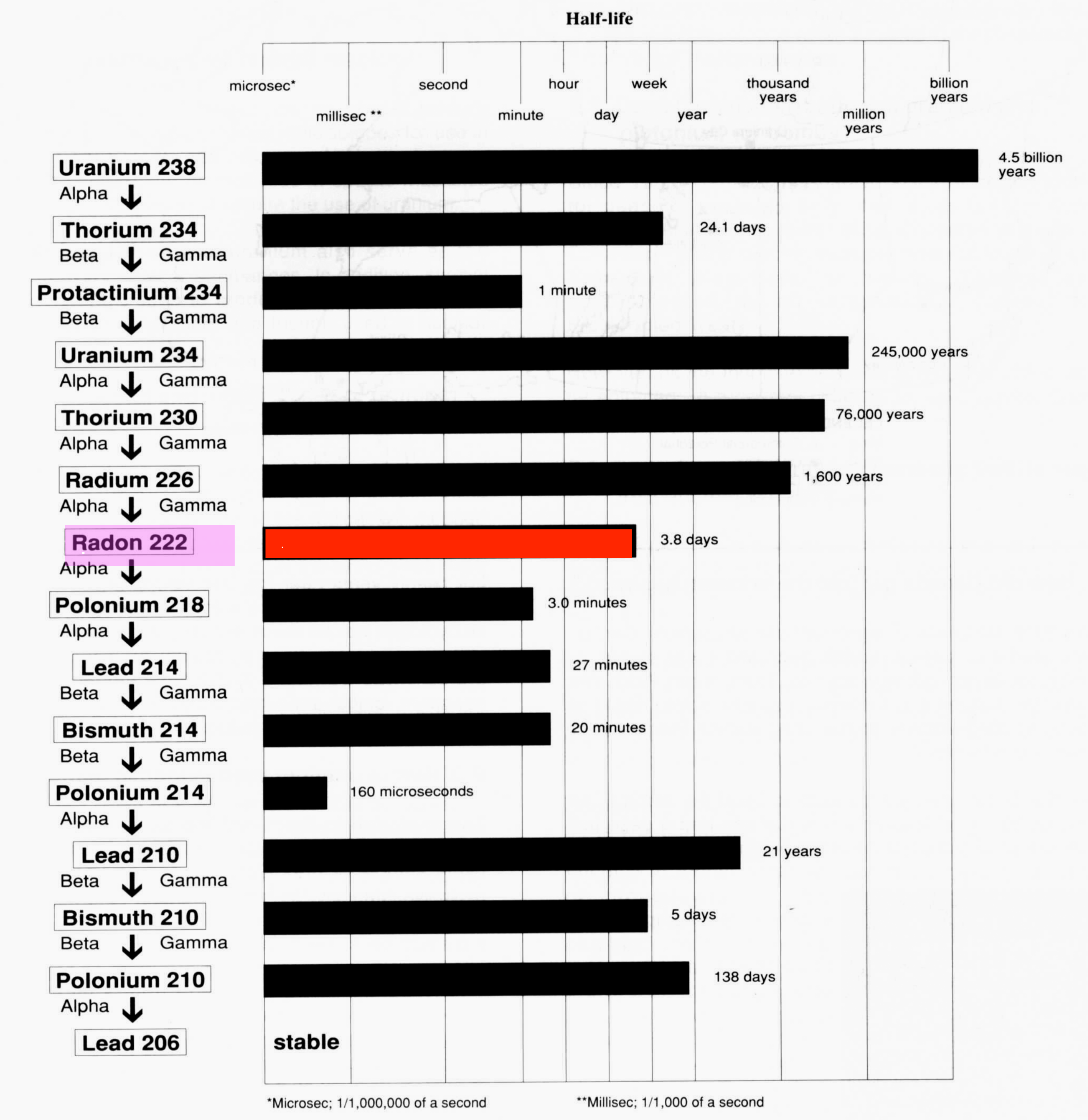


RADON GAS

Radon-222 (known as radon gas) has killed thousands of underground miners for centuries.

It is the second leading cause of lung cancer after cigarette smoking.

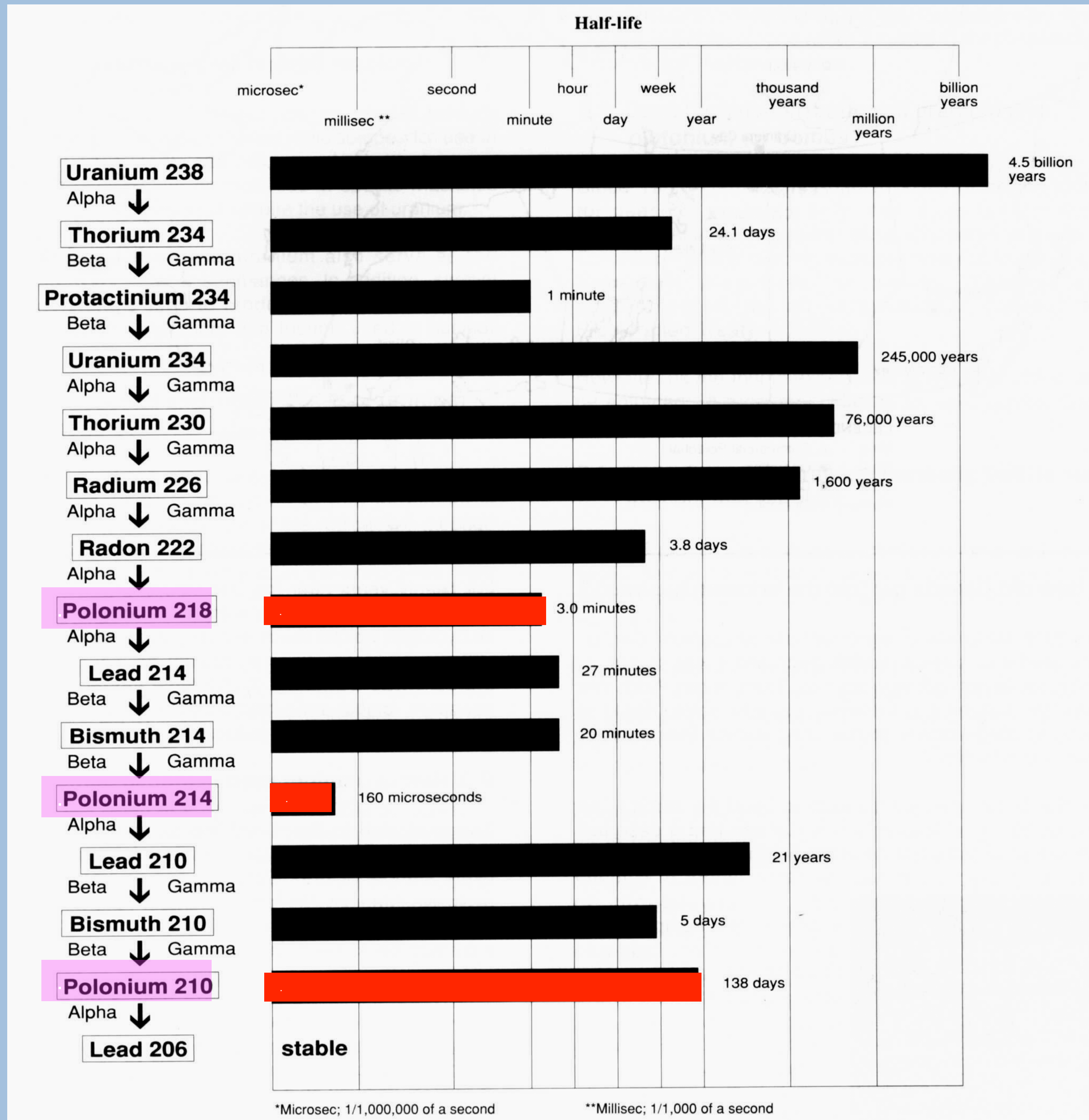
Indoor radon kills tens of thousands of American citizens every year according to the US EPA.



POLONIUM

Polonium is millions of times more toxic than cyanide. It was used to murder Alexandre Litvinenko.

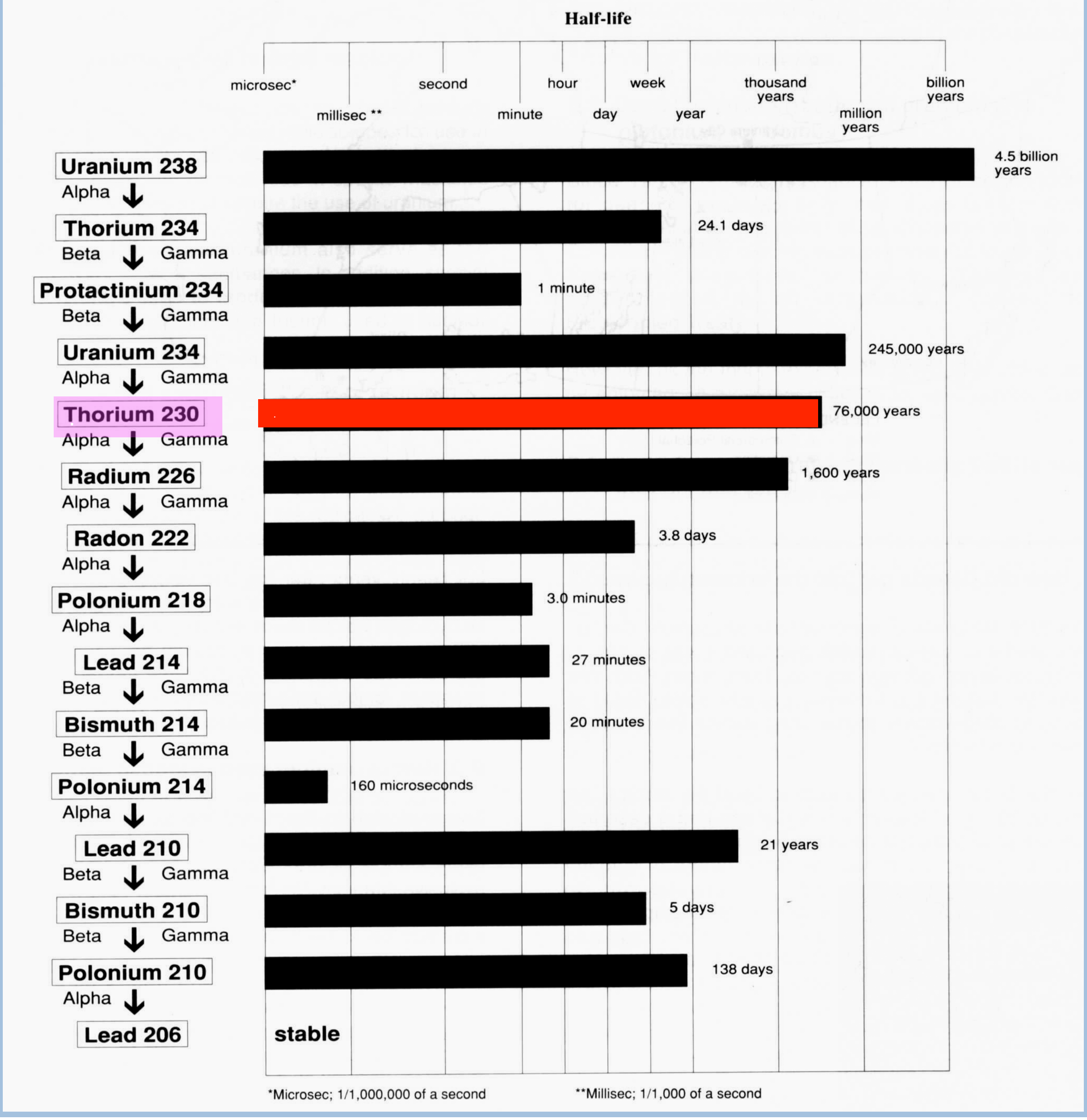
The American Health Physics Society states that up to 90 percent of deaths attributed to smoking are due to polonium-210.



THORIUM-230

Thorium-230 has a 76,000 year half life.

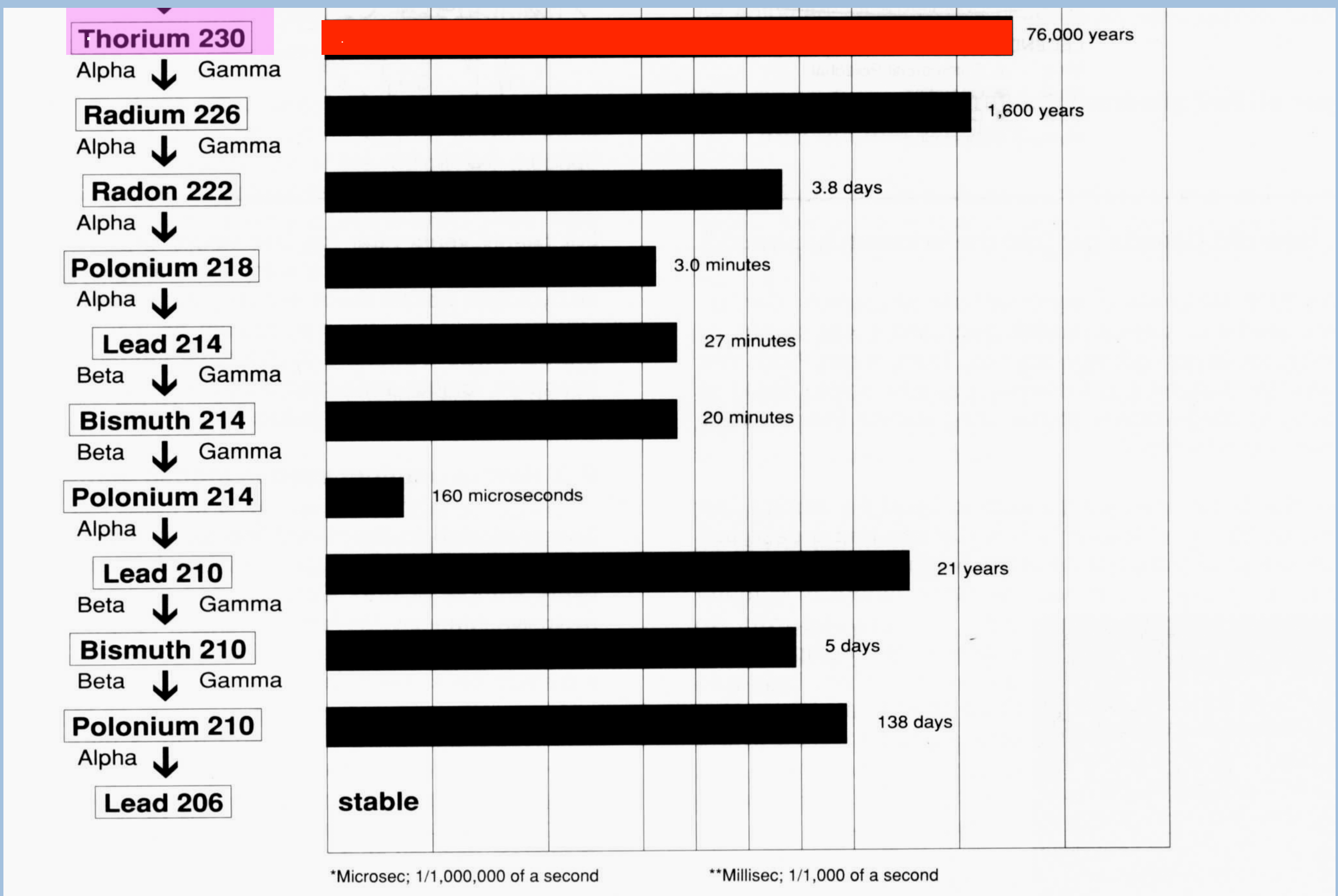
It remains dangerous for at least a million years.



When uranium is extracted,
the radioactive decay products
are left in the mill tailings
as radioactive wastes.

As thorium-230 atoms disintegrate, they continually replenish the supply of radium, radon, and polonium In the tailings.

Thus ALL of these radioactive poisons will remain present for hundreds of thousands of years.



Alpha radiation ~ harmless outside the body, deadly inside.

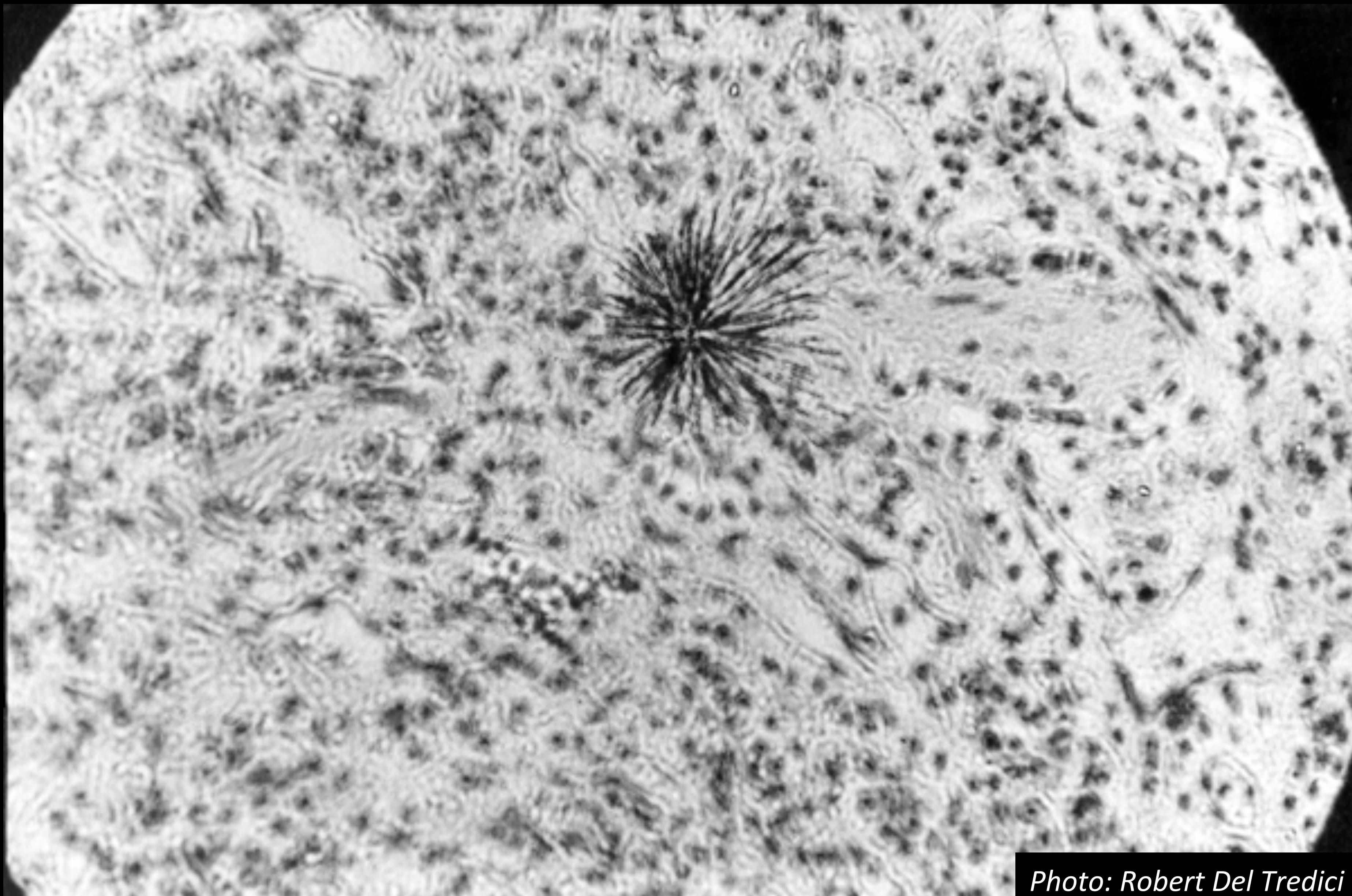
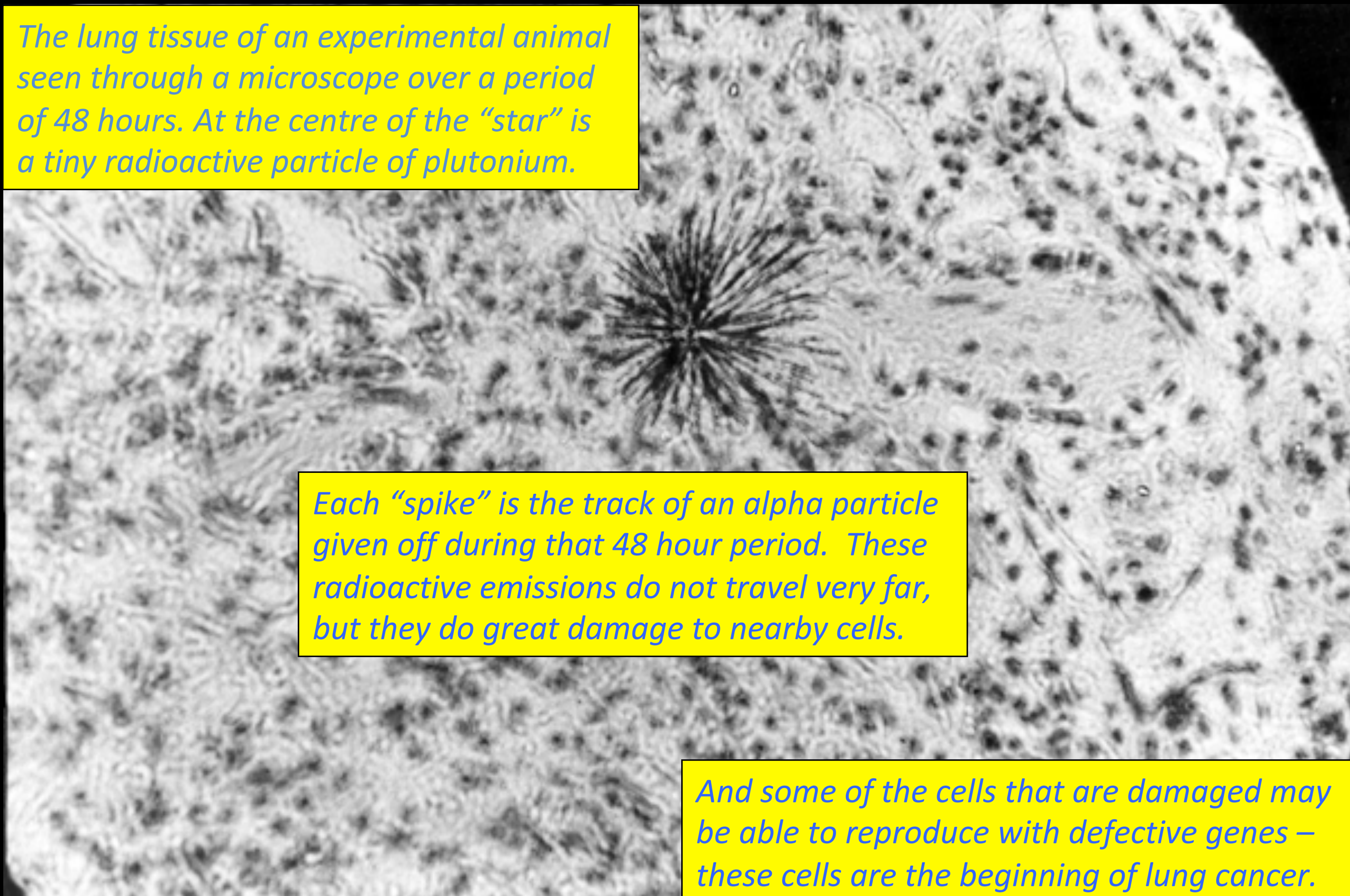


Photo: Robert Del Tredici

Radium, Radon, Polonium, Thorium, Uranium, Plutonium ~ all alpha emitters

Alpha radiation ~ harmless outside the body, deadly inside.



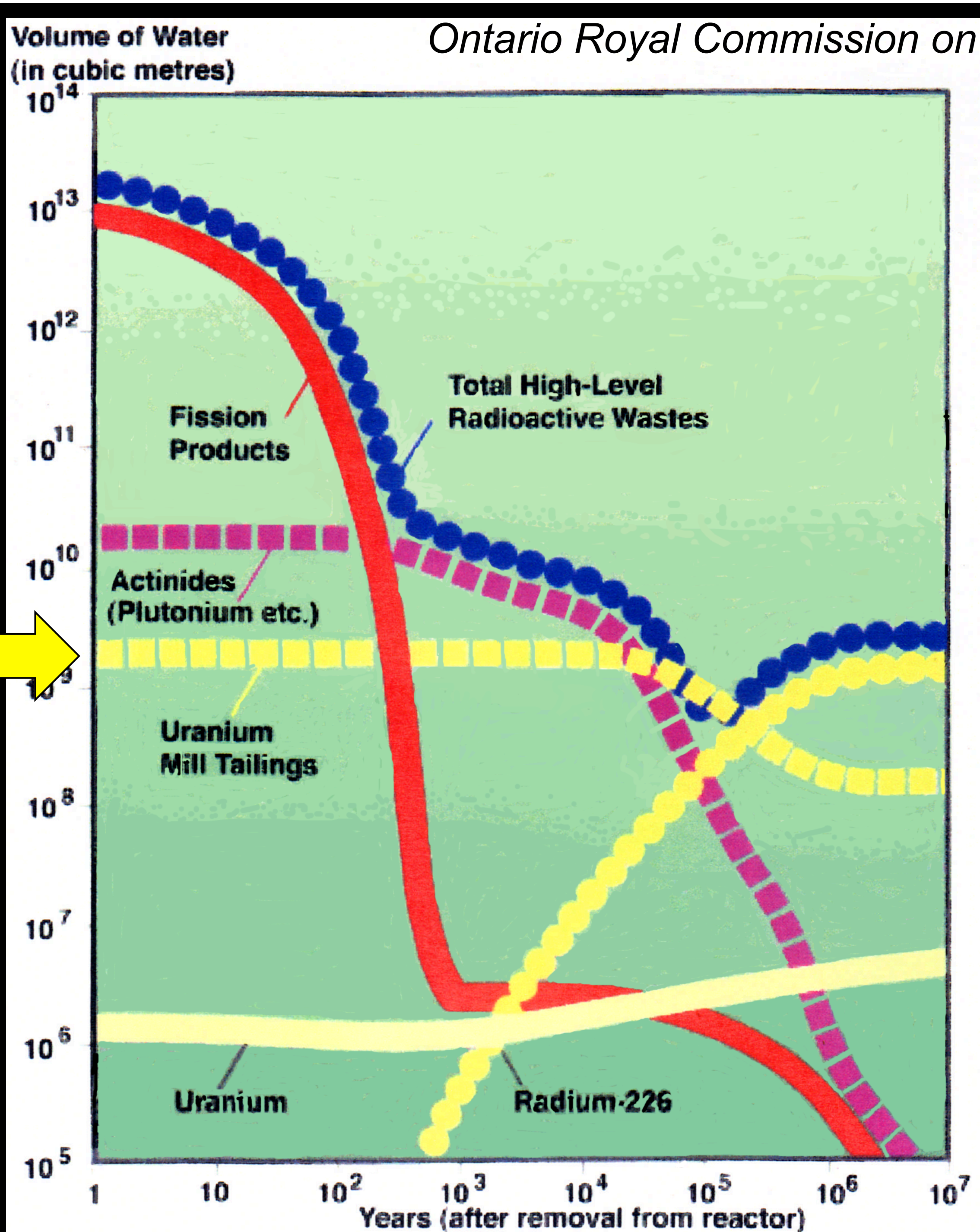
The lung tissue of an experimental animal seen through a microscope over a period of 48 hours. At the centre of the "star" is a tiny radioactive particle of plutonium.

Each "spike" is the track of an alpha particle given off during that 48 hour period. These radioactive emissions do not travel very far, but they do great damage to nearby cells.

And some of the cells that are damaged may be able to reproduce with defective genes – these cells are the beginning of lung cancer.

Radium, Radon, Polonium, Thorium, Uranium, Plutonium ~ all alpha emitters

Ontario Royal Commission on Electric Power Planning (1978)



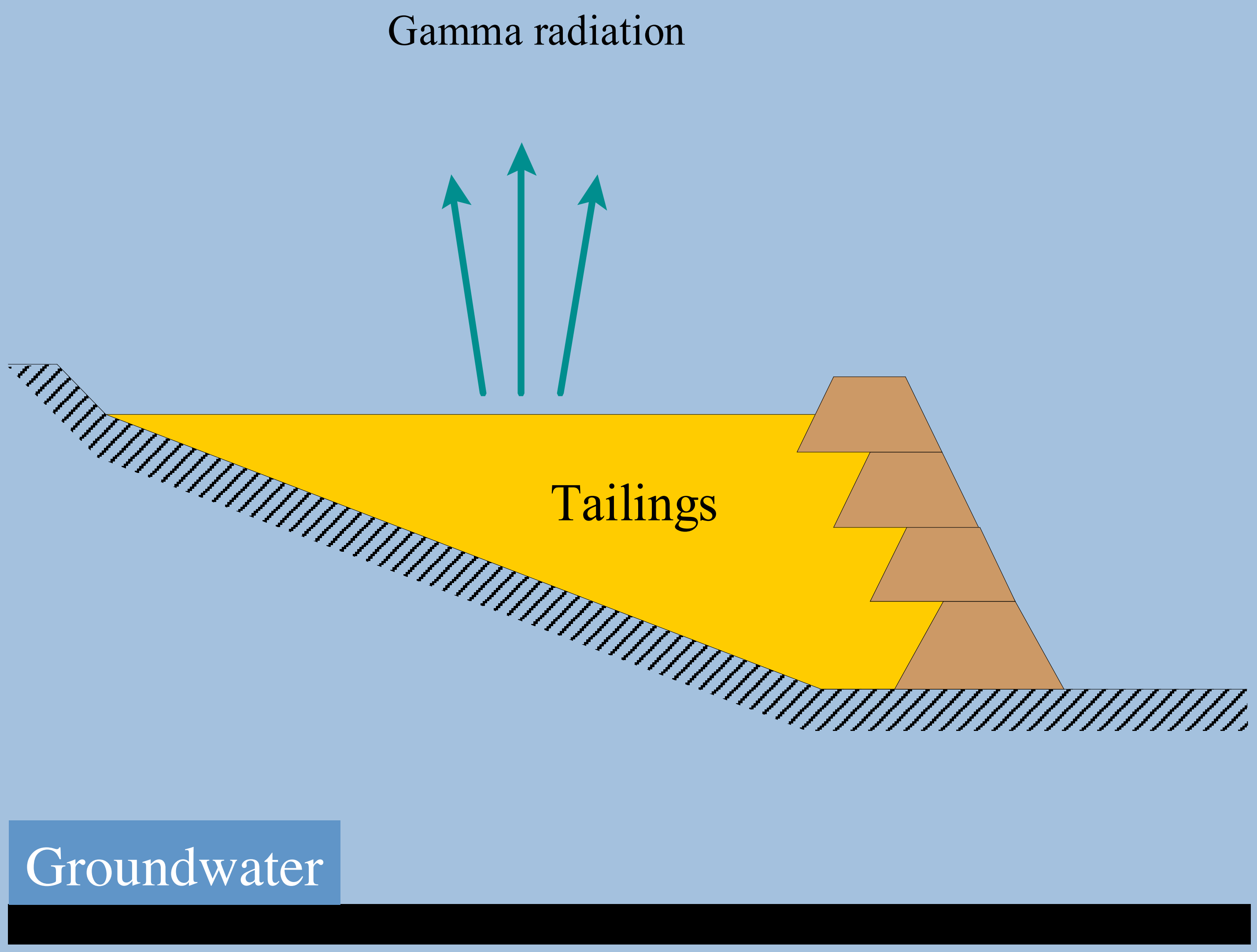
NOTE:
In the long term, U mill tailings are about as toxic as high level waste

The toxicity of uranium mill tailings is indicated by the middle yellow line.

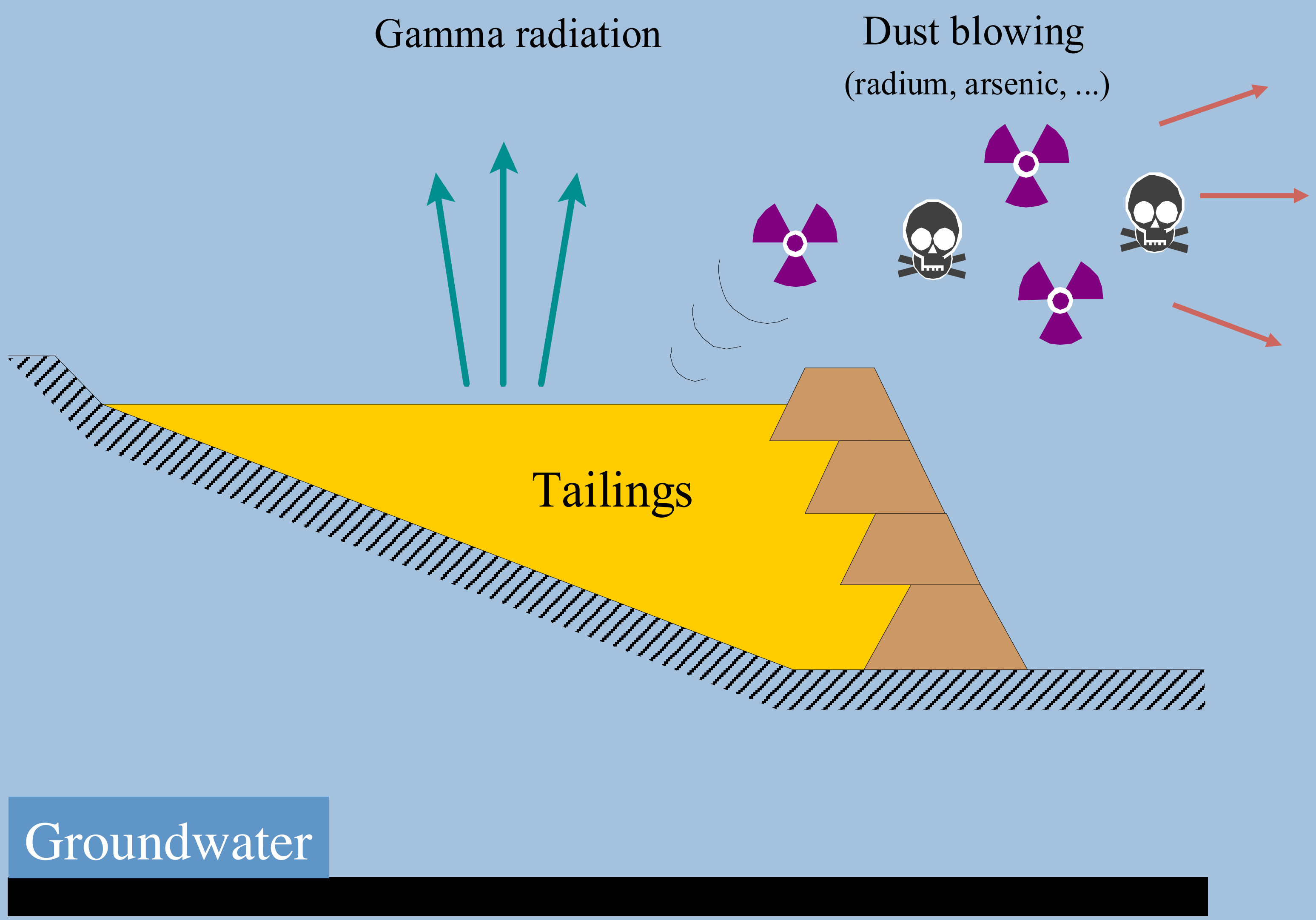
The red and blue lines represent the toxicity of spent nuclear fuel over 10 million years.

from "A Race Against Time", Royal Commission Report, 1978

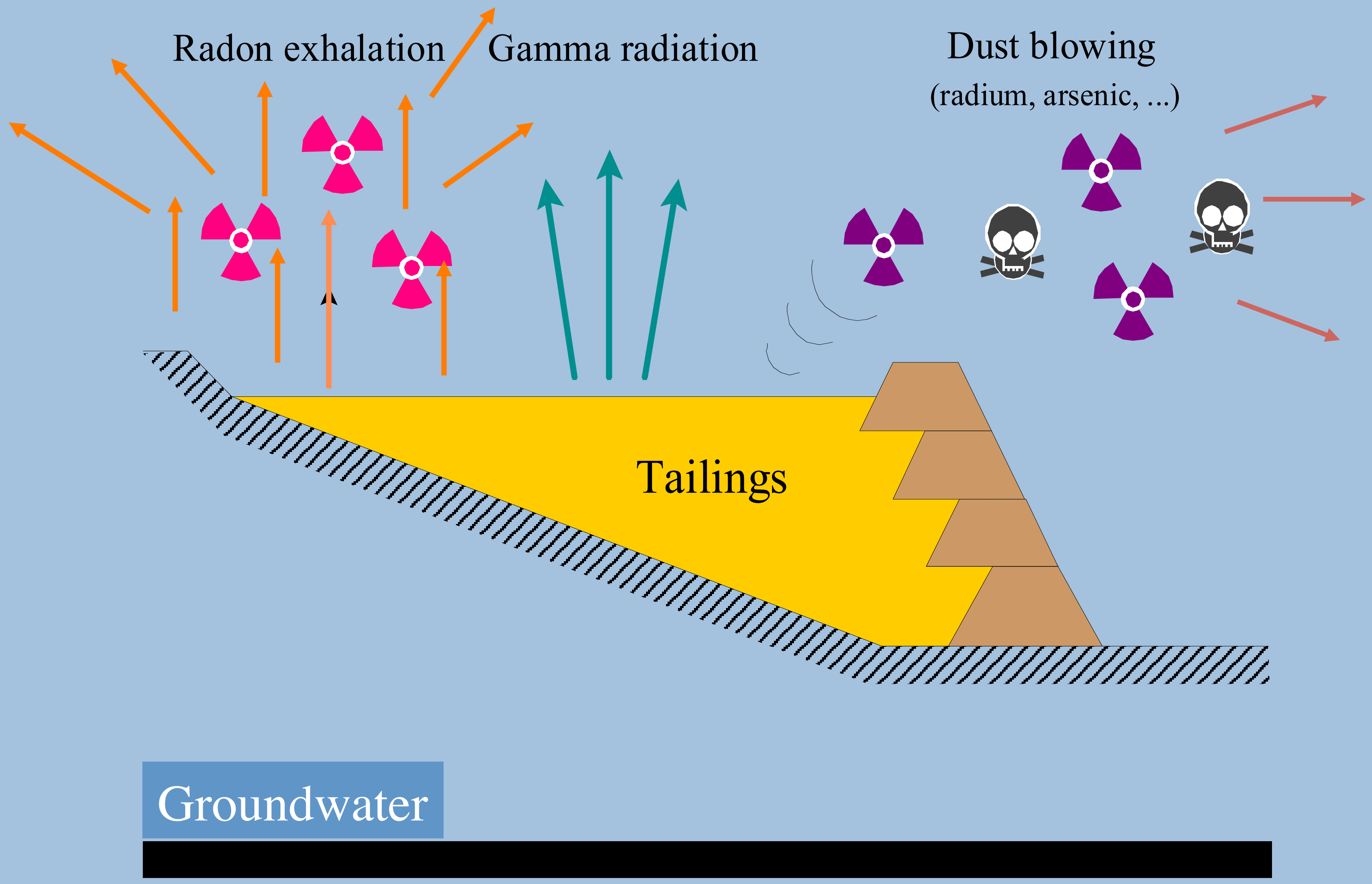
Uranium Mill Tailings Hazards

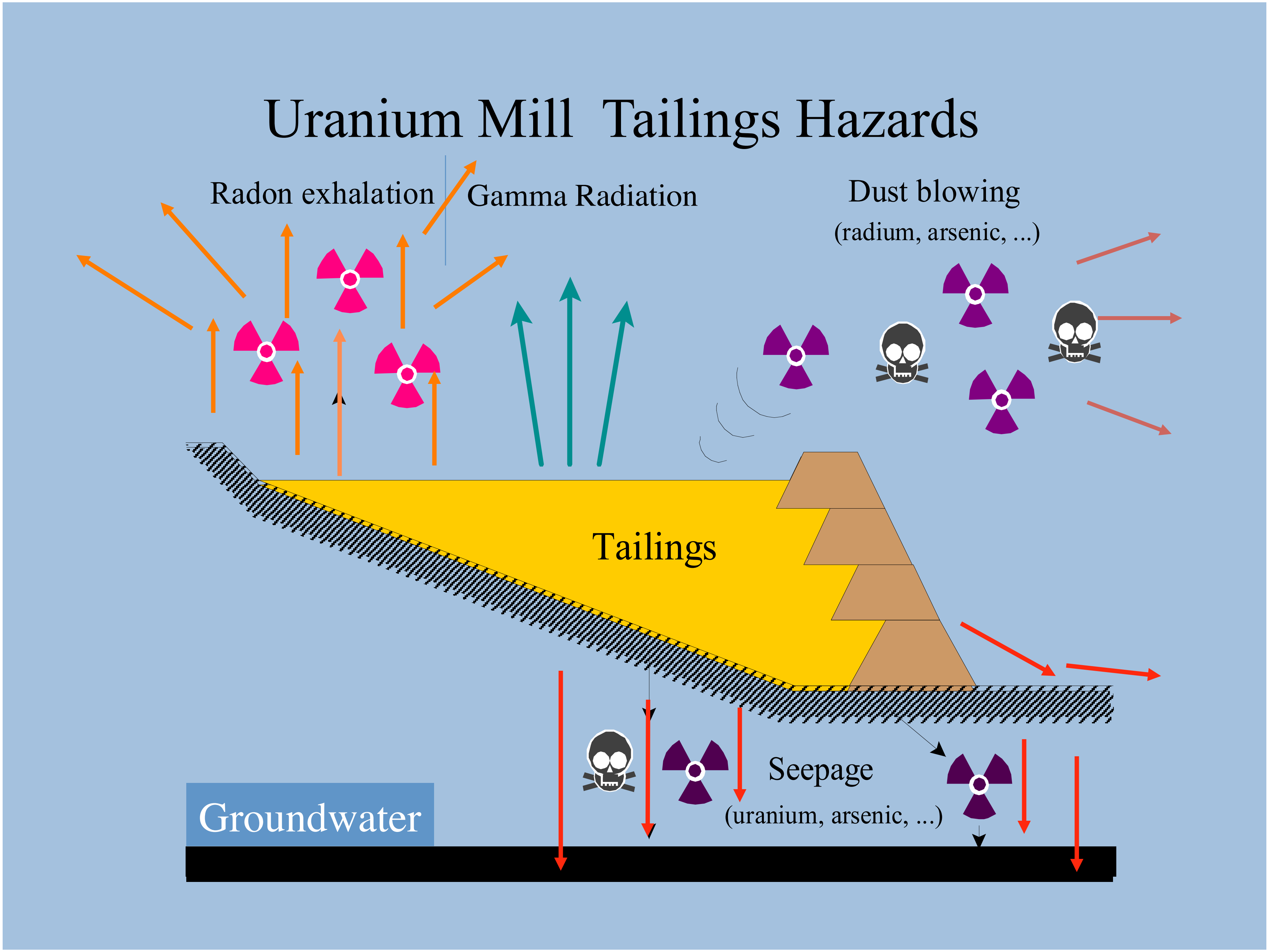


Uranium Mill Tailings Hazards



Uranium Mill Tailings Hazards




Uranium Mill Tailings Hazards
Radon exhalation
Gamma Radiation
Dust blowing
(radium, arsenic, ...)
Tailings
Seepage
(uranium, arsenic, ...)
Groundwater

Nuclear Waste Governance in Canada

6. Other Reactor Wastes

(Low and Intermediate-Level)

LLW & ILW from Reactors

Low Level Wastes

Intermediate Level – short-lived

Intermediate Level – long-lived

Refurbishment & Dismantling Wastes

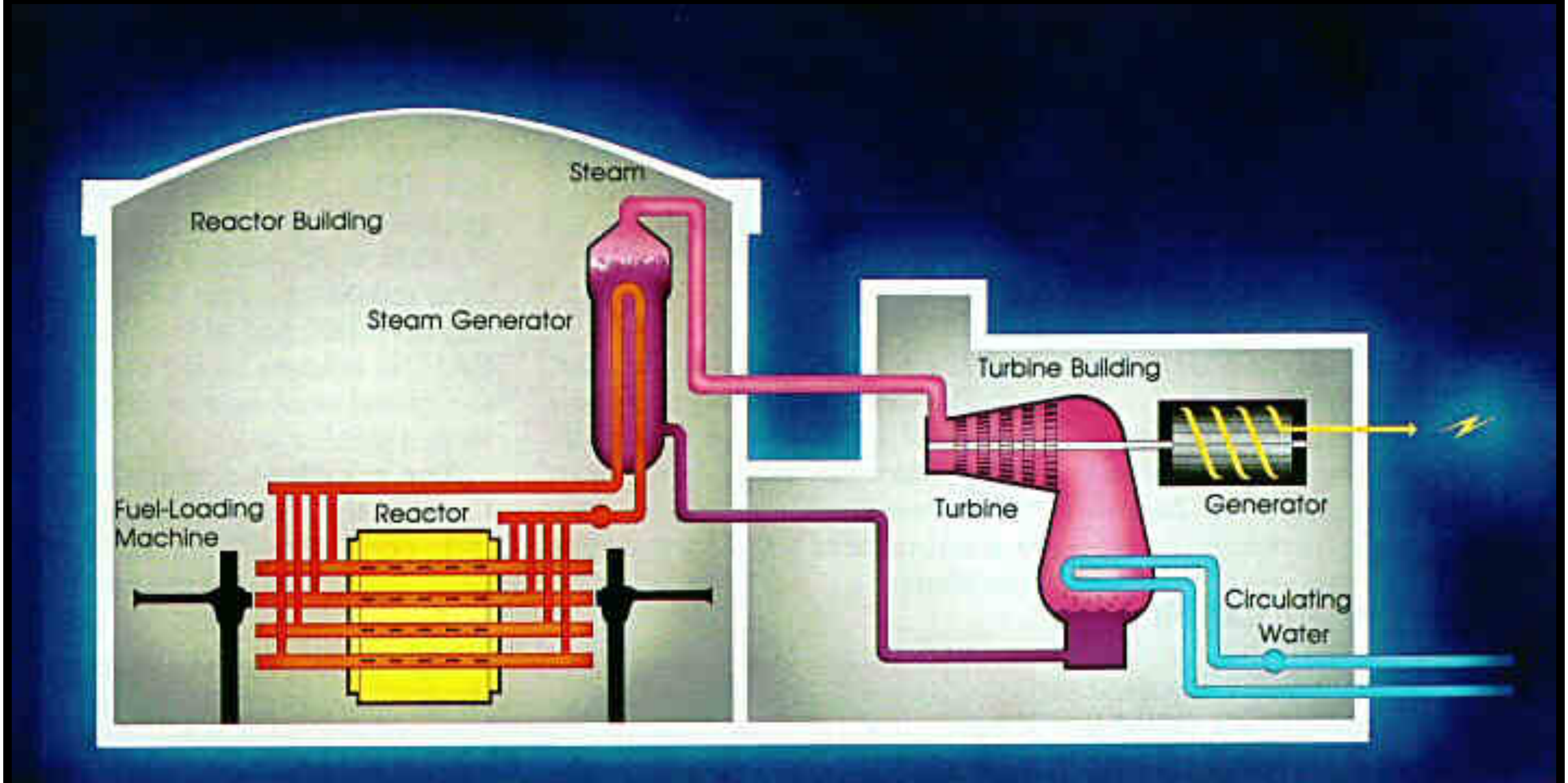
Just One Example

Fission products, activation products, and transuranic elements accumulate in the pipes carrying coolant from core

– ***the same materials as in spent fuel***, but at very much lower concentrations.

All these pipes become radioactive waste.

The CANDU reactor is a "Pressurized Heavy Water Reactor"



Heat from the core goes to the Steam Generator (Boiler).

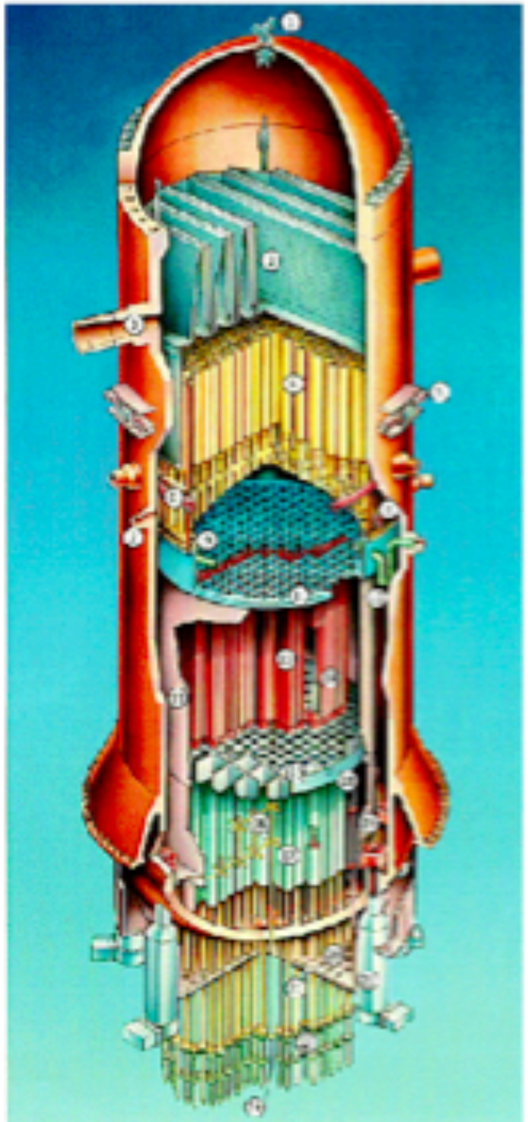
The steam spins a turbine and generates lots of electricity.

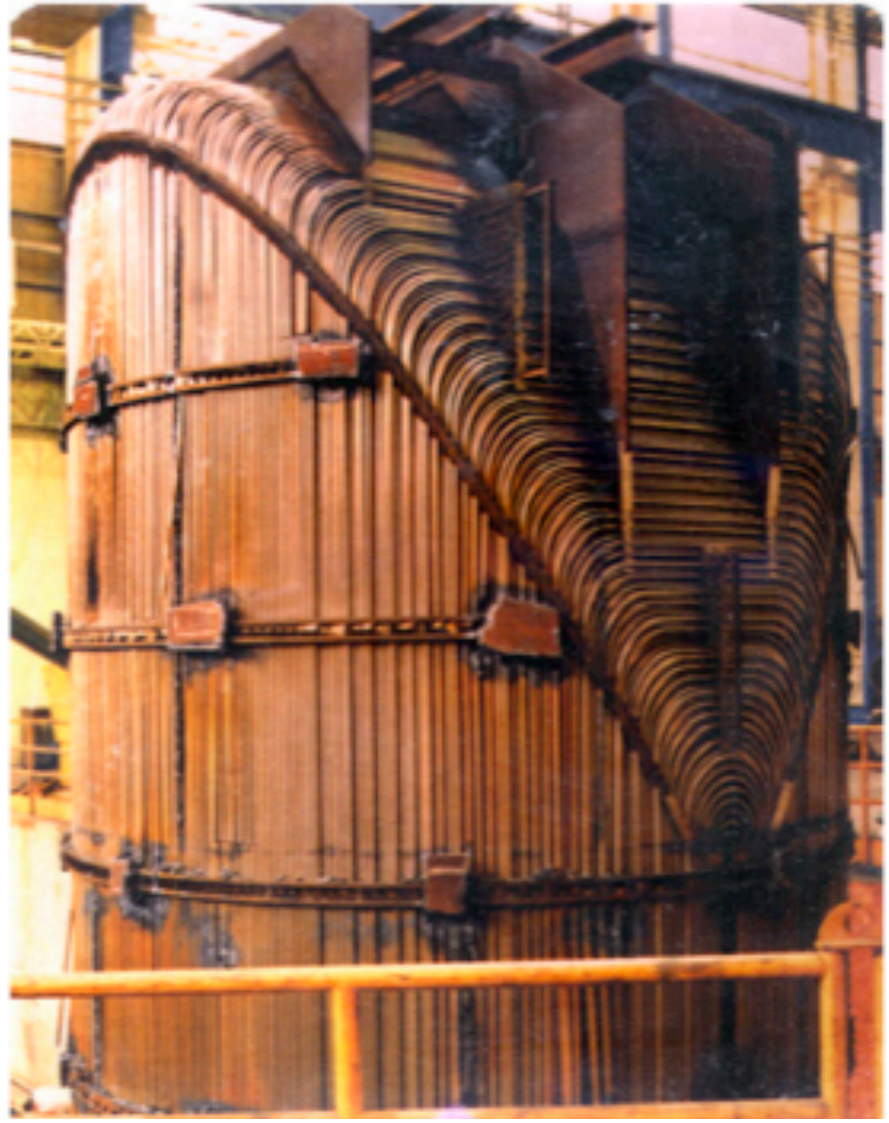
Everything in the red "primary cooling circuit" is very radioactive.

CANDU Steam Generator or Boiler (8 per reactor)

Nuclear Intestines

Inside each of the old steam generators from Bruce reactors are 4200 radioactively contaminated tubes, similar to those shown here.





Plutonium in the Bruce "A" nuclear steam generators

Here is a partial list of radioactive contaminants inside a single used steam generator from each one of the two reactors (Units 1 and 2 of Bruce A), according to CNSC (document CMD-10-H19B). The mass (in grams) of each of the radioactive materials listed is estimated by CNSC staff.

RADIONUCLIDE		***MASS***	
Name of Isotope (with Atomic Mass)	Half-Life (years)	Unit 1 (grams radioactive material)	Unit 2
Americium-241	430 y	0.103412	0.102412
Americium-243	7 400 y	0.002162	0.002432
Carbon-14	5 700 y	0.009065	0.072501
Curium-244	18 y	0.002644	0/000347
Cobalt-60	5.3 y	0.001781	0/000881
Cesium-137	30 y	0/000249	0.000238
Europium-154	8.8 y	0.000027	0.000290
Iron-55	2.7 y	0.000272	0.000290
Hydrogen-3 (Tritium)	13.0 y	0.000057	0.000051
Hafnium-181	2.7 y	0.000001	0.000001
Iodine-129	17 000 000 y	0.000060	0.000060
Niobium-94	20 000 y	0.002159	0.002158
Nickel-59	75 000 y	0.173601	0.036723
Nickel-63	96 y	0.030194	0.006526
Neptunium-237	2 100 000 y	0.028703	0.033295
Plutonium-238	*88 y*	*0.007507*	*0.004703*
Plutonium-239	*24 000 y*	*2.124977*	*2.471769*
Plutonium-240	*6 500 y*	*0.827304*	*0.957105*
Plutonium-241	*14 y*	*0.021309*	*0.030809*
Plutonium-242	*380 000 y*	*0.048762*	*0.056317*
Antimony-125	2.8 y	0.000001	0.000001
Strontium-90	29 y	0.009097	0.007581
Technetium-99	210 000 y	0.000143	0.000092
TOTALS			
Long-lived (> one year half-life)		**3.416108**	**3.787315**
Mass of plutonium isotopes only		**3.029859**	**3.520703**
Percent plutonium		**88.7%**	**93.0%**
	TOTAL MASS		
		(Source: CNSC)	

There are 5 plutonium isotopes present in the steam generators.
In addition there are 18 other long-lived isotopes listed.

Inside each steam generator:

8 radionuclides	half-lives	>1,000,000 years
13 radionuclides	half-lives	>100,000 years
19 radionuclides	half-lives	>1,000 years
21 radionuclides	half-lives	>100 years

Includes 5 different varieties of plutonium.

There are about 18 grams of plutonium-239 in

8 Bruce steam generators (from one reactor).

In principle, that

is enough to overdose

over 25 million atomic workers

FREE RELEASE OF NUCLEAR WASTE

"recycling of contaminated metal"

To reduce its nuclear waste volume, Bruce Power plans to ship 16 radioactive steam generators (from 2 of its 8 reactors) to Sweden, for Studsvik to "recycle" the contaminated metal.

During public hearings Studsvik said the contaminated metal would go to another company they would not name, who would blend it in a 1 to 10 ratio with uncontaminated metal. The blend is then sold, without labelling, as "clean" scrap metal suitable for unrestricted use. This practice is called 'free release'.

Hundreds of municipalities in Canada and the USA pass resolutions opposing this plan, whereby man-made nuclear waste products would end up in consumer goods. First Nations also express strong opposition to the proposed transport.

THE SHIPMENTS WERE STOPPED

the steam generators remain on-site

Although Bruce Power obtained all necessary approvals to proceed with the shipments, the steam generators never went to Sweden – because of massive public opposition.

*Instead of "recycling contaminated metal" the project was seen as "contaminating recycled metal" – and it was **stopped**.*

"contamination of recycled metal"

The Steel Manufacturing Association strongly opposes any radioactive contamination of recycled metal, and the UN declares the practice to be an alarming one.

Yet "free release" is already occurring in Europe because the population is "asleep at the switch". This should be addressed.

BUT:

Where will they Dump all the Nuclear Wastes?

With or without "free release" there is a large volume of nuclear waste from reactor operations and decommissioning – radioactive waste that will remain dangerous for hundreds of thousands of years.

In Ontario, consideration is being given to a DGR beside Lake Huron for such nuclear waste:

A Great Lakes Dump For Nuclear Wastes?

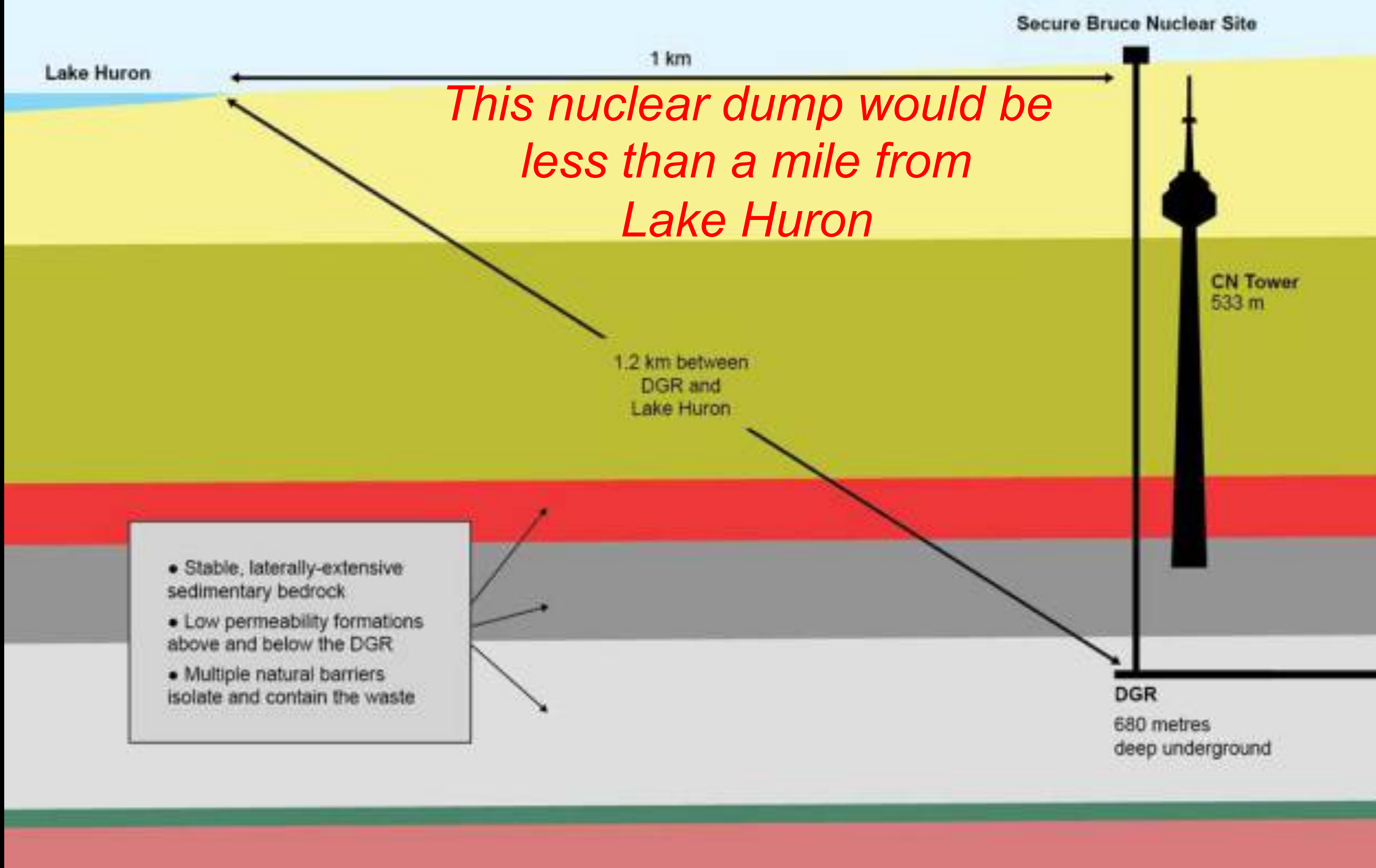
Georgian Bay
Nottawasaga Bay
Collingwood
Owen Sound
Lake Huron
Deep Geologic Repository
for Low and Intermediate Level
Radioactive Waste
Kincardine
Goderich
Quebec
Québec
Ontario
N
0 15 30 60 km

Municipalities in Ontario and Michigan have passed resolutions opposing the plan . . .

. . . to abandon all nuclear waste (except spent fuel) from all of Ontario's 20 nuclear reactors in a DGR within a mile of Lake Huron.

KOFI MYLER/DETROIT FREE PRESS

DGR = “Deep Geological Repository” for LILW Nuclear Waste



The concept of
Rolling Stewardship
is also being invoked
for the currently proposed
Great Lakes Nuclear Dump.

Public environmental hearings are
conducted under the auspices of the
Canadian Nuclear Safety Commission
(Canada's nuclear regulator) as well as the
Canadian Environmental Assessment Agency.

Q: Should society be ABANDONING nuclear waste?
Or should we accept the responsibility to MANAGE it?

The End

Thank You!

www.ccnr.org