Uranium, Radioactivity, and Ionizing Radiation

A Slide Show

Prepared for the

Nuclearisation of Africa Symposium

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Lesson One

radioactivity is a form of
nuclear energy

it was discovered 120 years ago
by Henri Becquerel

the unit of radioactivity
is called a “becquerel”

What is Nuclear Energy?

Every atom has a tiny core called the NUCLEUS.
It is surrounded by one or more orbiting electrons.

Chemical energy involves only the outer electrons.

Battlefield explosion

Forest fire

Nuclear energy comes directly from the nucleus – it is millions of times more powerful than chemical energy.

H-Bomb Blast

TWO VERY DIFFERENT types of nuclear energy :

RADIOACTIVITY –
nuclei spontaneously "disintegrate"
(think of "clicks" on a Geiger counter)
DISCOVERED : 1896 by Henri Becquerel

NUCLEAR FISSION –
nuclei are "split" by neutrons
(think of A-Bombs & nuclear reactors)
DISCOVERED : Dec 1938 – Jan 1939

Radioactivity is unstoppable. Nobody knows how to shut it off. We can't speed it up, or slow it down. It just happens.

Nuclear Fission can be speeded up, slowed down, stopped and restarted by controlling the number of neutrons.

Nuclear fission creates
hundreds of new materials
that are intensely radioactive

that's why we have
a nuclear waste problem . . .

Radioactive contamination at West Valley NY from nuclear fuel waste


Detecting radioactivity requires special equipment & protection

. . . and nobody knows
how to shut off radioactivity

if we could only turn it off
there would be no problem

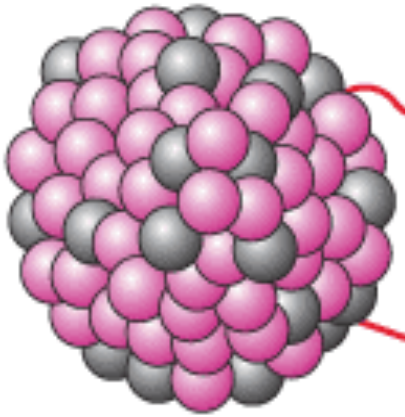
Lesson Two

a radioactive atom is unstable

it will disintegrate
suddenly and violently

giving off "atomic radiation"

Radioactive Disintegration



Energy

Radioactive Atom

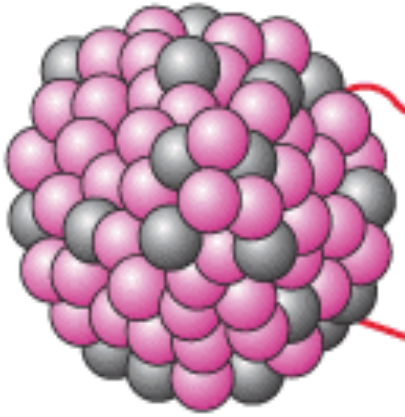
The nucleus disintegrates giving off 1 or 2 projectiles

"Atomic Radiation"

Particle

A radioactive atom has an unstable nucleus. It will suddenly disintegrate, giving off a highly energetic particle and/or a photon of energy. These emissions are damaging to living cells.

Three types of emissions: Alpha, Beta and Gamma



Radioactive Atom

(also called a radionuclide)

gamma

(sometimes)

Energy

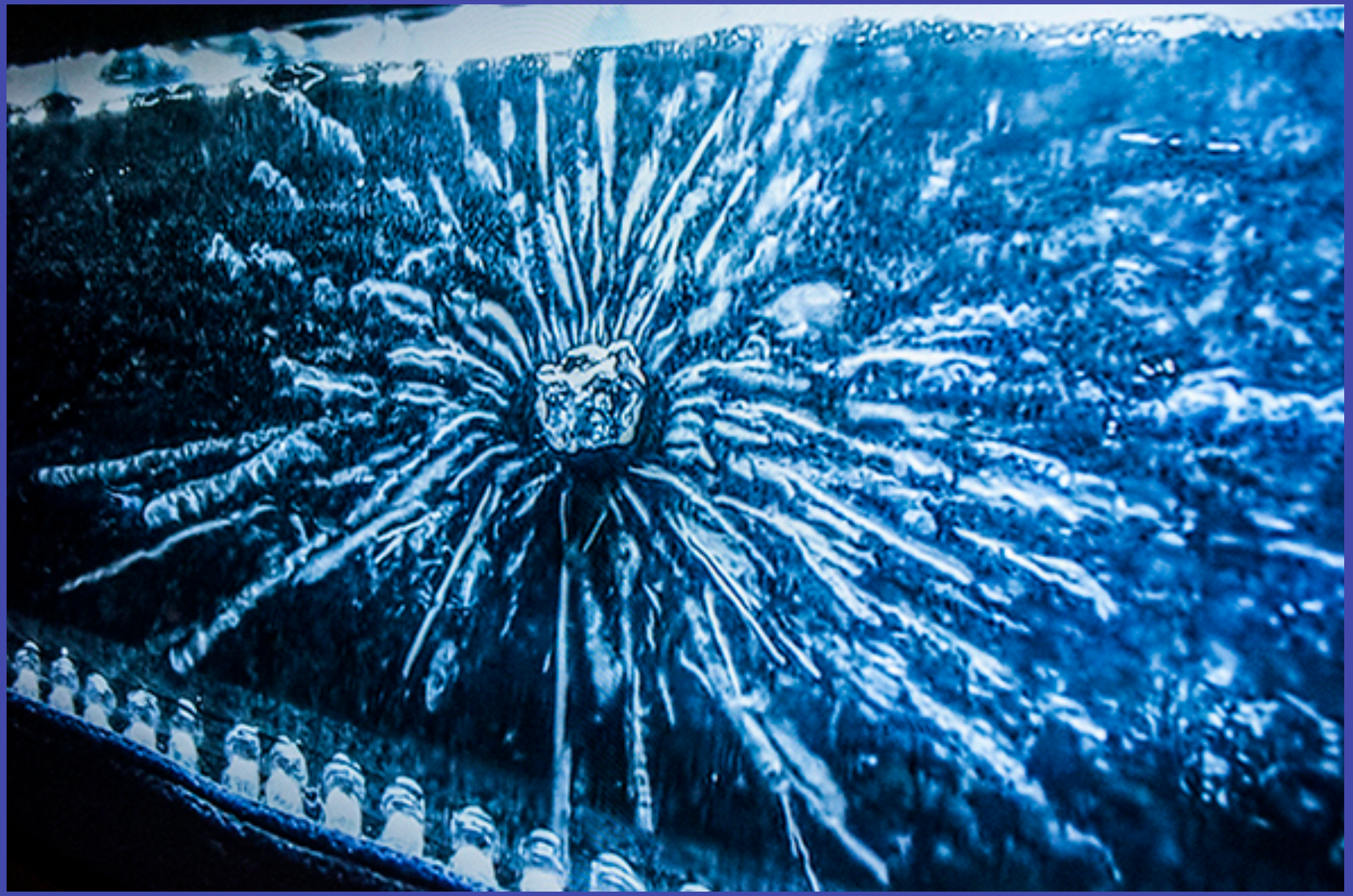
alpha or beta

(always)

Particle

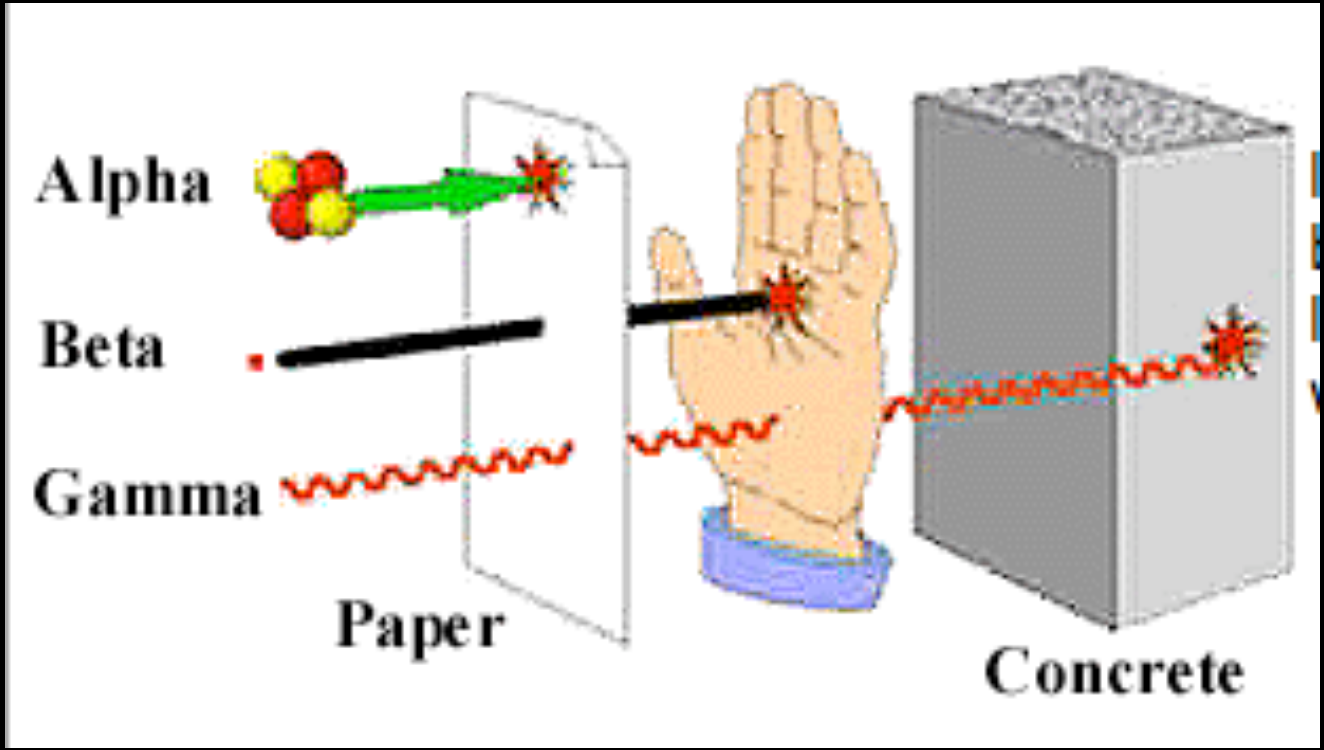
"Atomic Radiation"

Every radionuclide emits either an alpha or a beta particle.
Such particles are electrically charged and move very fast.
In some cases a powerful gamma ray is also given off.
All three forms of atomic radiation damage living cells.



In a “cloud chamber” you can see the tracks of all 3 types of emissions from uranium ore

Alpha particles can be stopped by a sheet of paper.
Alpha emitters are harmless outside the body, but
exceedingly dangerous when ingested or inhaled.



Beta particles penetrate only part-way.
They can damage eyes or skin externally.
But the main danger is internal exposure.

Gamma rays are highly penetrating.
They give "whole body" radiation.
Heavy shielding is often needed.

A gamma ray is like an x-ray, but more powerful.
highly penetrating ~ most easily detected

A beta particle is like a sub-atomic bullet.
moderately penetrating ~ harder to detect

An alpha particle is like a subatomic cannon ball.
least penetrating, but most damaging ~ often undetected

Alpha and Beta particles are INTERNAL hazards.
Gamma rays are both internal & external hazards..

Lesson Three

radioactive elements have distinct
pathways through the human body

radioactivity breaks chemical bonds
creating molecular fragments (called ions)
– for this reason atomic radiation
is called "ionizing radiation"

when DNA molecules are so damaged
the altered cells develop abnormally

Radioactive Materials are chemical substances which are also radioactive.

They all have their own unique pathways through the environment and through the human body.

RADIOACTIVE CONTAMINATION

THYROID
iodine–131
beta (gamma) ; 8 days

SKIN
sulphur–35
beta ; 87 days

LIVER
cobalt–60
beta (gamma) ; 5 years

OVARIES
iodine–131
beta (gamma) ; 8 days
cobalt–60
beta (gamma) ; 5 years
krypton-85
gamma ; 10 years
ruthenium–106
gamma ; 1 year
zinc–65
gamma ; 245 days
barium–140
gamma ; 13 days
potassium–42
gamma ; 12 hours
cesium–137
gamma ; 30 years
plutonium–239
alpha ; 24 000 years

MUSCLE
potassium–42
gamma ; 12 hours
cesium–137
gamma ; 30 years

LUNGS
radon–222 (and whole body)
alpha ; 3,8 days
uranium–233 (et os)
alpha ; 162 000 years
plutonium–239 (and bone)
alpha ; 24 000 years

SPLEEN
polonium–210 (and whole body)
alpha ; 138 days

KIDNEYS
uranium–238 (and bone)
alpha ; 4 500 000 years
ruthenium–106
gamma (beta) ; 1 year

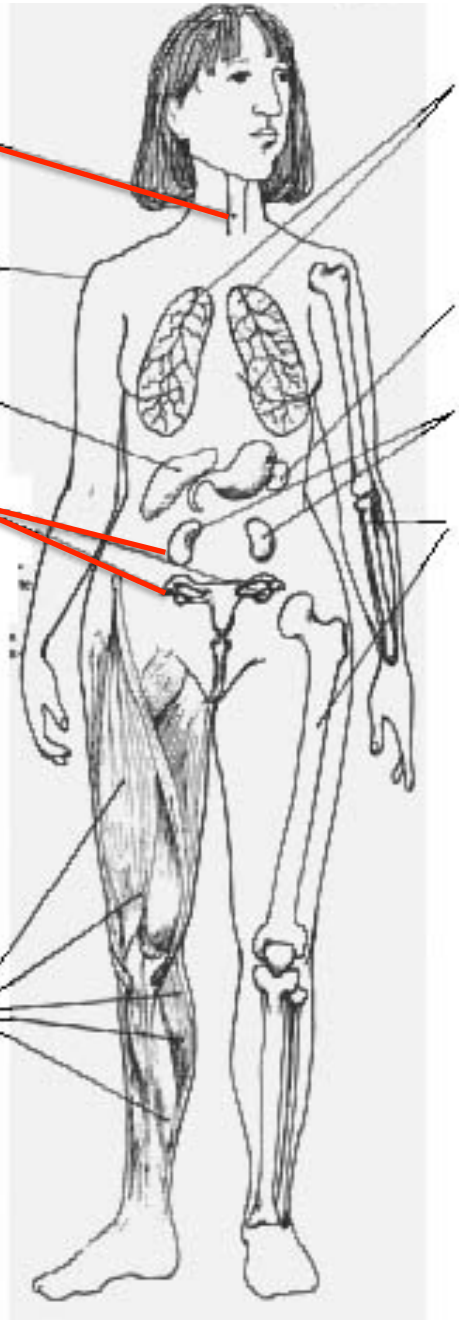
BONE
radium–226
alpha ; 1 620 years
zinc–65
gamma ; 245 days
strontium–90
beta ; 28 years
yttrium–90
beta ; 64 hours
promethiium–147
beta ; 2 years
barium–140
beta (gamma) ; 13 days
thorium–234
beta ; 24,1 days
phosphorus–32
beta ; 14 days
carbon–14 (and fat)
beta ; 5 600 years

RADIOACTIVE CONTAMINATION

Iodine-131 goes to the thyroid gland (in the throat) and damages it.

thyroid cancer, mental retardation, stunted growth, can be caused.

young children are especially at risk.



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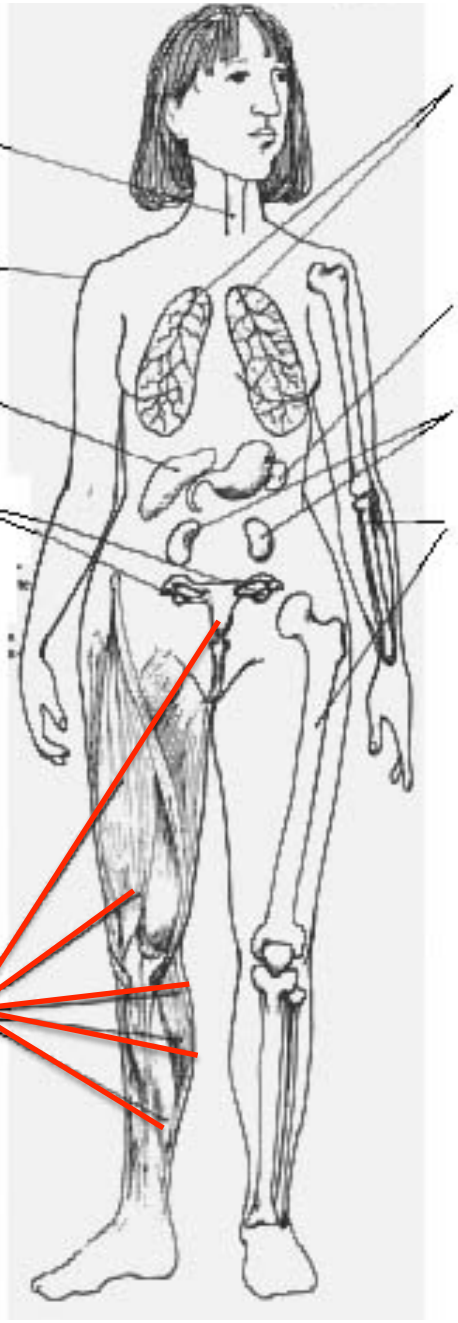
RADIOACTIVE CONTAMINATION

Cesium-137 behaves like potassium, going to the blood and soft tissues

it makes meat unfit for human consumption

it stays in the food chain for decades



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RADIOACTIVE CONTAMINATION

Strontium-90 behaves like calcium; it goes to the bones, the teeth and mother´s milk

bone cancer or blood diseases may result

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Lesson Four

chronic exposure
increases the incidence of
cancer, leukemia, genetic damage,
strokes, heart attacks, other blood diseases
and low intelligence in young children

…but there is a "latency period";
the onset of disease may occur years
or decades after exposure

Marie Curie 1898

discovered radium and polonium,
-- two of the “decay products” of uranium

Girls hired to use radioactive paint to make numerals on watch dials glow in the dark …

… ingested minute amounts of radium when they licked the tips of their brushes to get a very fine point .

Radium Dial Painters 1920

radium-226

deaths from
Fatal anemia
Bone cancer
Head cancer

Deaths of Radium Dial Painters

from ingesting minute amounts of radium

Fatal anemias

Bone cancers

Head cancers

radium is a bone-seeker

radium (like calcium) – goes to **bones and teeth**

dial painters developed severe dental damage called "**radium jaw**"

radium also damaged **blood-forming organs** in their bone marrow

many **died of anemia** (as did Marie Curie and her daughter Irene) and others **of bone cancer**

radon gas (produced by radium) was **carried by blood to the head** and caused cancers there

Alexander Litvinenko 2006

polonium-210

murdered by polonium poisoning in London England
(a tiny amount added to a cup of tea)

polonium is chemically similar to potassium – it attaches itself to the **red blood** corpuscles …

polonium travels throughout the body damaging **soft organs** …

polonium is 250 billion times **more toxic than hydrogen cyanide** …

polonium is the only material that can deliver a dose of **whole-body alpha radiation**…

polonium is produced by the **disintegration of radon** atoms …

American Health Physics Society

polonium-210

is probably the cause of

up to 90 percent of the deaths

attributed to tobacco

(lung cancers, heart attacks, strokes)

polonium is a blood-seeker

radon gas from soil and uranium-rich fertilizer builds up under a canopy of tobacco leaves …

radon disintegrates to form radioactive **lead-210 that sticks to the resinous hairs on tobacco leaves** …

harvested tobacco has very minute amounts of radioactive lead-210 …

lead-210 disintegrates to form polonium-210 that is inhaled by smoker …

polonium-210 **damages the lung** to cause cancer and **enters the blood** to cause strokes and heart attacks…

Los Alamos National Laboratory's Chemistry Division

http://periodic.lanl.gov/elements/84.html

Polonium-210

Weight by weight

it is about 250 billion times

as toxic as hydrogen cyanide.

Underground Miner (Navajo)
with lung cancer

Radon Gas

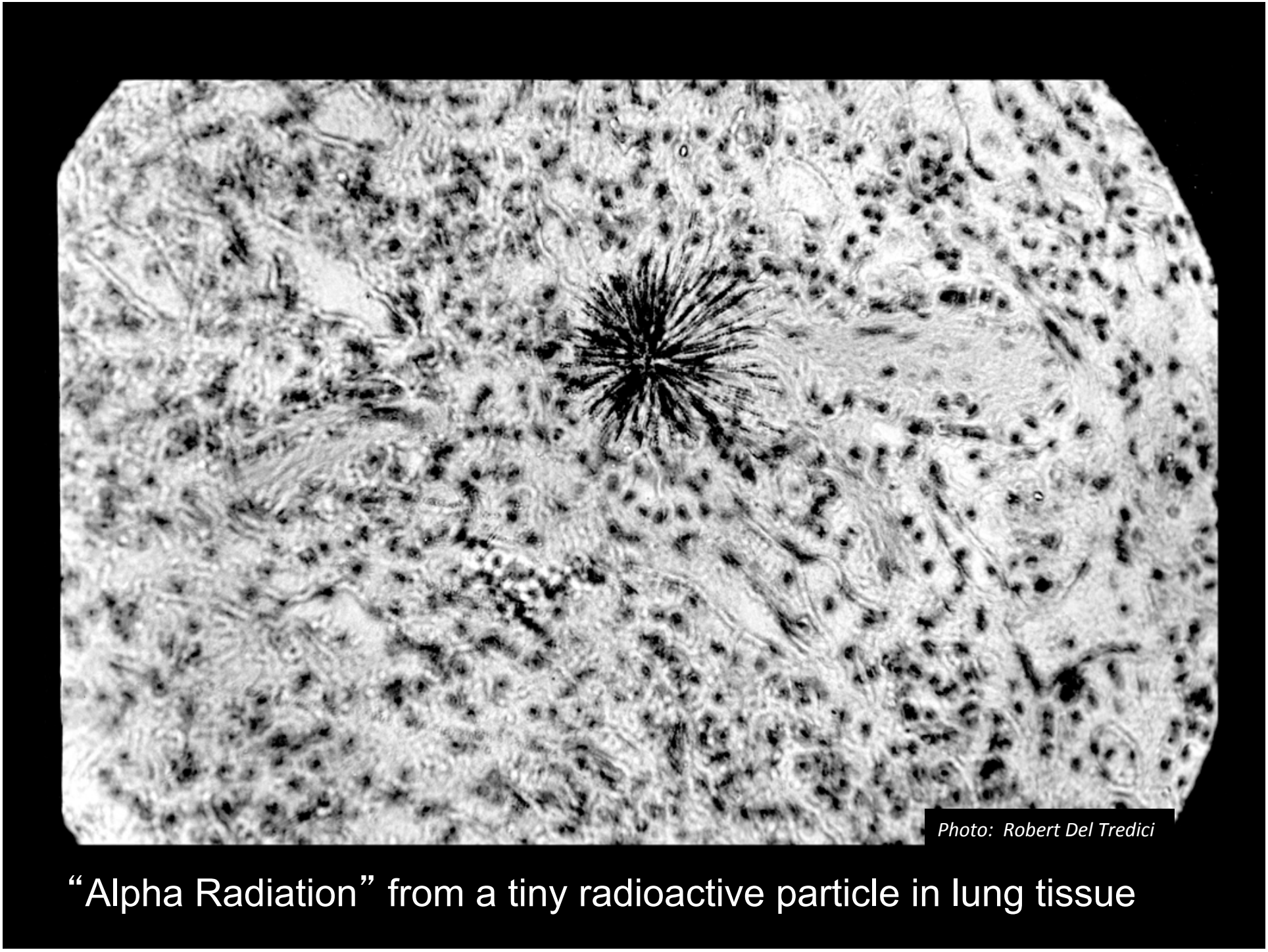
radioactive **radon gas** is produced when radium atoms disintegrate

radon is the leading cause of **lung cancer** among non-smokers

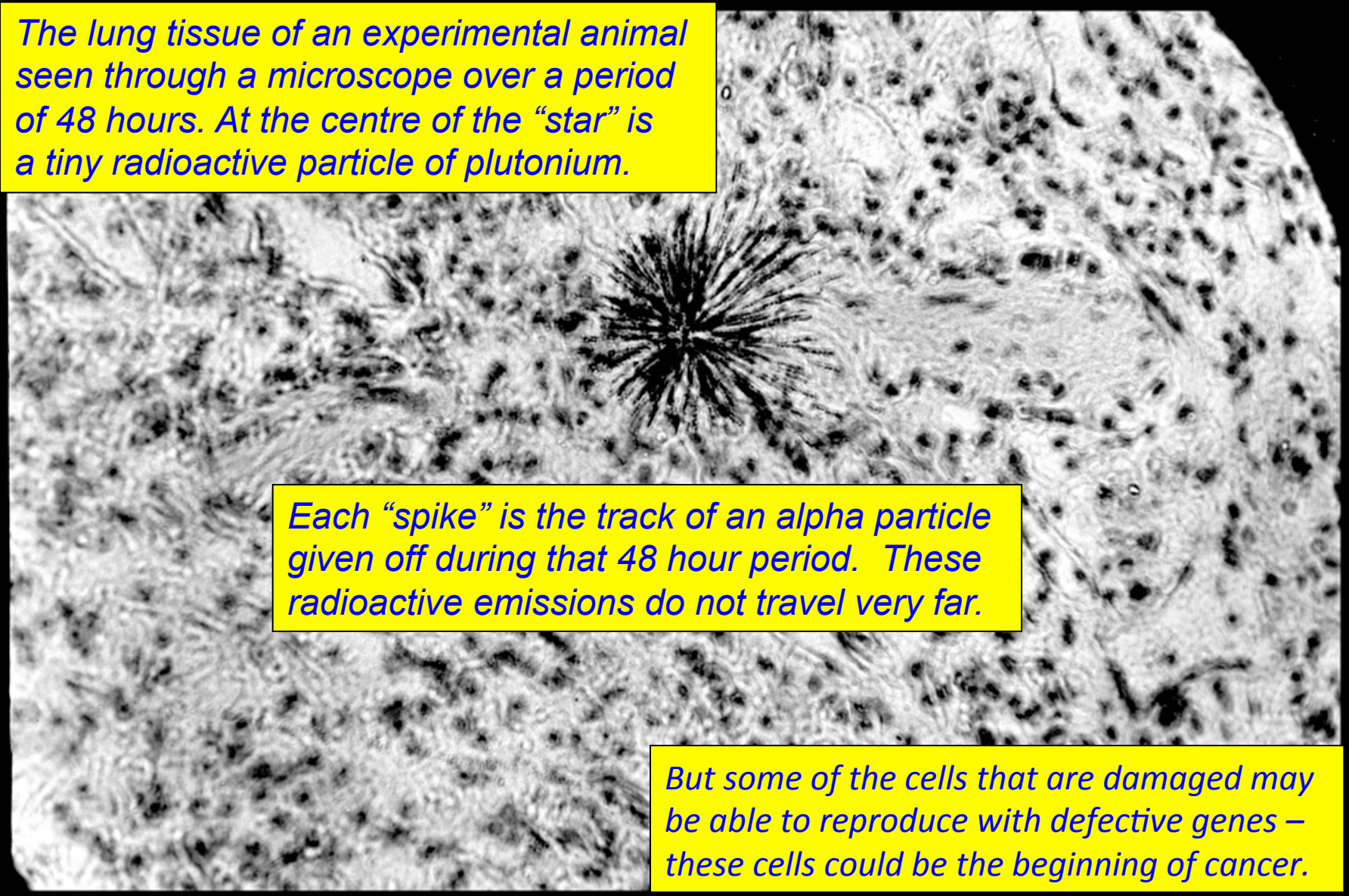
radon causes lung cancers and other lung diseases in **uranium miners**

radon gas deposits solid **radioactive materials** in lung tissue

radon is seven times **heavier than air** and travels great distances …



"Alpha Radiation" from a tiny radioactive particle in lung tissue



Alpha radiation ~ harmless outside the body, deadly inside.

by the way . . .

these deadly radionuclides

~ radium, radon, and polonium ~

are all alpha emitters

harmless outside the body,
but deadly inside

uranium and plutonium
are also alpha emitters

Lesson Five

The incidence of disease depends on the "population dose".

The larger the population the larger the number of cases of illness.

The "Linear Non-Threshold" Model applies.

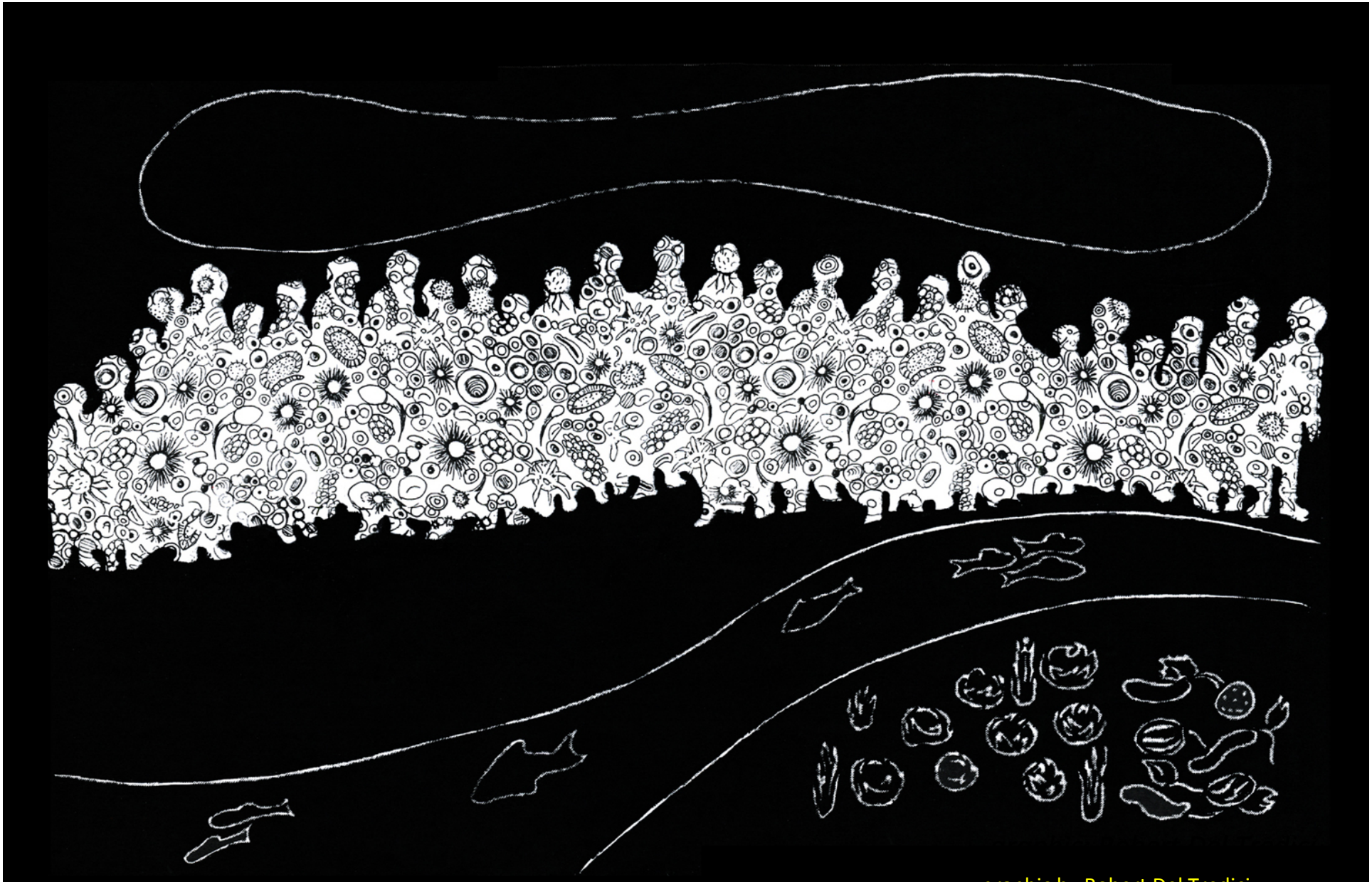
The health of a population depends on clean air to breathe, unpolluted water to drink, and wholesome food to eat.

Radioactive materials enter into the air, water and soil.
They get into fish, plants, animals, and humans.

A small fraction of the population will develop cancer, years later. Infants and children are especially vulnerable.

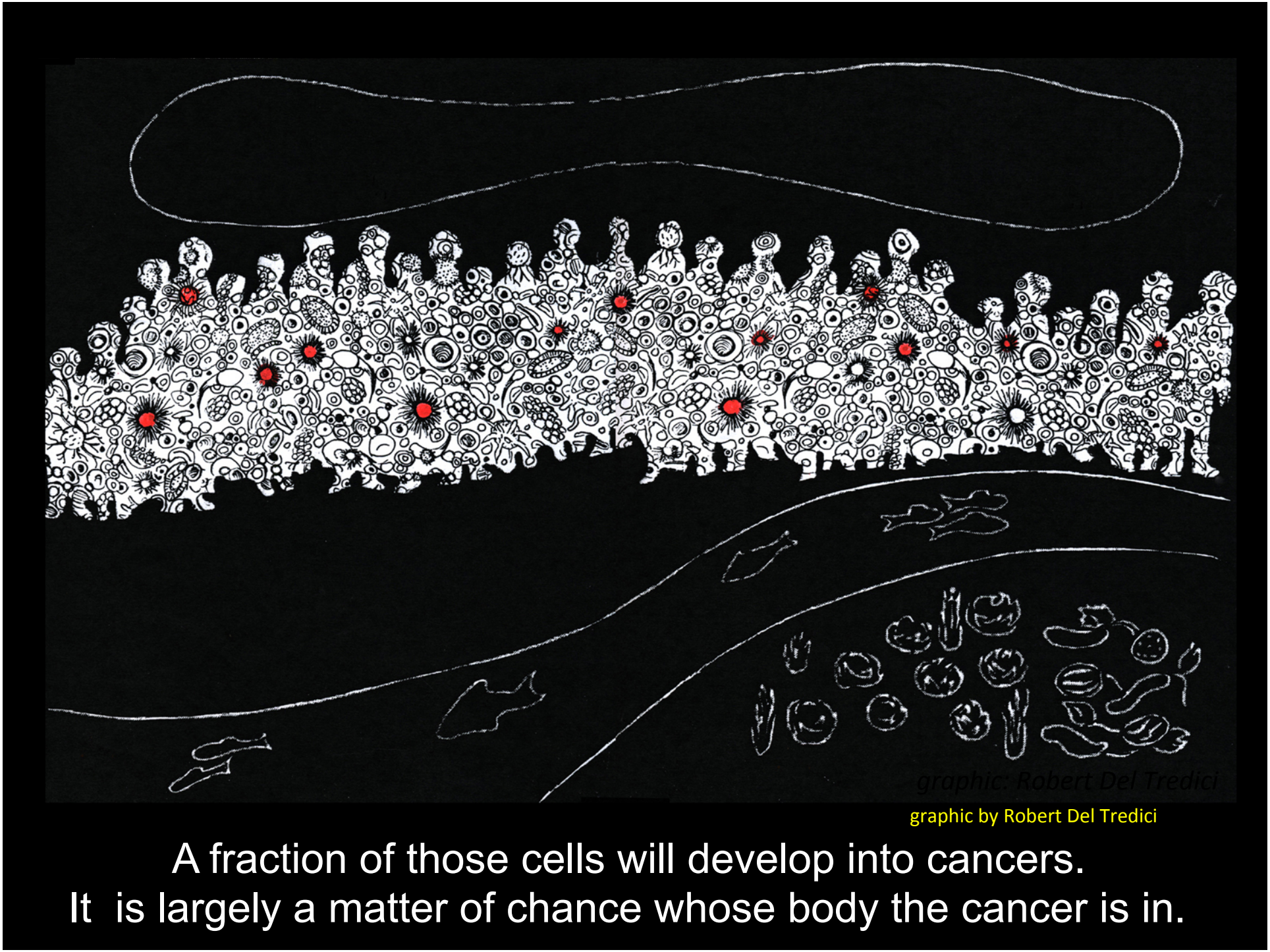
If a larger population is exposed to the same level of contamination, we say that the “population dose” is greater.

The greater the population dose, the more cases of adverse heath effects – like cancer – will be seen.



graphic by Robert Del Tredici

At low levels, radioactivity does not attack humans directly – it damages cells. A population is like an ocean of cells.



graphic by Robert Del Tredici

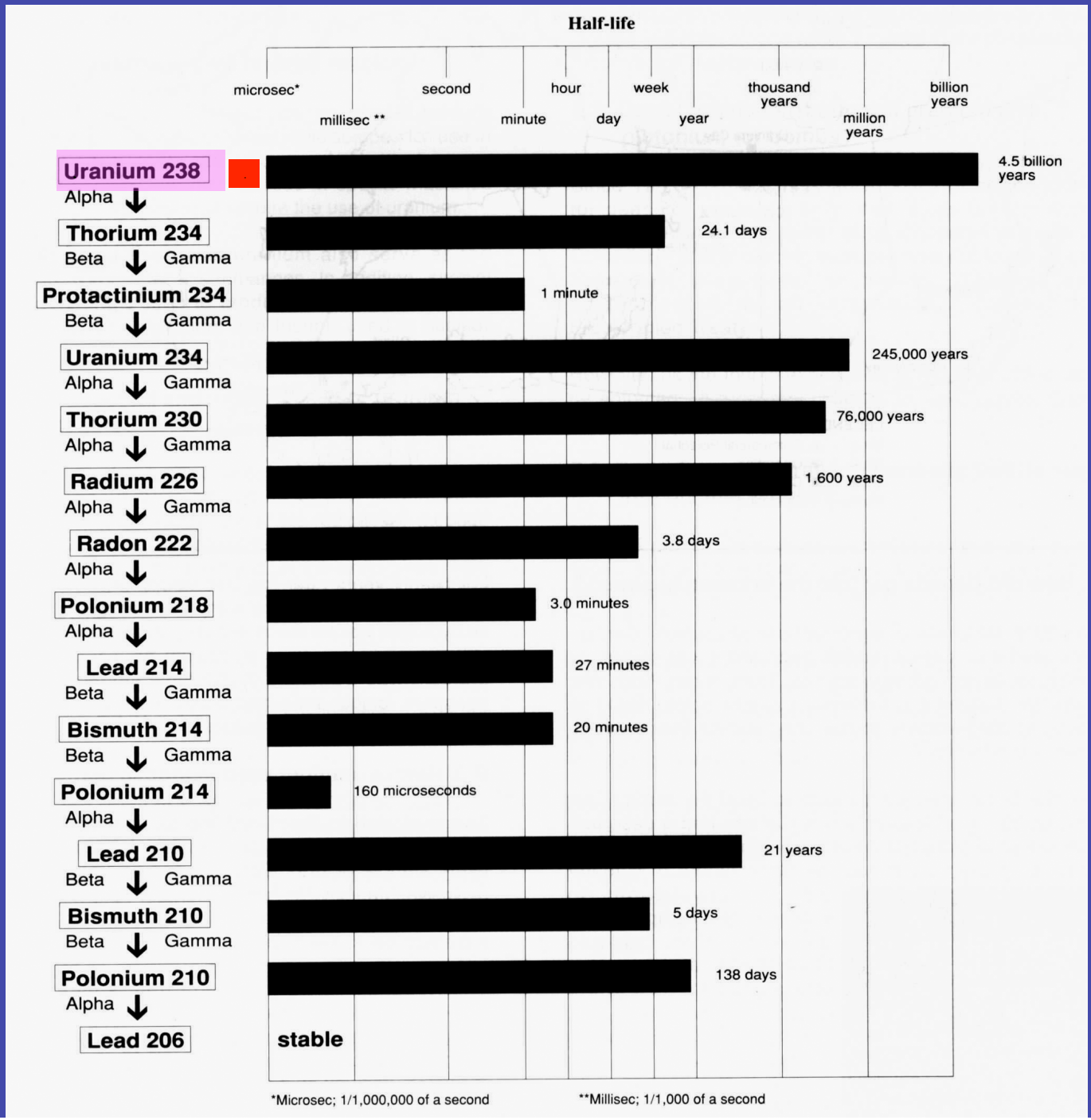
A fraction of those cells will develop into cancers.
It is largely a matter of chance whose body the cancer is in.

Lesson Six

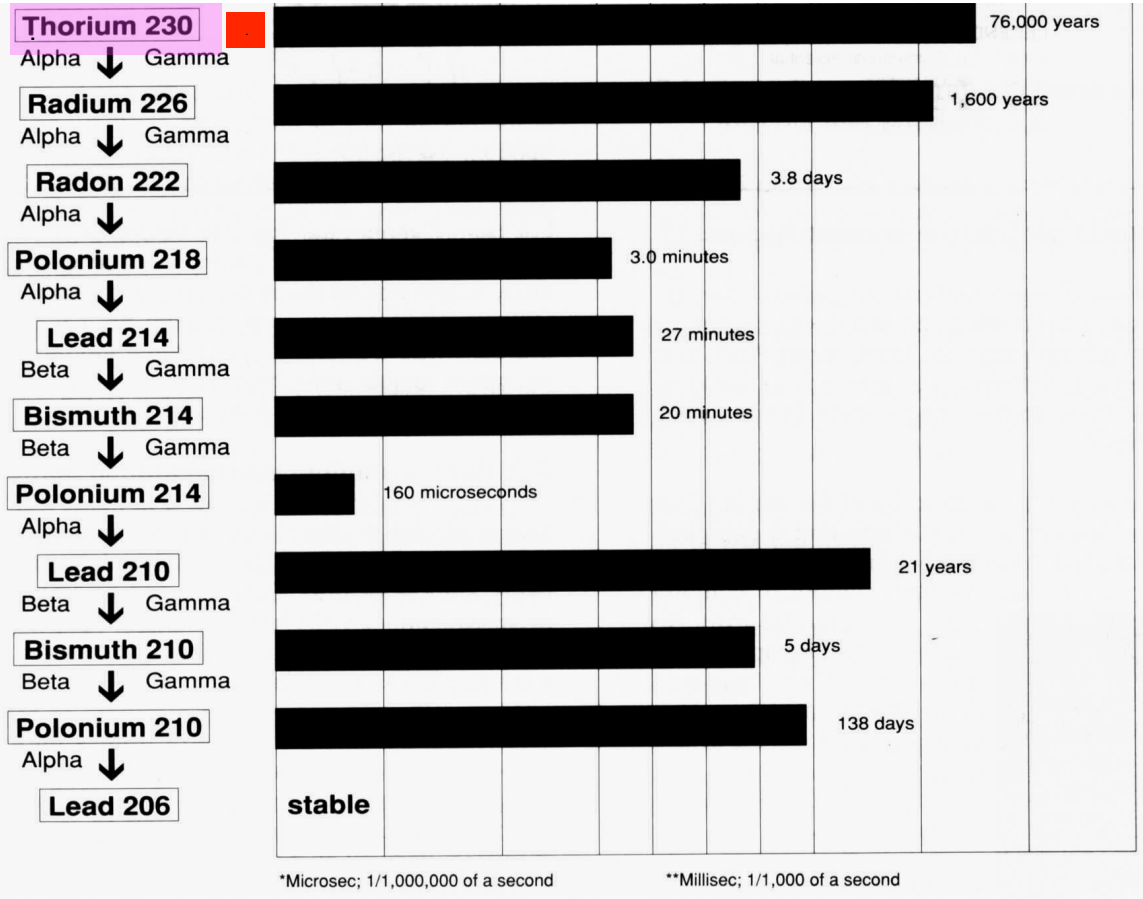
Each disintegration creates a new element called a "decay product"

Uranium has a long "decay chain"

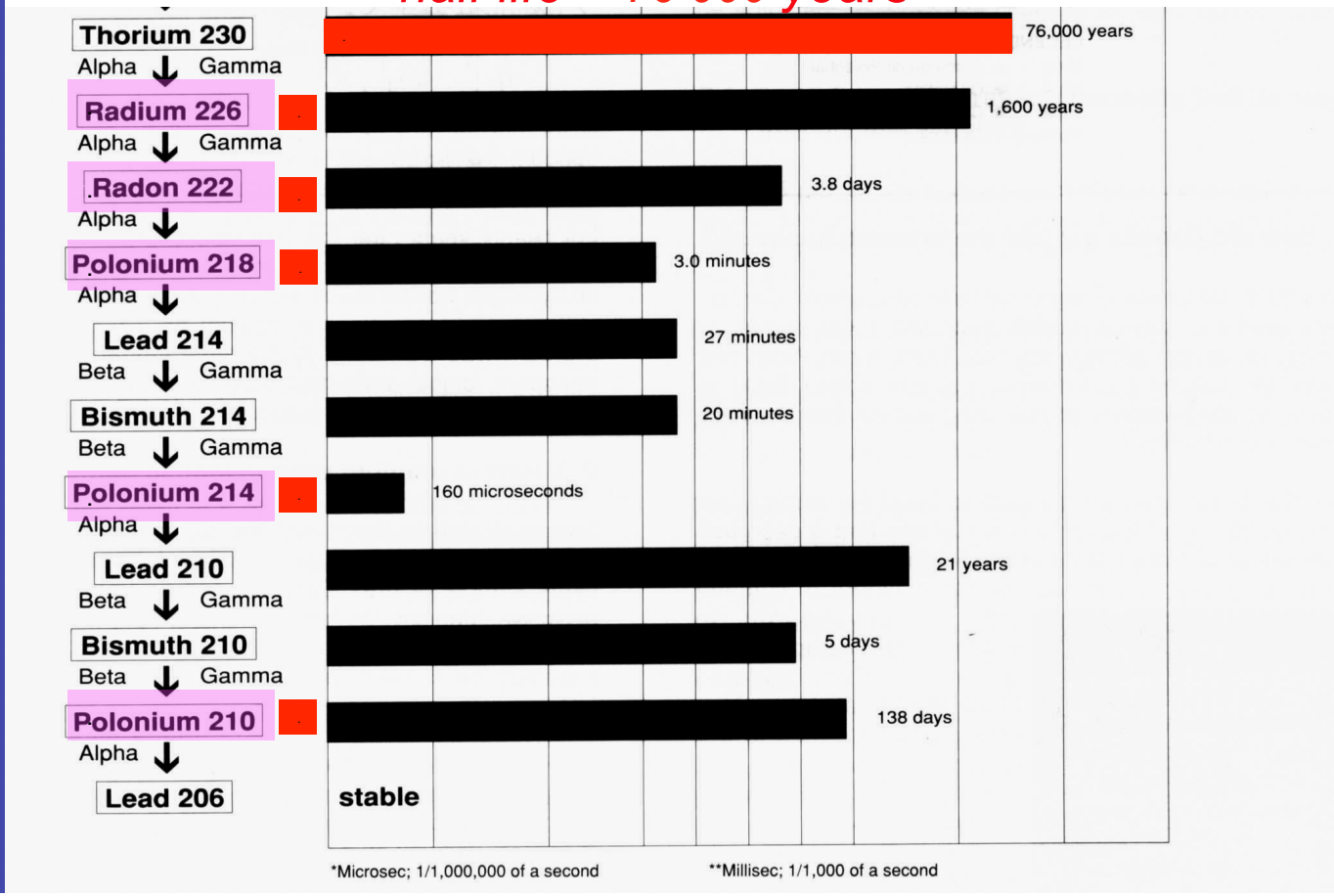
Its decay products are much more radioactive than uranium itself


Half-life
microsec*
millisec **
second
minute
hour
day
week
year
thousand years
million years
billion years
Uranium 238
4.5 billion years
Alpha
Thorium 234
24.1 days
Beta
Gamma
Protactinium 234
1 minute
Beta
Gamma
Uranium 234
245,000 years
Alpha
Gamma
Thorium 230
76,000 years
Alpha
Gamma
Radium 226
1,600 years
Alpha
Gamma
Radon 222
3.8 days
Alpha
Polonium 218
3.0 minutes
Alpha
Lead 214
27 minutes
Beta
Gamma
Bismuth 214
20 minutes
Beta
Gamma
Polonium 214
160 microseconds
Alpha
Lead 210
21 years
Beta
Gamma
Bismuth 210
5 days
Beta
Gamma
Polonium 210
138 days
Alpha
Lead 206
stable
*Microsec; 1/1,000,000 of a second
**Millisec; 1/1,000 of a second

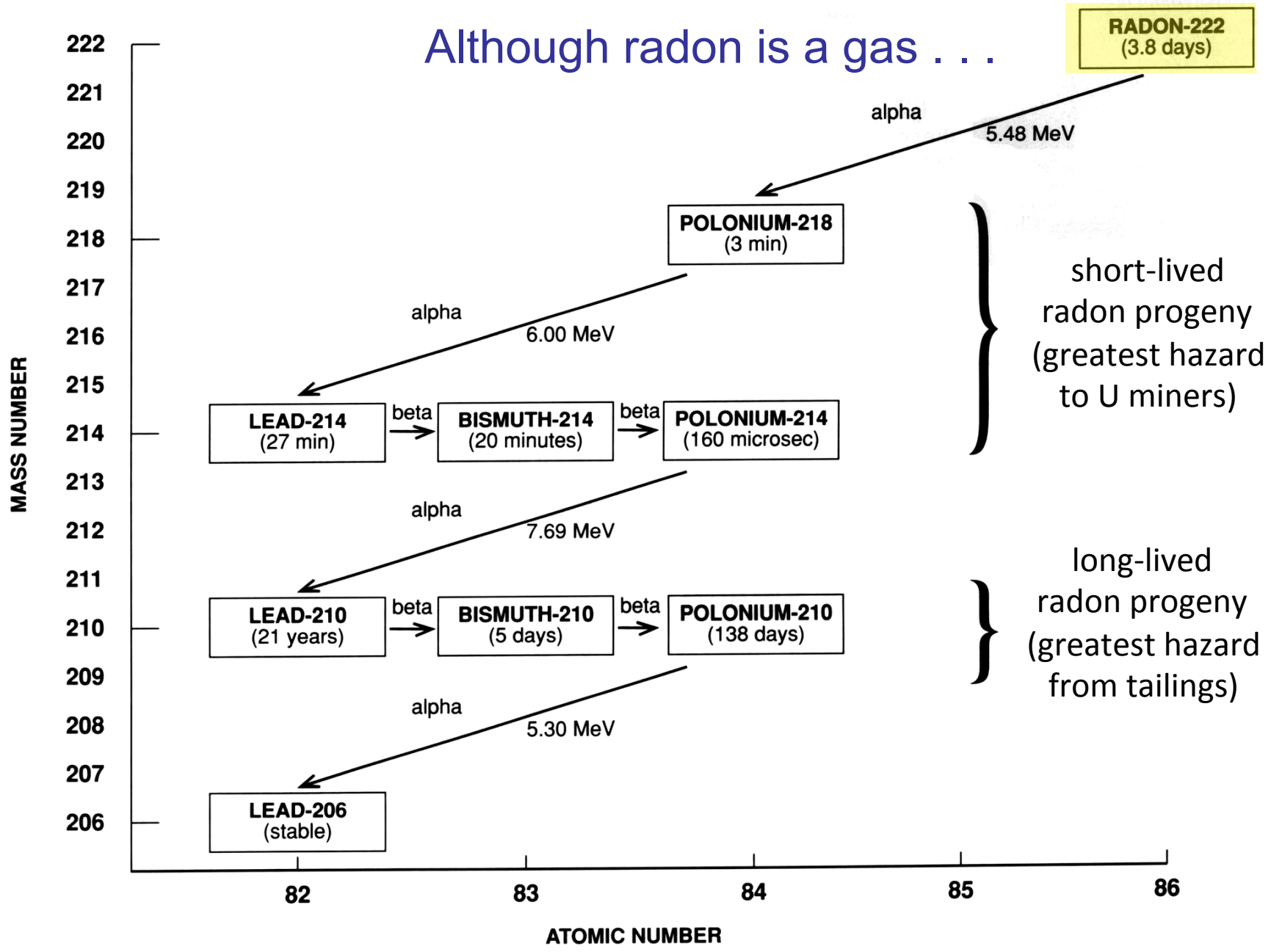
After the uranium is extracted
85% of the radioactivity in the ore
Is left behind in the uranium tailings



In the voluminous uranium tailings thorium-230 replenishes the inventory of radium, radon and polonium for hundreds of thousands of years

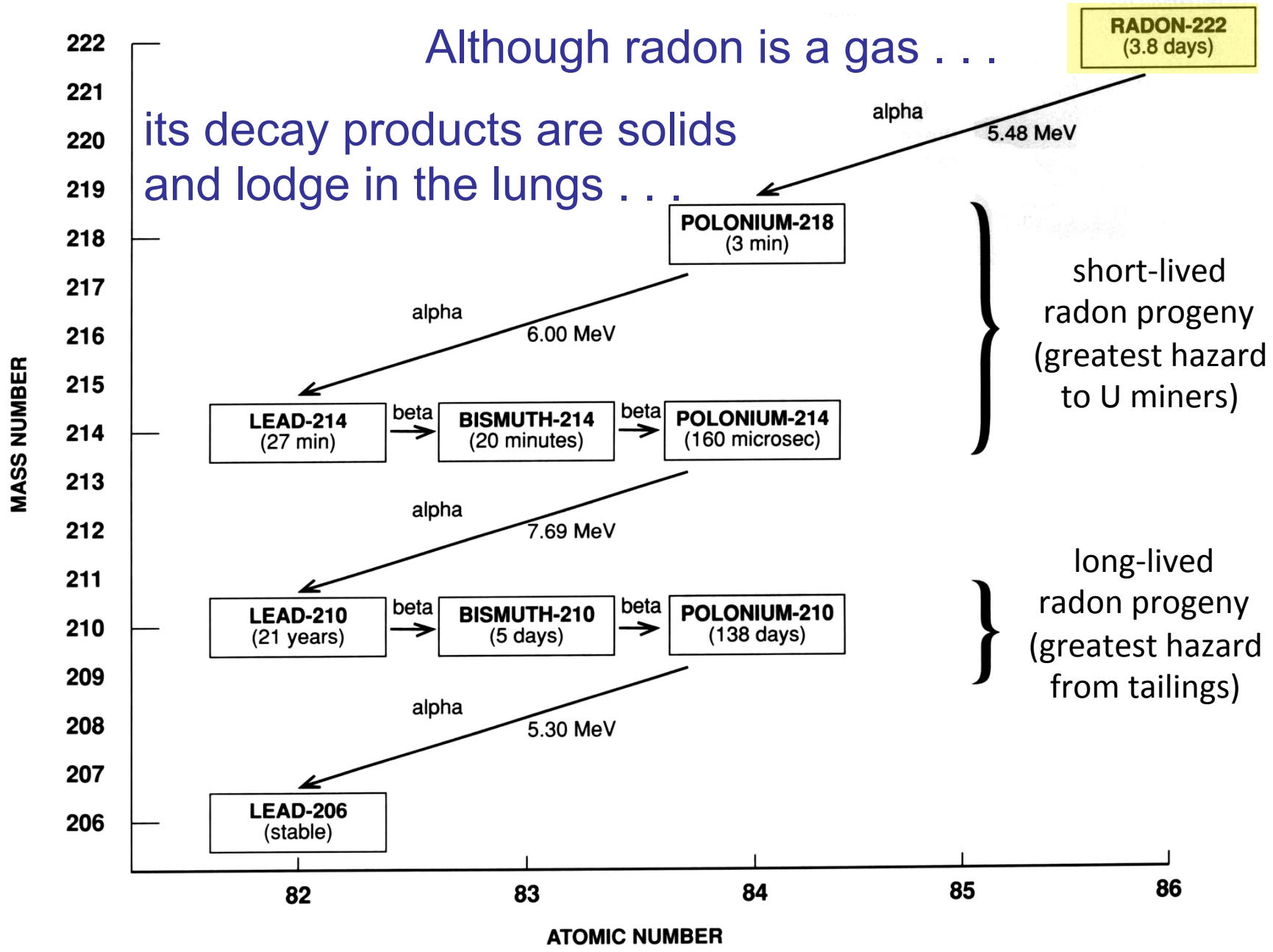


Although radon is a gas . . .



Although radon is a gas . . .

its decay products are solids and lodge in the lungs . . .



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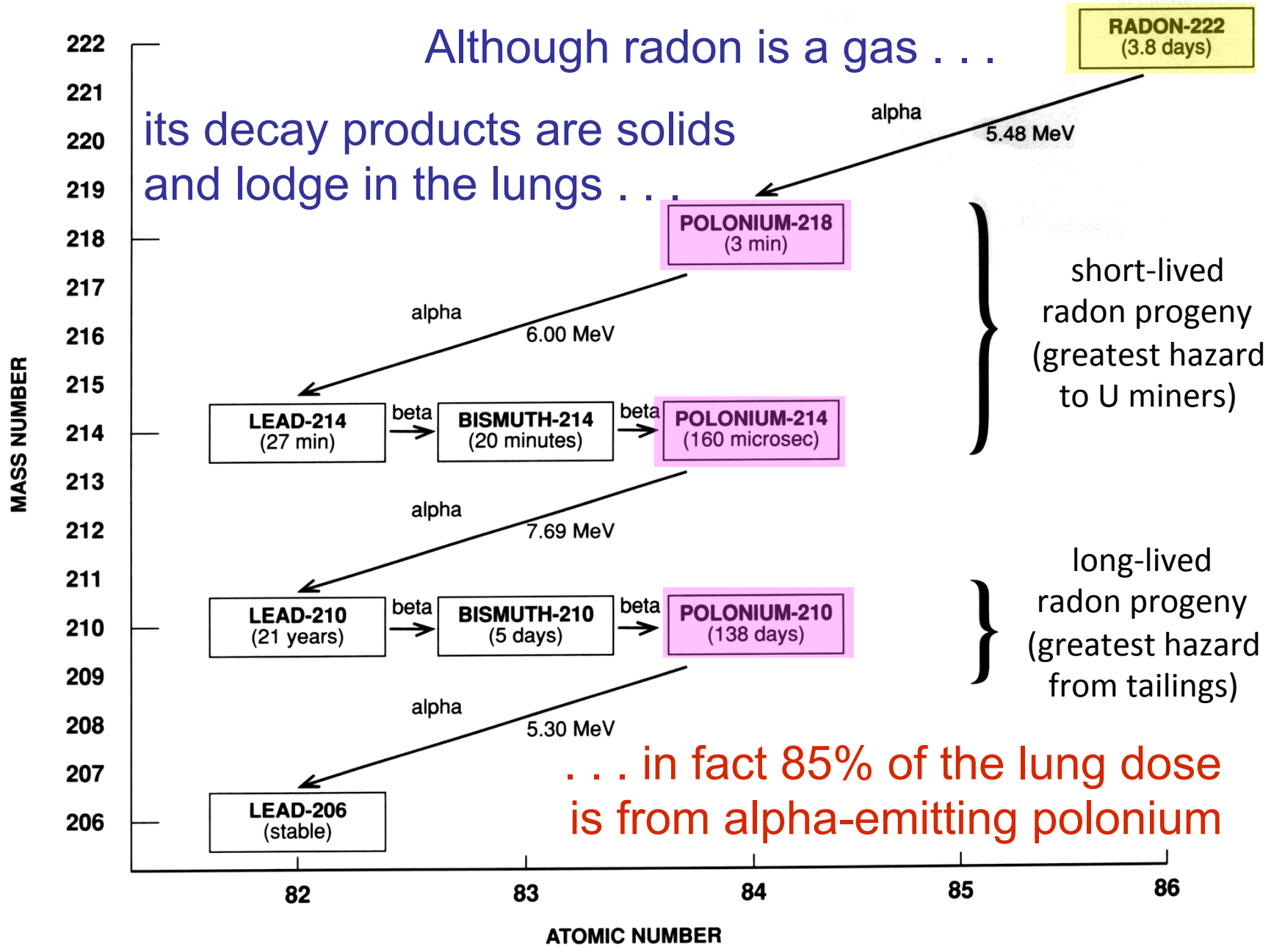


short-lived radon progeny (greatest hazard to U miners)

long-lived radon progeny (greatest hazard from tailings)

. . . in fact 85% of the lung dose is from alpha-emitting polonium

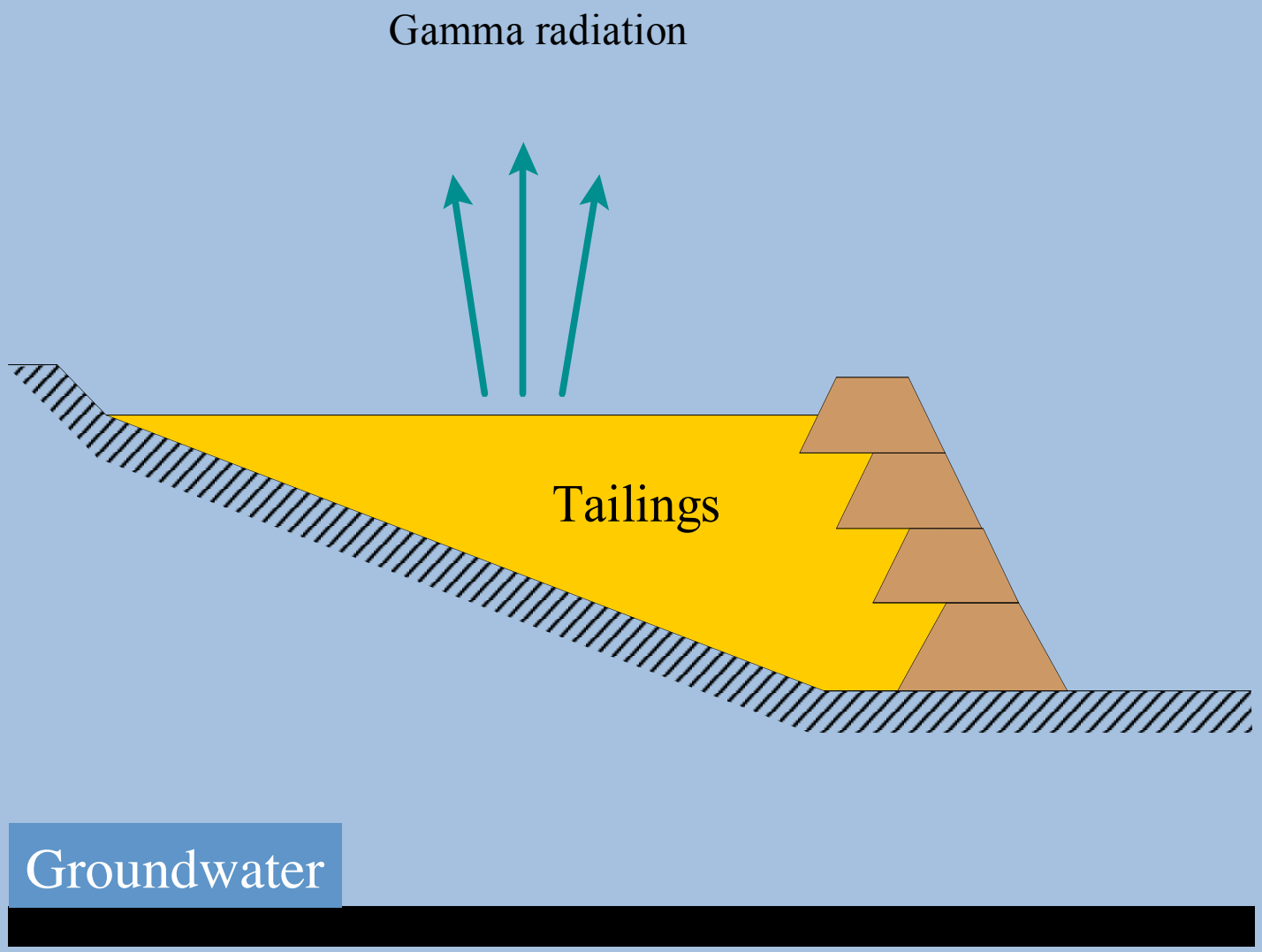
Lesson Seven

Uranium wastes (mill tailings)
stay hazardous for 500,000 years

Contamination spreads by wind,
rain, erosion, animals, excavations . . .

Without specialized equipment it
is not possible to detect the danger

Uranium Mill Tailings Hazards



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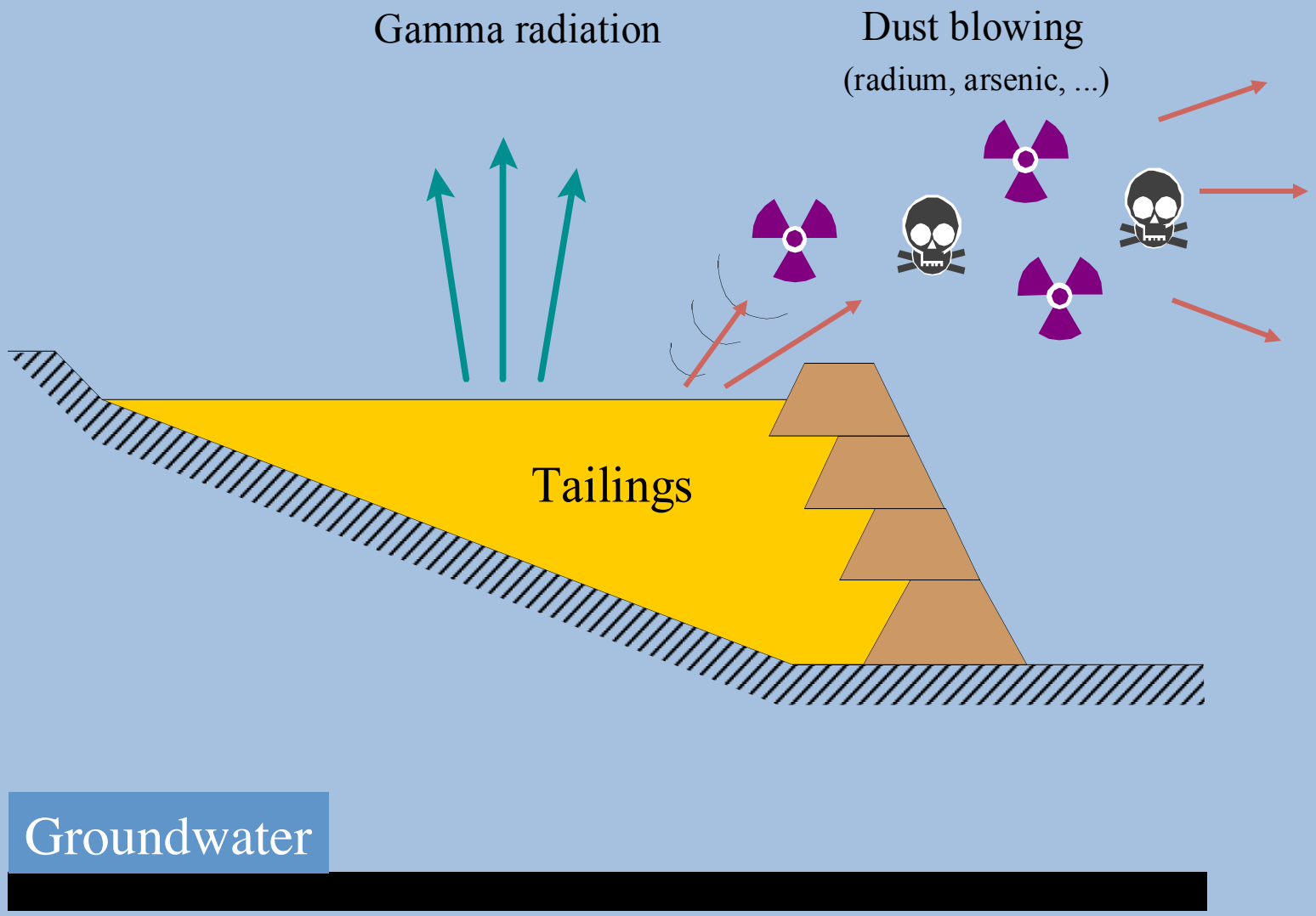

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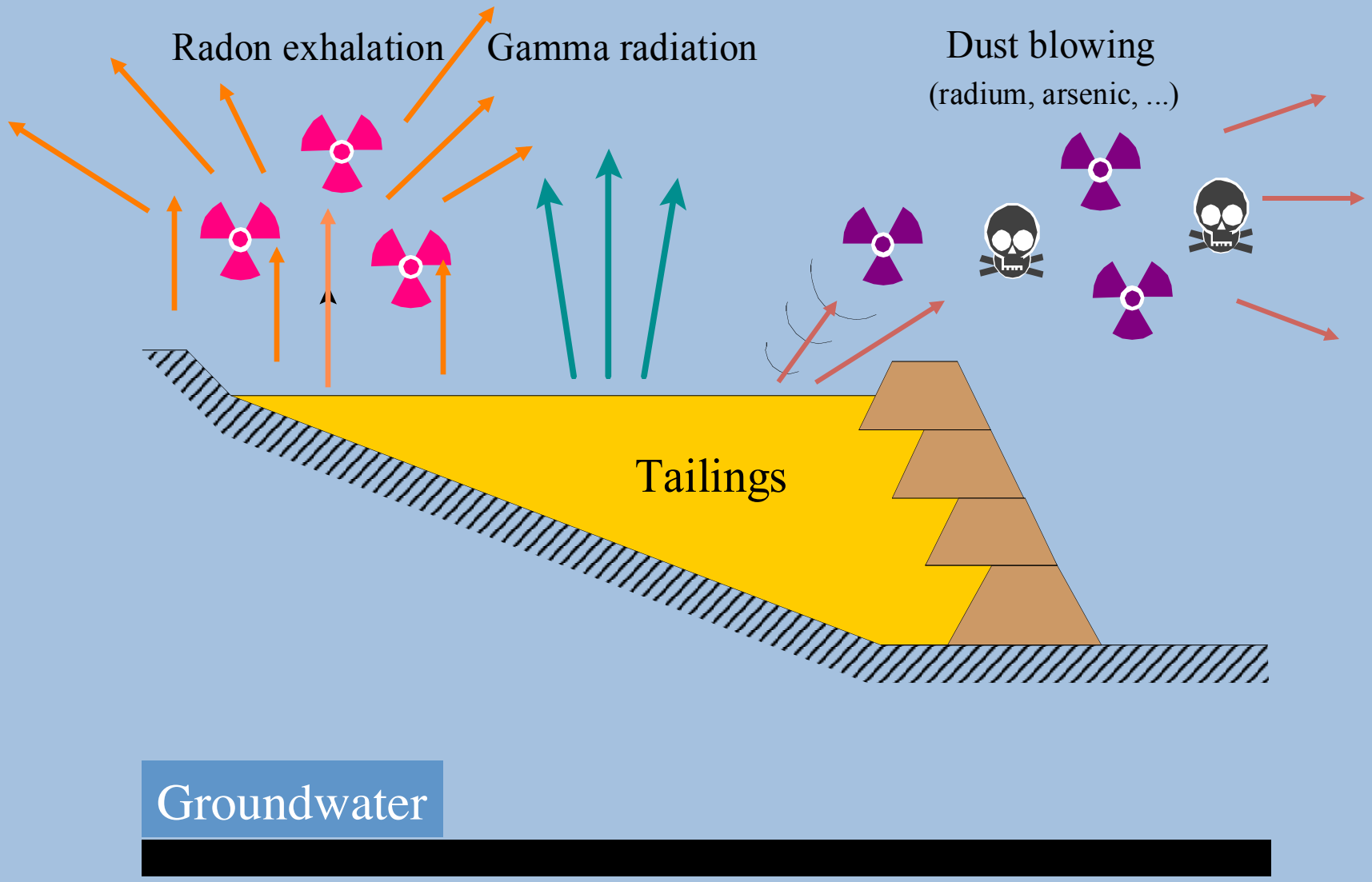

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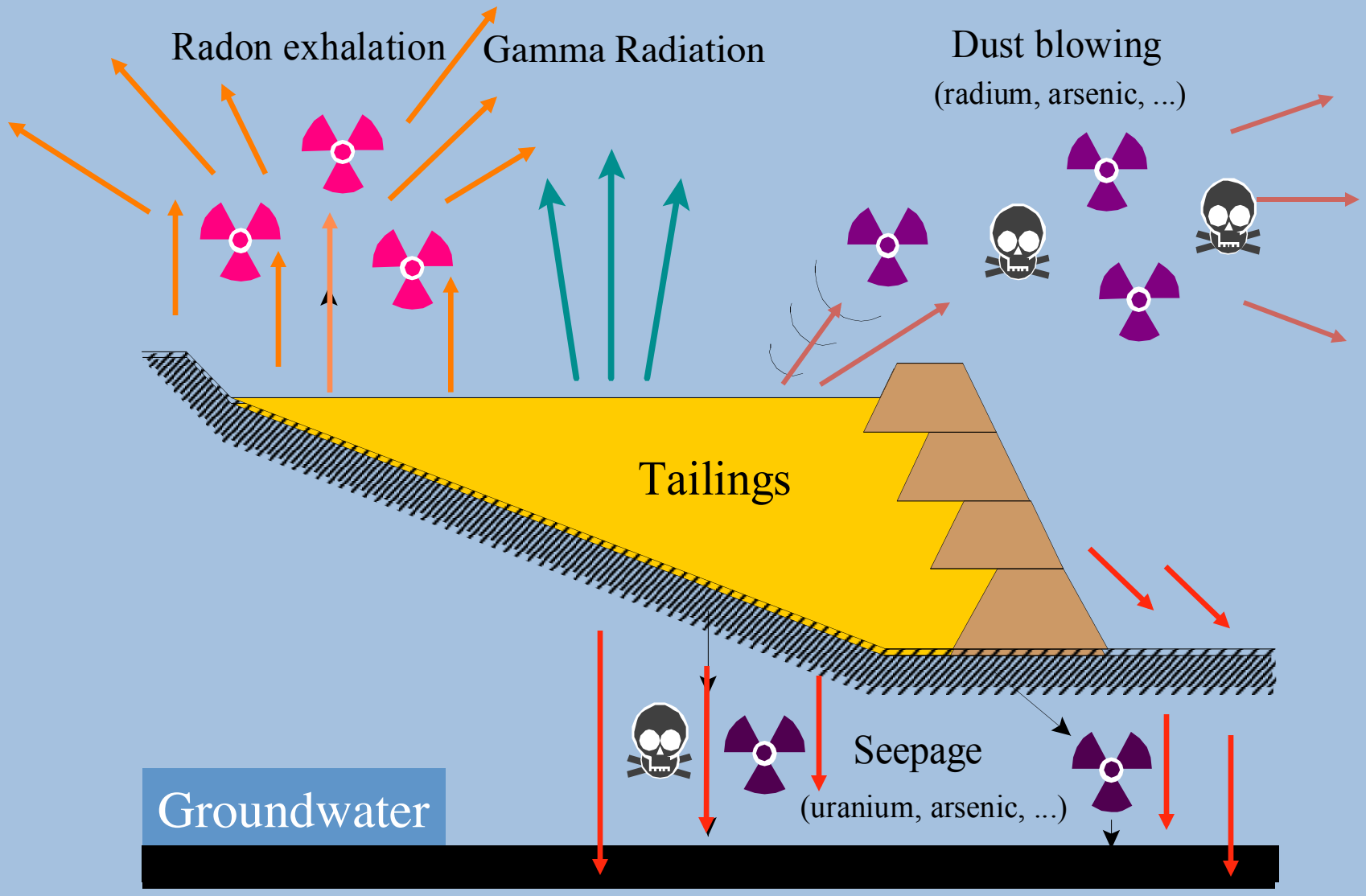
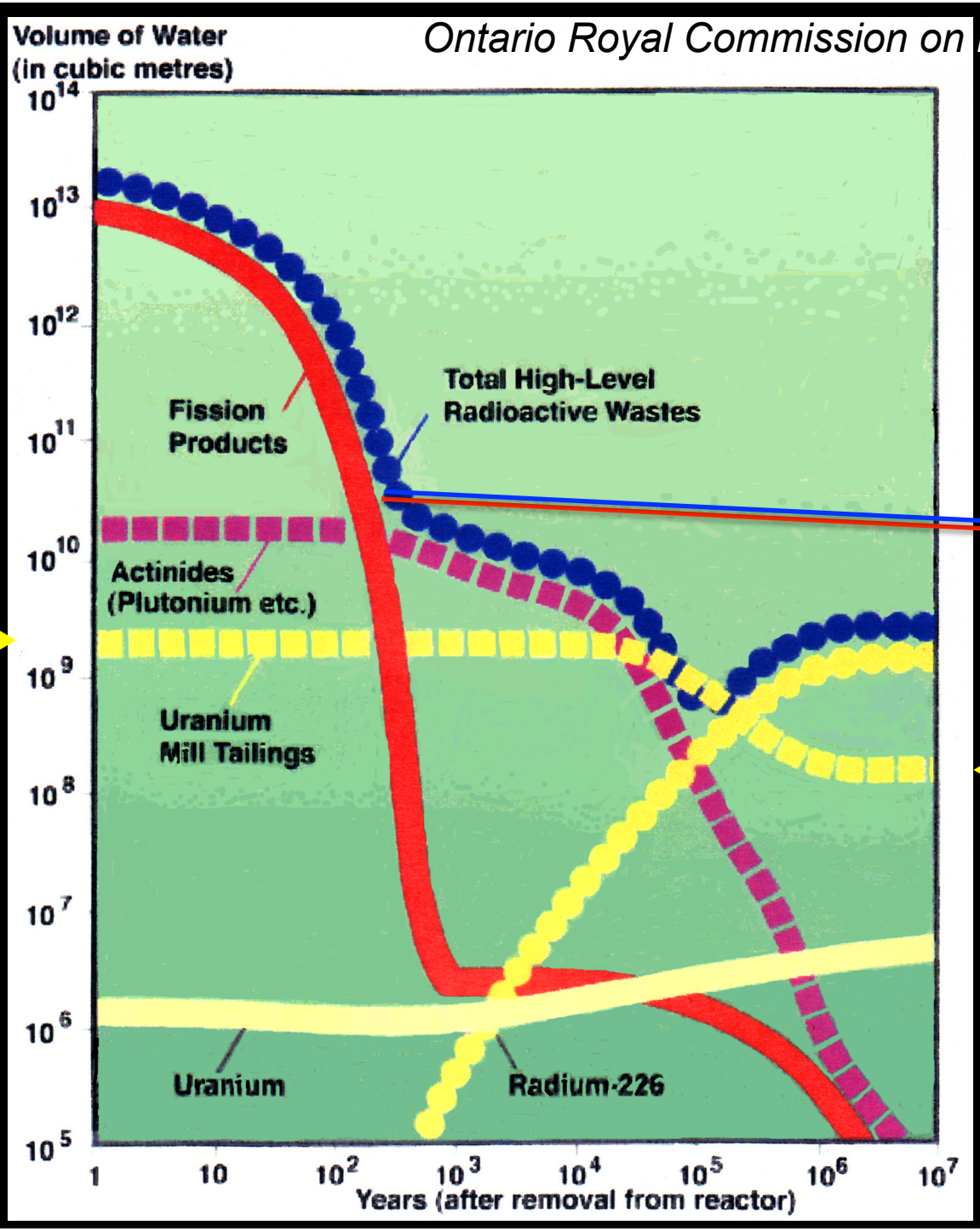


Ontario Royal Commission on Electric Power Planning (1978)



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

The red and blue lines represent the toxicity of high level waste over 10 million years.

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

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

Lesson Eight

radioactivity generates heat
called “decay heat”

science has no way
to slow down, speed up or stop
the rate of radioactive heat production

that’s why irradiated nuclear fuel
has to be cooled for years ….

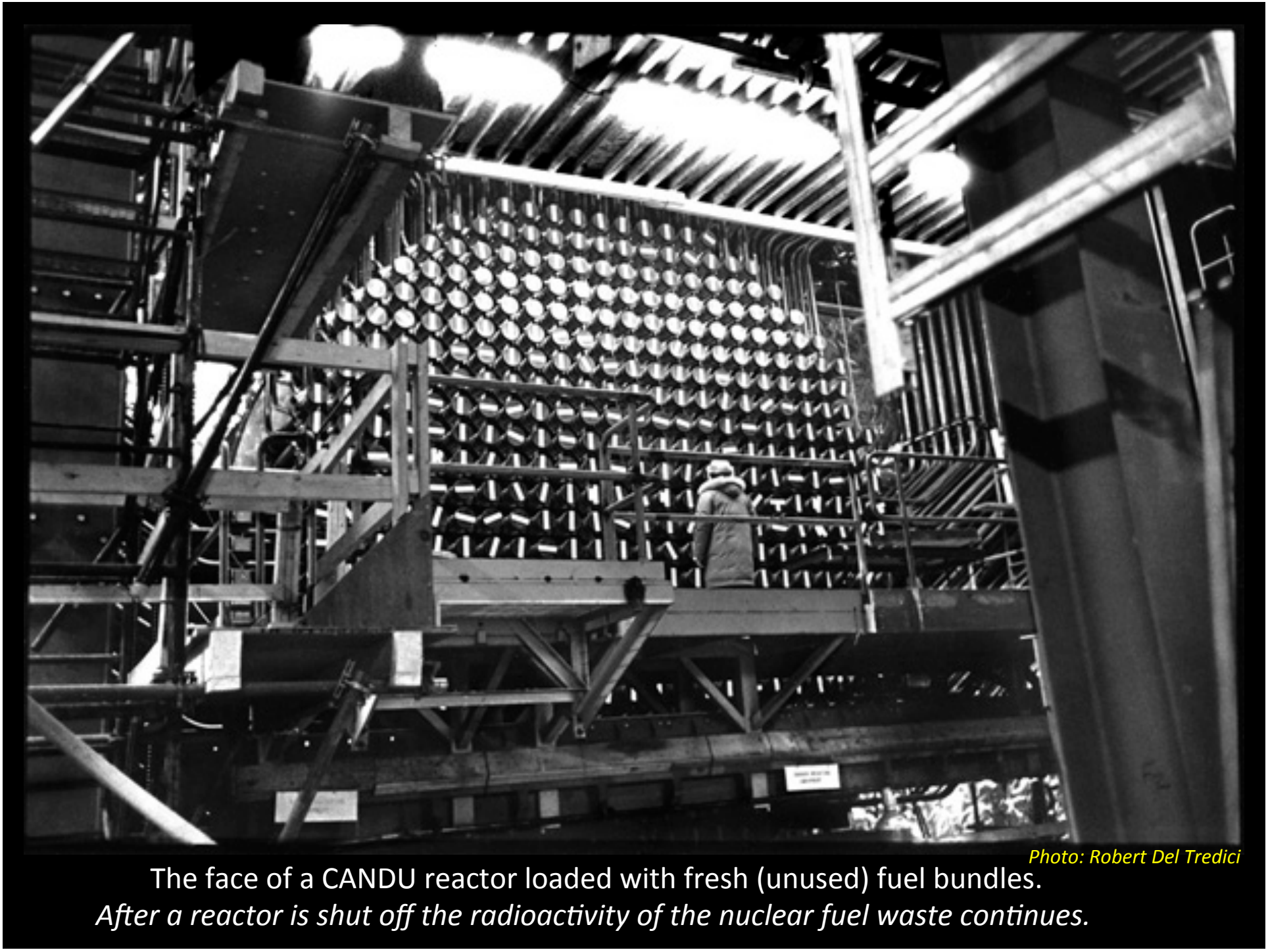
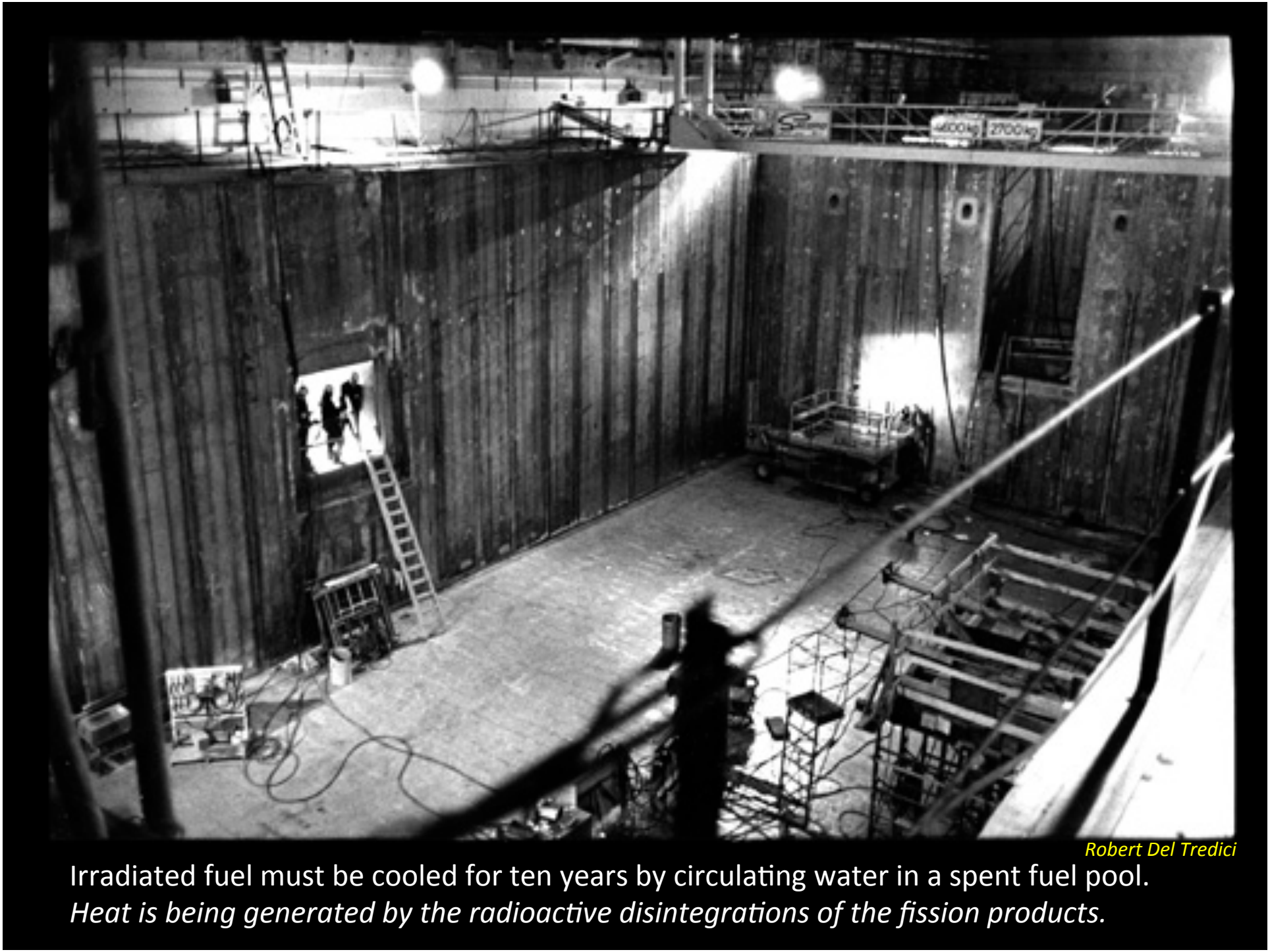


Photo: Robert Del Tredici

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

After a reactor is shut off the radioactivity of the nuclear fuel waste continues.



Robert Del Tredici

Irradiated fuel must be cooled for ten years by circulating water in a spent fuel pool.
Heat is being generated by the radioactive disintegrations of the fission products.

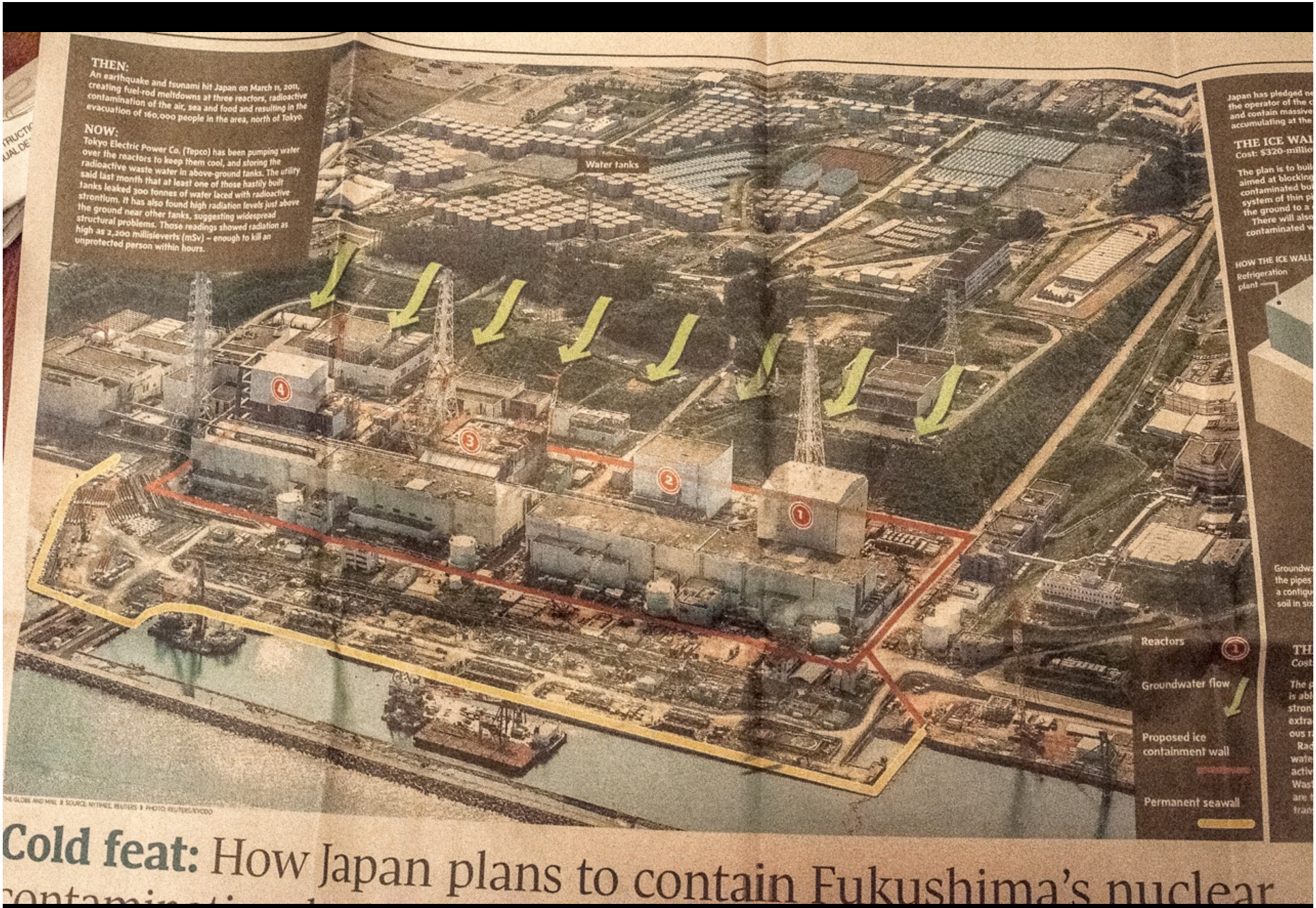
Fukushima Dai-Ichi Nuclear Power plant, Units 1 – 4

All reactors were shut down safely when earthquake struck on March 11, 2011.

Three hydrogen gas explosions were caused by nuclear fuel waste

(heat + ionization → chemical reactions → hydrogen gas buildup → explosion)

Radioactive heat led to three core meltdowns and four demolished reactor buildings. Without cooling*, the radioactive heat drives temperatures up to 2800 degrees Celsius*.



Cold feat: How Japan plans to contain Fukushima's nuclear

Flowing groundwater – 300 tonnes per day – washes melted nuclear fuel debris into the ocean

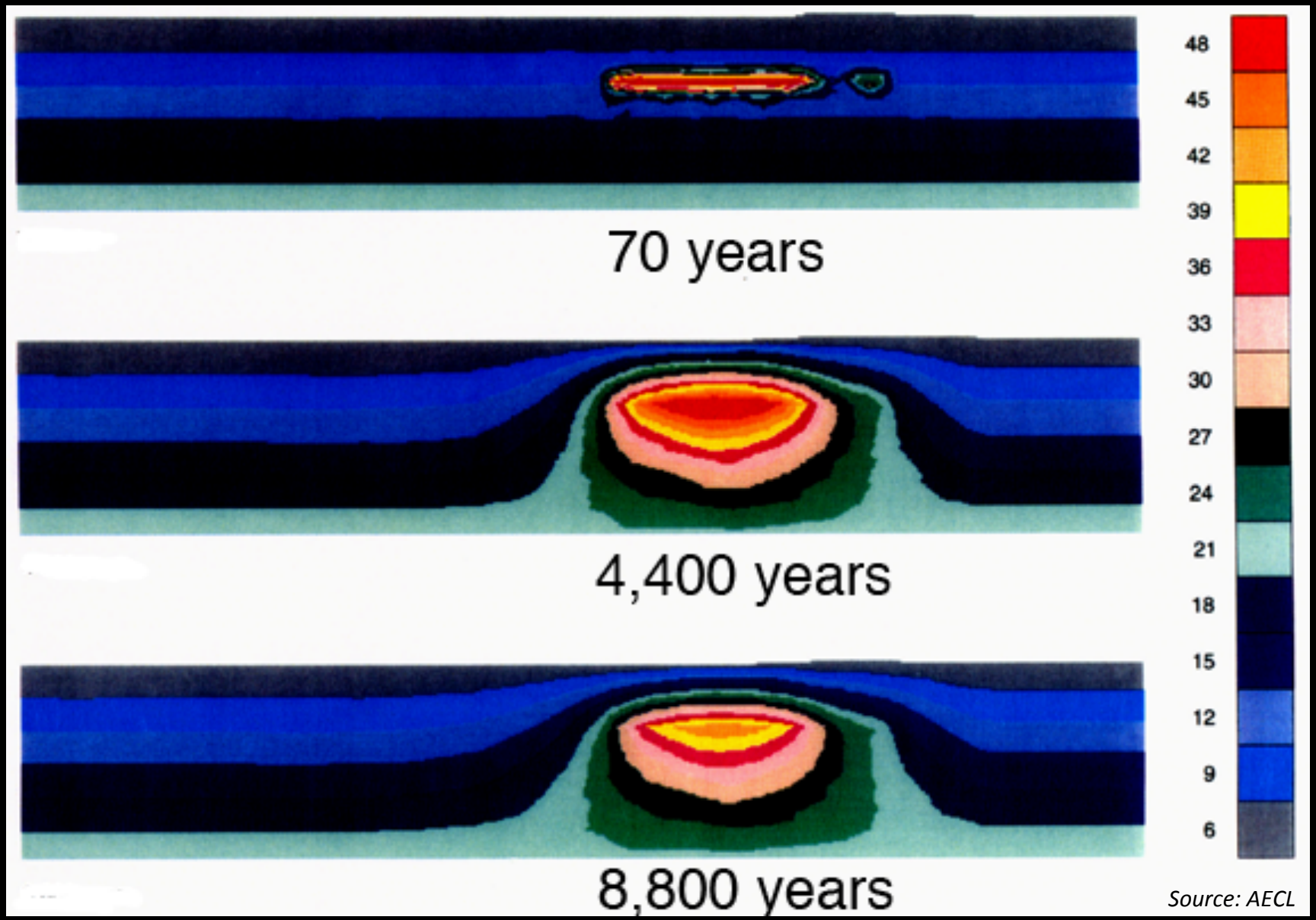
Every day, 400 tonnes of water are used to cool the melted cores.

When pumped back to the surface the water is highly contaminated.

Huge steel tanks are used to hold the radioactively contaminated water as workers try to prevent radioactive leaks.

1500 tanks of highly radioactive water are already stored in above-ground areas near the plant

Fact: nuclear fuel waste generates heat and causes chemical reactions long after it is buried.



In this graph from Atomic Energy of Canada Ltd., the horizontal lines indicate rock layers. Heat generated by buried nuclear fuel waste raises the temperature of surrounding rock.

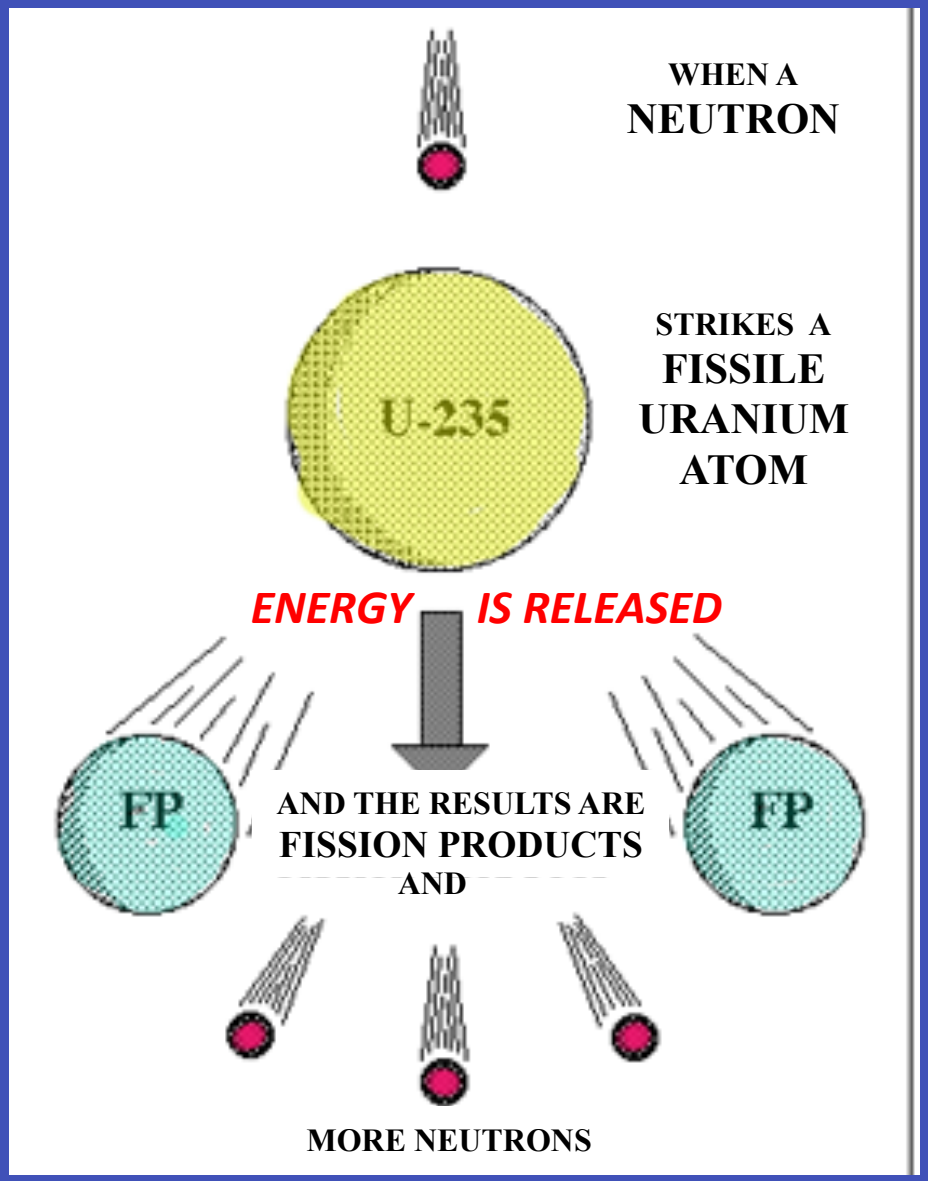
Lesson Nine

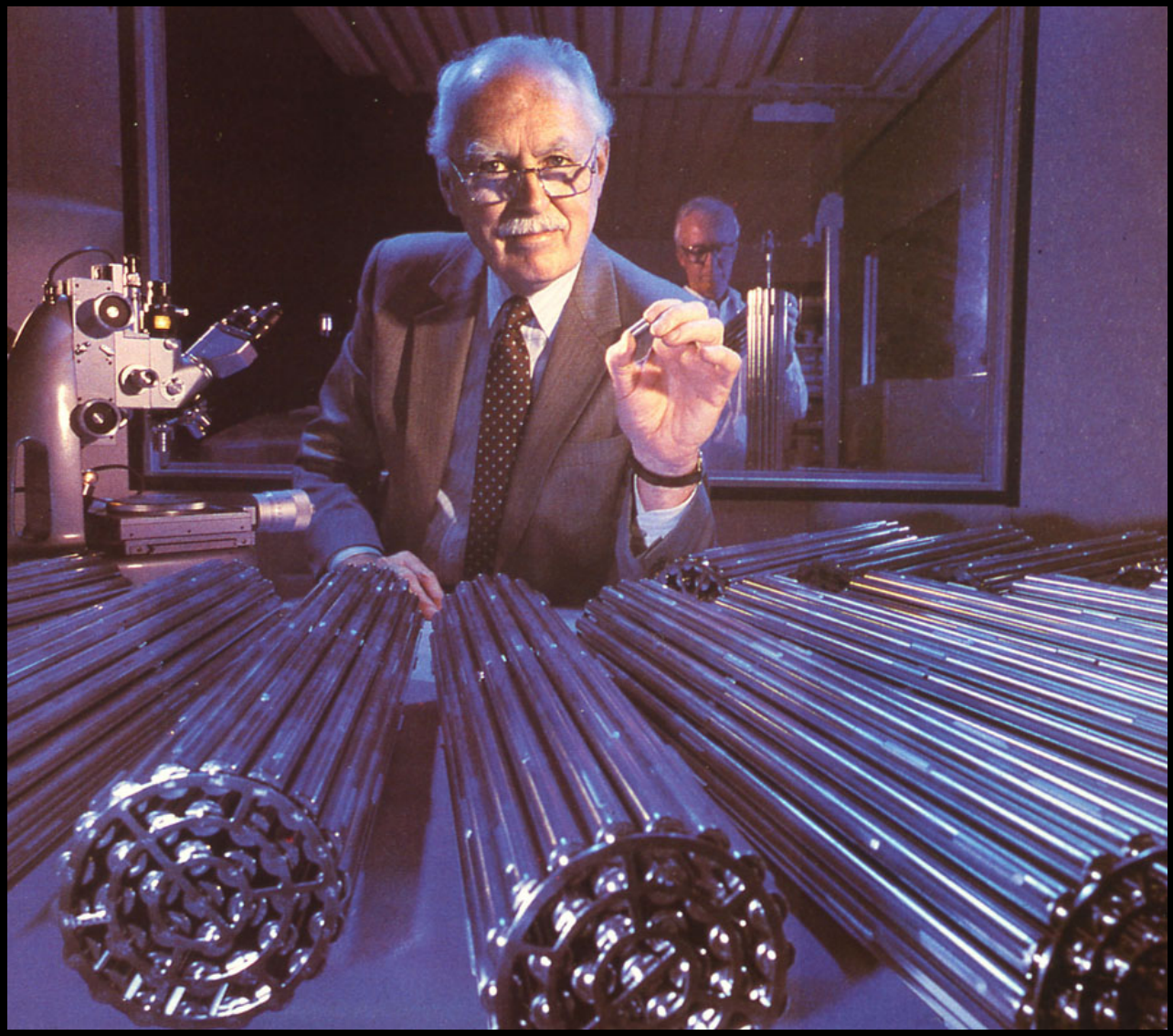
abandoning nuclear waste
is irresponsible

nuclear waste must be constantly
monitored and retrievable

Rolling Stewardship is the alternative

Nuclear Fission

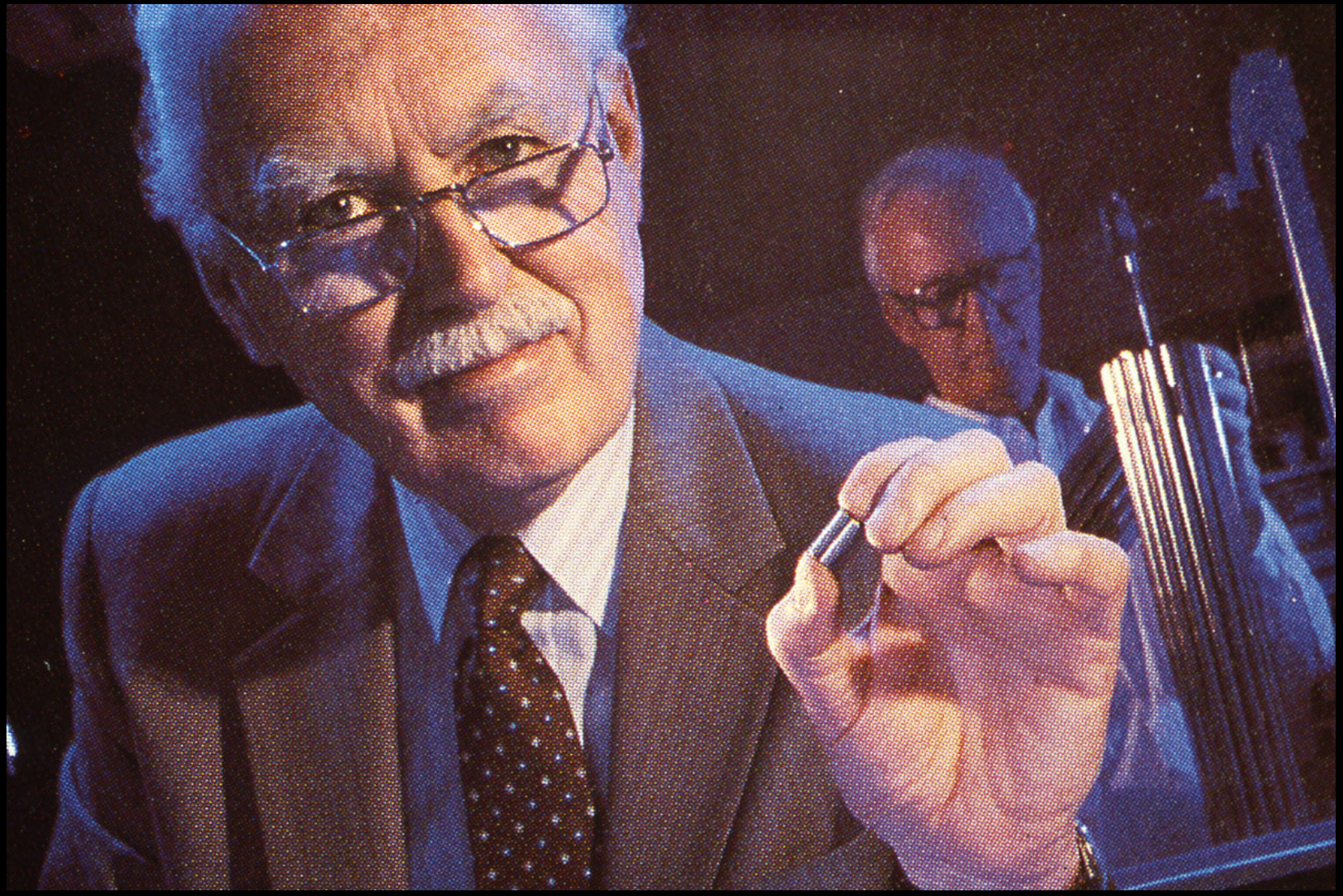




"Small Wonder" : Canadian Nuclear Association Ad

A CANDU fuel bundle can be handled safely before it is used,
but after it is used it delivers a lethal radiation dose in seconds.
This is caused by the intense radioactivity of the fission products.

The main attraction of nuclear energy : one small pellet of uranium fuel, utilizing nuclear fission, gives as much energy as a tonne of coal – with no greenhouse gas.



The main disadvantage of nuclear energy : after it is used you cannot throw that pellet away – you have to keep an eye on it for the next ten million years.

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 Ar	Argon Argon	39 42		¥ ¥	¥ ¥	
K K	Potassium Potassium	40 42		¥	 ¥	
Ca Ca	Calcium Calcium	41 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 Fe	Iron Iron	55 59		¥¥¥	¥¥¥ ¥	
Co Co	Cobalt Cobalt	58 60		¥ ¥¥¥	¥ ¥¥¥	
Ni Ni	Nickel Nickel	59 63		¥ ¥¥¥	¥¥¥ ¥¥¥	
Zn	Zinc	65		¥	¥	
Se	Selenium	79	¥¥¥			
Kr Kr	Krypton Krypton	81 85	¥ ¥¥¥			
Rb	Rubidium	87	¥			
Sr Sr	Strontium Strontium	89 90	¥ ¥¥¥	 ¥	¥ ¥	
Y	Yttrium	90	¥¥¥	¥	¥	

F.I.A.P. = fuel impurity activation product Z.A.P. = zirconium cladding activation product [source: AECL]

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)
Y	Yttrium	91	¥		¥	
Zr	Zirconium	93	¥¥¥	¥	¥¥¥	
Zr	Zirconium	95	¥	¥	¥	
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	¥		¥	

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)
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	¥		¥	
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		¥		

F.I.A.P. = fuel impurity activation product Z.A.P. = zirconium cladding activation product [source: AECL]

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

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**

F.I.A.P. = fuel impurity activation product Z.A.P. = zirconium cladding activation product [source: AECL]

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

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				¥

F.I.A.P. = fuel impurity activation product Z.A.P. = zirconium cladding activation product [source: AECL]

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

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				¥¥¥

F.I.A.P. = fuel impurity activation product Z.A.P. = zirconium cladding activation product [source: AECL]

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

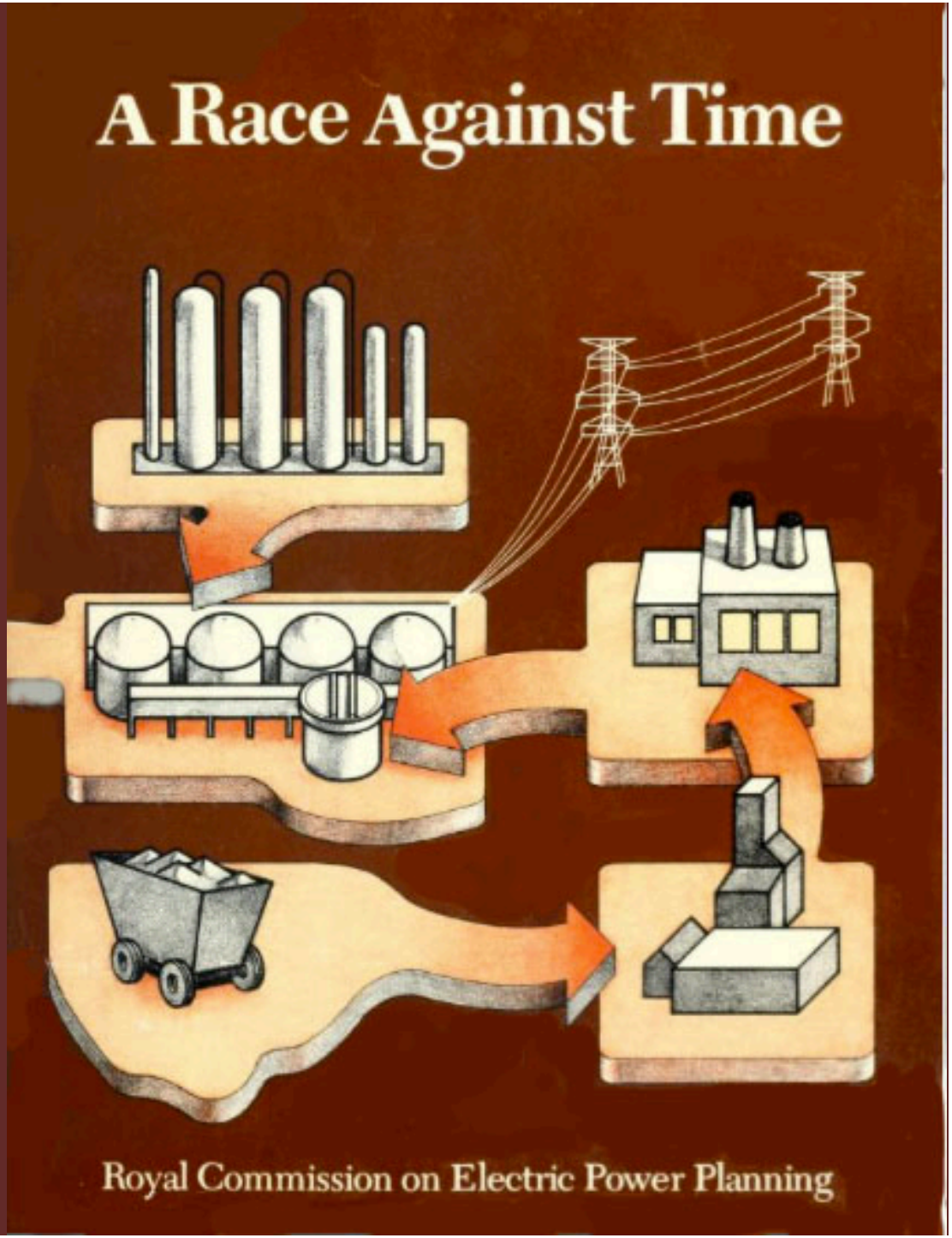
Cm	Curium	244				¥¥¥
Cm	Curium	245				¥
Cm	Curium	246				¥
Cm	Curium	247				¥
Cm	Curium	248				¥
Cm	Curium	250				¥
Bk	Berkelium	249				¥
Bk	Berkelium	250				¥
Cf	Californium	249				¥
Cf	Californium	250				¥
Cf	Californium	251				¥
Cf	Californium	252				¥
Standard Chemical Symbol	Common Name of element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

F.I.A.P. = fuel impurity activation product Z.A.P. = zirconium cladding activation product [source: AECL]

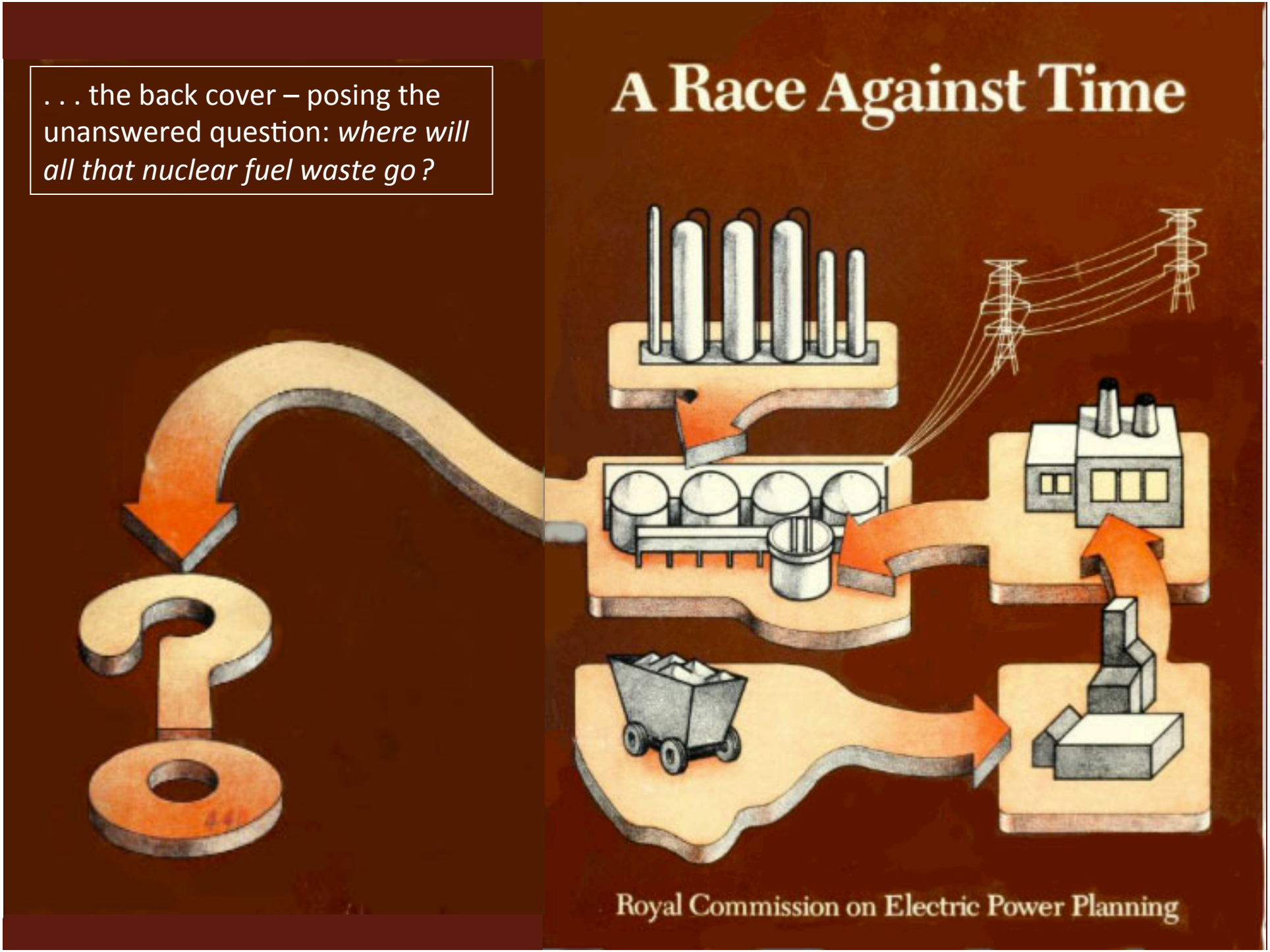
This list of 211 man-made radionuclides contained in irradiated nuclear fuel is by no means complete! (AECL)

[AECL = Atomic Energy of Canada Limited]

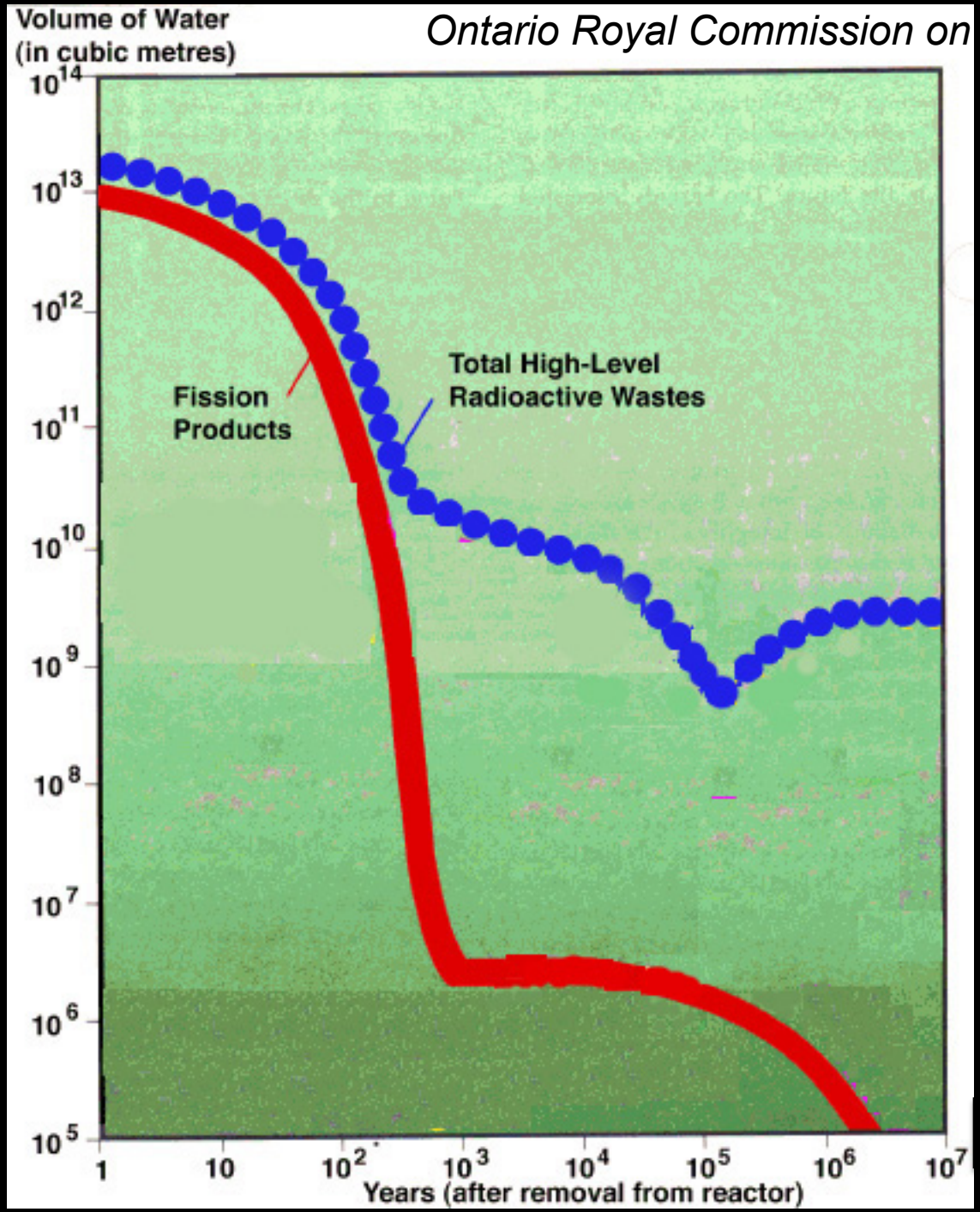
The front cover of the Royal Commission report shows the "nuclear fuel chain", from mine, to mill, to fuel fabrication, to nuclear power plant, to . . .



. . . the back cover – posing the unanswered question: *where will all that nuclear fuel waste go ?*



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 about equal to the volume of Lake Superior.

Royal Commission Report, 1978

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.

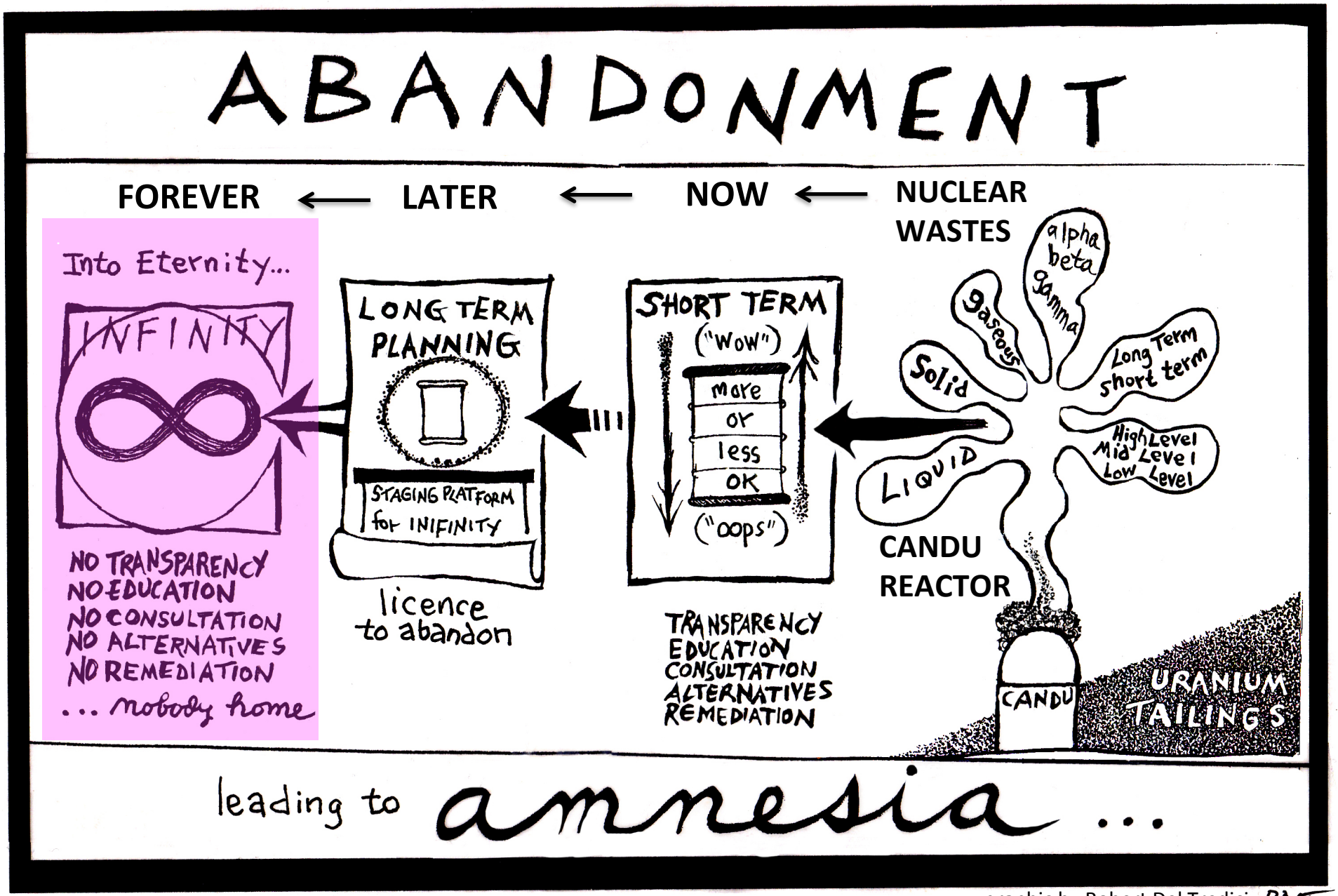
Lack of precedent: humans have never safely “disposed” of anything.

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



leading to amnesia ...

graphic by Robert Del Tredici Robert

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.

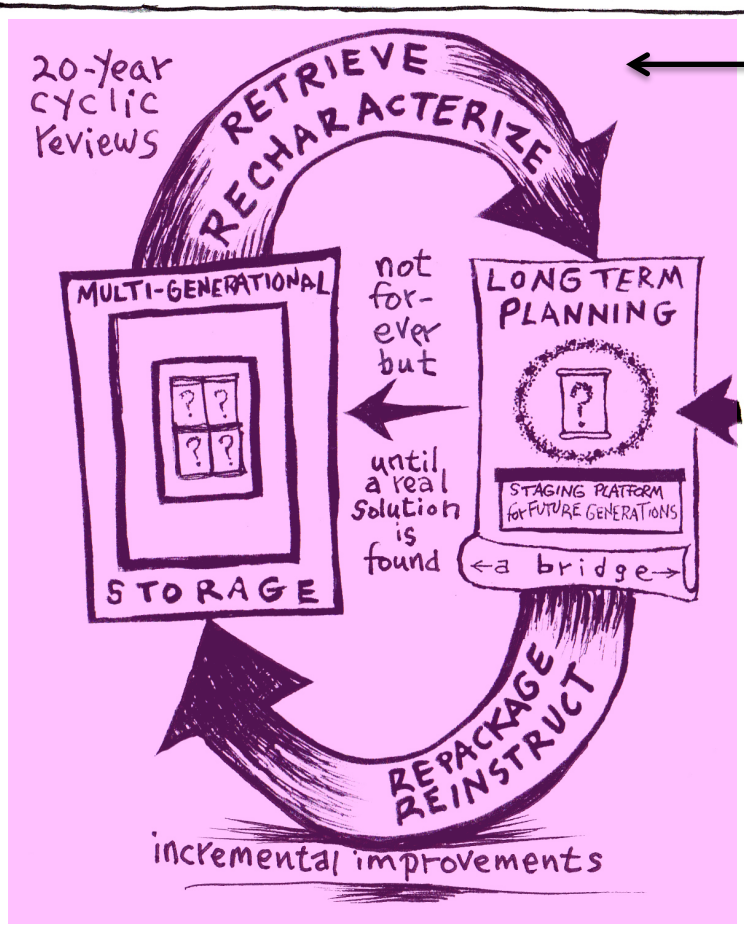
Wastes are packaged safely for extended periods & repackaged later.

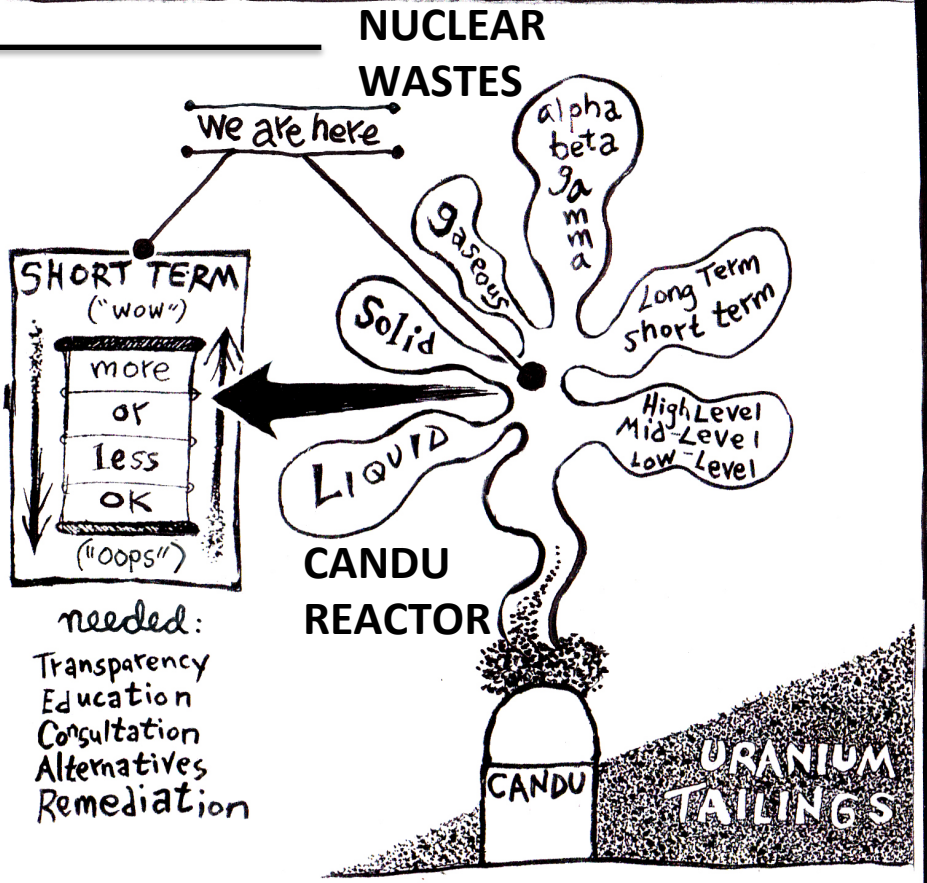
This is not a solution – it is only an ethical waste management scheme.

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

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

ROLLING STEWARDSHIP

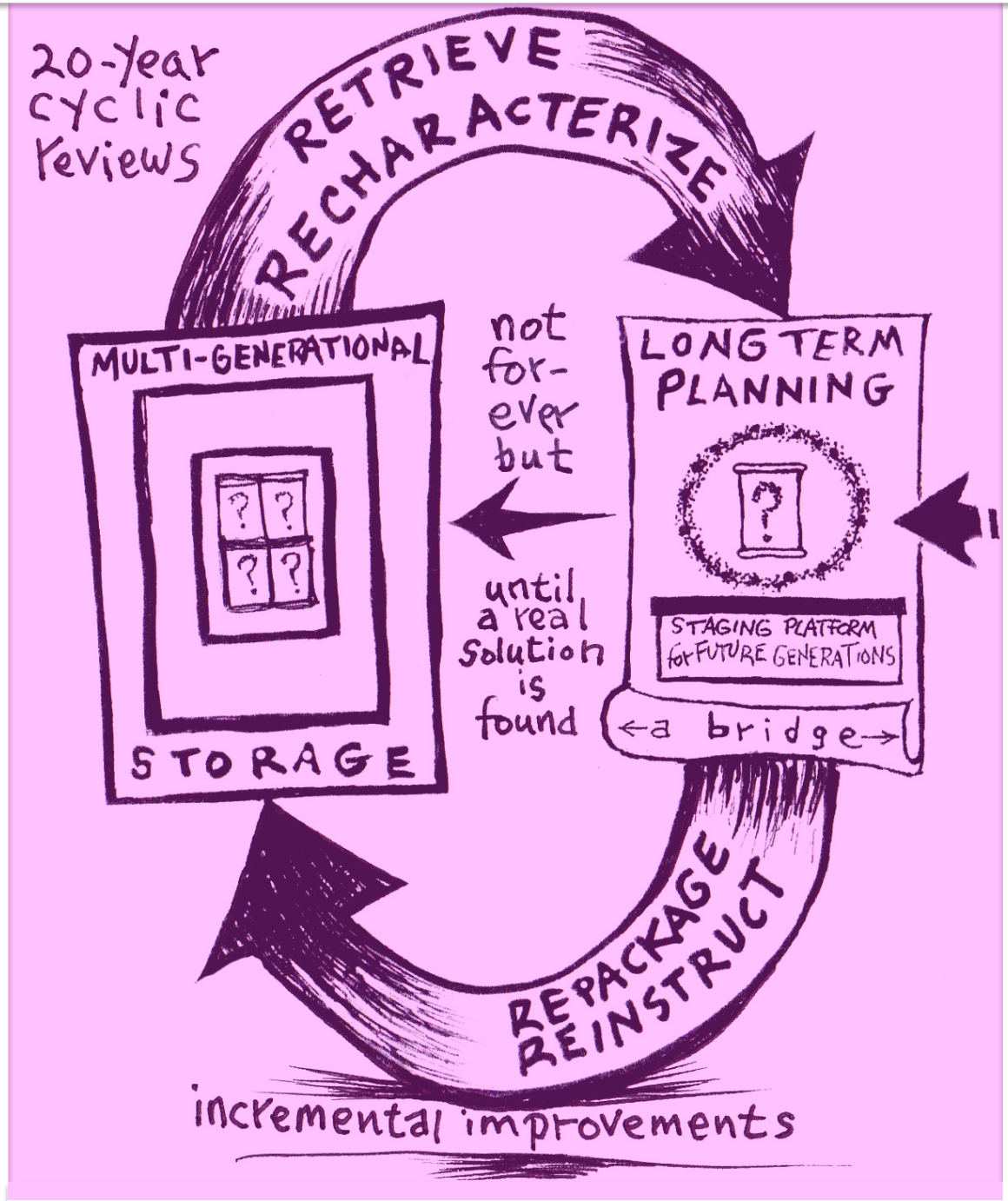




PERSISTENCE of MEMORY

Future generations have an incentive to find a genuine solution

graphic by Robert Del Tredici



Rolling Stewardship is an

intergenerational

management strategy

With a "changing of the guard" every 20 years the necessary knowledge and resources can be communicated to the next generation.

Those in charge should be

independent

of the nuclear industry.

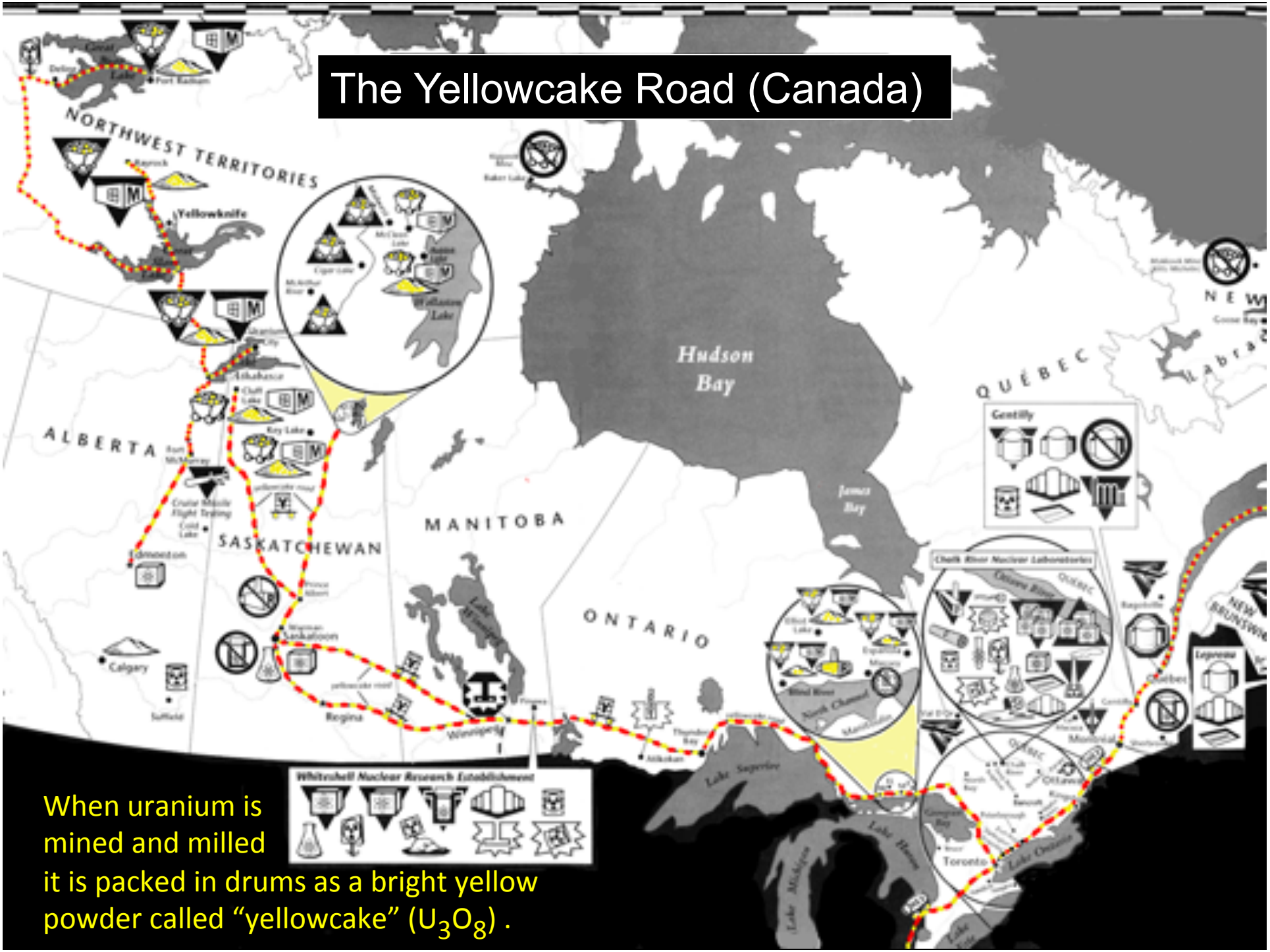
graphic by Robert Del Tredici

Lesson Ten

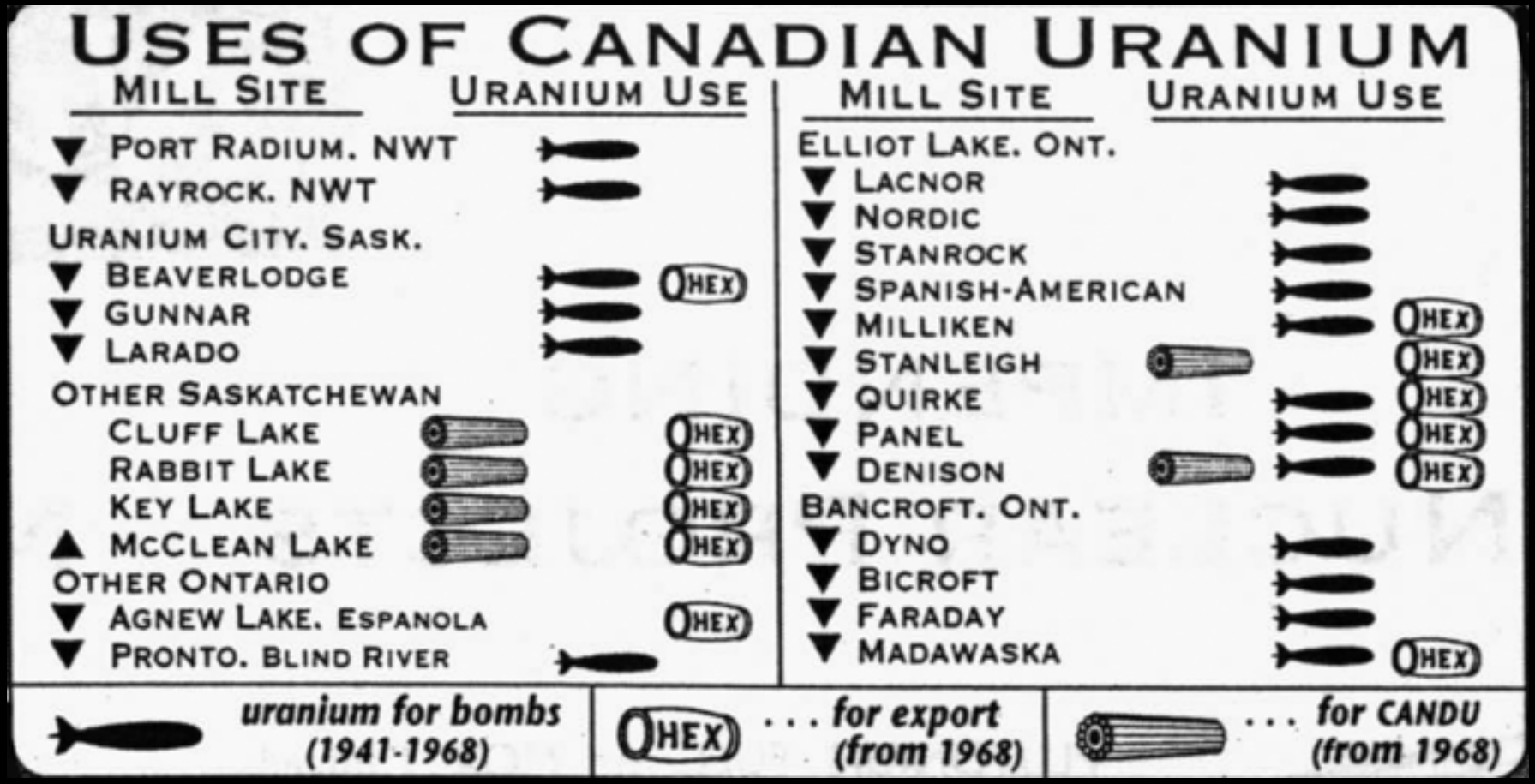
uranium is the key element
behind all nuclear fission technology

without uranium there would be
no nuclear weapons of any kind

and there would be
no high-level nuclear waste


The Yellowcake Road (Canada)
NORTHWEST TERRITORIES
Yellowknife
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUÉBEC
Hudson Bay
James Bay
Calgary
Regina
Saskatoon
Toronto
Ottawa
Montreal
Gentilly
Chalk River Nuclear Laboratories
Whiteshell Nuclear Research Establishment
When uranium is mined and milled it is packed in drums as a bright yellow powder called “yellowcake” (U_3O_8) .

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



Over 85% of Canada's uranium is exported to other countries.
It has all ended up as radioactive waste or in nuclear weapons.

The Grand Chief of the Crees of Quebec who declared a moratorium on uranium mining

Photo: Robert Del Tredici

U-BAN = International Campaign to Ban Uranium Mining Worldwide

The End

web site: www.ccnr.org

e-mail: ccnr@web.ca