Some Lessons from the First Licensed Geologic Repository for Radioactive Waste in America

Norbert T. Rempe
Carlsbad, NM

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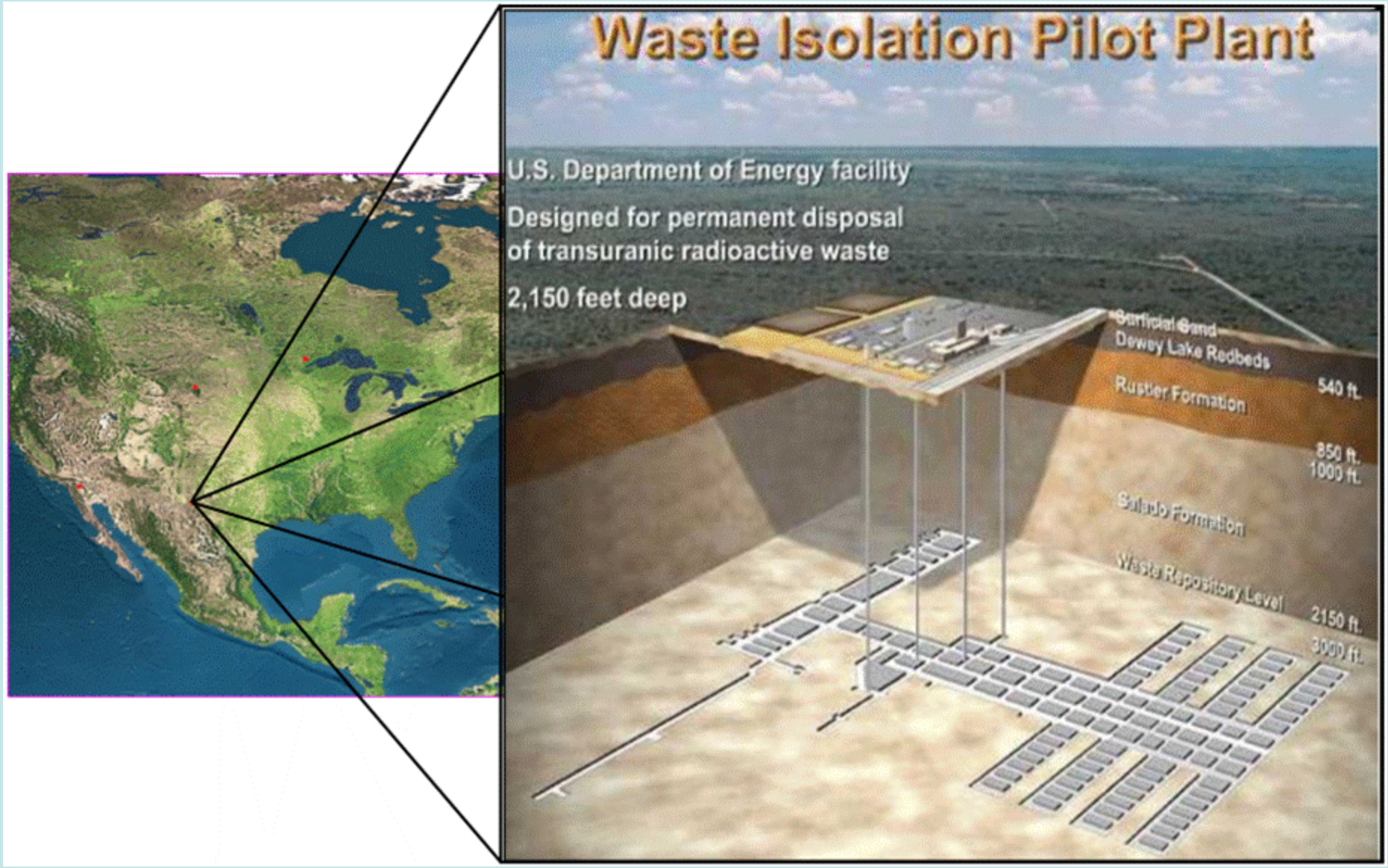
ng(o)$_3$


Waste Isolation Pilot Plant
U.S. Department of Energy facility
Designed for permanent disposal
of transuranic radioactive waste
2,150 feet deep
Surficial Sand
Dewey Lake Redbeds
Rustler Formation
540 ft.
850 ft.
1000 ft.
Salado Formation
Waste Repository Level
2150 ft.
3000 ft.

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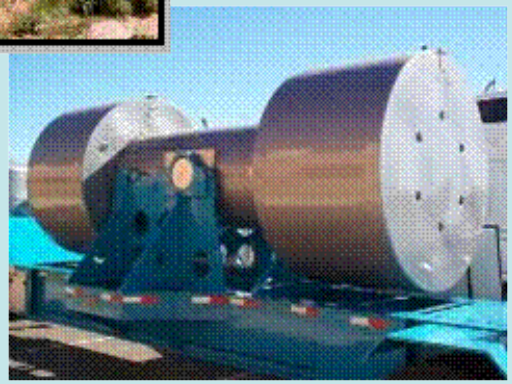
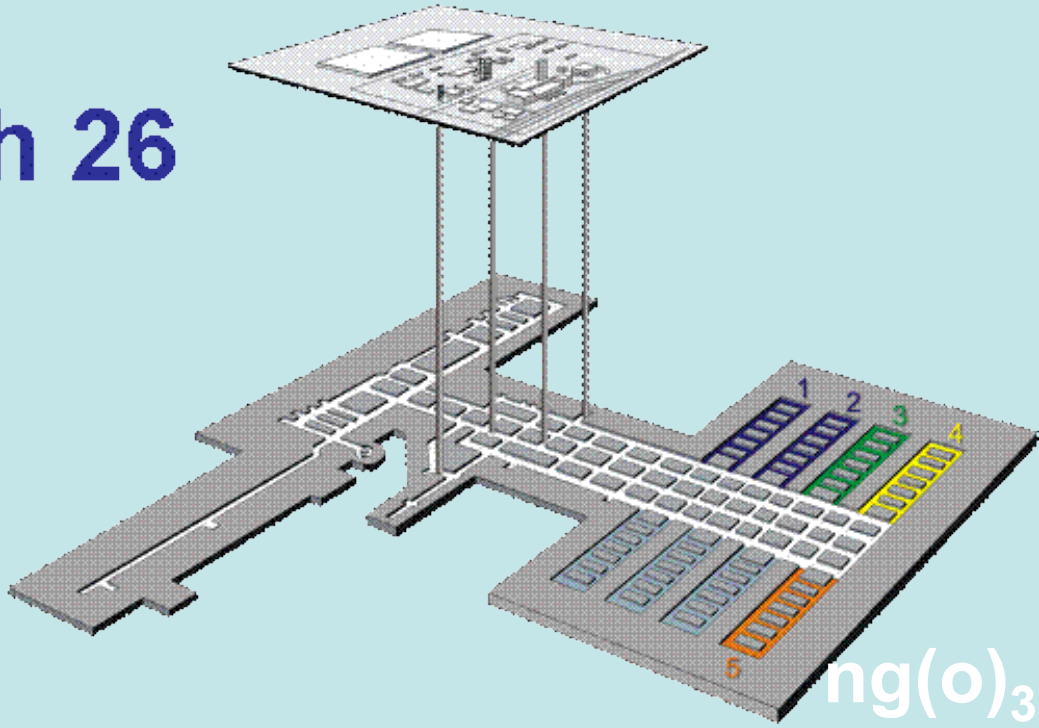
Waste Isolation Pilot Plant

WIPP

since
March 26
1999





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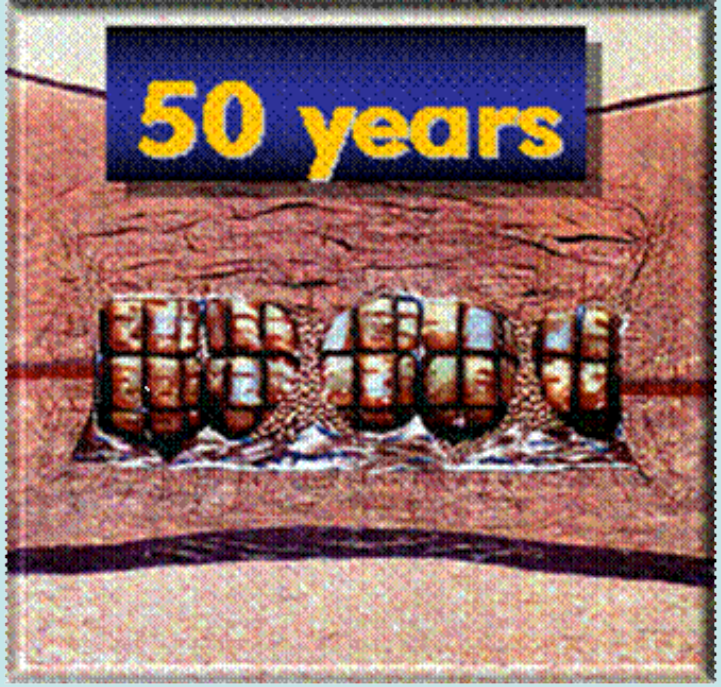
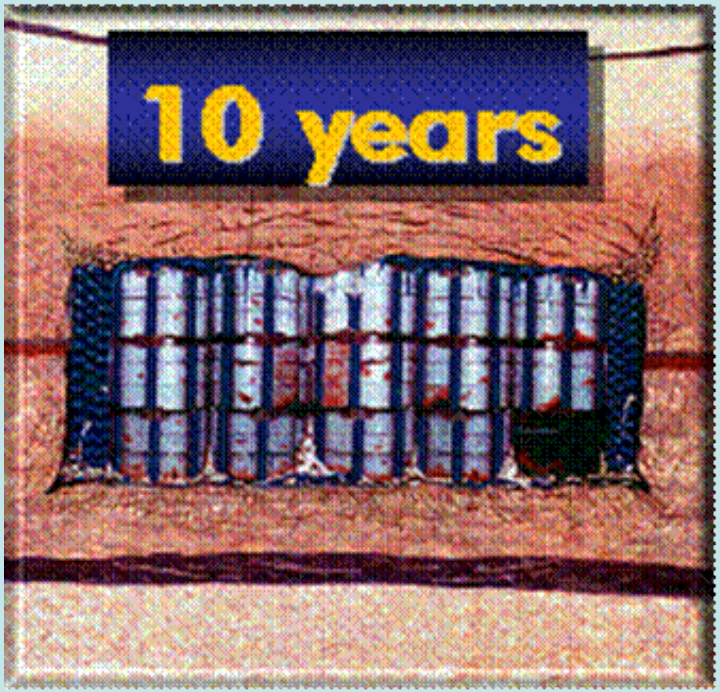
http://wipp.energy.gov/WIPPRecovery/Images/Emplaced%20Waste.pdf



Nature's Trash Compactor



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ὁ δὲ ἀνεξέταστος βίος οὐ βιωτὸς ἀνθρώπω (Socrates)

the unexamined life is not worth living (for a *proper* human being)

Common unexamined assumptions in geologic waste isolation:

The fascinating impressiveness of rigorous mathematical analysis, with its atmosphere of precision and elegance, should not blind us to the defects of the premises that condition the whole process (T. C. Chamberlin, 1899)

- Liquid waste must be solidified before geologic disposal
- New excavations are better than old mines
- Known mineral resource areas should be avoided
- **Radioactivity is more insidious than chemical toxicity**
- We must understand everything "perfectly"
  - down below the yocto (10^{-24}) scale
  - up above the n^{th} dimension
  - before deciding to do anything

Your system is perfectly designed to give you the results you're getting

(W. Edwards Deming)

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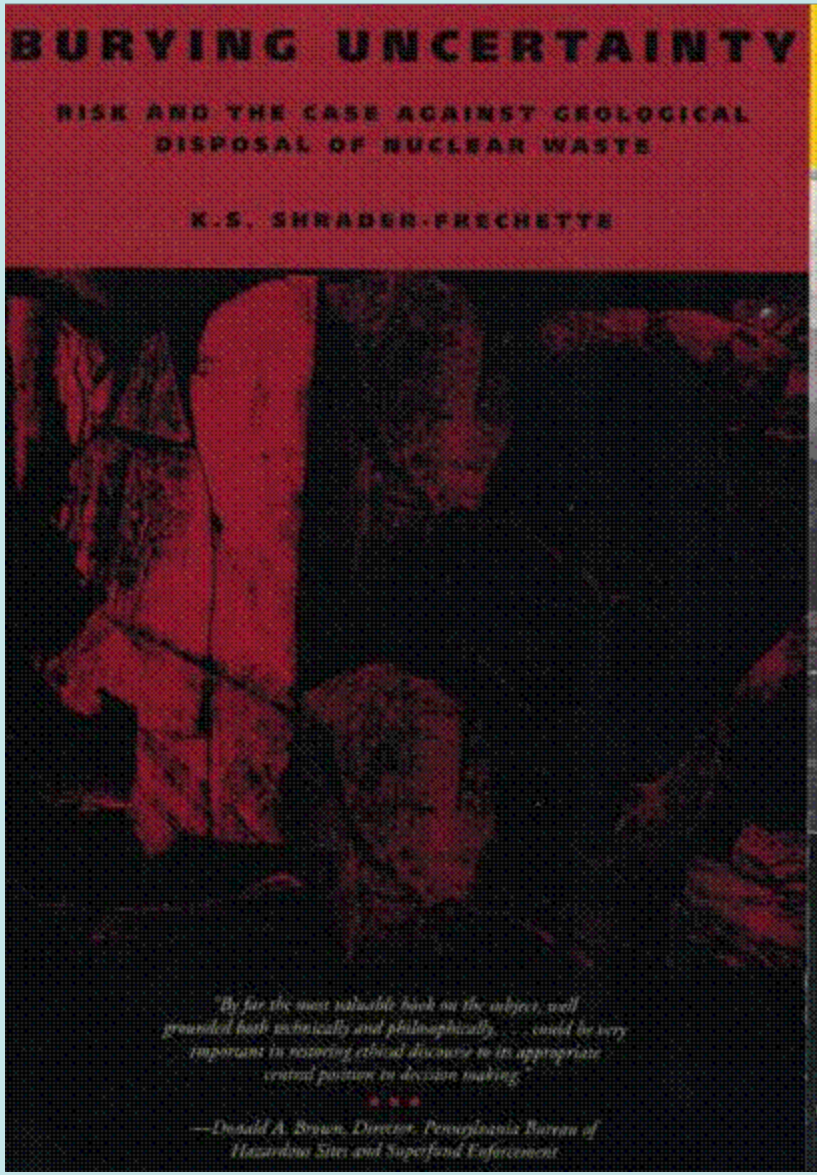
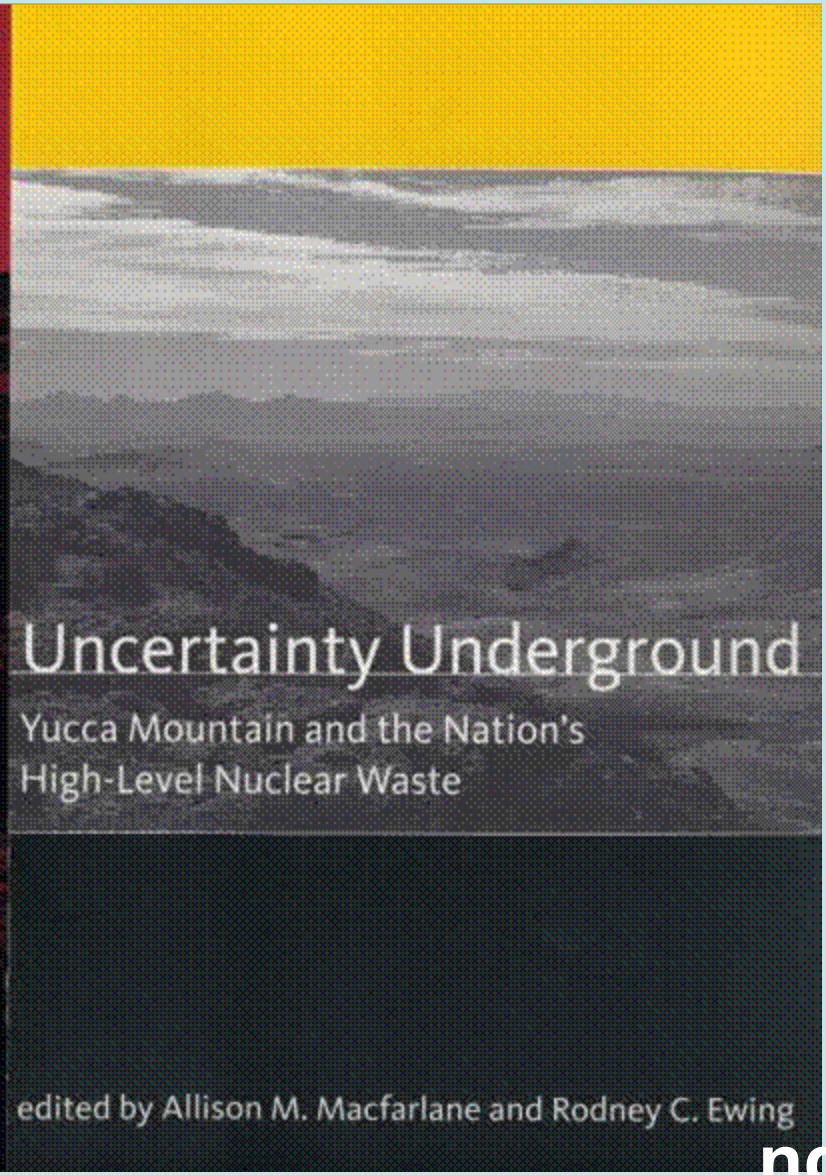
Cottage Industry in Uncertainty

1993 University of California



2006 MIT



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Peace Justice Environment since 1983

Avner Vengosh, Duke University
Rooting Out Radioactive Groundwater (Geotimes, May 2006)
When the **Chernobyl** nuclear power plant exploded in 1986… The accident demonstrated the **fragility of any nuclear facility** and raised the level of awareness over the health **threats that radiation poses** to people and the environment.
…the general population is still **at risk from** a different source: **Naturally occurring radioactive particles** exist in many groundwater systems worldwide…
The global **community must aggressively address these challenges, to ensure a safe water supply**.

Laurence A. Coogan & Jay T. Cullen, University of Victoria
Did natural reactors form as a consequence of the emergence of oxygenic photosynthesis during the Archean? (GSA Today, October 2009)
Natural reactors act as point sources of…**toxic byproducts**.
Natural fission reactors would clearly be **environmentally detrimental**.
…whether the formation of these natural reactors had any significant **biocidal impacts**…

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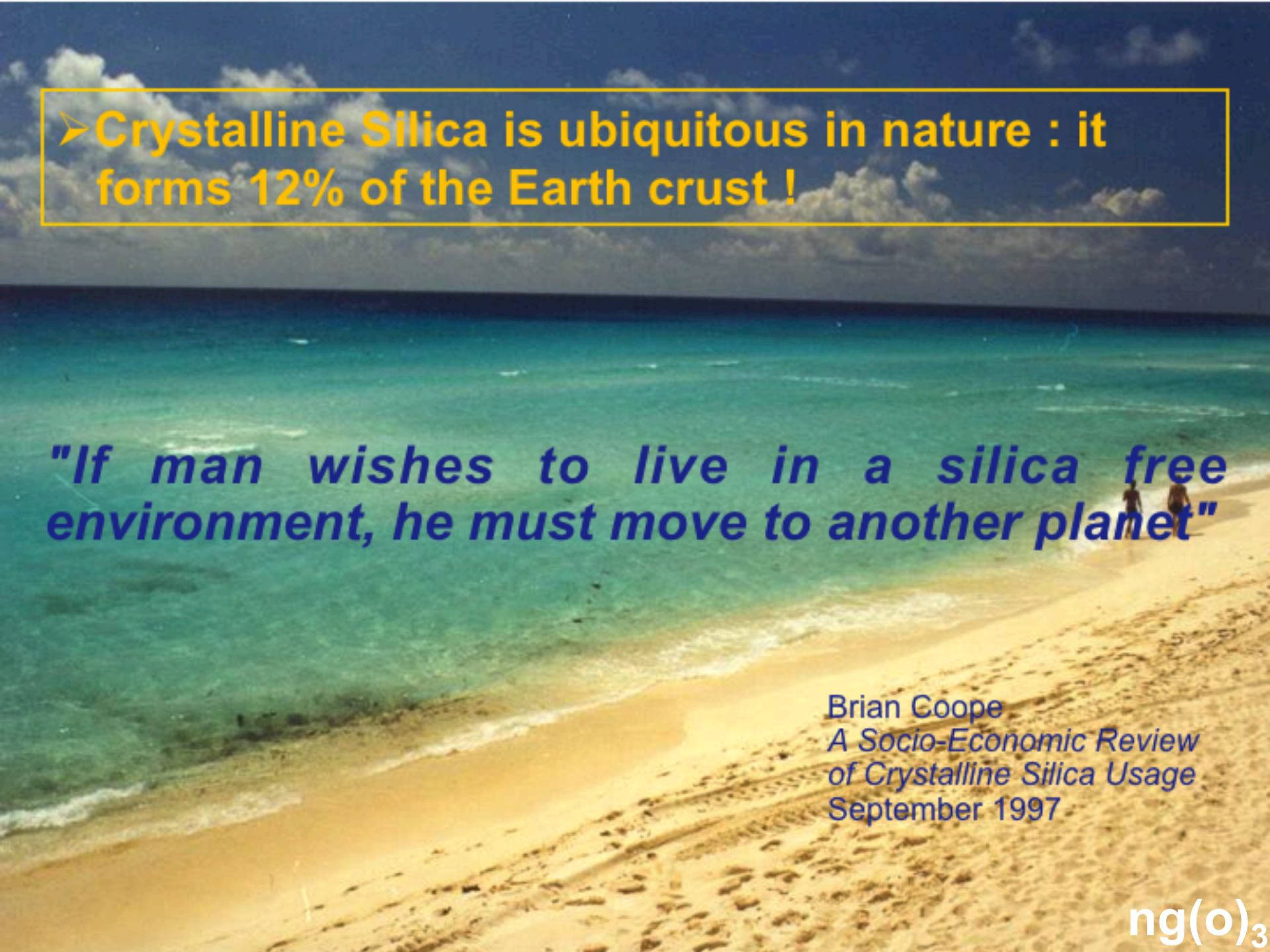
Decrease in the natural radioactivity of Earth's crust from the decay of its most common radioactive isotopes

(Significant conclusion: All natural uranium is depleted uranium)

Million years ago	Relative decrease in radioactivity			
	U-238	**U-235**	**Th-232**	**K-40**
5000	2.14	128	1.29	14.3
2000	1.35	7.05	1.08	2.82
present	~1	~1	~1	~1

Simplified from L.A. Pertsov, The natural radioactivity of the biosphere, Israel Program for Scientific Translations, Jerusalem, 1967



- **Crystalline Silica is ubiquitous in nature : it forms 12% of the Earth crust !**

"If man wishes to live in a silica free environment, he must move to another planet"

Brian Coope
A Socio-Economic Review of Crystalline Silica Usage
September 1997

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"Normal" or average v. highest known natural background radiation on Earth

"normal"	Ramsar
Radium in groundwater (Bq/l)	
<10	~500
Radium in soil, rock, food (Bq/g)	
<0.5	~350
Radon inside homes (Bq/l)	
<0.5	>4
Population dose (mSv/yr)	
2-3	20-250

"no consistent detrimental effect has been detected so far"

http://www.ecolo.org/documents/documents_in_english/RamsarHLNRAPaper.doc

Source:
The Very High Background Radiation Areas of Ramsar, Iran: Geology, Radiobiology, and Policy
Andrew Karam, Ph.D., CHP
University of Rochester
Presented to NO CHPS, Radiation Safety Without Borders
November 12, 2002

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Natural Uranium in Groundwater

- Can vary considerably from place to place depending on local mineralization, hydrology and geochemistry
- Although typically a few micrograms / liter (a few pCi / liter), U has been measured in public drinking water sources 10 -100 + greater than this
- No permanent health effects have been observed in populations drinking water for generations with these high natural levels

Sources:(1) *Assessing Potential Risks from Exposure to Natural Uranium in Well Water. Hakonson-Hayes A.C, P.R.* Fresqueza,, F.W. Whicker, Journal of Environmental Radioactivity, 59 (2002)
(2) *Public Health Goal for Uranium in Drinking Water.* Office of Environmental Health Hazard Assessment California Environmental Protection Agency, 1997 (3) U.S. Dept. of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry. *Toxicological Profile for Uranium. 1999.*

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http://www.nma.org/pdf/urw/brown.pdf

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Background Radiation and EPA and NRC Regulations

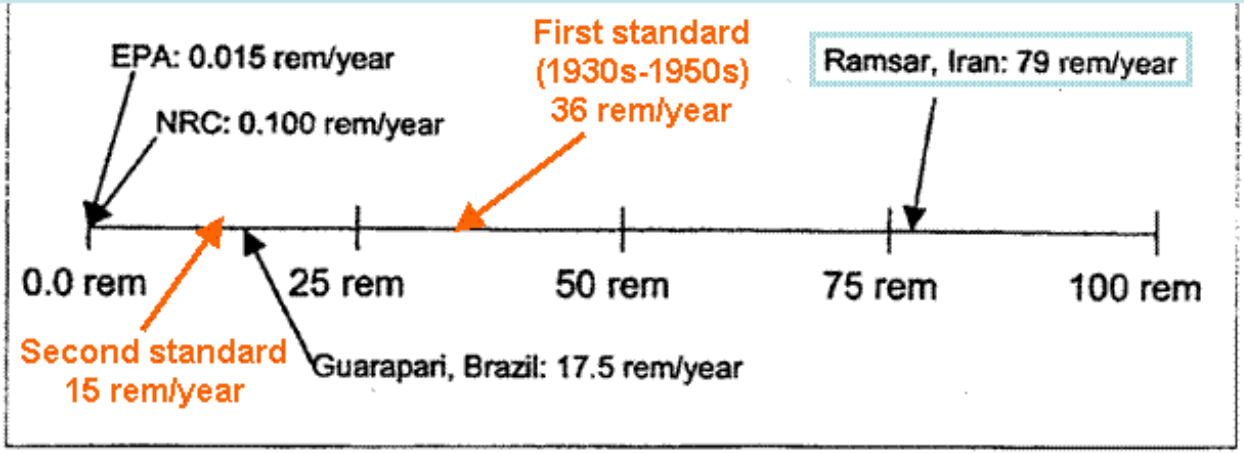

Fig. 2. Scale comparing EPA and NRC regulatory limits to natural background radiation environments (100 rem = 1 sievert; 100 rad = 1 gray)

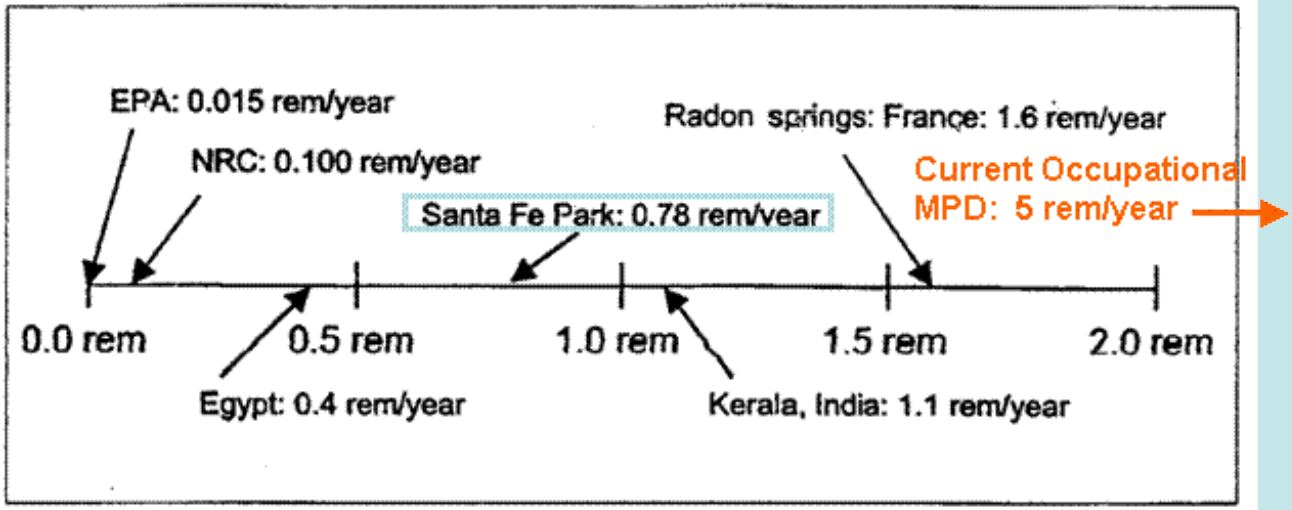

Fig. 3. Expanded scale comparing EPA and NRC regulatory limits to natural background radiation environments (100 rem = 1 sievert; 100 rad = 1 gray)

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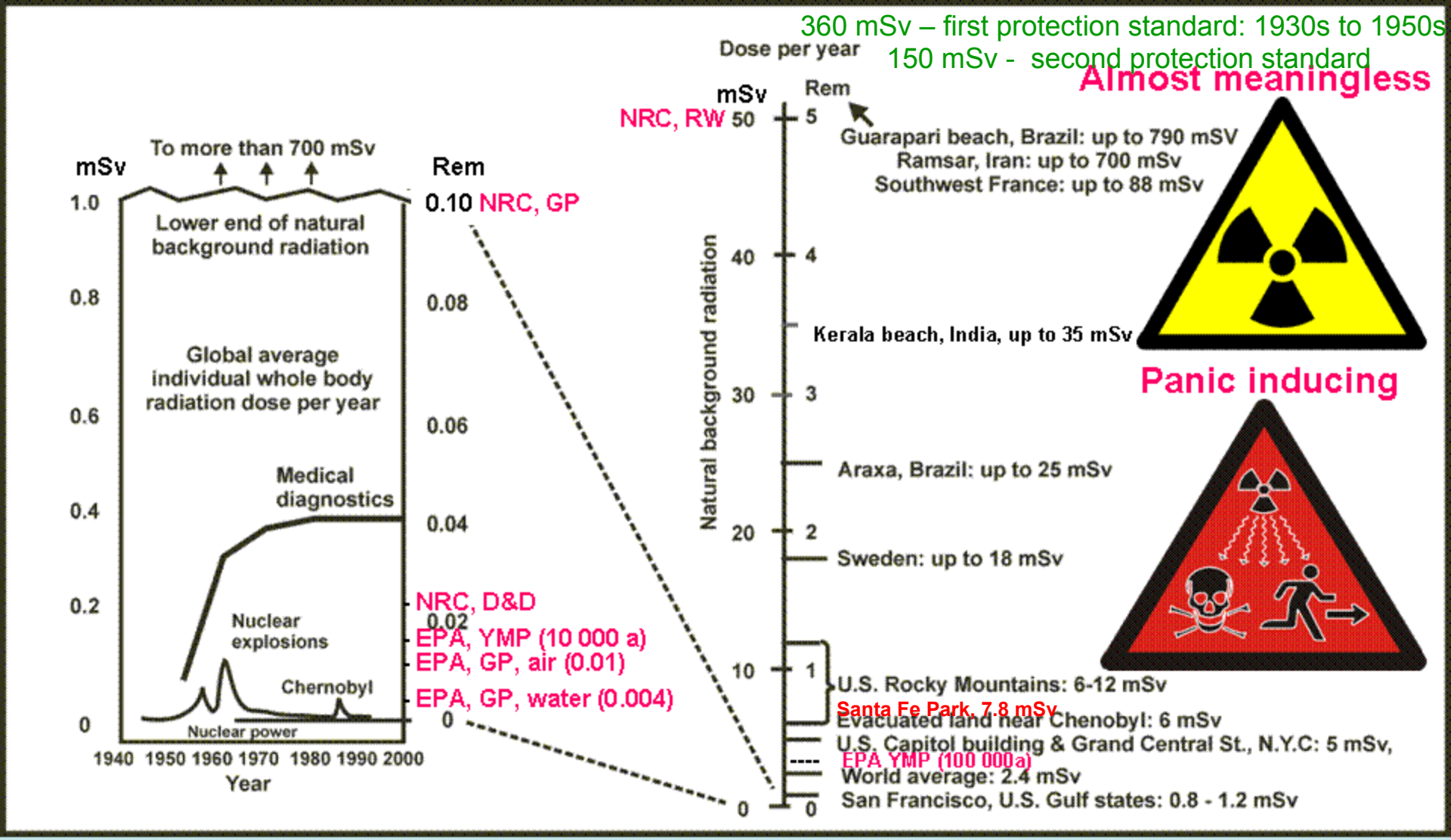
From Mark M. Hart, "Disabling the terror of radiological dispersal," *Nuclear News* July 2003



Modified from a
Figure prepared by Ted Rockwell from data found in "Radiation Risk and Ethics", Z. Jaworoski, published in Physics Today, American Institute of Physics, September, 1999 and "Ionizing Radiation and Radioactivity in the 20th Century", Z. Jaworoski, presented at the International Conference on Radiation and its Role in Diagnosis and Treatment", Tehran, Iran October, 2000.

http://www.cns-snc.ca/media/uploads/branch_data/branches/Toronto/radiation/natural_and_human_radiation.html
http://hps.org/publicinformation/ate/faqs/regdoselimits.html
http://dspace.mit.edu/bitstream/handle/1721.1/41588/213482682.pdf?sequence=1

March 15, plant perimeter:
11.9 mSv/hr, then 6 mSv/hr
250 mSv: barely clinically detectable

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various Fukushima estimates:
7800: av. 7.7 mSv
2200-20000: 20-100 mSv
30: >100 mSv
2200: >100 mSv

The (preceding)figure shows the average radiation dose we get each year from various sources. We get so little from nuclear power and its associated operations (including the meltdown at Three Mile Island), that it hardly shows up on this graph. The fallout from the reactor accident at Chernobyl produced a measurable peak that is now quite low. The fallout from testing nuclear weapons made a much larger peak, but it too has largely subsided. But all these radiation doses are dwarfed by the average radiation dose we get from medical diagnostics: dental and other x-rays, radioisotope tests, body imaging procedures such as CAT scans, etc. (The large radiation doses given to burn out tumors would be in addition to this.) At the very top of the left hand curve, we enter the lowest levels of natural radiation background. The top of the chart is a radiation level of 1.0 millisieverts or 0.1 rems per year. At that point, a note tells us that the natural radiation background goes up to more than 700 mSv per year. That is, the highest natural background levels would be several hundred feet off the top of the graph! So on the right, we have a new scale, going not from 0 to 1.0 mSv, but from 0 to 50 mSv per year. The numbers on the first chart are now all squeezed into the space between 0 and 1.0 on the 0 to 50 scale. And on this new scale, we see what the natural radiation levels are at various places in the world. The world average is 2.4. Some rooms in the US Capitol building and in New York's Grand Central Station are over 5-too high to be allowed in nuclear power plant work areas. The evacuated land near Chernobyl is about 6-lower than prime real estate in Denver. Places in Sweden are 18, parts of southwestern France are 88. And there are places in Iran and Brazil that are over 700! These are not down in some mine or other inaccessible location. These are places where generations of people have lived healthy long lives. We hear arguments over the number of "people who will die" if they are exposed to 0.25 mSv instead of 0.15 mSv, and whether water around nuclear facilities must be reduced to 0.04 mSv. But when we fly or go on a ski trip or get an x-ray, we willingly exceed those numbers, and are none the worse for it.

Text and figure prepared by Ted Rockwell from data found in "Radiation Risk and Ethics", Z. Jaworoski, published in Physics Today, American Institute of Physics, September, 1999 and "Ionizing Radiation and Radioactivity in the 20th Century", Z. Jaworoski, presented at the International Conference on Radiation and its Role in Diagnosis and Treatment", Tehran, Iran October, 2000.
http://www.cns-snc.ca/media/uploads/branch_data/branches/Toronto/radiation/natural_and_human_radiation.html

Current clean-up cost for US/DOE facilities is estimated at $350 billion for EPA standard of 15 mrem above background

(15 mrem is <5% of average natural background in USA)

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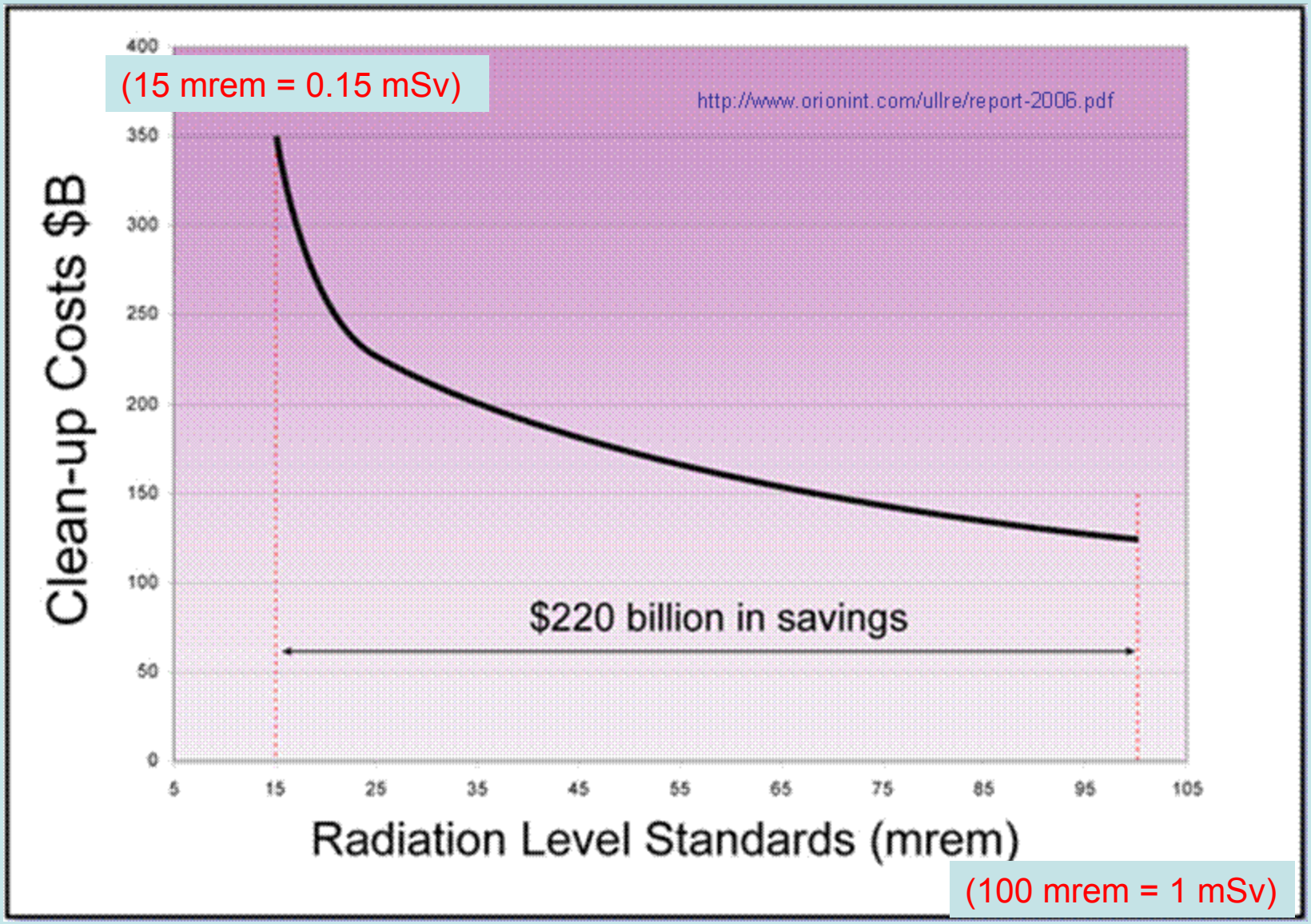

Insistence on, and
cadaverous compliance with,
regulations without continuously
questioning and justifying
their factual and rational basis

is the last refuge of
the lazy, incompetent, and
malevolent

ng(o)3

Everything is:

porous
permeable
wet
and radioactive

(personal lesson learned in 23 years at WIPP)

Thank you for the opportunity to bring this information to your attention!

Who has the first question or comment?

contact: rempent@yahoo com

Recommended reading :

EPA-600/2-75-040
EPA-600/2-85-021A

Progress in Nuclear Energy 49 (2007) 365-374

Deep Geologic Repositories (Reviews in Engineering Geology XIX), GSA, 2008

Auxiliary Slides

General Caution

1. Presentations are open to misinterpretation without (or likely even with) the presenter's interaction with his audience.
2. Data, ideas, and conclusions that are extracted may be in error outside the original context or intent.
3. The presenter or provider of this material is not liable for inappropriate or erroneous use of the material or its consequences.
4. None of the material should be assumed to be be original.

Special Note

Norbert T. Rempe prepared this presentation as a private individual, not for profit. This work was *NOT* sponsored by any private organization or government agency.

ABSTRACT

Practical geologic isolation of some radioactive waste in America began 15 years ago at the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico and will continue for several years or even a few decades. By geologically sequestering natural and anthropogenic radionuclides from the easily accessible biosphere, WIPP mitigates and eliminates their legacy impact on our environment.

WIPP science, engineering, and practical operating experience demonstrate that geologic isolation is as feasible and effective in America as it has been elsewhere since the 1960s. **But that experience also raises questions about the intellectual and scientific foundation of modern radiation protection standards. Those reflect mainly the technological limits of available instrumentation rather than an assessment of the natural range of radiation exposure in time and space and its effects (or the lack thereof) on humans and the environment.**

A significant factor determining the natural range of exposure to ionizing radiation is the character of our geological environment. Particularly suited to address evolutionary change through time and space, geology and its related disciplines can help establish a framework for rational regulatory reform.

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Example Conclusions from Studies on Health Impacts on Populations Living Near Uranium Mines and Mills

" The absence of elevated mortality rates of cancer in Montrose County over a period of 51 years suggests that the historical milling and mining operations did not adversely affect the health of Montrose County residents."[1]

"No unusual patterns of cancer mortality could be seen in Karnes County over a period of 50 years suggesting that the uranium mining and milling operation had not increased cancer rates among residents."[2]

[1] *Cancer and Noncancer Mortality in Populations Living Near Uranium and Vanadium Mining and Milling Operations in Montrose County, Colorado, 1950 -2000. Boice,* JD, Mumma, MT et al. Journal of Radiation Research, 167:711-726; 2007

[2] *Mortality in a Texas County with Prior Uranium Mining and Milling Activities, 1950 – 2001. Boice, JD,* Mumma, M et al. Journal of Radiological Protection, 23:247 – 262; 2003

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Annual Background Radiation Exposure vs. Annual Public Exposure Limits: U Mines and Mills

- Background Levels (from previous slide)
  - > Colorado average = 400 mrem
  - > Leadville, Colorado = 526 mrem
  - > U.S. average = 310 mrem
- Regulatory Limits
  - > EPA drinking water standard = 4 mrem[1]
  - > EPA limit for all exposure pathways = 25 mrem[2]
  - > NRC Limit with radon = 100 mrem; excluding radon = 25 mrem[3]

[1] U.S. Environmental Protection Agency. Radionuclides in drinking water. Available at: http://www.epa.gov/safewater/radionuclides/index.html.

[2] U.S. Environmental Protection Agency. Environmental radiation protection for nuclear power operations, 40 CFR 190.10; 2006.

[3] U.S. Nuclear Regulatory Commission; Domestic Licensing of Source Material ; 10 CFR 40

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http://www.nma.org/pdf/urw/brown.pdf

Radiation Background in Kerala India

- Unusually high natural radiation background has been known for many years due to natural thorium in the monazite sands of the region
- Annual outdoor exposure levels as high as 7000 mrem have been measured where people live
- Recent epidemiological studies have concluded no excess cancers in over 69,000 residents studied for 10 years[1]

[1] R Naire, B Rajan, et al; Background radiation and cancer incidence in Kerala,India—Karunagappally cohort study; Health Physics, 96,1, January, 2008

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Natural background radiation: 3 mSv/y. (range: 1-10 mSv/y.)

20 *Int. J. Low Radiation, Vol. 2, Nos. 1/2, 2006*

Cancer incidence in areas with elevated levels of natural radiation[1]

S.M.J. Mortazavi* Senior author: A. Niroomand-Rad

National Radiation Protection Department (NRPD),
Iranian Nuclear Regulatory Authority (INRA),
PO Box 14155-4494, Tehran, Iran

Natural background radiation levels "… in Ramsar are approximately 55-200 times higher than that of the global average rate." (typ. 260 mSv/y.) "… no increased level of chromosome aberrations. … It can be concluded that prolonged exposure … decreases the frequency of chromosome aberration and the cancer incidence rate."

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…the general population is still **at risk from** a different source: **Naturally occurring radioactive particles** exist in many groundwater systems worldwide…

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Natural reactors act as point sources of…**toxic byproducts**.

Natural fission reactors would clearly be **environmentally detrimental**.

…whether the formation of these natural reactors had any significant **biocidal impacts**…

This is nuts!

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The 1996 CCA* projects that the total amount of radionuclide releases during the 10 000-year regulatory period from a fully loaded, undisturbed WIPP will be 1/768th (0.13%) of the average natural background radiation in the USA or lower than 3% of the regulatory limit.

Subsequent EPA-requested performance assessment verification tests for the “worst-case” calculated still less than 10% of the regulatory limit.

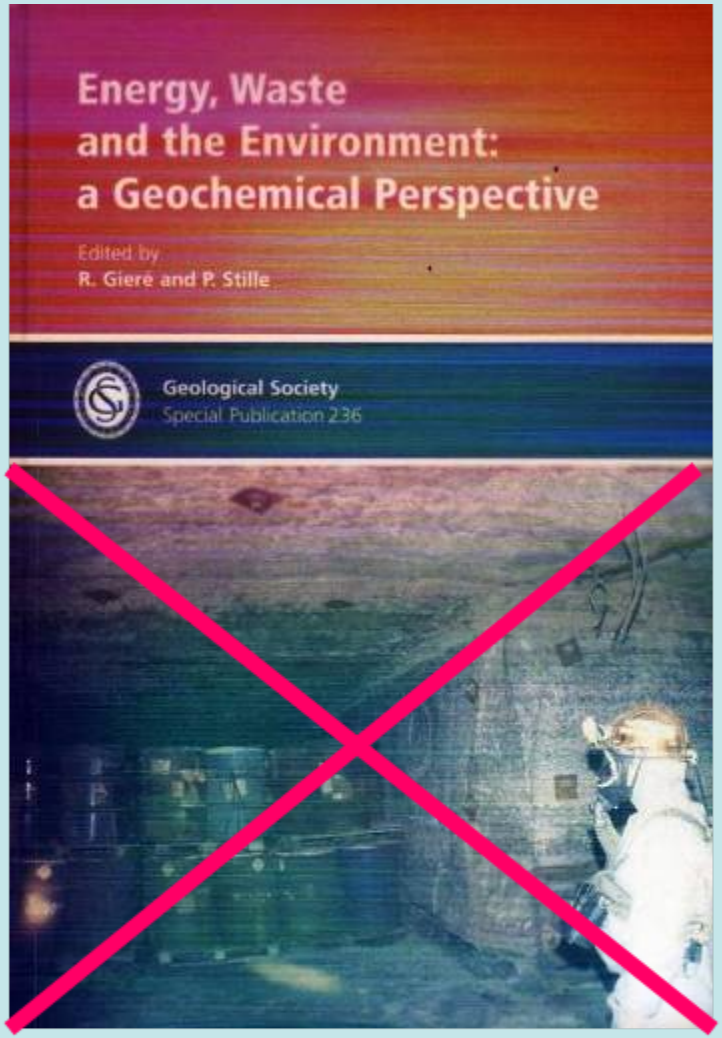
That means even if breached by multiple, low-probability, hypothetical human intrusions, such a disturbed WIPP repository will perfectly safely contain the emplaced TRU waste for at least 10 000 years.

*CCA: Compliance Certification Application (for WIPP, from DOE to EPA)

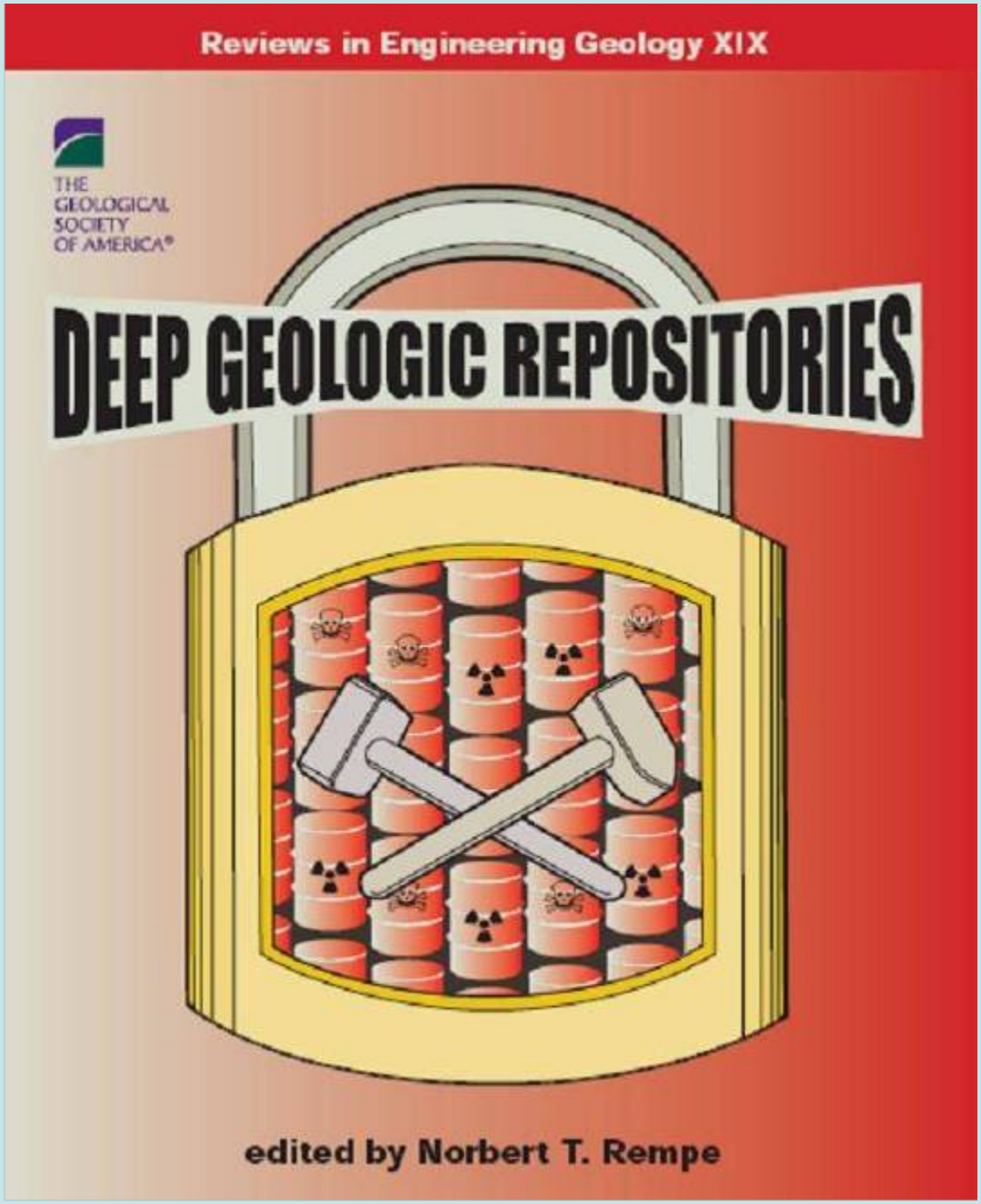
Simplified from Inés R. Triay, Mark L. Matthews, and Leif G. Eriksson:
“The Waste Isolation Pilot Plant: A Success Story Happening Now”,
WM ‘01 Conference, Tucson, AZ, 2001

Annual Radiation Dose Limits	Agency
Radiation Worker - 5,000 mrem	(NRC, "occupationally" exposed)
General Public - 100 mrem	(NRC, member of the public)
General Public - 25 mrem	(NRC, D&D all pathways)
General Public - 10 mrem	(EPA, air pathway)
General Public - 4 mrem	(EPA, drinking water pathway)

http://hps.org/publicinformation/ate/faqs/regdoselimits.html



This book, published by the Geological Society (of London) is not bad, but the title illustration is unattributed and defamatory



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ScienceDirect
ELSEVIER
Progress in Nuclear Energy 49 (2007) 365–374
PROGRESS IN NUCLEAR ENERGY
An International Review Journal
www.elsevier.com/locate/pnucene

Review

Permanent underground repositories for radioactive waste

Norbert T. Rempe*

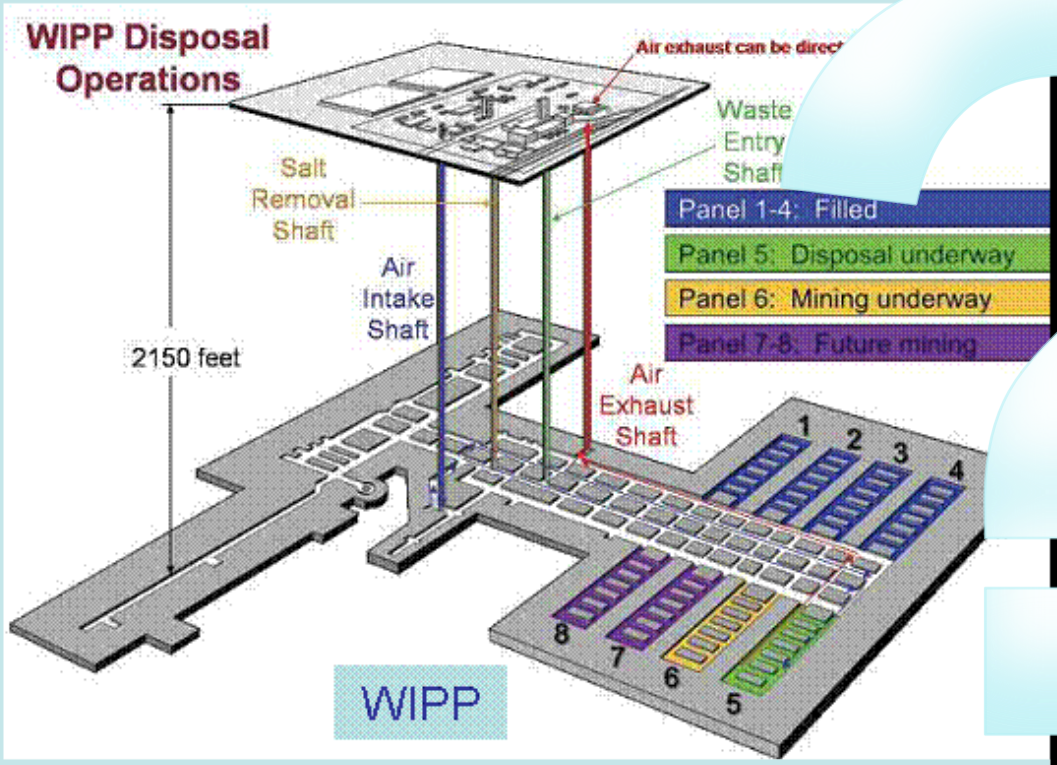
Abstract

Solid radioactive waste first entered a deep geologic repository in 1959. Liquid radioactive waste has been injected into confined underground reservoirs since 1963. Solid wastes containing chemically toxic constituents with infinite half lives have been isolated underground since 1972. Performance to date of these and other repositories has not caused any of their owners and operators to transfer or contemplate transferring the waste confined in them to presumably safer locations. Natural and engineered analogues offer sound evidence that deep geologic isolation is effective, safe, and compatible with responsible environmental stewardship. Underground isolation of dangerous, including radioactive, wastes is therefore increasingly being used as a safe and reliable method of final disposal.

A remarkable study in contrast

almost **15** years **success**

>27 years of study – then target of **political assassination**



largely ignored by textbooks and little known

academically "hot" and well known

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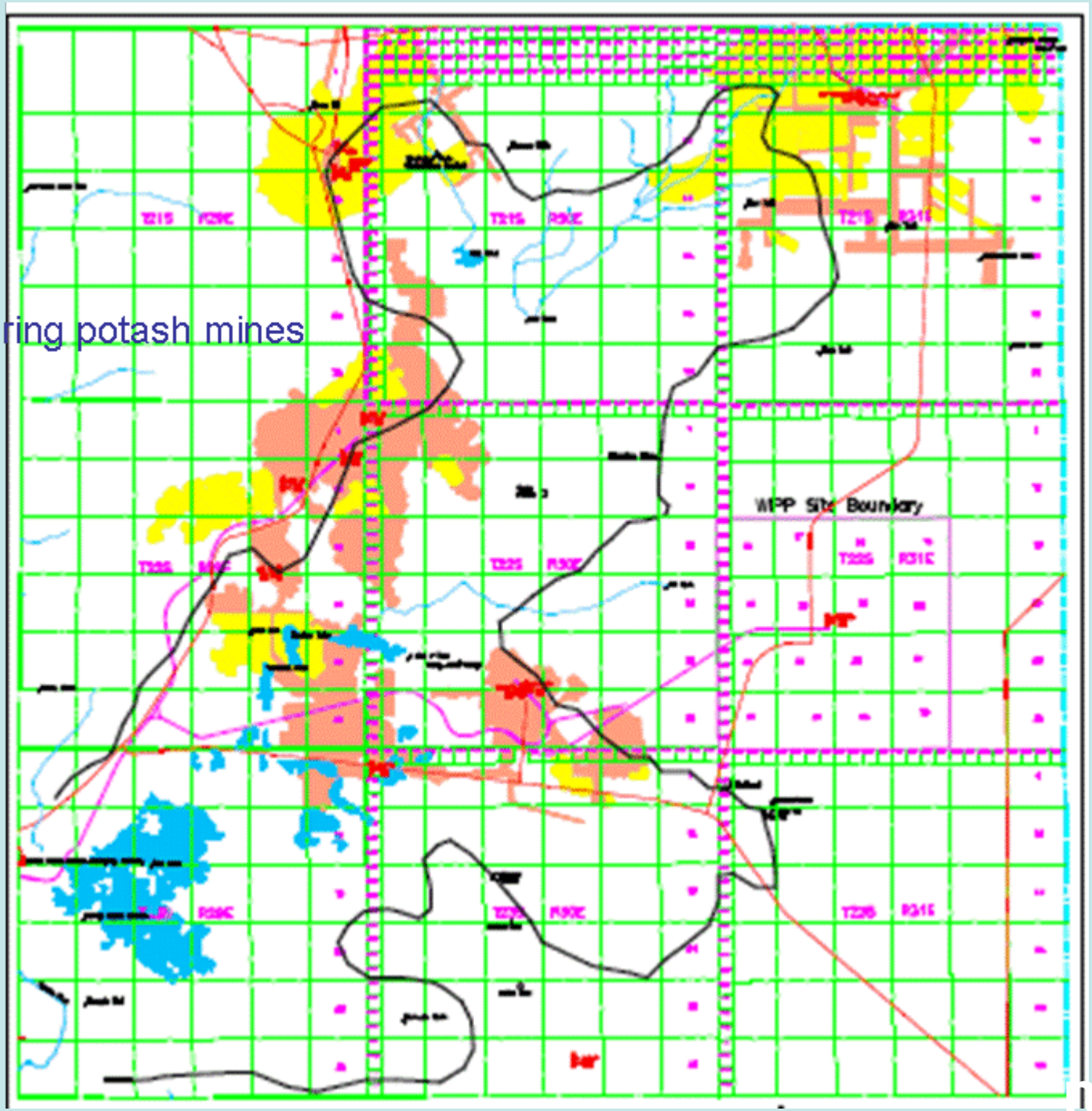
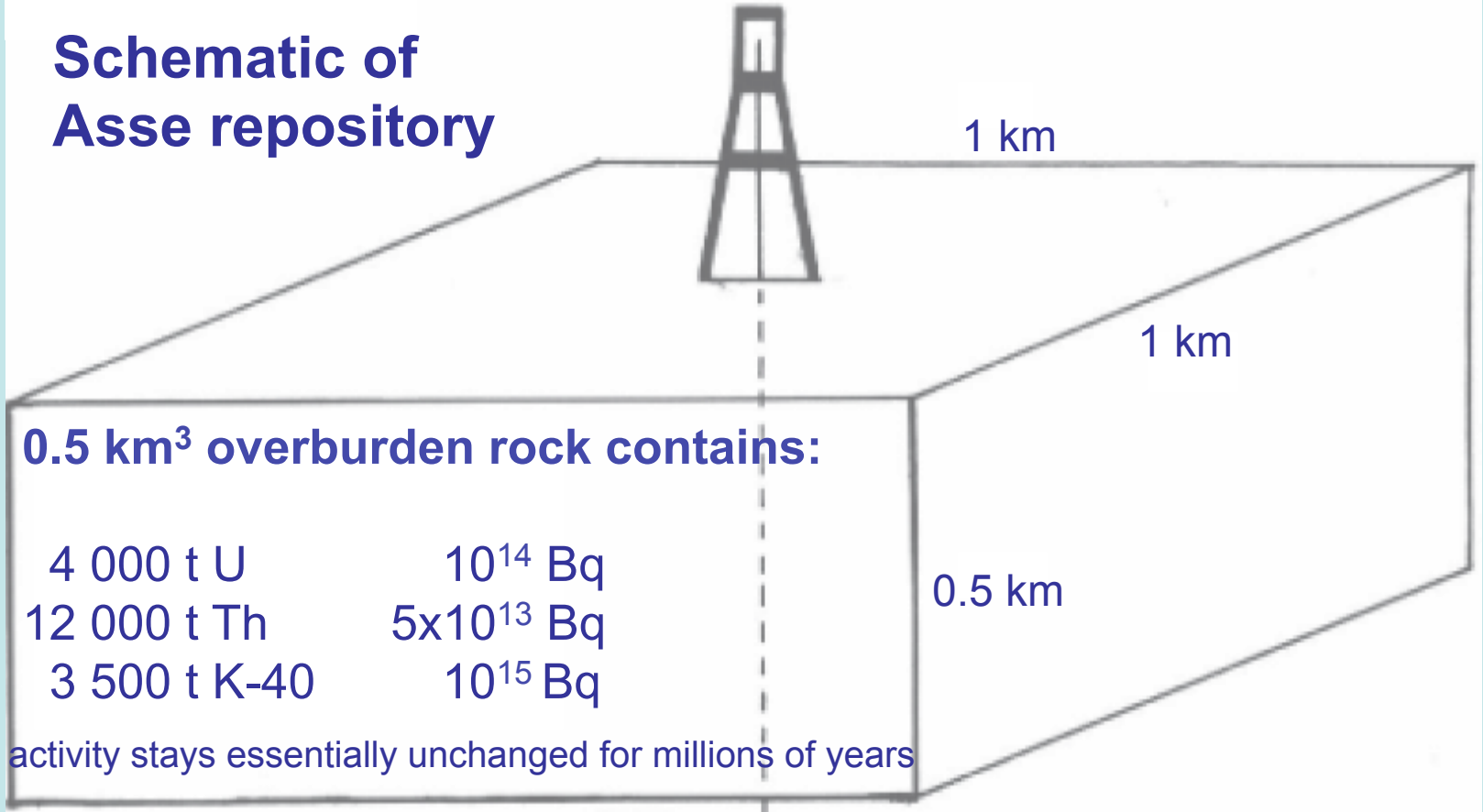
Neighboring potash mines



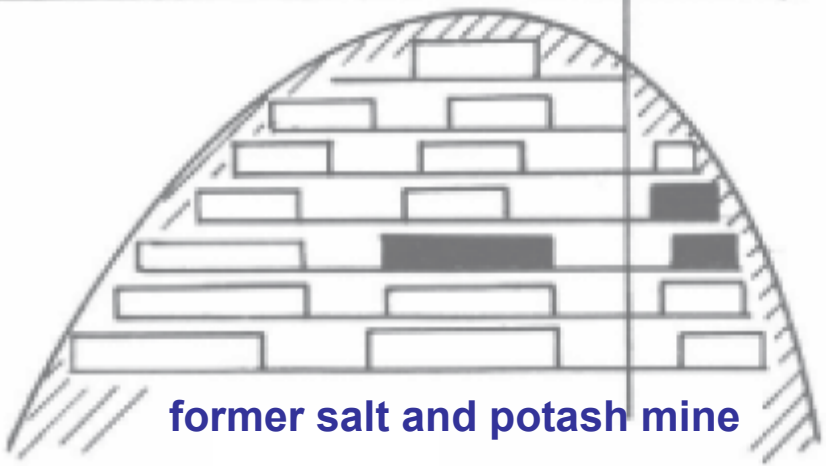
Schematic of Asse repository



0.5 km³ overburden rock contains:

4 000 t U	10^{14} Bq
12 000 t Th	5×10^{13} Bq
3 500 t K-40	10^{15} Bq

activity stays essentially unchanged for millions of years



former salt and potash mine

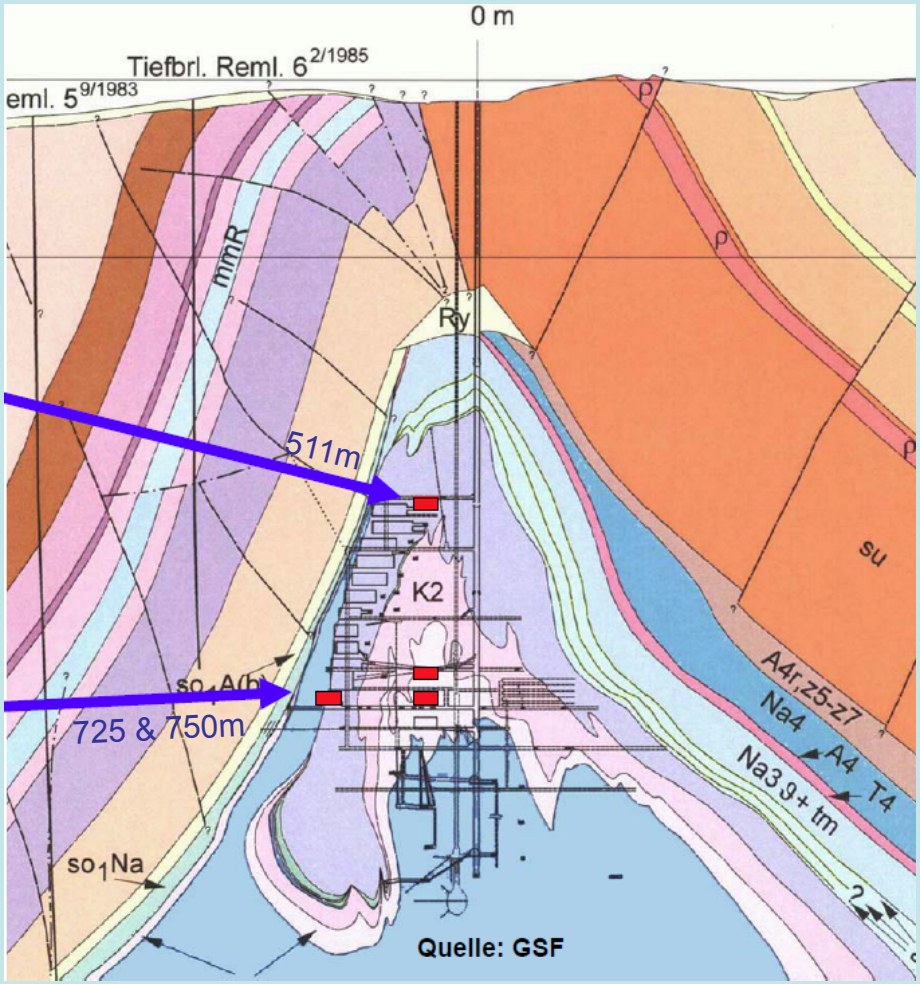
Waste inventory:

100 t U
100 t Th
10 kg Pu

Activity of all waste:

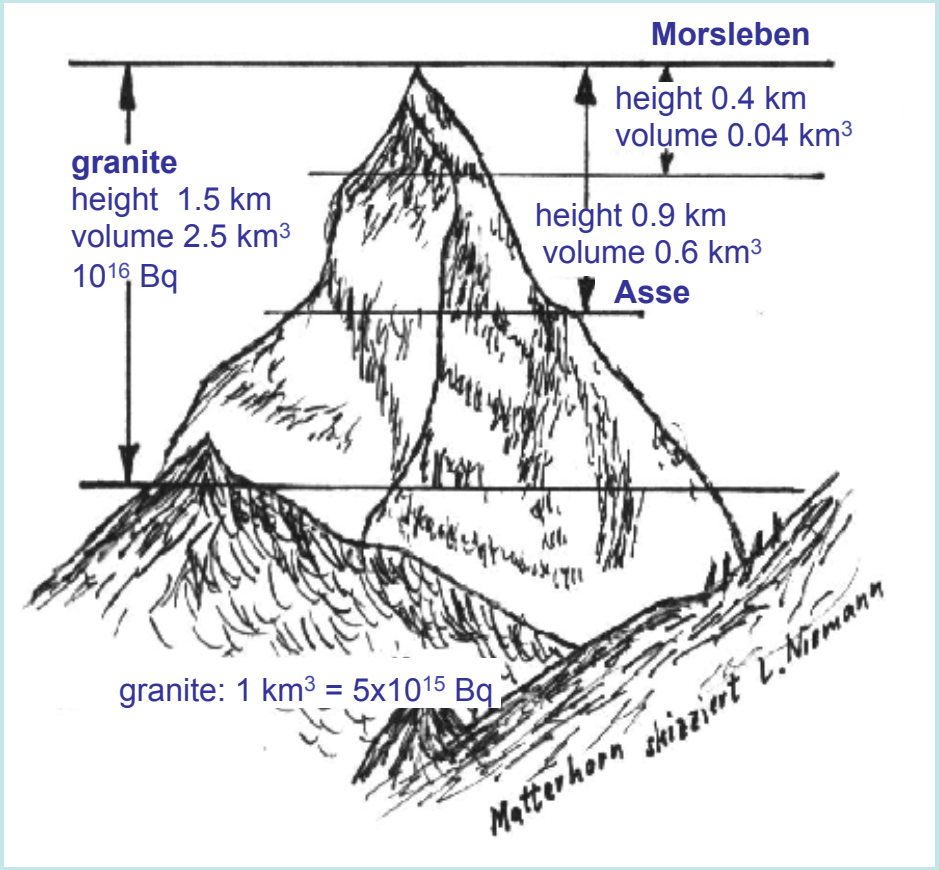
In 2000: 3×10^{15} Bq
In 2140: $< 3 \times 10^{13}$ Bq

translated from: http://www.novo-argumente.com/artikel/99/novo9943.pdf



Asse

Matterhorn



Under undisturbed repository conditions, the maximum annual radiation exposure to an individual from WIPP predicted in the 1996 CCA* is by a factor of 32 lower than the limit (i.e., 3% of the limit) defined as safe by the EPA in the disposal regulations and 1/768th (0.13%) of the average natural background radiation in the USA.

Even if breached by multiple, low-probability, hypothetical human intrusions, such a disturbed WIPP repository will safely contain the emplaced TRU waste for at least 10,000 years.

The CCA projects that the total amount of radionuclide releases during the 10,000-year regulatory period from a fully loaded WIPP repository will be lower than 3% of the applicable regulatory limits. Subsequent EPA-requested performance assessment verification tests for the "worst case" calculated less than 10% of the applicable regulatory limits for radionuclide releases during the 10,000-year regulatory period.

*CCA: Compliance Certification Application (for WIPP, from DOE to EPA)

Simplified from
WM'01 Conference, February 25-March 1, 2001, Tucson, AZ:
THE WASTE ISOLATION PILOT PLANT: A SUCCESS STORY HAPPENING NOW
Dr. Inés R. Triay, Mark L. Matthews
U.S. Department of Energy Carlsbad Field Office, P.O. Box 3090, Carlsbad, New Mexico 88221, USA
Leif G. Eriksson
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I have observed… that DOE scientists (shall we call them regulatory scientists?) who present results do not follow the usual presentation format used by research scientists. They present

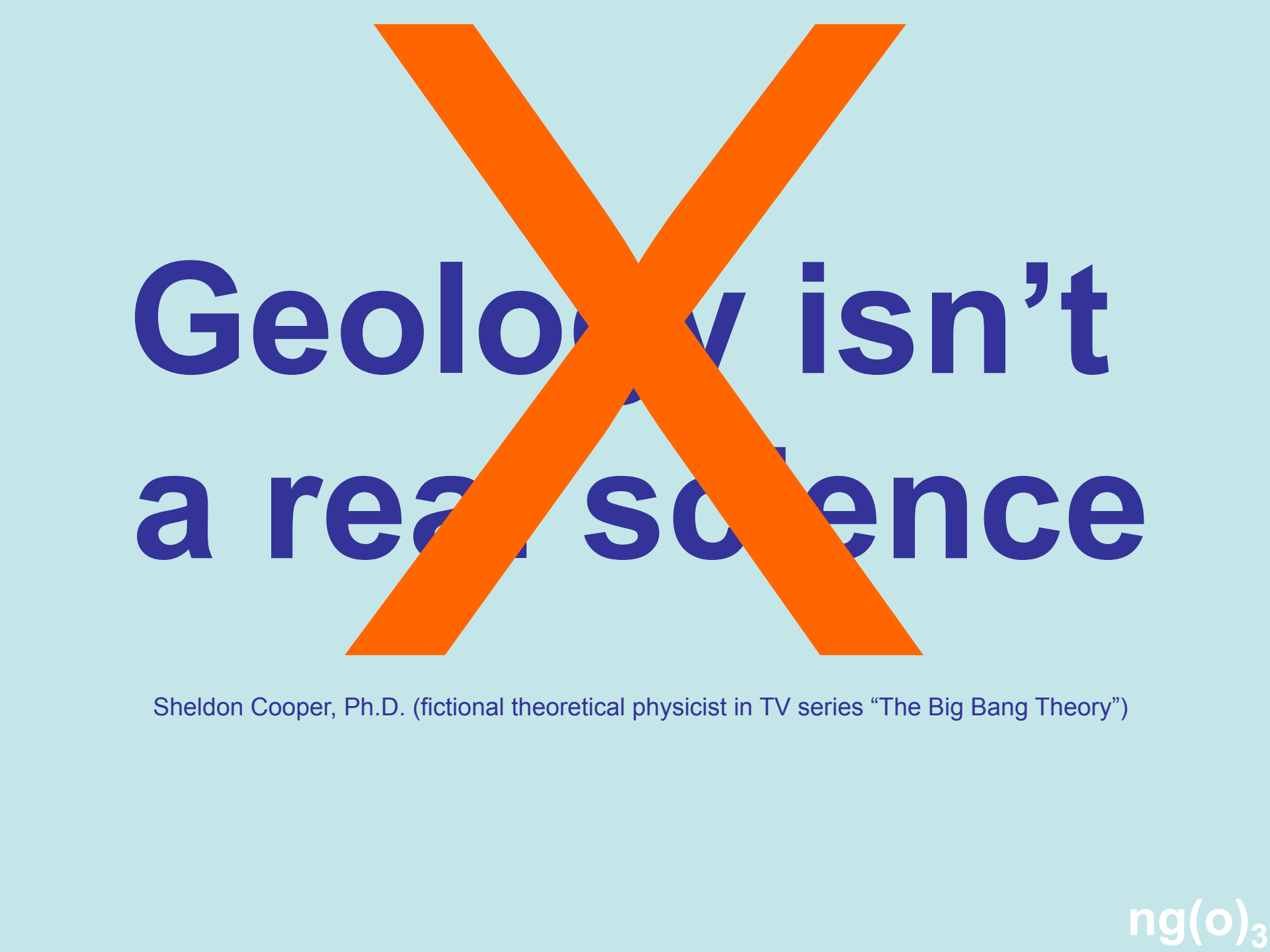
- the question motivating the research,
- the methodology they used to gather data,
- the data themselves,
- and nothing more.

They do not offer interpretations of the data or conclusions about the impact of the data on significant policy issues (which is an essential part of research science). My impression was that they were not allowed to do so by their managers.

Allison Macfarlane, 2003, in:
Underlying Yucca Mountain:
The Interplay of Geology and Policy in Nuclear Waste Disposal
Social Studies of Science 33/5(October 2003) 783–807
(http://www.state.nv.us/nucwaste/news2006/pdf/amacfarlane2003oct.pdf)

$ng(o)_3$

Allison Macfarlane is a member of the Secretary of Energy's Blue Ribbon Commission on America's Nuclear Future. She co-edited the book *Uncertainty Underground: Dealing with the Nation's High-Level Nuclear Waste* (MIT Press, 2006).



Sheldon Cooper, Ph.D. (fictional theoretical physicist in TV series “The Big Bang Theory”)