

Natural Radiation: Sources, Relevance and Uranium Levels

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First, a few facts:

- ◆ We live in a radioactive environment
 - ◆ We are continuously bombarded with radiation energy from space and from the earth's surface
 - ◆ We take in radioactive materials with the air we breath, the water we drink, and the food we eat
 - ◆ Our bodies contain radioactive materials
 - ◆ Our biosphere is powered by nuclear fusion reactions in the sun
 - ◆ Our earth and weather are respectively influenced by natural radioactivity and radiation from space
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- A stylized, layered mountain range graphic in shades of teal and blue, located in the bottom right corner of the slide.

Natural Sources of Radiation

- ◆ Cosmic (Galactic) radiation

- Originate from stars & our sun

- ◆ Cosmogenic radioactivity

- Radionuclides produced by cosmic rays

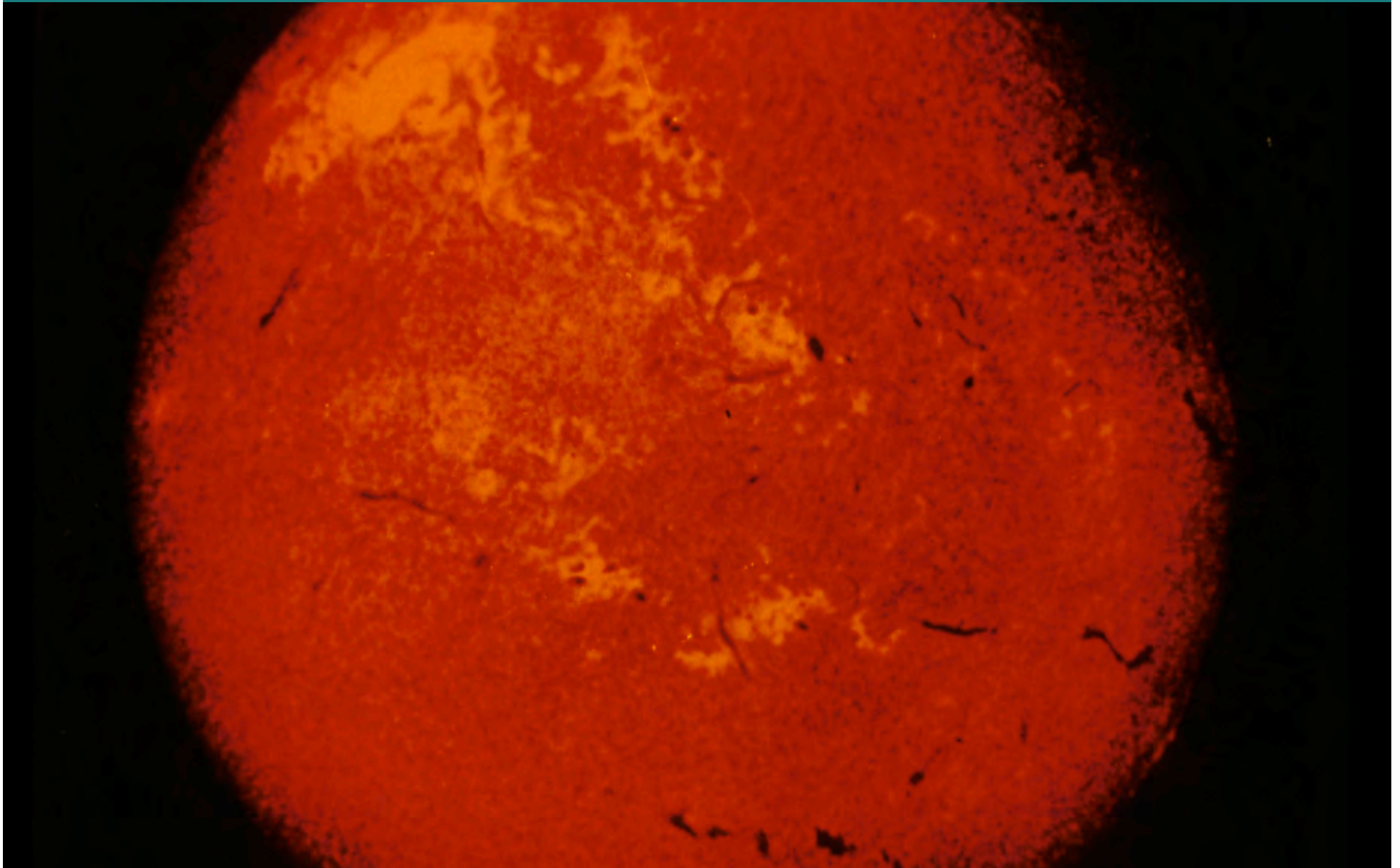
- ◆ Primordial radionuclides + progeny

- Long-lived radionuclides (uranium, thorium, potassium-40) that were formed when the earth was, some 4.5 billion years ago

Importance of Natural Radiation

- ◆ Life on earth
 - ◆ Human health
 - ◆ Effects on the earth
 - ◆ Effects on weather
 - ◆ Science
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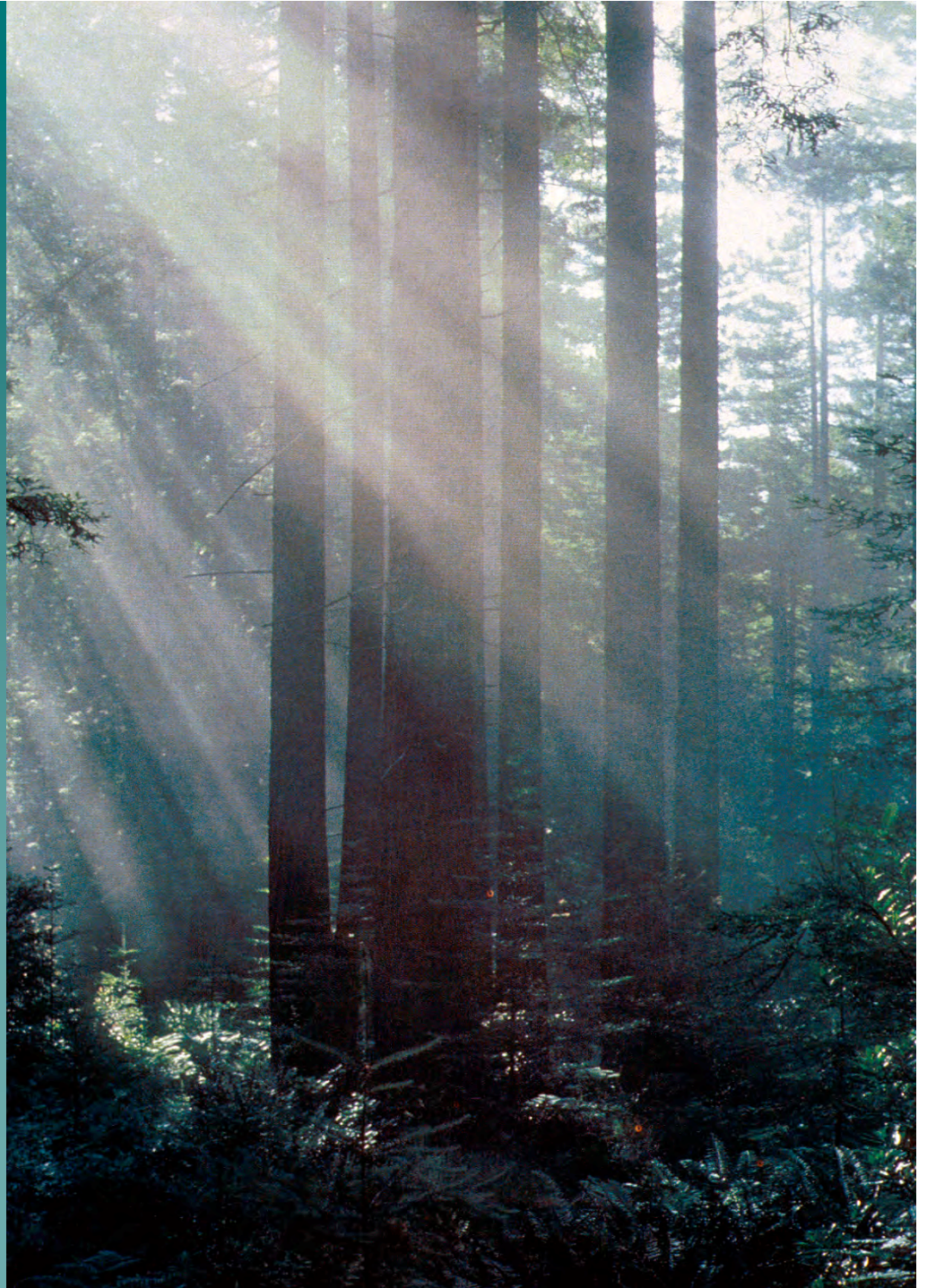
Our Sun: A continuous thermonuclear reaction



Photosynthesis:

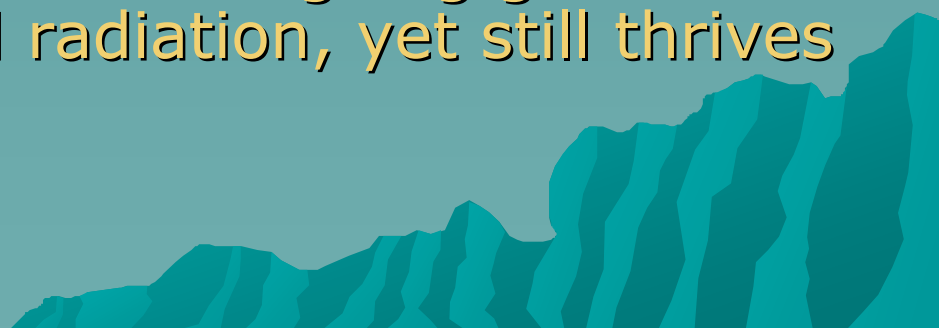
The conversion of CO_2 and H_2O to organic molecules by chlorophyll-bearing plants enabled by **sunlight**.

Solar energy is stored as chemical energy, which powers all life processes on earth.



Background radiation & human health

- ◆ Natural radiation can cause damage to DNA
 - The vast majority of such damage is quickly repaired, but some may cause genetic defects or heritable mutations
- ◆ A fraction of cancers in people are potentially caused by natural background radiation
 - However, long-term epidemiological studies of populations exposed to much higher than average background radiation do not show increased cancer risks
- ◆ Life in general has evolved with ongoing genetic damage from background radiation, yet still thrives





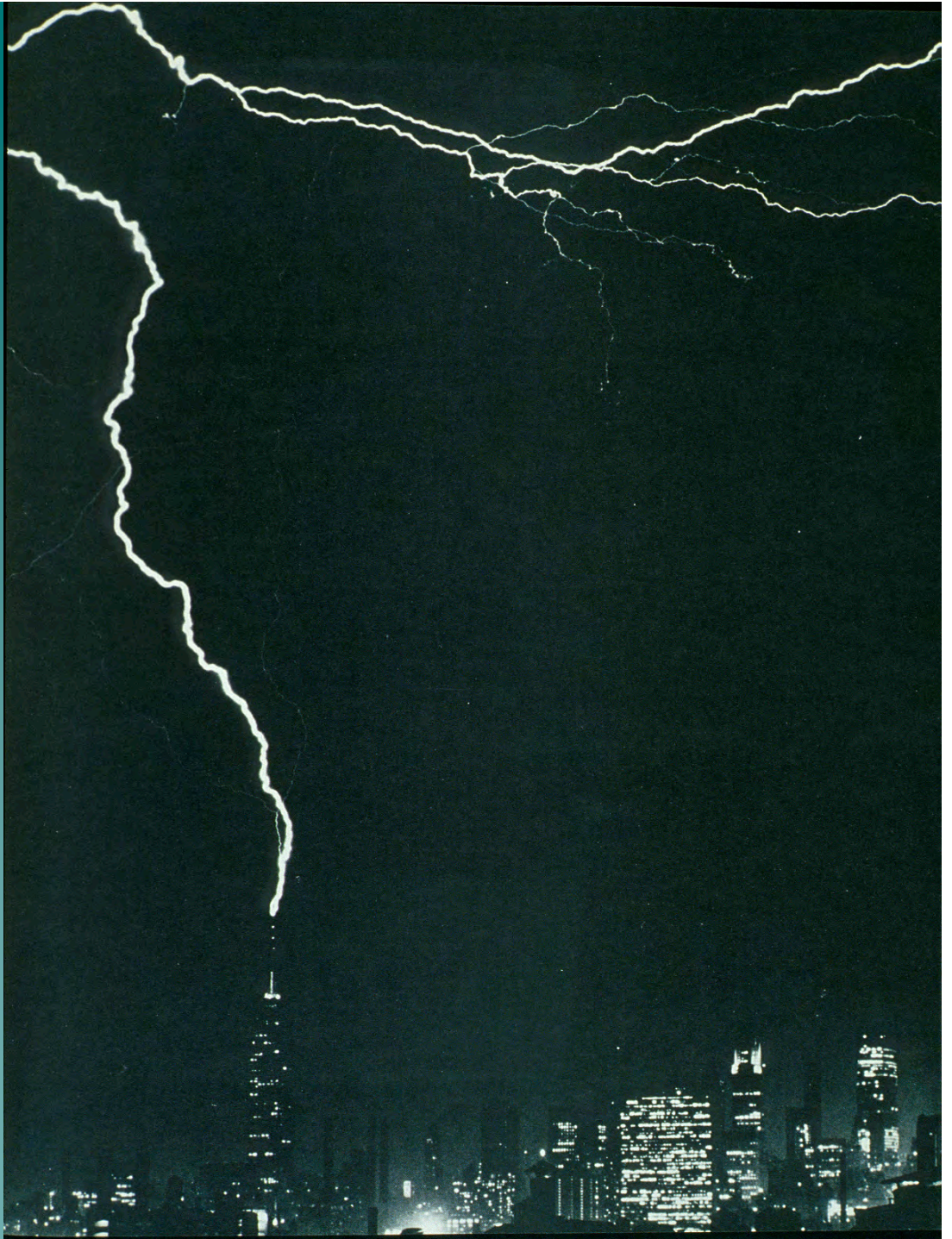
Some 45-90 % of heat within the earth is produced from decay energy of natural radioactivity. This heat causes:

- Volcanoes, continental drift, mountains, earthquakes, etc.
- Warming of soil, which affects plant growth, snowmelt, etc.
- Effects on weather



Cosmic radiation, generated from stars, produces tracks of ionization in our atmosphere, some think lightning, and the conversion of nitrogen to forms useable by plants.

Cosmic rays are thought to play a role in cloud formation, and cause charge polarity in them. This may help create the potential for lightning. The path of lightning appears to follow ionization paths created by cosmic particles and their interactions.



Primary Cosmic Rays

- ◆ These have not yet interacted with matter
- ◆ $\sim 85\%$ protons
- ◆ $\sim 14\%$ alpha particles
- ◆ $\sim 1\%$ heavier particles
- ◆ These gain very high energies during their travel through space

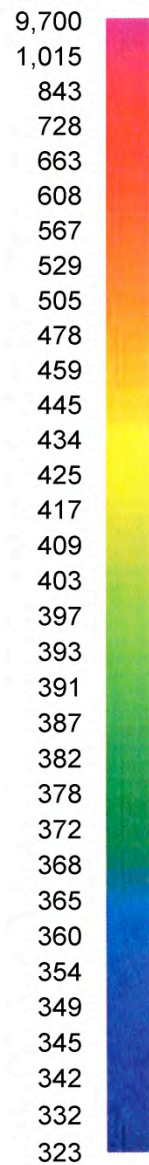
Secondary Cosmic Rays

- ◆ Formed by collisions of primaries with atoms (mostly N_2) in the atmosphere
- ◆ These collisions form:
 - neutrons & protons
 - lighter elements (H, He, Be, etc.)
 - sub-atomic particles called pions
- ◆ Pions rapidly decay to muons and electrons
- ◆ Muons account for about 70 % of the cosmic ray exposure at the earth's surface and are highly penetrating

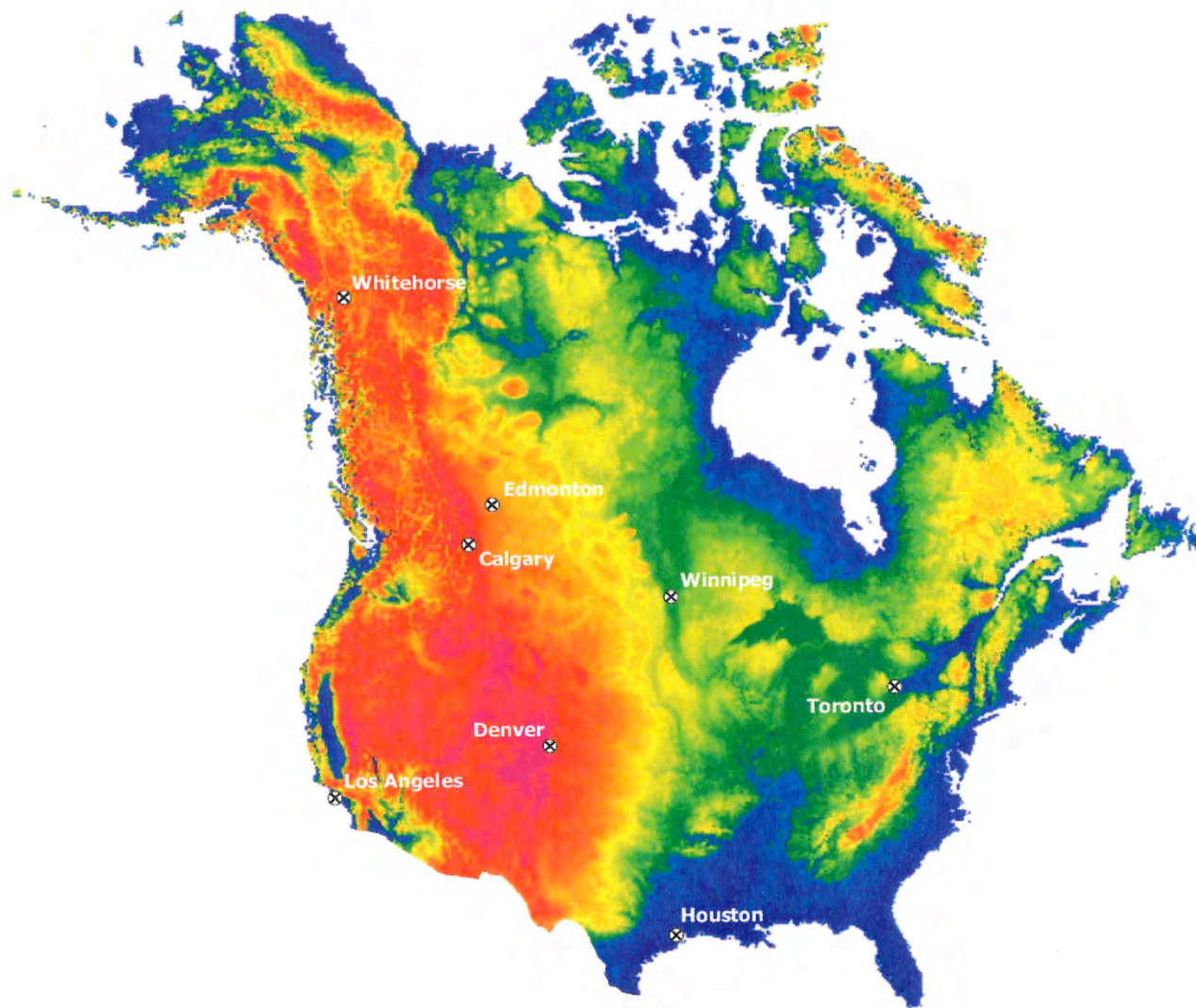
Cosmic Ray Exposure Rates

- ◆ Fluence $\sim 1/\text{cm}^2/\text{s}$ ($\sim 2,000$ /sec through the body!)
- ◆ Exposure rate increases with elevation and latitude
 - Avg. largest 99 urban locations, U.S.: 33 mrem/y
 - Avg. in Colorado: 50 mrem/y
 - 14,000' peaks in Colorado: 150 mrem/y
 - 20,000' Mt. McKinley, Alaska: 450 mrem/y
 - Jet airliners at mean altitude: 2,900 mrem/y
- ◆ Episodic increases (spikes) occur from solar activity

Cosmic Radiation Effective Annual Dose Rate



Annual (μSv)



By permission, from NCRP report 160

Cosmogenic Radionuclides

- ◆ Examples are ^{14}C , ^3H , ^{36}Cl , ^{22}Na , ^7Be , etc.
 - ◆ Produced by interactions of primary cosmic rays with atmospheric nitrogen and other materials
 - ◆ Radionuclides are present in $\sim 10^4$ tons of galactic dustfall/day on the earth's surface
 - ◆ Many uses: dating wood, water, wine, sedimentation rates etc.
 - ◆ Contribute $< 1\%$ to natural radiation dose
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Primordial Radionuclides

- ◆ Formed when the earth was
- ◆ Half-lives similar to earth's age (~ 4.5 billion years)
- ◆ ^{40}K (1.26×10^9 y); ^{238}U (4.5×10^9 y); ^{232}Th (1.4×10^{10} y)
- ◆ ^{238}U and ^{232}Th decay to many shorter-lived radioactive progeny (e.g. ^{226}Ra , ^{222}Rn , ^{210}Pb , ^{210}Po , etc.)

Importance of Primordial Nuclides

- ◆ Heating of the earth-the driving force for shaping continents, mountains, volcanoes
- ◆ They, and daughters (especially ^{222}Rn progeny, ^{210}Pb & ^{210}Po) form a large portion of our natural radiation dose
- ◆ ^{235}U (0.72 % of U) is the primary nuclear fuel for reactors, which produce 20% of electricity in the U.S., weapons; ^{238}U is used for projectiles
- ◆ Uranium and thorium have numerous industrial uses
- ◆ Primordial radionuclides have many uses in science (e.g. ratios of isotopes to date rocks, etc.)

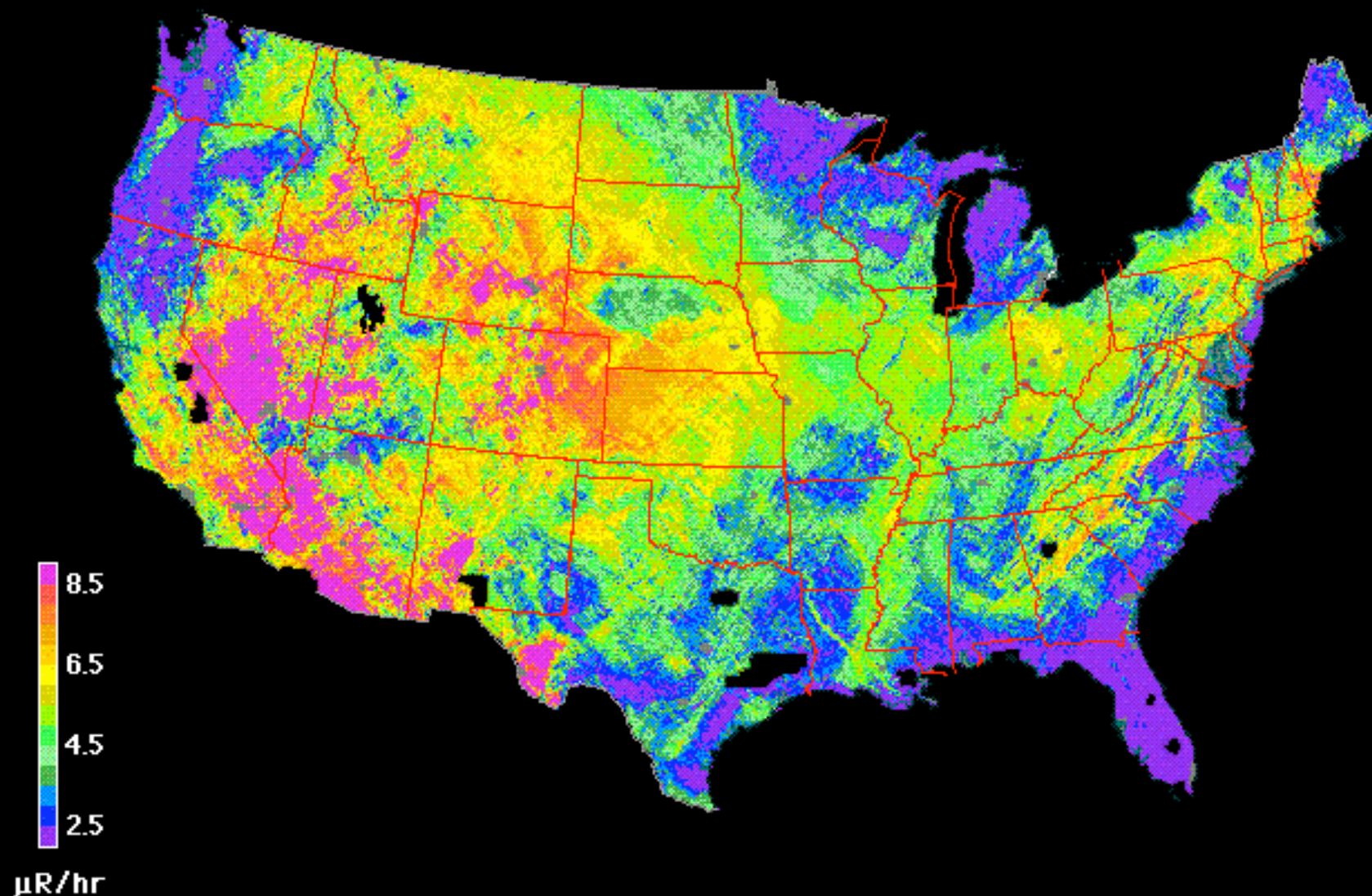


Uranium levels in the environment

Media	Typical U.S. avg. (pCi/g)	Range (pCi/g)
Rock	1.0	0.2-40
Soil	1.0	0.1-4.0
Uranium ore	500	200-5,000
Air (pCi/m ³)	0.0001	0.000001-0.001
Groundwater	0.0017	0.0001-0.2
Human foods	0.00024	0.5 -5 X avg.
Human bone	0.0005	0.5 -5 X avg.
Human soft tissues	0.0001	0.5 -5 X avg.

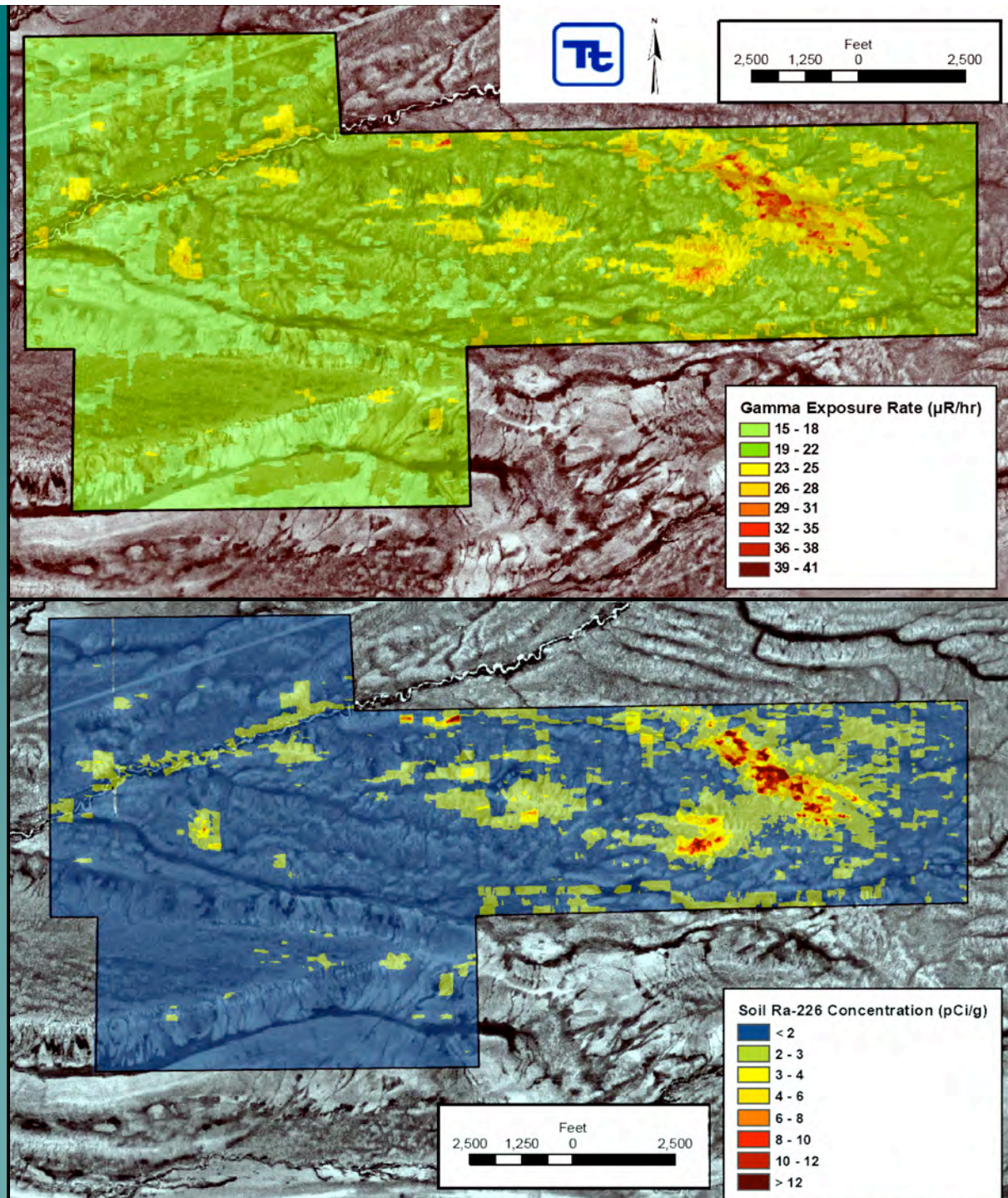
Large-scale variations in background external exposure:

Terrestrial Gamma-Ray Exposure at 1m above ground

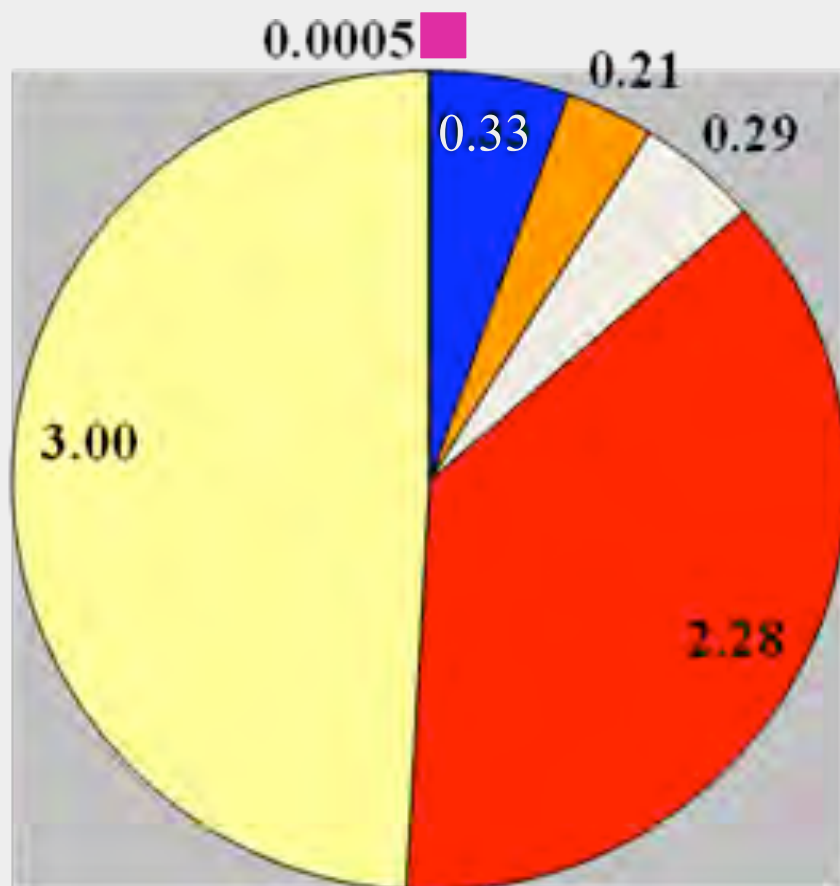


Source of data: U.S. Geological Survey Digital Data Series DDS-9, 1993

Small-Scale
Geographic
variations of
terrestrial gamma
radiation exposure
rates: Example
from Wyoming



Mean annual effective dose for US citizens-2006. NCRP Report 160.



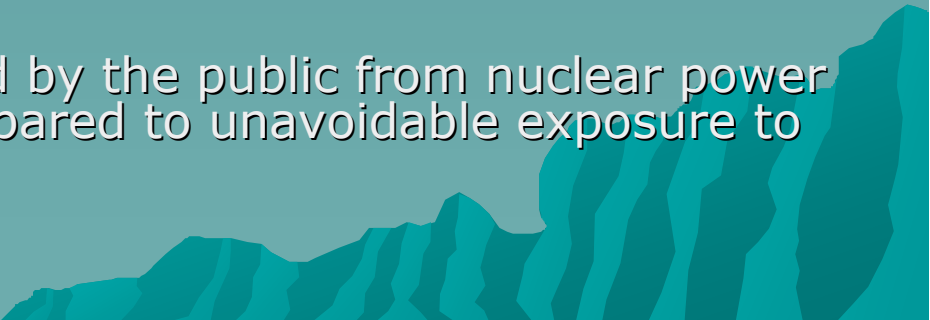
NATURAL

Total = 6.2 mSv (620 mrem)

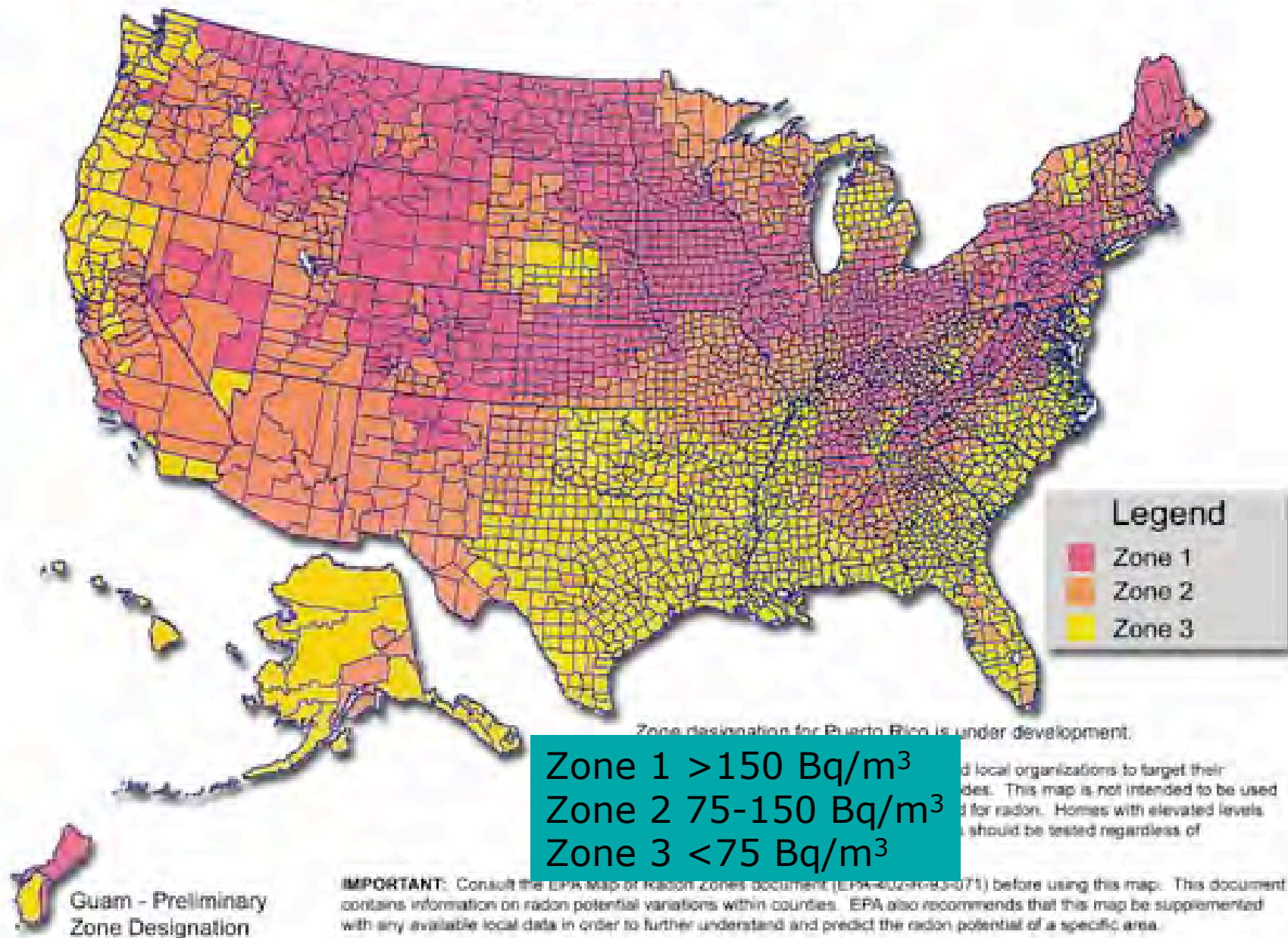
How do natural background radiation exposures (mrem/year) relate to the regulatory limit?

Federal exposure limit for the general public	100
U.S. average natural background from all sources	320
Colorado average natural background from all sources	600
Difference between Colorado and U.S. averages	280
Possible variation in residential locations in Colorado (cosmic + terrestrial radiation only)	130
Radon variation in Fort Collins homes Study by Dr. Tom Borak, CSU	<200->1,400

Facts worth remembering:

- ◆ We have always been exposed to natural radiation
 - ◆ Life on earth is made possible by nuclear fission and our earth & its weather are affected by natural radiation
 - ◆ Uranium is a common element in the rock and soil that has literally changed history. Concentrations vary greatly from place to place
 - ◆ Uranium & decay products are contained in the food we eat and water we drink everyday, thus found in the body
 - ◆ The background radiation exposure we receive varies dramatically from place to place, and how we manage radon exposures
 - ◆ The Federal radiation exposure limit for the public is of the order of our natural background exposure variation across the U.S.
 - ◆ Radiation exposures experienced by the public from nuclear power generation are insignificant compared to unavoidable exposure to natural background.
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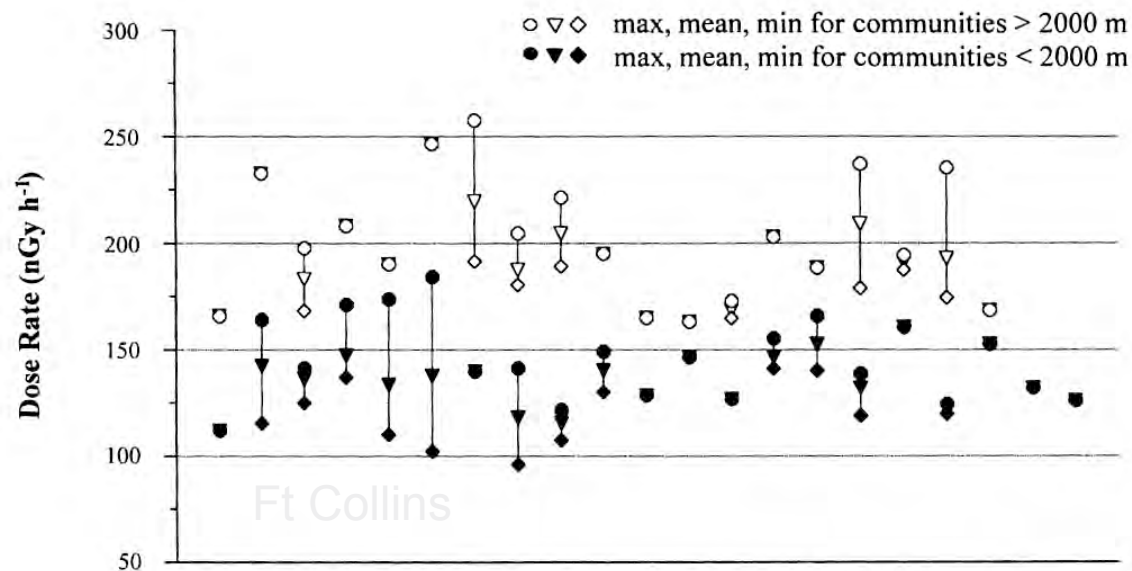
EPA Map of Radon Zones



Cosmic + terrestrial
radiation in 40 Colorado
Communities above and
below 6,500 ft. elevation

Geographic variations in natural background radiation in Colorado

Cosmic and terrestrial
Radiation along I-70



Communities < or > 2000 meters elevation (randomly arranged)

