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Ablation Mining Technology

May and June, 2016 Stakeholder Meetings

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Definitions

- AMT: Ablation Mining Technology
- ROM: Run-of-mine
- µS: microsieverts (1 µS = 0.1 mrem)
- mrem: millirem (1 mrem = 10 µS)
- nGy/hr: nanogray (1nGy = 10 micro Roentgens)
- uR: micro Roentgens (10 uR = ~0.01 mrem)
- Ma: million years
- µm: micron or micrometer (1 µm = 1 x 10^{-6} meters)
- WLM: working level month (1WLM = 1 WL exposure in 170 hours)

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Black Range and AMT History

- July, 2015 - White Paper submitted to CDPHE – AMT is a mining methodology and does not require a license
- April, 2016 – Request for Additional Information response submitted to CDPHE – Risk assessment and additional AMT details

- 2011 - Black Range Minerals meets with Ablation Technologies, LLC
- 2011 - Submitted Hansen Uranium Deposit core for AMT testing
- 2012 - Gained rights to joint venture
- 2013 - Mineral Ablation, LLC formed
- 2015 - Mineral Ablation, LLC dissolved – Black Range Minerals maintains license to operate and all developed assets
- 2015 - Western Uranium Corporation acquired Black Range Minerals and its assets
- 2015 - Sunday Mine Complex targeted as initial location for AMT

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What is AMT

- Applies to sandstone hosted uranium mineralization
- A series of baffled tanks, slurry pumps, piping, hose, and nozzles
- Mixes and subjects a slurry stream (water and ROM) to repeated collisions
- **Disassociates** the components of a mineralized material from each other
- Used in conjunction with additional ancillary components to mine ore

Photo of AMT in development

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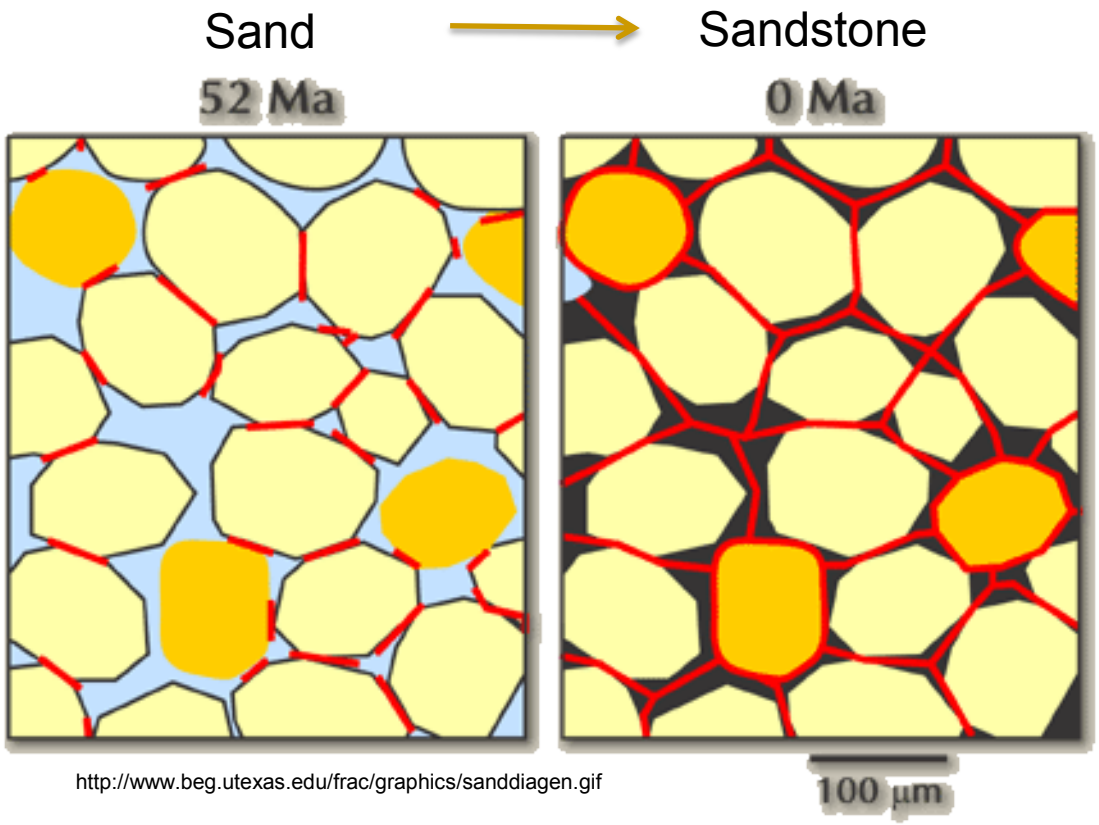
Sandstone Diagenesis



http://www.beg.utexas.edu/frac/graphics/sanddiagen.gif

Compaction, cementation, and/or dissolution turn sand to sandstone.

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Sandstone Diagenesis

Great Sand Dunes National Park

https://cdn-co.milespartnership.com/sites/default/master/files/sandunes_nps.jpg

Sandstone

http://www.rocksandminerals4u.com/sandstone.html

With appropriate geologic conditions these dunes may some day become sandstone

Mineralization: deposition of economically important metals in the formation of ore bodies

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Mineralization in Sandstone

Fluid Migration

Uranium and vanadium mineral bearing fluids migrate through permeable host sand or rock formation.

Deposition

With the right (reducing) geochemical environments, uranium and vanadium bearing fluids precipitate (deposit) minerals between sand grains. These newly deposited minerals are very fine-grained and form a crust on and between the larger sand grains.

Deposit formation

As fluids continue to migrate through a host sand or rock formation and mineral crusts continue forming, a mineral deposit forms.

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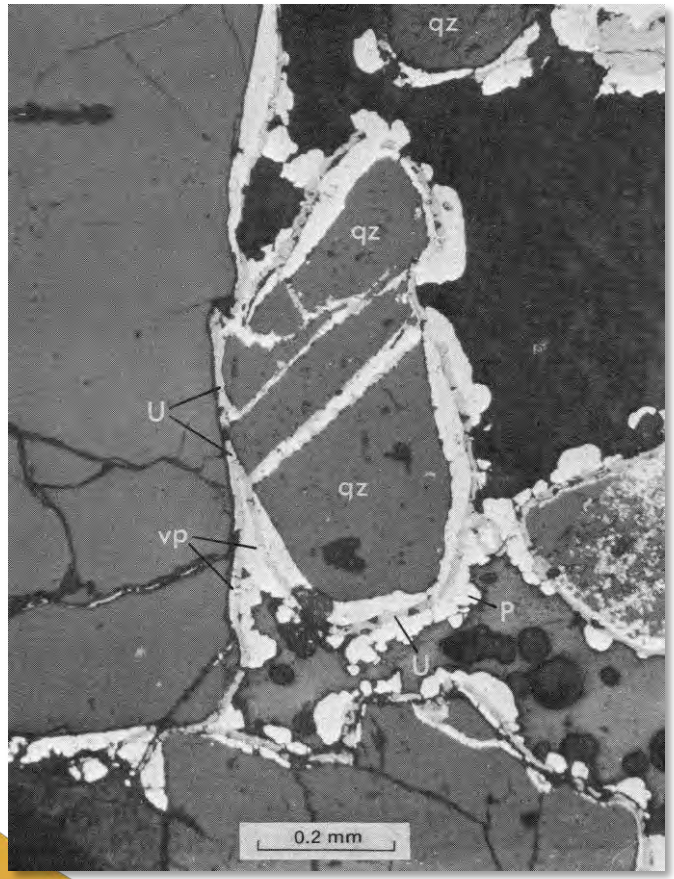
Uranium Mineralization in Sandstone



Example of mineralization in thin section

ID	Mineral
qz	quartz
U	uraninite
P	pyrite-marcasite
vp	veinlet pyrite-marcasite

Harshman, E. N. *Geology and Uranium Deposits, Shirley Basin Area, Wyoming*

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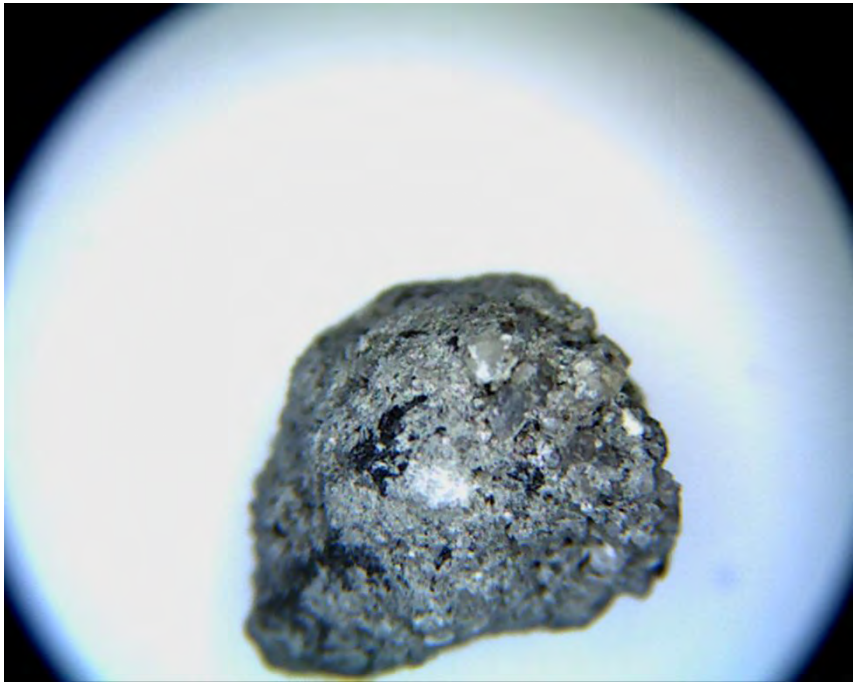
Uranium Mineralization in Sandstone

Example of mineralization on a per sand grain basis



Single Grain Pre AMT with Mineralized crust

Single Grain Post AMT

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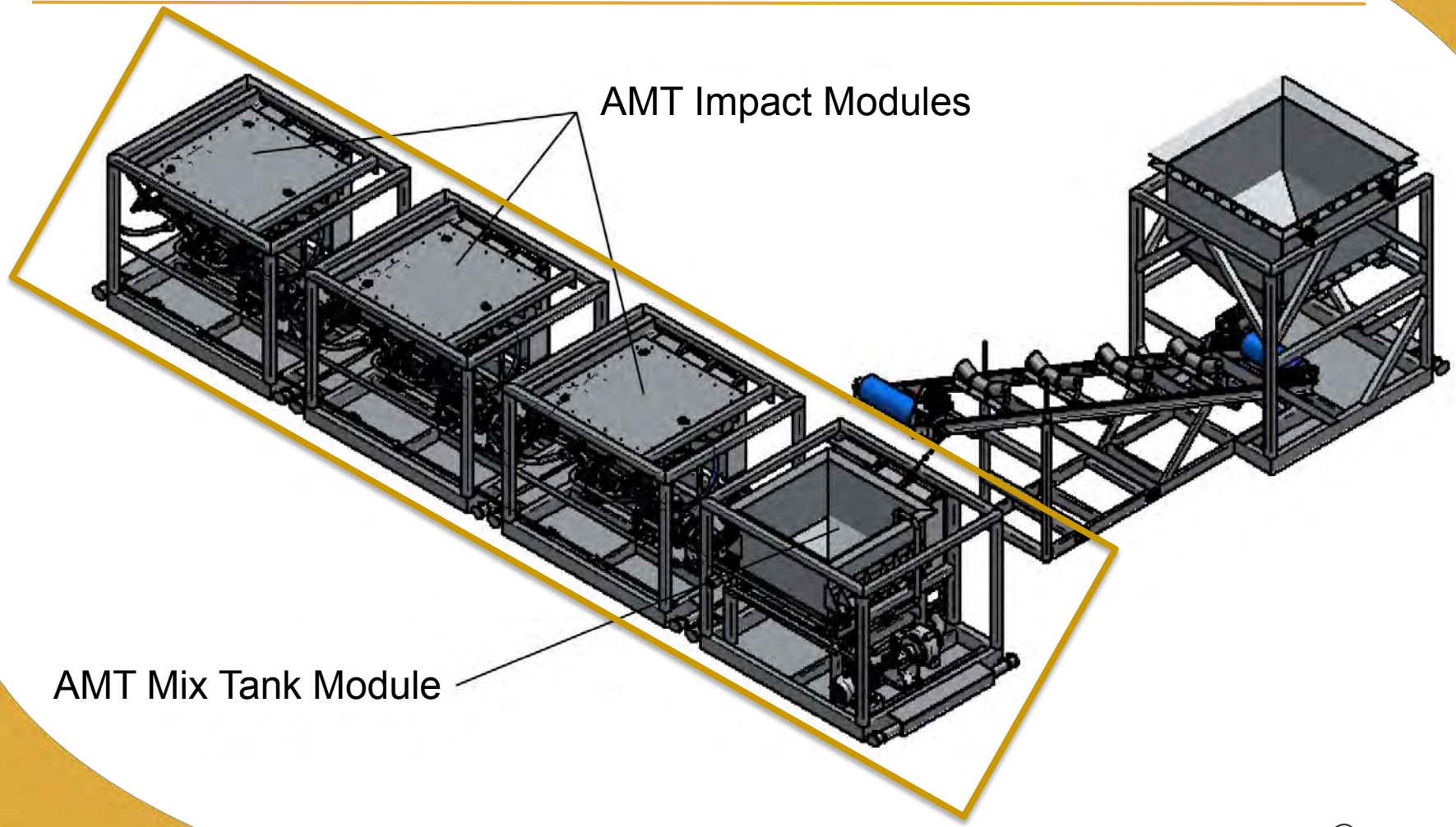
AMT Disassociation



Same material introduced to AMT exits AMT

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AMT Disassociation

The opposing slurry streams impact one another and collisions between the sandstone particles and fragments within each stream result in a disassociation of fine-grained, intergranular, mineralized material from coarser-grained and mineral-barren sand grains.

Nozzles offset for illustrative purposes

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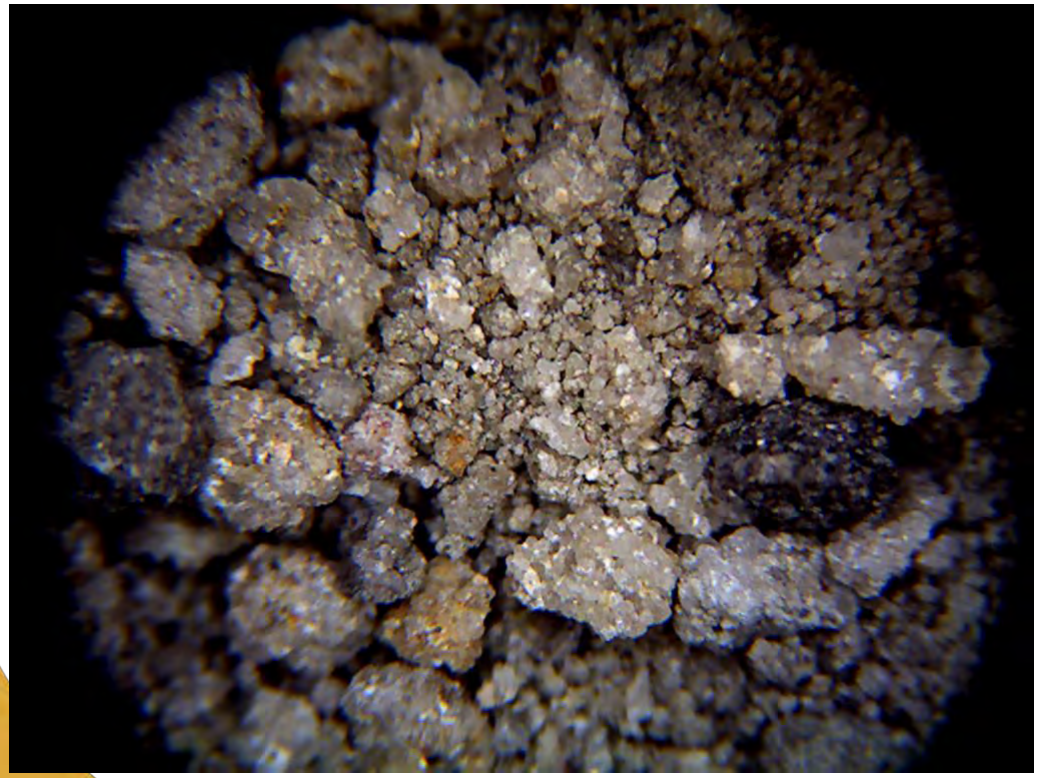
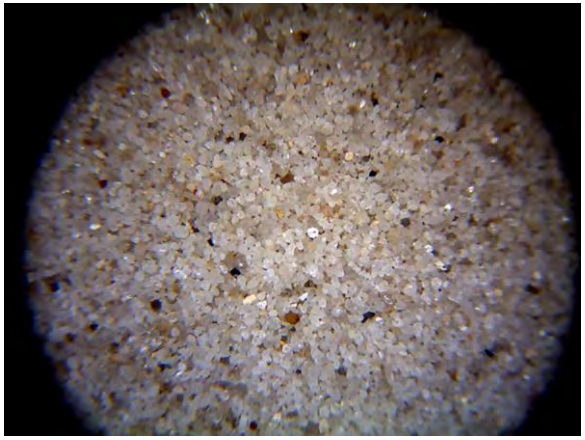
AMT Materials

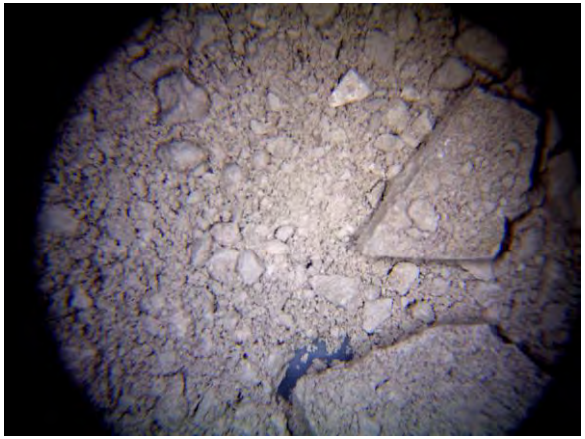
Crushed AMT ROM conveyed to AMT



AMT mines ore from between the grains

Separated Post AMT Waste (sand)





Dried Post AMT Ore

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AMT and Ancillary Components

- Crushing and Feeding
- AMT Disassociation
- Separation
- Dewatering
- Packaging
- Waste Handling
- Transport to offsite processing facility

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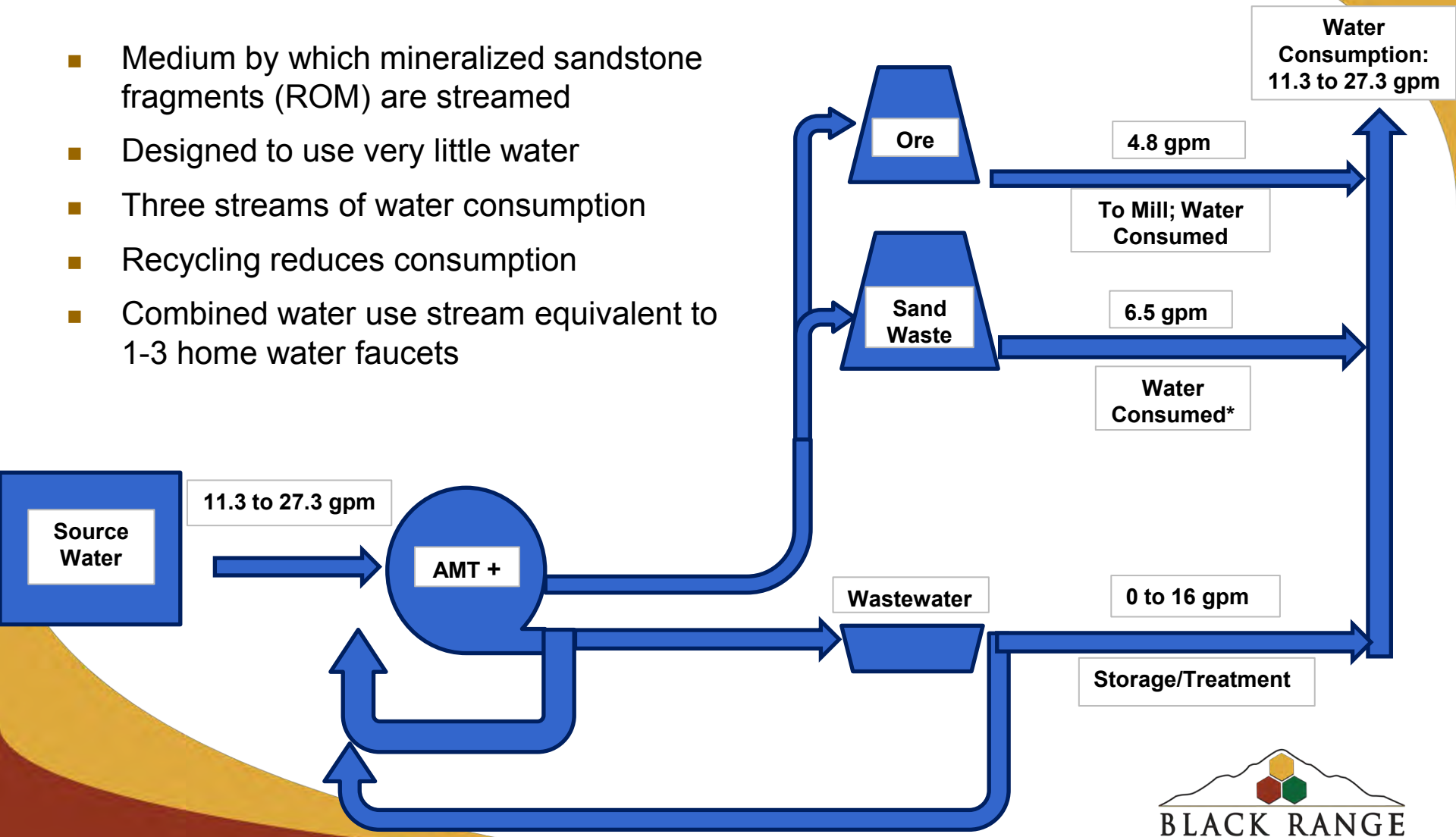
Water in AMT

- Medium by which mineralized sandstone fragments (ROM) are streamed
- Designed to use very little water
- Three streams of water consumption
- Recycling reduces consumption
- Combined water use stream equivalent to 1-3 home water faucets



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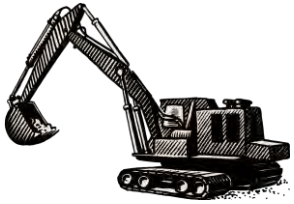
AMT as Best Practice

WITHOUT ABLATION



Mining:
- Open Pit
- Underground
- UBHM

Run of Mine Haul
- Nearby Mill
- Large Volume

Large Mill and more Mills

Large Impoundment

Same Amount of Product Production

Waste Reduction Technology

WITH ABLATION

Ablation with Waste Rock Returned to Mine

Ore Transported: Long Distances Few trucks

Small Mill and Fewer Mills

Small Impoundment

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AMT is Mining

- Methodology which mines ore from between the grains of a mineralized sandstone
- Chemical Free
- Low volume water consumption
- Waste reduction technology
- Many existing regulations to control the risk, e.g.:

As with all uranium mines in US, worker radiation exposure monitored and controlled to limits of Mine Safety and Health Administration (MSHA) - 30 CFR 57.5047 (gamma) and 30 CFR 57.5038 (radon and progeny)

As with all uranium mines in US, public exposure must be controlled to limits of US EPA 40 CFR 61.22 and monitored per 40 CFR 61.23(a)

Radiological composition of ROM and post ablation product = same, just higher grade: uranium and all progeny in equilibrium – no “tailings” produced – no “11(e).2 byproduct material”

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CDPHE Questions on Radiological Risks

Assessment of potential risks to the workers, members of the public and the environment, resulting from the operation of Ablation Mining Technology (AMT) including:

- **Quantitative estimate of occupational doses to workers**
- **Evaluation of potential risks to members of the public and environment**
- **Comparison of the above estimation between the AMT operation and other traditional ore mining operations and uranium milling operations**
- **Assumptions**

Detail provided in Attachments 1.1 thru 1.4 of BRM submittal on CDPHE web site

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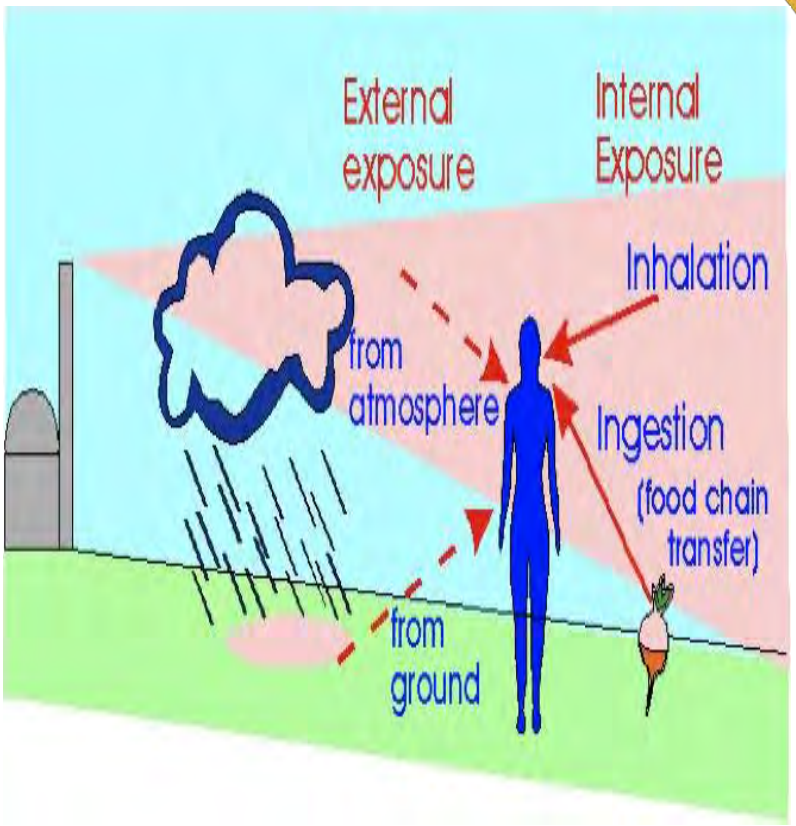
We Live in a Radioactive Environment – It's Always Been This Way

- We are continuously bombarded with radiation from space and earth's surface
- Uranium is a common element in rock and soil
- Uranium is in the food and water we consume everyday
- Background radiation in Rocky Mtn. States can be several times higher than other parts of the U.S. – Elevation and Mineralization!



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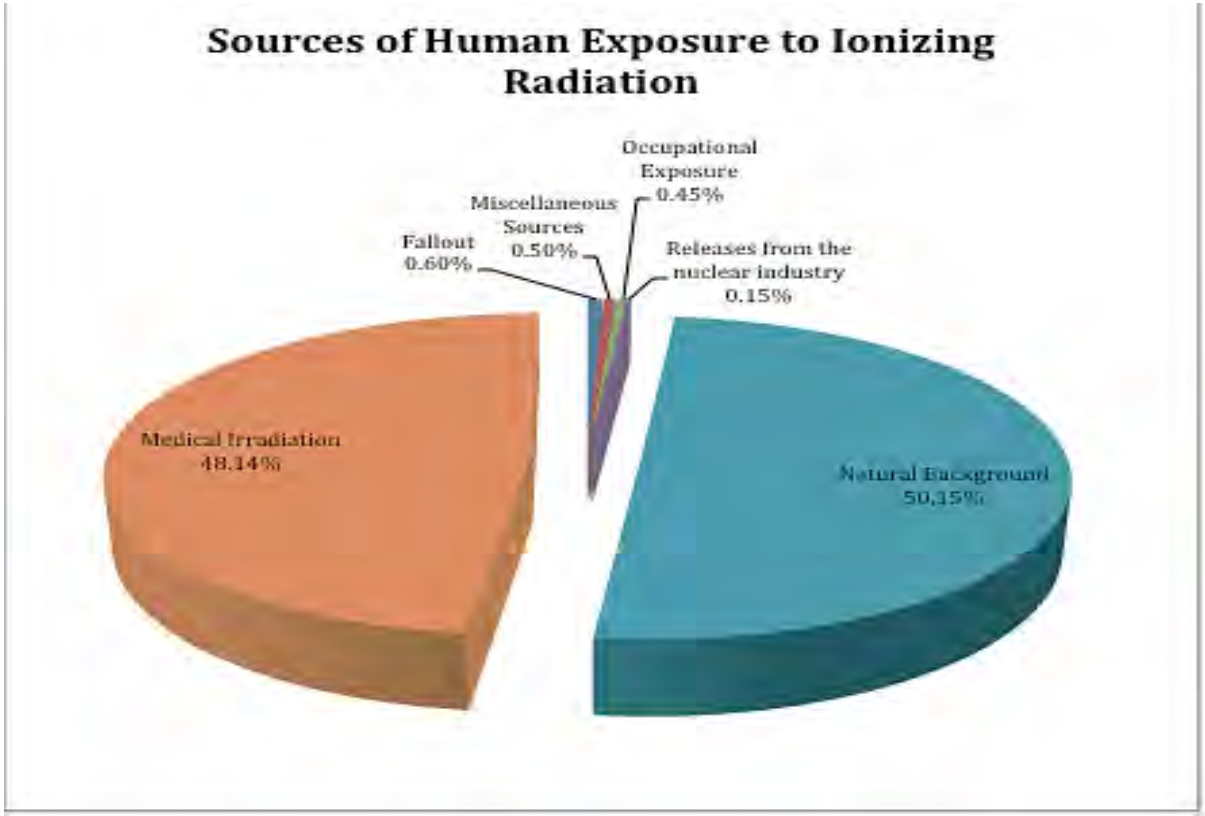
Sources of Radiation Exposure to Humans



NCRP Report 160, National Council on Radiation Protection and Measurements
Ionizing Radiation Exposure of the Population of the United States, 2006

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Comparison Of Average Radiation Backgrounds In US vs. Colorado (Units of millirem/yr.)

Source	Colorado Avg.[a]	Florida Avg.[a]	Illinois Avg.[a]	Leadville Avg.[b]
Cosmic Radiation	49	27	28	85
Terrestrial Radiation	39	13	24	97
Internal Radiation including Radon Inhalation, Food and Water Ingestion	300	54	181	344
Totals	387	93	233	526

[a] From USEPA 2005 [b] From Moeller 2006

millirem = mrem = common unit of radiation exposure in the US; energy absorbed in tissue; ergs per gram

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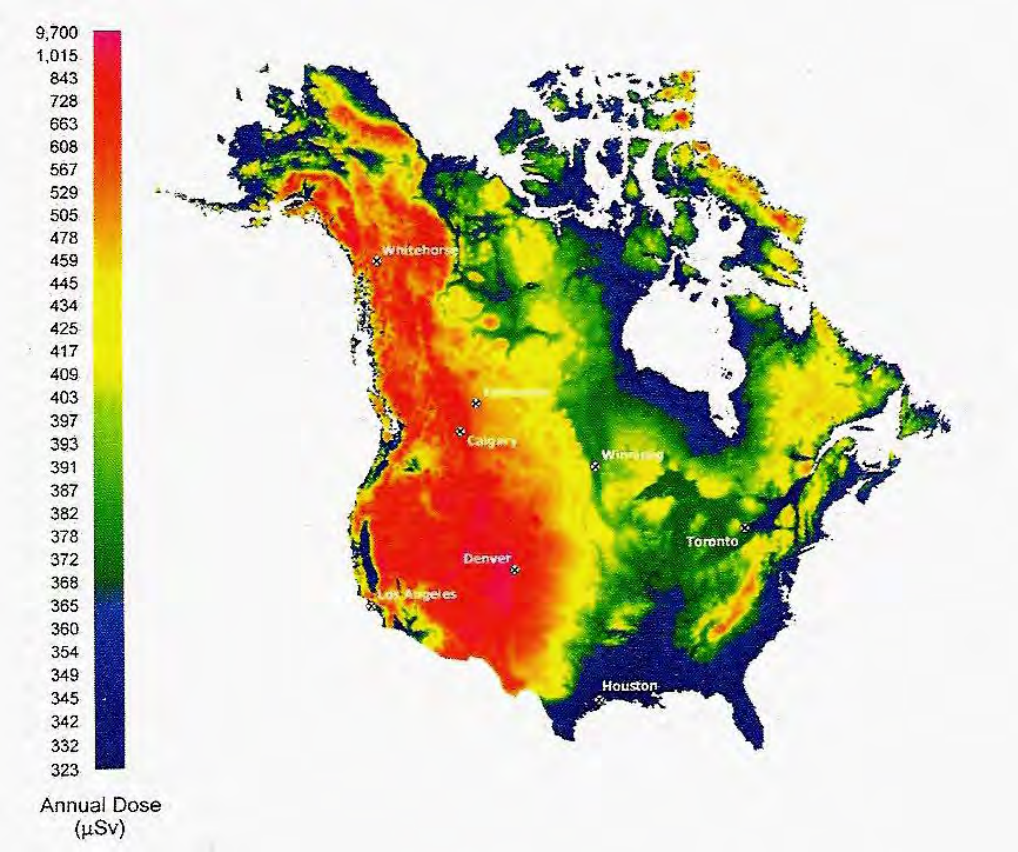
Cosmic Ray Background Varies Considerably Across US



National Council on Radiation Protection and Measurements; NCRP Report No. 160, "Ionizing Radiation Exposure of the Population of the United States", 2006

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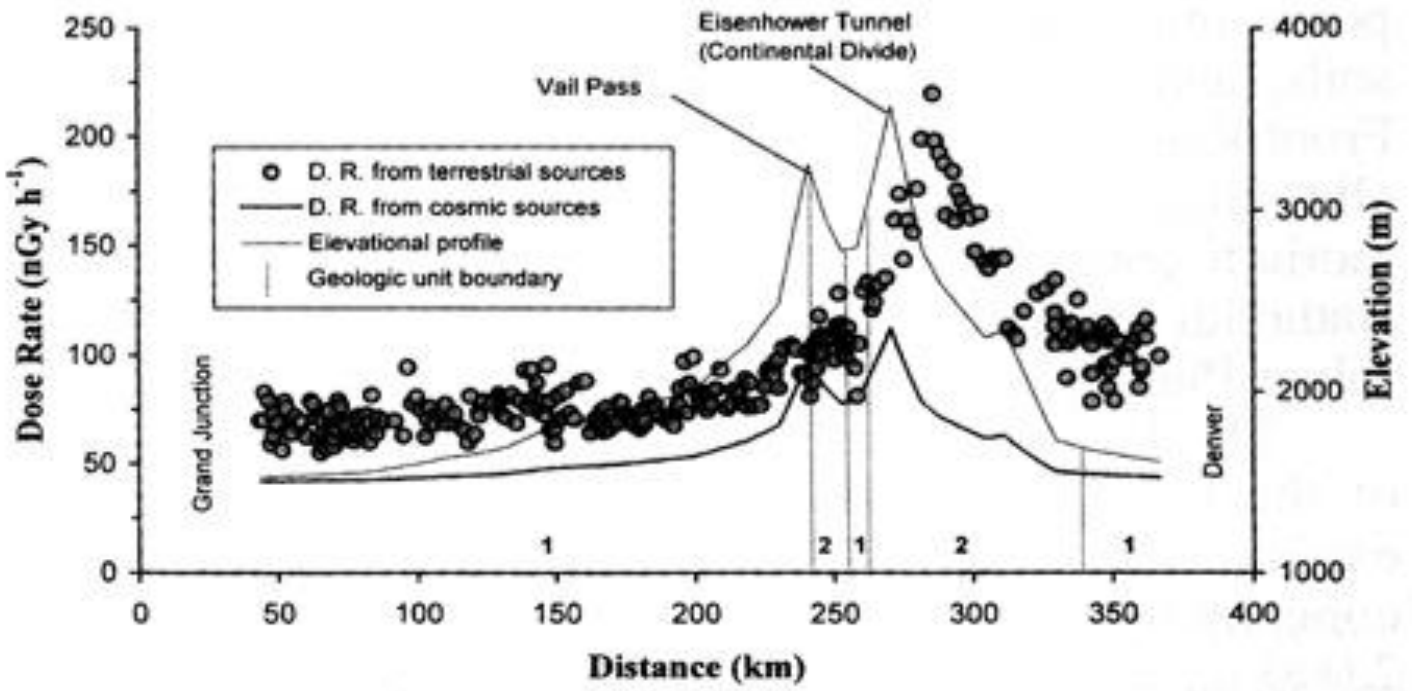
Variability of Natural Background from Place to Place – Example: Colorado



Stone, JM, Whicker, RD et al, *Spatial Variations in Natural Background Radiation: Absorbed Dose Rates in Air in Colorado.*
Health Physics, Vol. 9(5), May 1999

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Example Federal and Colorado Radiation Exposure and Dose Limits Applicable to Uranium Mining and Milling

Exposure Condition	Annual Limit (mrem)	Regulatory Reference
Worker Annual Radiation Exposure	5000	**USNRC**: 10 CFR 20.1201, *Occupational Dose Limits;* **Colorado**: *6 CCR 1007-1 Part 4.4.1, Occupational Dose Limits;* **USMSHA:** 30 CFR 57.5047
Limit for Members of the Public Including Radon	100	**USNRC**: 10 CFR 20.1101, *Radiation Dose Limits for Individual Members of the Public;* **Colorado**: 6 CCR 1007-1 Part 4.paragraph 4.14.1, *Radiation Dose Limits for Individual Members of the Public*
Limit for Members of the Public – Radon from Uranium Mines	10	**US EPA:** 40 CFR 61, Subpart B - National Emissions Standards Hazardous Air Pollutants (NESHAPS)

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Doses to Canadian Uranium Mine and Mill Workers For Selected Job Categories, 2010 - 2014 (Health Canada 2016)*

Job Category	Average Annual Dose (millirem)	Average # workers per year in Job Category
U Mill Workers	110	318
U Mine Support Workers	82	670
U Mine Surface Workers	28	75
Underground U Miner	192	637

Average radon (progeny) dose to underground miners = 0.6 WLM* / year or about the same as > 1 million residents of Colorado http://co-radon.info/CO_general.html

* US MSHA was contacted in Dec 2015 for US miner data but had to submit FOIA request since not a State or Fed agency. Data not released as of May 23 2015, but this population is very small compared to the Canadian data base

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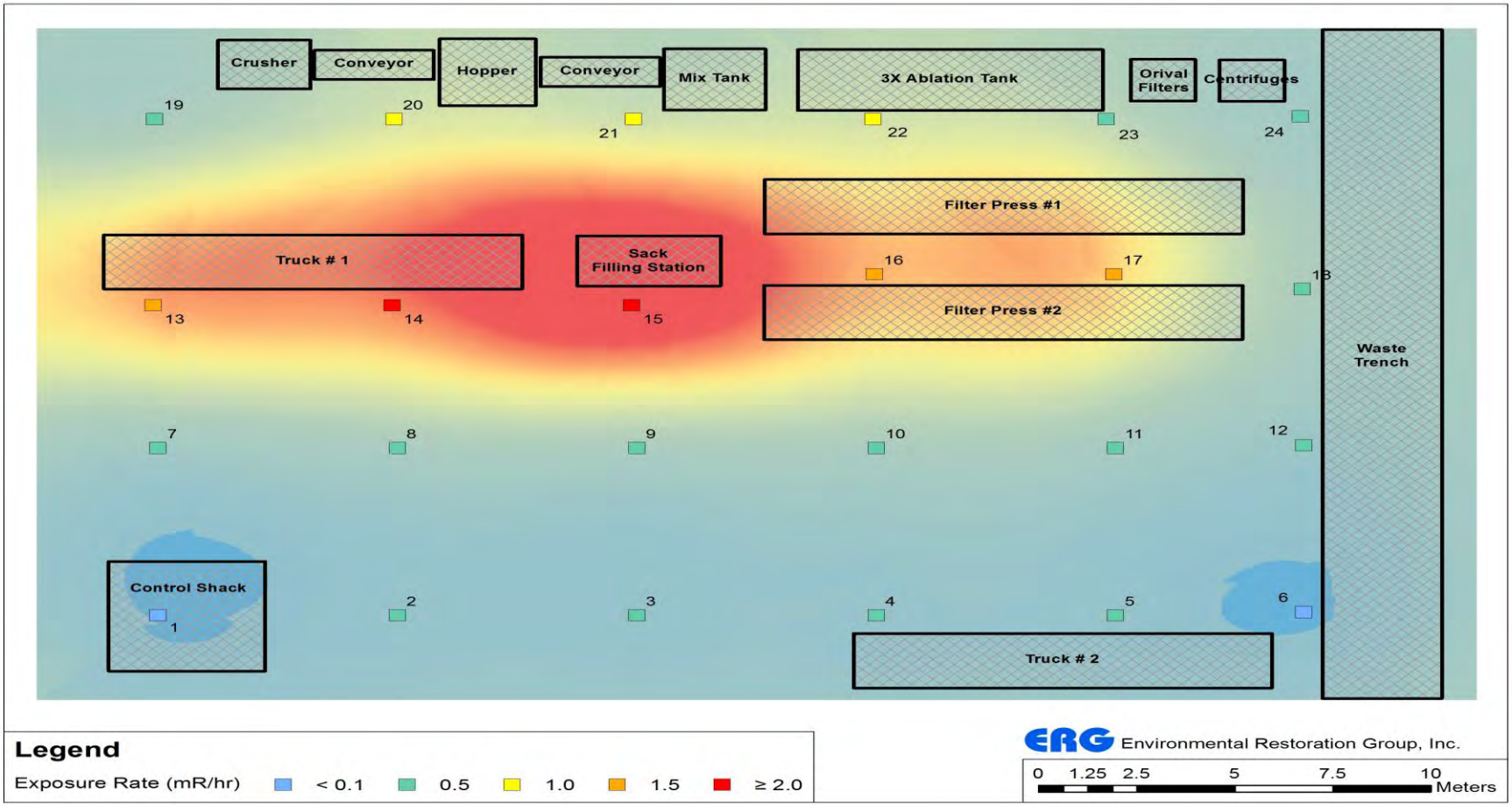
AMT Worker Radiation Exposure - Mapped Exposure Rate (millirem/hr.)



Worker Exposure Estimate = 174 millirem per year

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Public Exposure: Sunday Mine EPA NESHAPS Compliance Summaries – Annual reports for the years 2008, 2009 and 2010

Year	# Of Vents Active and Monitored	Max. Annual Dose to Member of Public* (mrem / yr.)
2008	10	0.5
2009	16	7.5
2010	10	1.7

* Nearest resident approximately 4 miles

Denison Mines. Annual Reports (2008, 2009, 2010) to the USEPA for the Sunday Mine Complex Under Code of Federal Regulations CFR 40 Part 61, Subpart B - National Emissions Standards for Hazardous Air Pollutants.

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Risks of Accidents and Off Normal Operations

No reactive, explosive or otherwise toxic or hazardous materials; only uranium ore and water is used

Only credible ”accident” or “off normal” condition would be loss of fluids and/or slurries from containment within vessels

Operation takes place within an existing uranium mine, loss of radioactive material (ore) would be contained within the mine.

Many vessels will be bermed and area sumps will contain and control spills and facilitate recovery

Process continuously monitored from control panel – off normal conditions (pressures, flow rates) quickly identified

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Underground at Rabbit Lake

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Robotics, Remote Control, Ground Freezing at McArthur River>20% U Mine

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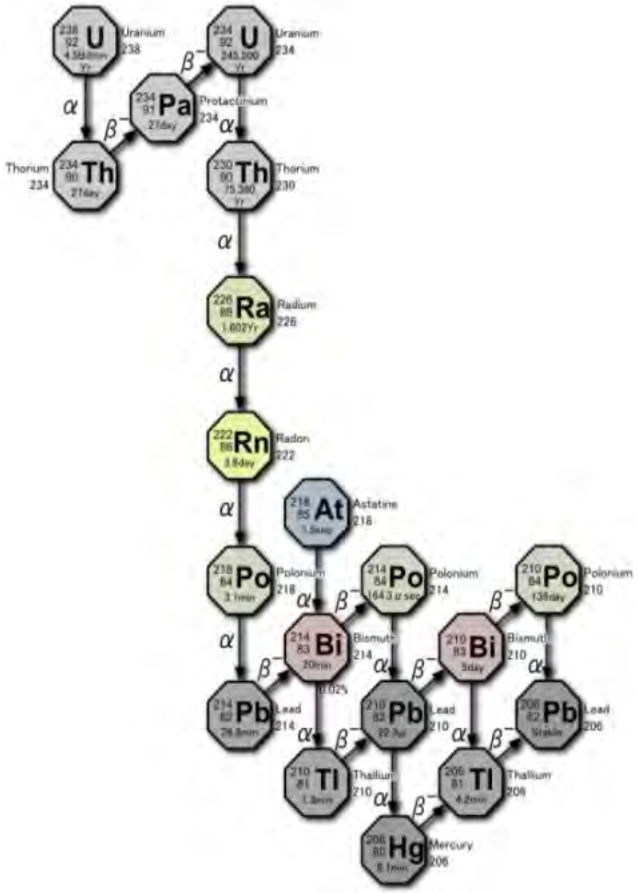
Radiological Nature of ROM (Ore) vs. Ablation Mining Product Are the Same



Isotope	% Mass in Natural Uranium	% Radioactivity in Natural Uranium
U 238	99.3	48.9
U 234	0.72	2.2
U 235	0.005	48.9

Only difference radiologically is AMT Product = "higher grade ore"

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US Atomic Energy Act and Colorado Regulations for Radiation Control - Definitions

Source Material **(10 CFR 40.4 and 6 CCR 1007-1 Part 1.2): ≥ 0.05 % by weight U and/or Th; any economically viable U ore is this (e.g., walls of the mine)**

Unimportant Quantities of Source Material **(10 CFR 40.13 - Not licensed): includes unrefined and unprocessed ore containing source material.**

Byproduct Material **(10 CFR 40.4 and 6 CCR 1007-1 Part 1.2): The tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content *{* specifically this is referred to as "11 e.(2) byproduct material"}**

Uranium Milling **(10 CFR 40.4): *Any activity that results in the production of byproduct material as defined in this part*.**

Source Material Milling **(6 CCR 1007-1 Part 1.2): any activity that results in the production of radioactive material that meets byproduct material definition**

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Regulatory Implications for AMT

Source material remains in AMT ore – has not (yet) been processed to extract the source material content.

Byproduct material not produced since uranium series radionuclides remain in equilibrium with the uranium in the AMT ore and the source material (uranium) has not been extracted from it.

Accordingly AMT ore = unrefined and unprocessed ore since the source material has not yet been extracted

AMT process is NOT Milling

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Radiological Risk Reduction Features

- ***Many vessels bermed with sumps to contain and control spills***
- ***Ablation units with local exhaust to minimize radon releases into processing area***
- ***Surface vents monitored for radon releases***
- ***Traditional dust suppression methods during ore excavation***

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Radiological Risk Reduction Features - Continued

- ***All workers and operating areas continuously monitored for radiation levels***
- ***Processing operations continually monitored from control panel (flows, pressures, etc.)***
- ***Radiation Protection Plan in accordance with industry best practices and regulatory requirements***
- **Dose savings at mill estimated to be about 2000 millirem per yr. assuming 4 – 6 ore handlers**

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Radiological Risk Assessment - Conclusions

- **Radiation exposure of workers expected to be similar to or less than typical exposures of conventional uranium miners - within variability of natural background in US and < 10 % of MSHA, CO and USNRC exposure limits for miners or radiation workers**
- **Worker Radiation Protection Program consistent with national and international standards which have been protective for many years – ANSI 1973, USDOE 2009, USNRC 1992, IAEA 2004**
- **Radiation exposure of public historically < limits and expected to continue; EPA radon limit from U mines about 2% of bkg. in Colorado; radon in effluents continually monitored; engineering adjustments if necessary**
- **Radiological character of AMT ore = Uranium + all progeny; "source material" remains and not yet extracted from ore; no 11e.(2) tailings produced - not milling**

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