Ablation Mining Technology

May and June, 2016 Stakeholder Meetings
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)
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
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
Sandstone Diagenesis

Compaction, cementation, and/or dissolution turn sand to sandstone.
With appropriate geologic conditions these dunes may some day become sandstone

**Mineralization**: deposition of economically important metals in the formation of ore bodies
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.
Uranium Mineralization in Sandstone

Example of mineralization in thin section

<table>
<thead>
<tr>
<th>ID</th>
<th>Mineral</th>
</tr>
</thead>
<tbody>
<tr>
<td>qz</td>
<td>quartz</td>
</tr>
<tr>
<td>U</td>
<td>uraninite</td>
</tr>
<tr>
<td>P</td>
<td>pyrite-marcasite</td>
</tr>
<tr>
<td>vp</td>
<td>veinlet pyrite-marcasite</td>
</tr>
</tbody>
</table>

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

Example of mineralization on a per sand grain basis

Single Grain Pre AMT with Mineralized crust

Single Grain Post AMT
AMT Disassociation

AMT Mix Tank Module

AMT Impact Modules

Same material introduced to AMT exits AMT
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.
AMT Materials

Crushed AMT ROM conveyed to AMT

AMT mines ore from between the grains

Separated Post AMT Waste (sand)

Dried Post AMT Ore
AMT and Ancillary Components

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

Water Consumption: 11.3 to 27.3 gpm

- 4.8 gpm
- 6.5 gpm
- 0 to 16 gpm

Storage/Treatment
AMT as Best Practice

**WITHOUT ABLATION**

Run of Mine Haul
- Nearby Mill
- Large Volume

Large Mill and more Mills

Large Impoundment

Mining:
- Open Pit
- Underground
- UBHM

**WITH ABLATION**

Ablation with Waste Rock Returned to Mine

Ore Transported:
- Long Distances
- Few trucks

Small Mill and Fewer Mills

Waste Reduction Technology

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

<table>
<thead>
<tr>
<th>Source</th>
<th>Colorado Avg. a</th>
<th>Florida Avg. a</th>
<th>Illinois Avg. a</th>
<th>Leadville Avg. b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmic Radiation</td>
<td>49</td>
<td>27</td>
<td>28</td>
<td>85</td>
</tr>
<tr>
<td>Terrestrial Radiation</td>
<td>39</td>
<td>13</td>
<td>24</td>
<td>97</td>
</tr>
<tr>
<td>Internal Radiation including Radon Inhalation, Food and Water Ingestion</td>
<td>300</td>
<td>54</td>
<td>181</td>
<td>344</td>
</tr>
<tr>
<td>Totals</td>
<td>387</td>
<td>93</td>
<td>233</td>
<td>526</td>
</tr>
</tbody>
</table>

* 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
Cosmic Ray Background Varies Considerably Across US

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

<table>
<thead>
<tr>
<th>Exposure Condition</th>
<th>Annual Limit (mrem)</th>
<th>Regulatory Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker Annual Radiation Exposure</td>
<td>5000</td>
<td><strong>USNRC:</strong> 10 CFR 20.1201, <em>Occupational Dose Limits</em>; <strong>Colorado:</strong> 6 CCR 1007-1 Part 4.4.1, <em>Occupational Dose Limits</em>; <strong>USMSHA:</strong> 30 CFR 57.5047</td>
</tr>
<tr>
<td>Limit for Members of the Public Including Radon</td>
<td>100</td>
<td><strong>USNRC:</strong> 10 CFR 20.1101, <em>Radiation Dose Limits for Individual Members of the Public</em>; <strong>Colorado:</strong> 6 CCR 1007-1 Part 4.paragraph 4.14.1, <em>Radiation Dose Limits for Individual Members of the Public</em></td>
</tr>
<tr>
<td>Limit for Members of the Public – Radon from Uranium Mines</td>
<td>10</td>
<td><strong>US EPA:</strong> 40 CFR 61, Subpart B - National Emissions Standards Hazardous Air Pollutants (NESHAPS)</td>
</tr>
</tbody>
</table>
### Doses to Canadian Uranium Mine and Mill Workers For Selected Job Categories, 2010 - 2014 (Health Canada 2016)*

<table>
<thead>
<tr>
<th>Job Category</th>
<th>Average Annual Dose (millirem)</th>
<th>Average # workers per year in Job Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>U Mill Workers</td>
<td>110</td>
<td>318</td>
</tr>
<tr>
<td>U Mine Support Workers</td>
<td>82</td>
<td>670</td>
</tr>
<tr>
<td>U Mine Surface Workers</td>
<td>28</td>
<td>75</td>
</tr>
<tr>
<td>Underground U Miner</td>
<td>192</td>
<td>637</td>
</tr>
</tbody>
</table>

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](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.
Worker Exposure Estimate = 174 millirem per year
Public Exposure: Sunday Mine EPA NESHAPS Compliance Summaries – Annual reports for the years 2008, 2009 and 2010

<table>
<thead>
<tr>
<th>Year</th>
<th># Of Vents Active and Monitored</th>
<th>Max. Annual Dose to Member of Public* (mrem / yr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>10</td>
<td>0.5</td>
</tr>
<tr>
<td>2009</td>
<td>16</td>
<td>7.5</td>
</tr>
<tr>
<td>2010</td>
<td>10</td>
<td>1.7</td>
</tr>
</tbody>
</table>

* Nearest resident approximately 4 miles

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.
Underground at Rabbit Lake
Robotics, Remote Control, Ground Freezing at McArthur River > 20% U Mine
Radiological Nature of ROM (Ore) vs. Ablation Mining Product Are the Same

Only difference radiologically is AMT Product = “higher grade ore”

<table>
<thead>
<tr>
<th>Isotope</th>
<th>% Mass in Natural Uranium</th>
<th>% Radioactivity in Natural Uranium</th>
</tr>
</thead>
<tbody>
<tr>
<td>U 238</td>
<td>99.3</td>
<td>48.9</td>
</tr>
<tr>
<td>U 234</td>
<td>0.72</td>
<td>2.2</td>
</tr>
<tr>
<td>U 235</td>
<td>0.005</td>
<td>48.9</td>
</tr>
</tbody>
</table>
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): \( \geq 0.05 \% \) 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
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
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
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
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