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UNDERGROUND BOREHOLE MINING AND IMPACT ABLATION TUTORIAL

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Two experimental uranium recovery technologies are being proposed by Black Range Minerals as a more economic and environmentally friendly way to exploit sandstone hosted uranium resources than either conventional open pit or underground mining as well as in-situ leach solution mining.

Although both underground borehole mining (UBHM) and Impact Ablation can be utilized individually and independent of each other, this presentation is primarily devoted to describing the two as a closed loop processing system that extracts sandstone hosted uranium ore from the underground ore body and concentrates its uranium oxide component on the surface into approximately ten percent of the original mass, which then must be chemically converted in a conventional uranium mill to produce U3O8 yellowcake.

The UBHM component of the process:

- **An individual 22" diameter borehole is drilled from the surface into the ore body (the depth appears not to be a significant constraining factor). It is cased (presumably in steel) to the target depth.**
- **Two pipes are inserted into the borehole, one to pump water down that has a horizontal rotating nozzle at the tip, and a second to return the water/ore slurry to the surface.**
- **Water is pressurized on the surface for injection into the borehole. Actual required pressurization and other details have not been disclosed by the company but independent sources suggest that up 1500 pounds per square inch (100 times standard atmospheric pressure) or greater is required to fragment sandstone depending on the ore body geology.**

- The pressurized water is injected into the borehole and is horizontally redirected to fragment the ore into small pieces to create a water/ore slurry and creating an unconfined underground cavern. Independent sources suggest that up to 50,000 gallons per hour (800 gal/minute) would be required to excavate a cavern approximately eleven meters in diameter.
- The slurry is then brought to the surface by suction in the second pipe for injection into the ablation machine system.
- When the cavern is exhausted of ore, the entire system is removed from the borehole and relocated to an adjacent site and the process is repeated. At the Hansen site in Tallahassee, the company believes that 2600 boreholes would be required to mine-out the uranium resource.
- Each borehole and cavern would be backfilled and the borehole abandoned.
- The multi-unit UBHM system consisting of heavy duty drill rig, pressurizing and power units, pumping/suction units, etc. is transportable.
- This technology as described has never been utilized commercially for uranium recovery and has not been tested in the field by Black Range.

The Impact Ablation component of the process:

- The slurry recovered from underground is injected under pressure into opposing sides of the first part of the multi-part ablation system. The ore fragments impact in a kinetic high energy zone which breaks them into smaller particles.
- The particles of ore are then separated in a series of gravity screening processes. The majority of the uranium oxide particles are concentrated in the finer grain material. Depending on the source of the ore and the performance of the unit, the company has reported experimental results of the concentration of up to 90-99% of the uranium oxide in approximately 10% of the original ore mass.

- **The "ablated concentrate" is then dried and packaged for transport offsite to a conventional uranium mill.**
- **The waste products from this process consist of the recovered process water and 90% of the original ore mass containing from 1-10% or more of the original uranium oxide plus the radium and other elements, such as iron and/or arsenic, found in the ore body.**
- **An experimental 0.5 ton/hour unit has been in the testing mode in Casper, WY by the developer, Ablation Technologies LLC. A semi-commercial 5 ton/hour multi-component system is in the final stages of construction (as of early November 2013) and will be utilized in Casper to process 100 tons of stockpiled ore transported from Mesa County, Colorado to validate the process. A 20 ton/hour production unit is proposed.**
- **These units are reported to be transportable by heavy trucks and would be assembled and operated at remote mine sites.**

If the technologies are operated individually (as with the 100 ton ore stockpile test) there are some modified procedures required,

- **For ablation, the raw ore, either stockpiled or from conventional mining, must be reduced in particle size by crushing or grinding before adding water to form the injectable slurry.**
- **For UBHM, the recovered water/ore slurry would likely have to be dried or dewatered for economic reasons before the recovered ore would be shipped to a conventional mill.**

Neither of the technologies, either independently or as a consolidated uranium recovery system, have been formally presented to uranium mining or radiation control regulators – federal or state – and their regulatory status is unsettled and at the very beginning of being determined.

- **For UBHM, the process clearly falls within the Colorado definition of *in-situ mining* but does not meet the definition of *in-situ leach (solution) mining (ISL or ISR)* which requires concurrent regulation by both mining**

and radiation control agencies. As a uranium extraction process, UBHM is a Designated Mining Operation under Colorado law.

- **NRC staff has provisionally stated that the UBHM process is a "continuation of mining" until the water/ore slurry reaches the surface. A discussion of the conflict between this position and existing NRC guidance is presented below.**
- **For Impact Ablation, the process has been determined by both the NRC and the Colorado Radiation Program Unit of CDPHE to be "source material processing requiring a source material radioactive material license, at a minimum". Neither agency has specifically identified ablation as "uranium milling" nor has commented on the regulatory status of the solid and liquid waste that is produced. Black Range Minerals considers ablation to be a mining process not requiring radiation control permitting.**
- **Consideration of these technologies by regulators have not been reported by any state other than Colorado to date although this is likely in Utah, at least, in the near future.**

There are a number of public policy, environmental, health & safety, and technical & scientific issues that should be considered and resolved before these technologies are approved for use in addition to being assured that the regulatory scheme is consistent, science-based, and protective to the environment and to the health & safety of both workers and the public.

- **The demand for uranium in the U.S. is expected to be flat for the foreseeable future. These technologies produce considerable air pollution and greenhouse gas emissions. Is it good public policy to encourage uranium recovery locally to provide carbon-free nuclear power in Asia and the Middle East promoted by foreign companies financed by Asian investors?**
- **UBHM requires the massive consumptive use of water. Whether the water could or should be recycled and reused is discussed below, however when water is scarce and needed for future growth and agriculture, is it good policy to approve its use for uranium recovery?**

- **Even if the closed loop UBHM/Ablation process is well managed to prevent adverse health & safety impacts to the workers with respect to the production of the concentrated ablated ore, the waste products are a radiological hazard and must be handled in a similar manner as tailings at conventional uranium mills.**
- **The solid waste, reduced in size essentially to sand, contains residual uranium, radium, and heavy metals. Although no added chemicals are present, the environmental and health hazards are significant, including the expected production of radon emissions.**
- **The recovered process water will contain significant concentrations of uranium and radium. The Ablation Technologies patent application discloses that they found a high enough amount to be recoverable by an ion exchange process. This is the same procedure used in ISL to recover the dissolved uranium from the leachate. Whether or not the uranium is recovered from the waste water, the hazard remains, both radiological as well as from the dissolved heavy metals and acid forming materials from the ore body.**
- **In ISL, water containing added oxygen and other chemical oxidizers is pumped through the intact underground ore body to chemically convert a maximal amount of the insoluble uranium oxide to its soluble state. This "leachate" is then pumped to the surface for the uranium to be recovered by ion exchange.**
- **One of the technical requirements for employing ISL is that the ore body be in a confined aquifer, thereby minimizing the potential for underground migration of the uranium bearing leachate beyond the wellfield. UBHM has been proposed for areas that are geologically unsuitable for ISL due to fractures or unconfined aquifers.**
- **A percentage of the water injected into the ore body will, under pressure, be forced out of the cavern into the surrounding sandstone aquifer. This out-migration is not controlled, as it is in an ISL wellfield, and has the potential of contaminating local groundwater, springs, and domestic water wells. Since each cavern is uncased and independent, and many**

hundreds of them would be required to fully exploit the ore body, the environmental and health hazards are difficult to forecast.

- **The actual amount of uranium solubilized and dissolved into the UBHM process water is dependent upon the oxidation potential of the water in contact with the newly fragmented ore pieces. Water naturally contains some dissolved atmospheric oxygen (DO) at standard atmospheric pressure. A basic principle of physical chemistry, Henry's Law, states that when water and air are at equilibrium, the amount of air (primarily Nitrogen and Oxygen) that can be dissolved into the water is a function of pressure. At a fixed temperature, as the pressure increases so does the DO. The theoretical increase is linear – four times standard pressure, fourfold increase in DO; one hundred times standard, one hundred times DO increase. The actual DO concentration in the UBHM pressurized water will have to be determined empirically.**
- **This increased amount of DO in the water in the underground cavern will cause oxidation of the insoluble uranium oxide – less efficiently than ISL, but to a significant amount – to the soluble form. The actual concentration of dissolved uranium, radium, and other heavy metals in the water will have to be determined empirically but some unknown percentage of this hazardous, contaminated water will out-migrate from the individual caverns into the groundwater aquifer while the bulk of it will be brought to the surface as the slurry.**
- **The level of contamination in the process water will increase as it passes through the ablation machine and would increase further if the output process water is repressurized and reinjected into the UBHM boreholes.**

The regulatory issues relating to UBHM and Impact Ablation do not fit easily into the current radiation control regulations administered by NRC or any of the Agreement States. It is neither conventional mining nor *in-situ leach* mining. It is neither conventional uranium milling, heap leaching, nor uranium recovery by ion exchange from ISL leachate.

- **The NRC is mandated to establish policy and regulations implementing the Atomic Energy Act. Agreement States are permitted to promulgate their own regulations governing radiation control but those regulations must be "compatible" with NRC and may be more stringent.**
- **NRC guidance in Health Physics Position 184 states that the line to be drawn between uranium mining (which is not regulated under the AEA) and milling is at the point where unrefined and unprocessed ore has had it gross appearance and chemical nature altered from the point of mining. It is at that point that the changed radiological environment, potentially adversely affecting the health and safety of workers and others, becomes a matter of legitimate regulatory concern.**
- **In the UBHM process NRC acknowledges that the gross appearance of the ore is changed by the water fragmentation of the natural ore body (arguably the point of mining) and that its chemical nature may be changed to an unintentional and limited degree. What the NRC has not yet considered is that the radiological environment underground would be significantly changed by the production of uranium and radium contaminated water which will out-migrate to the groundwater aquifer.**
- **If that point is recognized, UBHM as an independent process would be considered a non-conventional uranium milling activity and subject to the uranium milling regulations.**
- **The EPA, as part of its implementation of the federal Clean Water Act, has determined that a UBHM borehole requires an Underground Injection Control (UIC) Permit as a Class III Well, similar to ISL wellfields. In order to permit an UIC well, the affected aquifer must be declared exempt, i.e. not a source of drinking water. In Tallahassee, for example, there are four to five aquifers in the watershed supporting well over one hundred domestic water wells. It is unknown as to the extent of cross-communication among these aquifers.**
- **Ablation is already recognized as a source material processing activity. *Source Material* is defined as ore containing at least 0.05% Uranium. What distinguishes ablation from routine crushing or grinding of ore (also**

licensable source material processing activities) is that ablation produces waste material which is "byproduct material" as defined in the AEA.

- ***Byproduct Material*** **means the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes.**
- **The production of byproduct material is the heart of the definition of uranium milling*: Uranium Milling* means any activity that produces byproduct material as defined.**
- **Ablation as an independent process is a non-conventional uranium milling activity subject to the uranium milling regulations.**
- **NRC guidance recognizes that non-conventional milling activities may occur at different locations than at conventional uranium mills but are still subject to the milling regulations.**
- **When UBHM and Impact Ablation are considered as a closed loop system, the entire process in a non-conventional milling activity, regardless of a determination that UBHM itself is not milling.**
- **If the output process water from the ablation machine is processed to recover uranium, the ISL regulations apply as well.**
- **It is unclear what the regulators will require for dealing with the waste products generated by the UBHM/Ablation system. Black Range Minerals is proposing to 1) reuse and recycle the process water for reinjection into the borehole; and 2) to use what they call the "barren rock" or "clean sand", representing 90% of the original ore mass, to backfill the boreholes and caverns. Usually, uranium mill tailings (byproduct material) are impounded on the surface and have stringent guidelines for maintenance.**

(Prepared by Lee J Alter, Chairman, TAC Government Affairs Committee)