CONGRESSIONAL FIELD HEARING ON ***"Community Impacts of Proposed Uranium Mining Near Grand Canyon National Park"*** **–** 28 MARCH 2008 – FLAGSTAFF, AZ.

Uranium Mining in Arizona Breccia Pipes – Environmental, Economic, and Human Impact

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The race for military nuclear supremacy during and following World War II resulted in the rapid development of a worldwide uranium production industry. The adage, 'haste makes waste', created this legacy. The frantic pursuit of these early military programs created environmental hazards and health risks throughout the world that left a multi-billion dollar Cold War uranium production legacy. Above ground military nuclear testing at the Nevada Test Site before and during the Cold War resulted in radioactive fallout in a trackway that runs across the Arizona Strip. These manmade radioactive isotopes can still be found in the soil today at levels far exceeding those of naturally occurring uranium or its daughter products from mining.

Lessons learned from this legacy have had a profound influence on modern uranium production, thereby minimizing long-term environmental impact and health risks during uranium exploration, mining and milling. The industry has come a long way from the time when tailings were left unprotected and allowed to be transported by water and wind into nearby streams and rivers. The mining industry has since learned to embrace the philosophy that it is more effective to prevent pollution than to clean it up. This can readily be seen by the reclamation of the Hack 1, 2, 3 mines, the Pigeon Mine and the Hermit Mine, where not only can one no longer tell there was ever a mine present, but in the case of the Hack 1 mine the former mining company actually cleaned up the sprawling mine debris left over from the late 1800s through the 1940s.

Geological & Historical Background

Mining activity in the Grand Canyon breccia pipes began during the nineteenth century, although at that time production was primarily for copper with minor production of silver, lead, and zinc. It was not until 1951 that uranium was first recognized in the breccia pipes. Despite periods of depressed uranium prices, the breccia pipes commanded considerable exploration activity in the 1980's because of the high-grade nature of their uranium ore. During the period 1956-69, the Orphan Mine produced 4.26 million lb of U_3O_8 with an average grade of 0.42% U_3O_8 (Chenoweth, 1986). The Orphan Mine is located within Grand Canyon National Park where the head frame projects above Powell Point commemorating our US heritage through mining history. This history includes one of Teddy Roosevelt's Rough Riders packing his burro down the trails of the Grand Canyon to his Orphan mine where he dug for copper and silver during the end of the 19th century. In addition to uranium, 6.68 million lb of copper, 107 oz of silver, and 3400 lb of V_2O_5 (vanadium oxide) were recovered from the ore (Chenoweth, 1986). Between 1980 and 1988 four breccia pipes (Pigeon, Hack 1, Hack 2, Hack 3) were mined for uranium in northern Arizona with grades averaging 0.65% U_3O_8 and total production of 13 million lbs of U_3O_8 (Mathisen, 1987). During the end of the period of breccia pipe mining by Energy Fuels Nuclear, they had refined their mining methods and the average grade of ore production approached 1% (I.W. Mathisen, oral commun., 1990).

These breccia pipes are vertical pipe-like columns of broken rock **(fig. 1)**; the breccia formed when layers of sandstone, shale and limestone collapsed downward into underlying caverns. Brecciation of overlying sedimentary strata formed thousands of pipe-shaped columns of breccia (**fig. 2**). Upward stoping through the upper Paleozoic and lower Mesozoic strata, involving units as high in the section as the Triassic Chinle Formation, produced vertical, rubble-filled, pipe-like structures (fig. 1). A typical pipe is approximately 300 ft in diameter and extends upward as much as 3000 ft (Wenrich and Sutphin, 1989).

Breccia pipes extend across most of the Colorado Plateau in northwestern Arizona and into the Basin and Range Province (Wenrich and others, 1989). The potential for additional economic uranium mineralized breccia pipes is greatest beneath the flat plateaus where erosion and oxidation of the ore have been minimized. It is only on the Colorado Plateau, with its history of tectonic stability, that the uraninite has been preserved (**fig. 3**). Along the edges of the plateau and in the canyons, the ore-bearing minerals are usually oxidized to colorful secondary minerals (**fig. 4)** that are popular with mineral collectors. These mineral specimens lie in homes of mineral collectors and in most museums across the country and pose little threat to the casual viewer.

Human Impact

The mining ventures of the Navajo Reservations of the 1940s through 1960s are not relevant to the breccia pipe province, because the Navajo mines were surface mines into an entirely different geological and hydrological environment, and because mining technology and environmental practices used in the breccia pipe province are 21st century technology. Even if one does not trust the mining companies to self regulate, they are under strict control and monitoring by Arizona regulators governed by modern legislation and laws.

Mine safety for employees was strictly enforced in the breccia pipe mines of the Arizona Strip. During the previous mining operations of the 1980s and 1990s there were never any mine fatalities. In fact, the MSHA records show that for one of the 5 reclaimed mine about the worst accident was an employee smashing his thumb with a hammer. Ventilation within the mines was excellent, so there was minimal exposure of miners to radon gas and its daughter products. Smoking was strictly prohibited within the mines. Radon in itself is not the problem with its 3.8-day half-life; the miner breathes it in and breathes it out. It is actually the radon alpha emitting progeny (lead and polonium) in the form of aerosols that are the nasty devils. They attach themselves to various areas of the respiratory system. Epidemiological studies have shown that the lung cancer risk to smokers is 10-20 times greater than “never” smokers at exposures to environmental levels of radon (such as 20-150 Bq/m3). The uranium industry now understands this increased risk that smoking miners have, and have adjusted their operations accordingly.

It is interesting that the University of New Mexico Cancer Research Center records confirm that the cancer incidence rate among American Indians for McKinley and San Juan counties (with uranium mines) is far lower than the average rate among American Indians in other New Mexico counties where there is no known occurrence of uranium or history of uranium mining. This does not support the claim of increased cancer due to uranium mining. The U.S. Department of Health and Human Services, Indian Health Service (IHS) 2006 report “Facts on Indian Health Disparities” states “The American Indian and Alaska Native People have long experienced lower health status when compared with other Americans. Lower life expectancy and the disproportionate disease burden exist perhaps because of inadequate education, disproportionate poverty, discrimination in the delivery of health services and cultural differences. These are broad quality of life issues rooted in economic adversity and poor social conditions.” Breccia pipe mining would offer Indians a chance at improved economic status just as uranium mining has in the Athabasca Basin, Saskatchewan, Canada, where 50% of the staff for Cogema’s uranium mines is native people.

Economic Impact

Uranium mines have a significant impact on the economic condition of Northern Arizona. The opportunity for employment in economically ravaged towns such as Colorado City is enormous. During the 1980s and 1990s this town as well as Fredonia, Arizona and Kanab, Utah saw reduction in poverty and welfare from wages earned by their citizens from the mines and associated jobs. The royalties that the State of Arizona receives from these mines should not be dismissed by a state that is in financial strife. Previous uranium mining in 10 separate mines has had absolutely no detectable negative impact on tourism. Quite the contrary – the old head frame of the Orphan Mine, located within Grand Canyon National Park, is a tourist attraction, a symbol of the powerful attraction that brought early settlers westward. The Orphan mining claim was first located in 1893 by a prospector named Dan Hogan who discovered copper on the south wall of the Grand Canyon, 1100 feet below the rim. After serving as a Rough Rider during the Spanish American War, Dan Hogan returned to prospecting. In 1906 he filed for a mining claim patent on the Orphan Mine and his old Commandant, Theodore Roosevelt, signed it himself. From this it might be construed that Teddy Roosevelt believed in multiple land use, and that the beauties of the Grand Canyon could coexist with mining. The Orphan Mine was mined for uranium within Grand Canyon National Park from 1953 to 1969. The mine was situated off the scenic and well-traveled routes, resulting in most park visitors being unaware of the mine's existence. Similarly, the other 9 mines, 8 on the North Rim, are far from the view of most tourists. Mining has occurred for over 4 decades in the breccia pipe province, with only a positive financial impact on the economy of Arizona.

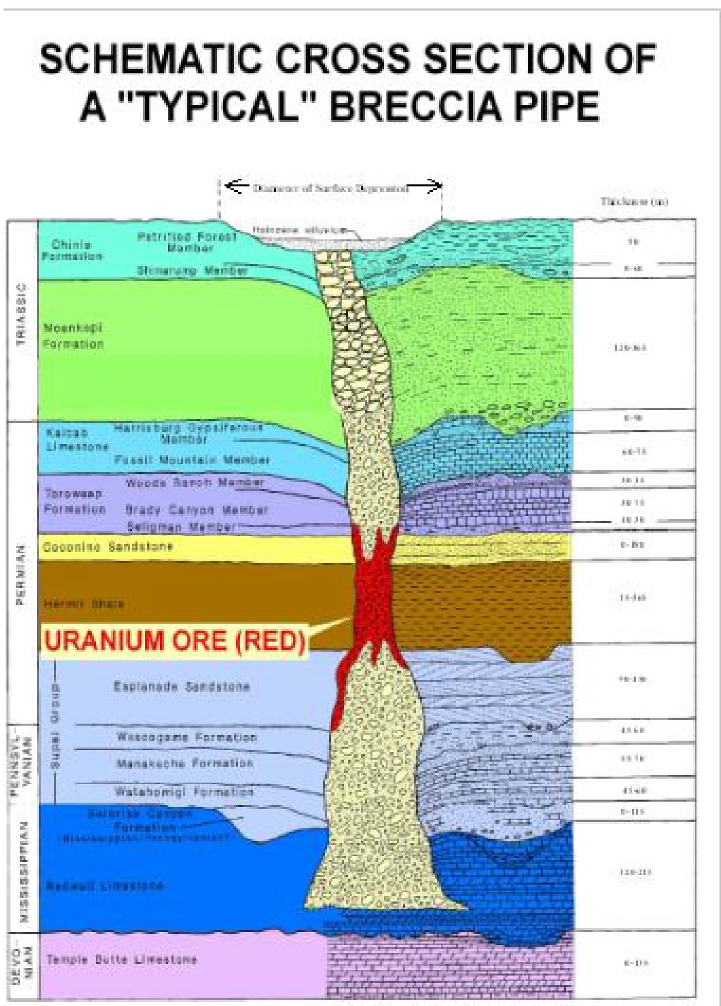

Figure 1. Cartoon of an actual breccia pipe formed by solution collapse. This collapse process left a cylindrical column of broken rock that was mineralized with uraninite about 260 million years ago. Diagram modified from Wenrich, Billingsley and Huntoon, 1996.

The highest-grade uranium deposits in the United States, and some of the highest in the world, occur in a breccia pipe environment in northwestern Arizona. Electricity generation in the US is 19% nuclear power; providing domestic US uranium to those plants would provide more jobs and cash flow for US citizens. Such deposits give the US a unique opportunity for energy self-sufficiency with fuel that is clean and emits no CO_2 gases. This is critical at a time when (1) there is intense global pressure for the US to reduce its greenhouse gases, and (2) we are being held financially hostage by dependence on imported oil. Such dependence jeopardizes our national security, and if the trade routes are severed our country's economy could shut down. We send off our youth to fight patriotically in wars in foreign countries to defend our access to oil. Would it not be best to save thousands of their lives by demonstrating patriotism at home through support for uranium mining that is clean, safe and will put us on the path to energy independence? There would be no more need to find oil or to fight for oil in the Middle East, supporting regimes that we would not normally support. True patriotism is the ability to use our own resources to become free of foreign economies whose goal is to dominate our own.

Figure 2. Breccia. Breccia is an Italian word for broken rock. Note the vuggy nature of the rock, which permits pore space for mineral-bearing fluids to create an orebody. Within the breccia the broken pieces are multi compositional. Photo by Karen Wenrich.

Figure 3. Uraninite, UO_2, is the primary ore mineral for the breccia pipes. Small crystals of natural uranium, such as these, pose minimal radiation hazard to the mineral collector.
Photo by Lou Perloff.

Figure 4. Metatorbernite, $Cu(UO_2)_2(PO_4)_2.8H_2O$. This uranium-copper-phosphate forms in oxidized zones above the breccia pipe orebody. Photo by Sugar White.

Environmental Impact

These deposits are higher grade than most uranium deposits elsewhere in the world, with the exception of the Canadian deposits (with an average grade around 20% uranium). However, the word uranium brings fear to many who live in Arizona because of the uranium legacy that was left behind on the Colorado Plateau over 50 years ago. Yet, these breccia pipe mines are different—the uranium is deep beneath the plateau surface, the mines are underground, and nothing extraneous is left on the surface after mine closure. The breccia pipe deposits were so successfully mined and reclaimed in the 1980s and early 1990s that few people even realize that there were eight producing mines in the Arizona Strip near the end of the 20th century. Today even uranium geologists can no longer find the location of the three former producing uranium mines that are located in Hack Canyon (**figs. 6-7).**

Watershed Impact: The major aquifers in the Grand Canyon are the Mississippian-age Redwall and Cambrian-age Muav Limestones. The breccia pipe orebodies extend no deeper than the Esplanade Sandstone of upper Pennsylvanian age (**fig. 5**). On the Kanab Plateau (where 8 of the producing mines are located) down hole data (Titan Environmental, 1994) indicate that the Redwall-Muav aquifer (fig 5) is the only significant source of ground water within the area. No other continuous ground water sources were encountered on the Plateau in the overlying formations because these strata have been intersected and drained by the deep canyons and the large-scale faults associated with the formation of the plateaus (USGS, 1979). Additionally, on the Kanab Plateau, the only other aquifer in the Grand Canyon region of any significance above the Redwall Limestone is the Permian Coconino Sandstone, which pinches out in this area to a thickness of 0 north of the Hack Canyon Mine, where dissection is less. Within the Kanab Plateau area, the Redwall-Muav aquifer is under significant artesian pressure. This high artesian pressure is an excellent safeguard preventing seepage from the mines on the Kanab Plateau from entering the Redwall-Muav aquifer. Additionally, a 1,089-foot thick unsaturated, practically impermeable, layer of Supai Group Sandstone protects the aquifer (**fig. 5**). "Therefore, it is inconceivable that mine seepage of substantially lower hydraulic head (20 ft) will ever seep through the Supai Group, even when geologic time is considered" (Titan Environmental, 1994). Similarly on the south rim in Kaibab National Forest, the Environmental Impact Statement (1986, US Dept of Agriculture) on the Canyon Uranium Mine concluded that "construction and operation of the Canyon Mine will not impact the Redwall-Muav aquifer, which is well below the shaft depth."

Water analyses taken between April 29, 1991 and May 15, 1991 in a water supply well into the Redwall-Muav aquifer adjacent to the producing Kanab North Mine shows uranium concentrations varying between 0.8-5.9 ppb (µg/l). This is lower than the uranium concentration in much of this nations public drinking water and 1-2 orders of magnitude lower than the EPA safe drinking level of 33 ppb.

Despite the good aquifer of the Redwall-Muav Fms they provide an almost imperceptible contribution, even when the entire Grand Canyon is considered in total, to the mighty Colorado River itself. The surface water impact of the mines is negligible even at Kanab Creek, because the level of the mine workings, at such mines as Kanab North that sits at the edge of Kanab Creek, is below the Kanab Canyon floor. All ore is trucked 300 miles into Utah, so little uranium-mineralized rock will remain on the surface even during the mining operation.

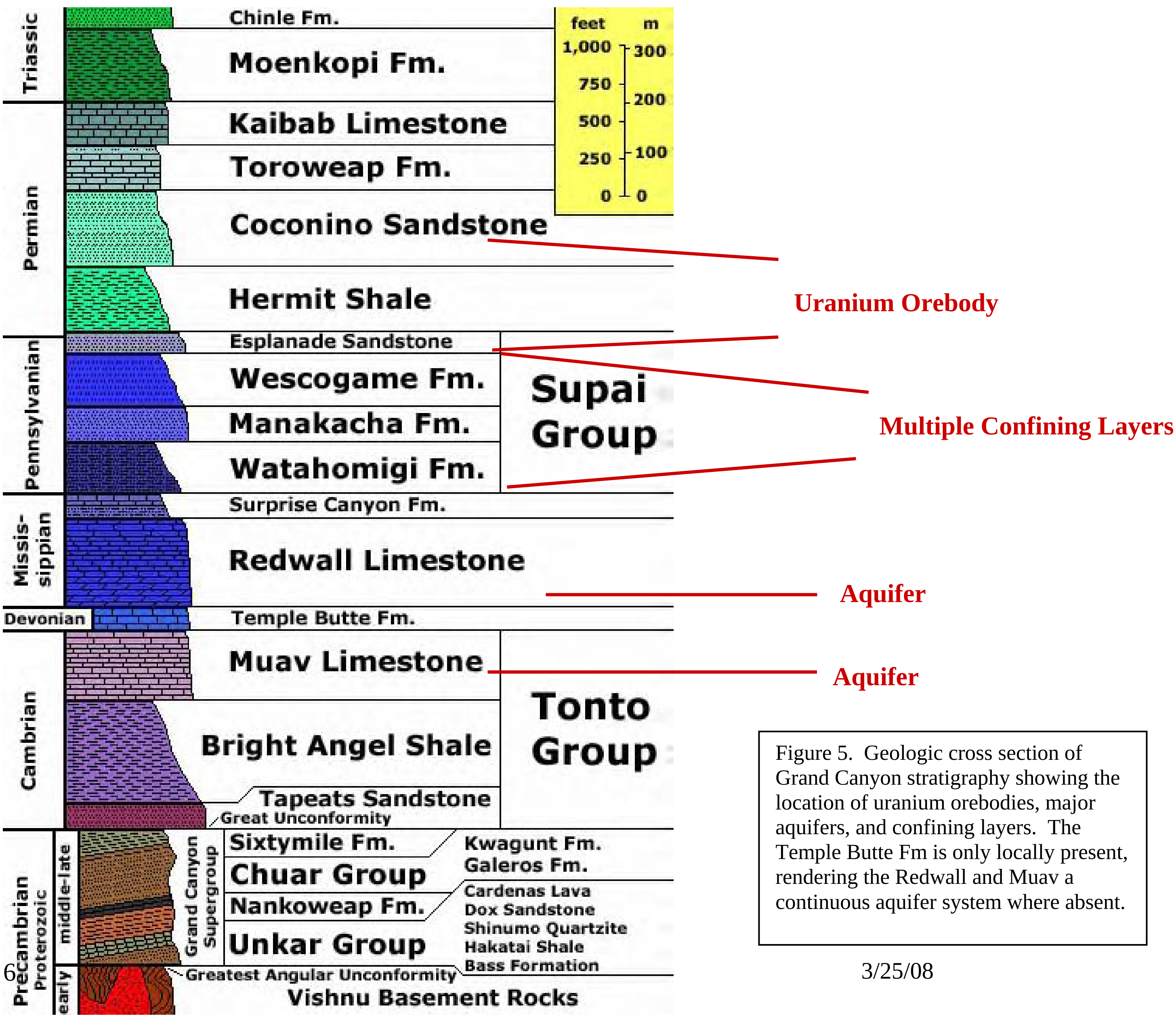

Figure 5. Geologic cross section of Grand Canyon stratigraphy showing the location of uranium orebodies, major aquifers, and confining layers. The Temple Butte Fm is only locally present, rendering the Redwall and Muav a continuous aquifer system where absent.

Figure 6. The Hack 1 Mine during mining (Hack Canyon, Arizona Strip). This was an underground mine that was in production during the 1980s. Note how little waste rock is sitting on the surface even during mining. As mining is closing the waste rock is backfilled into the drifts and stopes. Photo taken June, 1985 and courtesy of Pam Hill.

Figure 7. Hack 1 mine, after reclamation. During the reclamation the company also cleaned up debris that was left from early copper/uranium mining prior to 1950. Note that there are no longer any waste rock or tailings piled up on the surface, and in fact no evidence that mining ever occurred at this location. Photo taken October, 1989 and courtesy of Pam Hill.

The uranium production industry is well aware that they are faced with the environmental legacy of early uranium production. The uranium industry has undergone a significant evolution in the level of environmental understanding and management practices over the past 30 years. Experience has shown that there has been, and continues to be, ongoing development of enhanced environmental management practices in order to the meet the call from the public and the regulatory agencies for long-term environmental protection, and socio-economic benefits sharing with communities adjacent to the operations. Failure to incorporate best environmental practices in initial mining and milling plans can lead to such uranium legacies as we have witnessed in the past. The nuclear industry knows they cannot afford any more environment-damaging legacies.

Higher-grade deposits, such as the breccia pipes, produce more uranium with less environmental footprint. The environmental footprint duration for each mine is short as the life for each mine in the past was only 5-7 years. There is only a temporary disturbance of three or four acres per mine, as the mines are underground. The water table is deep, well below the level of mining. The mines are dry. There is no circulation of major northern Arizona aquifers within any of the mining levels so there is essentially little chance of any contamination to the ground water. There is no on-site processing, no chemicals and all mining is above the water table. Underground mining emits very little dust. Waste rock and tailings can always be, and have been, back-filled into the abandoned mine shafts and tunnels. Even the concrete from the former mining structures was broken up and backfilled into the old mine workings. As in the past the area to be disturbed would be searched by an archeologist and any cultural features found will be either avoided or mitigated by detailed study. The area will also be studied by a biologist to see if there are threatened, endangered, protected, or other special status species or critical habitat present. There is no greater testimony to the mining and environmental success of these breccia pipe operations than a view of the previous operations in comparison to the current environment of the terrain **(figs 6-9**). This former mining company followed the modern mining philosophy: "It is more effective to prevent pollution during mining operations than to clean it up later"

Figure 8. Pigeon Mine during production, November, 1989. The mine was located on the north side of Snake Gulch. Photo courtesy of Pam Hill.

Figure 9. The Pigeon Mine after reclamation, October 5, 1993.
Photo courtesy of Pam Hill.

Summary

1. Uranium mining in the region around the Grand Canyon has clearly demonstrated that it can be done with NO impact on the Grand Canyon watershed. Hence, there is no mining to protect the Grand Canyon watershed from, and the "Grand Canyon Watersheds Protection Act of 2008" is frivolous legislation. Mining was done for 15 years followed by a 13-year hiatus of no mining. During this hiatus no water analyses from in and around the Grand Canyon have detected any contamination with elevated radionuclides concentrations.

2. Mining uranium from the breccia pipe district gives the US a unique opportunity for energy self-sufficiency with fuel that is clean and emits no CO_2 gases. This is critical at a time when (1) there is intense global pressure for the US to reduce its greenhouse gases, and (2) we are being held hostage by dependence on imported oil. This dependence has created wars. If we are truly patriotic we will look away from the "not in my backyard" approach, and salute mining to promote clean energy and independence from other nations who currently supply our fuel. With energy independence we might not be caught in international wars.

3. We learn history in school so we learn from mistakes and can benefit from positive experiences. From 1980 to 1995 there were 15 years of uranium mining from the region around the Grand Canyon with positive economic gains for the northern Arizona communities and the State of Arizona. There was NO negative impact to water, land, vegetation, air, or humans. The spots that were mined and reclaimed show no visible sign of where the mine was located. The history lesson here is that mining can be positive.

4. Figure. 9 shows our dependence on mining. There is no indication that with our ever increasing population that there will be any reduction in stresses on the land for mining. Each person in the US will use 9383 pounds of uranium in their lifetime (Minerals Management Institute).

5. To use the sins of a 60-year old uranium mining legacy to punish mining in a different district, which has clearly demonstrated safe clean mining practices, is like the past punishing of the Navajo Tribe by moving them eastward to Texas because of the sins of a few renegade Apaches.

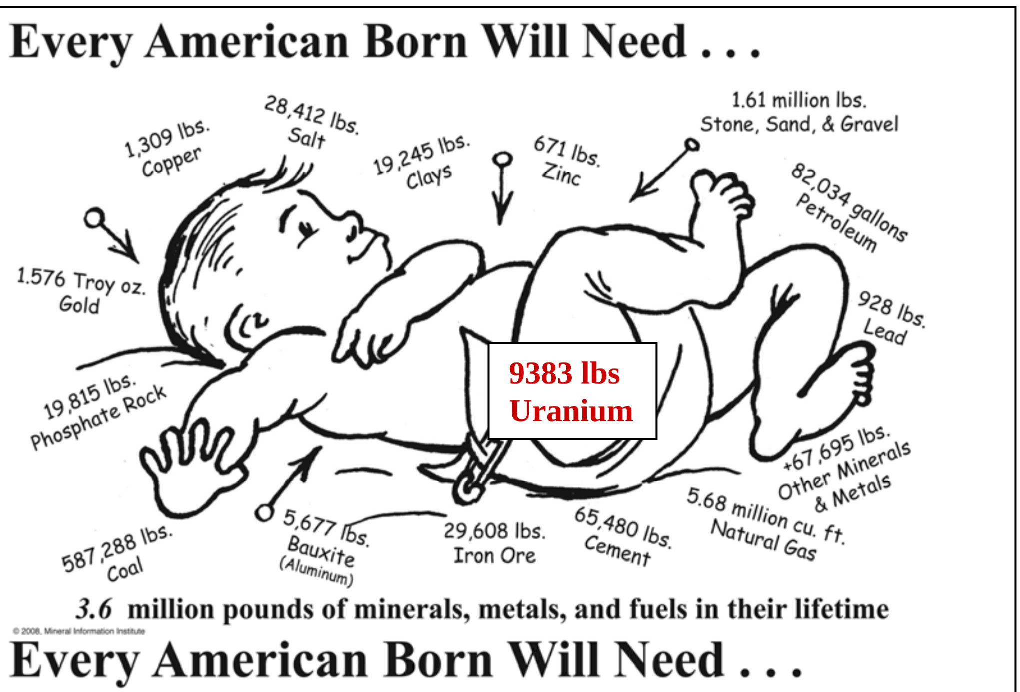

Figure 9. Amount of minerals, metals, fuels (uranium) needed by every American in a lifetime. Data and diagram from the Mineral Information Institute, Golden, CO (www.mii.org)

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Author's Background

Karen Wenrich received her Ph.D. from The Pennsylvania State University in Geology. She retired from the U.S. Geological Survey after 25 years of experience working on mining related and environmental projects. Following her retirement from the USGS she worked as a senior uranium geologist for the International Atomic Energy Agency (IAEA) in peaceful uses of atomic energy. While at the IAEA she was a recipient of the 2005 Nobel Peace Price. She is the author of over 150 published papers.