Geologic and Hydrologic Issues Related to Uranium Mining in the Grand Canyon Region, Northern Arizona.

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ABSTRACT

Rapid increases in the price of uranium beginning in 2004 has prompted renewed interest in the exploration and mining of uranium ore both north and south of Grand Canyon National Park . The increase in filing of mining claims and permits to develop mines in this region has heightened public awareness of these issues. As a result, Native American Tribes, Grand Canyon National Park, and the public have raised concern about the impacts of exploration and mining to natural resources of the region and especially to the resource value of Grand Canyon National Park and tribal cultures. Some of the highest grade uranium ore in the country is located in many potentially mineralized breccia pipes scattered across this region. The concern by the public, tribes, and Grand Canyon National Park has prompted the House Committee on Natural Resources to introduce federal legislation in both 2008 (H.R. 5583) and 2009 (H.R. 644) that would withdraw operation of the public land laws that allow mining from three separate areas both north and south of Grand Canyon National Park.

Among the many issues related to mining of uranium in the Grand Canyon region to be evaluated by the USGS and other federal land agencies if withdrawal is approved are: 1) the location and amounts of uranium reserve in the ground, 2) current extent of naturally occurring dissolved uranium in streams and springs tributary to the Colorado River and occurrence and extent of any post-mining waste release into the environment, and 3) concern over the possible contamination of regional water resources by future mining.

INTRODUCTION

Rapid increases in the price of uranium from about $25 per pound (lb) in 2004 to over $135 per lb in 2007 has prompted renewed interest in the exploration and mining of uranium ore both north and south of Grand Canyon National Park (GRCA). A surge in the number of mining claims staked for uranium began in 2004 and currently totals approximately 7,500 claims. Since 2004 the Arizona Strip Field Office of the Bureau of Land Management (BLM) has processed approximately 75 uranium exploration notices from six companies proposing to drill more than 300 exploratory holes. Of these 300 exploratory holes, 250 have been drilled as of 2008 and 100 have been reclaimed, with reclamation of the remaining 150 drilled in progress (BLM written Commun., 2009). Three mines, 3.5 to 10 miles north of the GRCA boundary, currently are authorized by BLM to operate once approvals have been obtained on all of the applicable permits from State agencies. According to BLM, a reasonable development scenario is for six additional mines (BLM written Commun., 2009). The increase in filing of mining claims and permits to develop mines in this region has heightened public awareness of the impacts of exploration and mining to natural resources and resulted in expressed concerns by Native American Tribes and GRCA.

Some of the highest grade uranium ore in the country is located in many potentially mineralized breccia pipes scattered across this region. A breccia pipe in northern Arizona commonly is a collapse feature that results from dissolution of the Redwall Limestone deep in the subsurface and stooping of material above the solution cavity through the successive layers of sedimentary rocks to the surface. Surficial expressions of breccias pipes are often depressions or ring fracture structures on the surface. An ore body, if present, is typically located several hundred to more than a thousand feet above the regional water table in brecciated sandstones in the pipes. A number of these breccias pipes have been exposed by erosion of the canyon walls in the Grand Canyon and its tributaries resulting in naturally elevated concentrations of dissolved uranium in the waters of some drainages. The Orphan Pipe which hosts the Orphan Mine on the South Rim of the Grand Canyon is probably the most famous of these structures. Dissolved uranium at or above the maximum contaminant level for drinking water has been documented in springs and the drainages of Horn and Salt Creeks downgradient from this site owing to decades of deposition of mining waste (Monroe and others, 2005, National Park Service, 2006). Five of these mineralized breccias pipes were mined to the North of GRCA in the 1970's and 1980's and one of these pipes was developed, but never mined, south of GRCA with no evidence of contamination.

The concern by the public, tribes, and GRCA has prompted the House Committee on Natural Resources to introduce federal legislation in both 2008 (H.R. 5583) and 2009 (H.R. 644) that would withdraw operation of the public land laws that allow mining from three separate areas both north and south of GRCA (fig.1). These areas include 741,541 acres of public land administered by Bureau of Land Management and 327,367 acres of National Forest administered by the U.S. Forest Service. If the legislation is passed there will be a two year study period to allow federal agencies to collection and evaluation of additional data on the natural occurrence of uranium and the potential for contamination related to mining before the withdrawal becomes final.

DISCUSSION

To help address controversy that surrounds mining development so close to a World Heritage site (GRCA) and other national monuments and public lands, federal land agencies and the U.S. Geological Survey (USGS), Bureau of Land Management (BLM), U.S. National Forest Service (USFS), and National Park Service (NPS) have provided information to the Department of the Interior and Congress about the natural resources of the Grand Canyon region and indentified some of the potential impacts to natural and cultural resources from anticipated exploration and mining of uranium. Among the many issues related to mining of uranium in the Grand Canyon region to be addressed by the USGS and other federal land agencies if withdrawal is approved are: 1) the location and amounts of uranium reserve in the ground, 2) current extent of naturally occurring dissolved uranium in streams and springs tributary to the Colorado River and occurrence and extent of any post-mining waste release into the environment, and 3) concern over the possible contamination of regional water resources by future mining. Three separate areas, all adjacent to the GRCA, are proposed for withdrawal: an area of public land north of the Canyon just west of Kanab Creek (North Parcel), an area of public land in House Rock Valley (East Parcel), and an area south of the Canyon on the Kaibab National Forest (South Parcel; fig.1).

The location and amounts of uranium reserve in the ground.

The Grand Canyon region hosts hundreds, possibly thousands, of breccia pipes formed by solution and collapse. Breccia pipe is the name given to these vertical, pipe-shaped solution and collapse features that are filled with broken rock (fig. 2). The USGS has mapped more than 1,200 possible breccia pipes in the northern Arizona region. Many of these breccia pipes contain concentrated deposits of uranium, copper, silver, lead, zinc, cobalt, and nickel minerals. Exploration in the region has shown that less than two percent of the identified breccia pipes will contain an economic uranium deposit (Billingsley and others, 1990, 1997, and 2000; Chenoweth, 1986 and 1987; Van Gosen and Wenrich, 1991; Wenrich, 1985; and Wenrich and others, 1989). Only drilling and sampling of the drilled material can determine if a collapse feature is mineralized at depth in economically minable grades; the uranium deposits occur deep inside the pipe, usually several hundred feet below the plateau surface.

Breccia pipes in northern Arizona formed sequentially by: (1) dissolution and karst development in the Redwall Limestone; followed by (2) collapse of the cavern ceiling (which forms the broken rubble); followed by (3) progressive upward collapse, forming a rubble-filled column—a "breccia pipe"—that over time propagates upward through the overlying rock units (fig. 2; Finch, 1992). A breccia pipe's expression on the plateau surface is a shallow structural basin that can be as much as a mile in diameter. Some pipes form a prominent circular depression with inward-dipping strata, whereas others are difficult to decipher and can only be confirmed by geophysical exploration and (or) drilling. The pipe can vertically transgress the Grand Canyon rock units from the Redwall Limestone to the Chinle Formation, covering a vertical range of as much as 4,000 feet (fig. 2). The breccia pipe column abuts against sedimentary rocks. The plane of contact between the breccia column and the surrounding, flat-lying rock is formed by a zone of concentric and circular, near vertical fractures and inward-dipping strata. The mineral deposits, including uranium deposits, occur in the matrix of the fracture zone and the breccia column; the mineral deposits do not generally extend into the surrounding sedimentary rocks.

Mining activity in breccia pipes of the Grand Canyon region began during the 1860's. However, prior to 1940 all of the production was for copper, lead, zinc, silver, and minor gold. The discovery of high-grade uranium deposits in the Orphan Lode breccia pipe led to uranium production in 1956 at this site, about two miles west of present-day Grand Canyon Village on the South Rim of Grand Canyon National Park (Billingsley and others, 1997). This seemingly unique deposit, an "orphan", led to the discovery of uranium ore inside numerous other breccia pipes in this region. As a result, a uranium exploration and mining business developed across the region. The primary uranium-bearing mineral in these breccias pipes is uraninite (U_3O_8), with a number of associated metallic sulfide and oxide minerals that are generally very fine grained in size (VanGosen and Wenrich, 1991 and Finch, 1992). Twenty-six mineralized breccia pipes have been identified to date by drilling in the Kanab Creek withdrawal area (North Parcel; Billingsley and others, 2003, 2006; Pool and Ross, 2007). Several of these uranium deposits were mined in the 1980s. All of these mines were reclaimed by the early 1990's. Most of the uranium deposits in the northern Arizona breccia pipes are high grade by U.S. standards, averaging between 0.40 and 0.70 percent uranium oxide content with individual ore bodies having concentrations as high as 2.0 percent (Wenrich and others, 1989; Finch, 1992). The average ore grade from other U.S. sources is about 0.18 percent. Worldwide, average uranium ore concentrations range from 0.05 to 25 percent uranium oxide with concentrations greater that about 1 percent being considered highest grade. (World Nuclear Association accessed March 2009 at: http://www.world-nuclear.org/info/inf26.html). Typical uranium-ore producing pipes of this region contain 105,000 to 500,000 tons of ore, yielding 500 to 3,000 tons of uranium oxide (Finch, 1992). It is thought that most of the high-grade undiscovered uranium resources in the United States are contained in these breccia pipes (DOE, 2003). Breccia pipe deposits in the Grand Canyon region are mined using underground techniques. The typical surface disturbance is 15-20 acres. No milling or processing of uranium ore is done on site. The mines are designed as "zero discharge" meaning there is no run-off to or from the sites (Pool and Ross, 2007). There is no solution mining.

One of the stated objectives of the current Administration is for the United States to achieve independence from foreign energy sources by expanding current domestic and alternate energy sources. There is no uranium resource estimate specific to the three withdrawal areas of the Grand Canyon region; however, the USGS estimated the total undiscovered uranium resource in breccia pipe deposits in northwestern Arizona and a small area in adjacent Utah (about 16,700 square miles) to be 1.3 million tons uranium oxide (Finch, 1992). U.S. uranium concentrate production totaled 3.9 million pounds (1,950 tons) in 2008, mostly from Wyoming. Uranium loaded into U.S. nuclear power reactors averages about 25,000 tons per year and produces about 20 percent of the nation's average annual electrical needs. About 80 percent of this uranium comes from foreign sources. The principal foreign sources for uranium in 2004 included Canada (26%), Australia (18%), Russia (16%), and Kazakhstan (7%; USGS, written commun., 2009).

Current extent of naturally occurring dissolved uranium in streams and springs tributary to the Colorado River and occurrence and extent of any post-mining waste release into the environment

One of the concerns expressed by the NPS, U.S. Forest Service (USFS), and Native American Tribes in the region is the potential for contamination of surface-water and groundwater resources. The ore bodies in breccias pipes are typically contained in dry rock several hundred to a thousand feet or more above the regional aquifer which is located in the Redwall-Muav limestone. It is possible, however, that a number of ore bodies may be in contact with perched groundwater above the Redwall-Muav aquifer (Orphan Mine; Chenoweth, 1986). Dissolved uranium occurs naturally in groundwater as precipitation infiltrates from the surface through the ore bodies to perched water-bearing zones and the Redwall-Muav aquifer through fractures in and around the breccia pipes. There are also a number of documented ore bodies that have been bisected by the Grand Canyon and its tributary canyons, exposing them to erosion and dissolution of minerals that can infiltrate into the groundwater flow system. Surface-water or stream sediment contamination could occur by erosion of natural or waste rock during ephemeral runoff events.

Over the years, USGS and GRCA have sampled selected springs that issue from the regional Redwall-Muav aquifer and wells that penetrate the aquifer on the south and north rims of the Grand Canyon. Salt and Horn Creek springs on the south side of the canyon have shown elevated concentrations of dissolved uranium near or exceeding the U.S. Environmental Protection Agency's (EPA) primary drinking water standard of 30 µg/L (fig. 3; Monroe and others, 2005; U.S. Environmental Protection Agency, 2009). These concentrations are probably related to past mining activities on the south rim of Grand Canyon where mining wastes were deposited on the land surface (NPS, 2006)). Ten springs and the baseflow of two streams have elevated dissolved uranium concentrations greater that 10 µg/L (fig. 3; Monroe and others, 2005; Bills and others, 2007). Most of these concentrations are naturally occurring. The same limited spring sampling in these studies have indicated that background levels for dissolved uranium in groundwater are 5 µg/L or less in this part of the Grand Canyon region. Water samples from springs and streams were also evaluated for gross alpha and gross beta emissions activity with many sites in excess of the primary drinking water standard for either or both (15pCi/L for gross alpha emission and the 5 pCi/L for gross beta emission). Water, rock, and soil sampling of the six uranium mines operated by Energy Fuels Nuclear (EFN) during the late 1970's, 80's and 90's, showed no evidence of contamination or release of uranium to the environment during operation of the mines or during mine reclamation (Pool and Ross, 2007). Of the six mines three were closed and have been reclaimed (Hack Mine Complex, Pigeon Mine, and Hermit Mine). The other three (Kanab North Mine, Arizona 1 Mine, and Pinenut Mine) were shut down and put on "care and maintenance" when the price of uranium declined in the early '90s. At the reclaimed sites, waste piles at the surface were used as backfill for underground mine openings. Surface-disturbances have been recontoured and revegetated. There has been no independent post-reclamation evaluation of the Kanab Creek drainage to determine if any trace element or uranium contamination has been release to the environment.

While the hydrogeology of the Coconino Plateau south of the Grand Canyon is reasonably understood in a regional context, there is little detailed hydrologic information to evaluate the occurrence and movement of water or dissolved uranium at specific breccia pipes. Hydrogeologic information for the Arizona Strip north of the Grand Canyon is sparse. Most of the studies available were done in the 1970's with little access to well or spring data. No recent hydrogeologic studies of the region have been conducted by the USGS or others. Subsequent uranium exploratory drilling seldom is deep enough to penetrate the Redwall-Muav aquifer and the few water wells drilled to support mining operations have little information relevant to potential uranium contamination of groundwater. Groundwater usually moves slowly through rock of the Redwall-Muav aquifer; however, the karst systems in these areas and faulting and fracturing create conduits that can transport contaminated water quickly from a mining site to the park's springs. Overall, there is not sufficient hydrologic data for these areas to quantify with any certainty the effects of uranium mining and exploration activities on the groundwater system(s).

Concern over the possible contamination of regional water resources by future mining.

Uranium is typically stable in oxygenated water and it also has an affinity for attaching to silts and clays. Uranium is far less toxic than radium because of longer half-life and shorter residence time on or in the body. The potential health effects of uranium ores include the effects of radioactivity and inhaled radon. Prolonged exposure to uranium can damage the lungs and kidneys. In addition, the potential health impacts of these uranium ore materials could include the effects of the accessory elements, many of which are commonly regarded as toxic to human health when concentrated, for example arsenic, lead, nickel, selenium. Sulfide minerals associated with breccia pipe deposits have the potential to produce acidic waters. However, the rock fragments (breccias) that host the ore bodies, as well as the sedimentary rock units that surround the breccia pipes, include limestone and calcareous sandstone that have a high capacity to buffer acid waters (Finch, 1992). Radon and gamma radiation occurs in active and abandoned mine workings and is emitted from mine waste piles. These mine and surface waste rocks are commonly used as backfill in the mine. Acid drainage and toxic metals (such as arsenic, lead, and zinc) can be mobilized in the immediate vicinity of active and abandoned mines, especially during flash flood events (Finch, 1992).

The State of Arizona, some counties, tribes, and the public have expressed concern for the impacts of exploration and mining to natural resources and especially to the resource values of the Grand Canyon and tribal cultures. Public concern prompted a resolution by the House Committee on Natural Resources and introduction of proposed federal which would withdraw from operation of the public land laws (including the mining laws) about one million acres of public land administered by BLM and the USFS. The Secretary of the Interior is formulating a response for the public and Congressional concerns and will decide whether to formulate a position for the proposed withdrawal. The issues in this situation surround development of an abundant, world class energy resource vs. protection of a World Heritage Site, the Grand Canyon, and resources on surrounding lands. Many species of plants and animals make up these diverse ecosystems. The Grand Canyon region supports the highest levels of diversity in both plant species and vegetative communities of any unit in the NPS system, harboring nearly 1,800 species in ecosystems that range from the mixed Mohave Desert scrub of the lower canyon to the coniferous forests of the North Rim (GRCA, written commun., 2009). Overall, nine known populations of special status plant species are located in the area. Two known endangered plant species are also found in the area, the sentry milk vetch and the Brady pincushion. While many wild creatures live out their entire lives within the protected park area, migratory species also benefit from the temporary sanctuary that the park affords. Wildlife in and surrounding the proposed withdrawal areas are characterized by threatened and endangered species, along with species of special concern. For example, the endangered California Condors have been reintroduced into the region; this reintroduction is one of the most celebrated keystones of success in the endangered species reintroduction program in the United States. The Grand Canyon region has been the only successful wild nesting area for California Condor in the country. California Condors are known to be attracted to construction activities and other disturbance activities such as the Orphan Mine site reclamation within Grand Canyon and would likely be attracted to other activities, putting these animals at risk (GRCA, written commun., 2009). Mining exploration may lead to increased roads that fragment habitat and prey populations. Increases in wildlife poaching within and near the park boundaries have been associated with increased mining exploration activities in previous years. Increased and new mining activity in the Grand Canyon region has the potential to introduce invasive plant species that have characteristics that allow them to spread rapidly once established. Noise events and activity associated with mining operations within feeder drainages (approximately 3 mile buffer) have the potential to affect wildlife movement and foraging patterns.

Water resources of the Grand Canyon region are imperative to the health of riparian zones and provide drinking water to wildlife, backcountry hikers, and boaters in an otherwise arid environment. The quantity and quality of springs, seeps, and perennial flow resources could be impacted by increased mining activity. Any decrease in the quantity and quality of flow at these sites could change the character of these areas and render them unusable by wildlife or humans. Seeps and springs are particularly critical to wildlife such as Kanab Ambersnail, humpback chub, southwest willow flycatcher, bighorn sheep, deer, and Mexican spotted owls. Seeps and springs represent some of the most diverse habitat in the Grand Canyon Region and new species are continually being discovered (Grand Canyon Wildlands Council, 2000). These springs, seeps, and streams are the focus of unique vegetative communities and thousands of archaeological sites representing the entire history of human use of the region.

The Grand Canyon, from rim to rim, is considered by many Native American tribes to be a Traditional Cultural Property, significant in the origins and continuing traditions of the cultures of the area. Over 12,000 years of human history are contained within the federal lands associated with the Grand Canyon region. GRCA has recorded over 4300 archaeological sites within the park representing an inventory of only about 5 percent of the total resource (GRCA, written commun., 2009). Similar numbers of archaeological resources are known for both BLM and USFS lands. Mining activity can impact Traditional Cultural Properties by affect seeps and springs, locations that are often sacred to tribal members and considered proprietary by traditional practitioners. Increased mining activity in remote/undisturbed areas could impede access to traditional resources for tribal practitioners. Many Native American tribes would likely consider extractive enterprises in the Grand Canyon region to be inconsistent with the multitude of sacred locations in this region. As of 2009, both the Havasupai and Hualapai Tribes have voted to ban mining of uranium on their Tribal lands.

The USFS has concerns about potential groundwater effects from future uranium mining operations; however, they do not think that exploration drilling, as has occurred in the past on the Forest, is a major environmental issue (USFS, written commun., 2009). As part of a recent court settlement, the Kaibab National Forest is beginning an Environmental Impact Statement (EIS) process to analyze the possible effects of VANE Minerals' proposal for exploration drilling at several sites on the Tusayan District (south parcel). Within that EIS process, the Forest Service is planning to contract out (thru the USGS or other entity) a groundwater risk analysis for conducting exploration drilling on the Tusayan Ranger District (USFS, written commun., 2009). GRCA is also concerned about potential impacts on the Park's water resources owing to past and future mining. As an example of the potential impact future mining could have on the region, the NPS has spent more than a million dollars to investigate the nature and extent of radionuclide and heavy metals contamination at the Orphan Mine (GRCA, written commun., 2009). Pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (aka "Superfund"), a final remedy will be selected and future cleanup is likely to cost tens of millions of dollars. There is one plan of operation pending for uranium exploration in the Kanab Creek Area of Critical Environmental Concern (ACEC; North Parcel).There is one in-active mine (Canyon Mine) south of the Grand Canyon which was started but never went into production due to environmental issues and a drop in prices for uranium. The Kanab North Mine, Arizona 1 Mine, and Pinenut Mine, all north of GRCA, are now owned by Denison Mine (USA) Inc., (Denison) and are in the process of obtaining Air Quality Permits and Aquifer Protection Permits among other permits from the Arizona Department of Environmental Quality prior to resuming operations.

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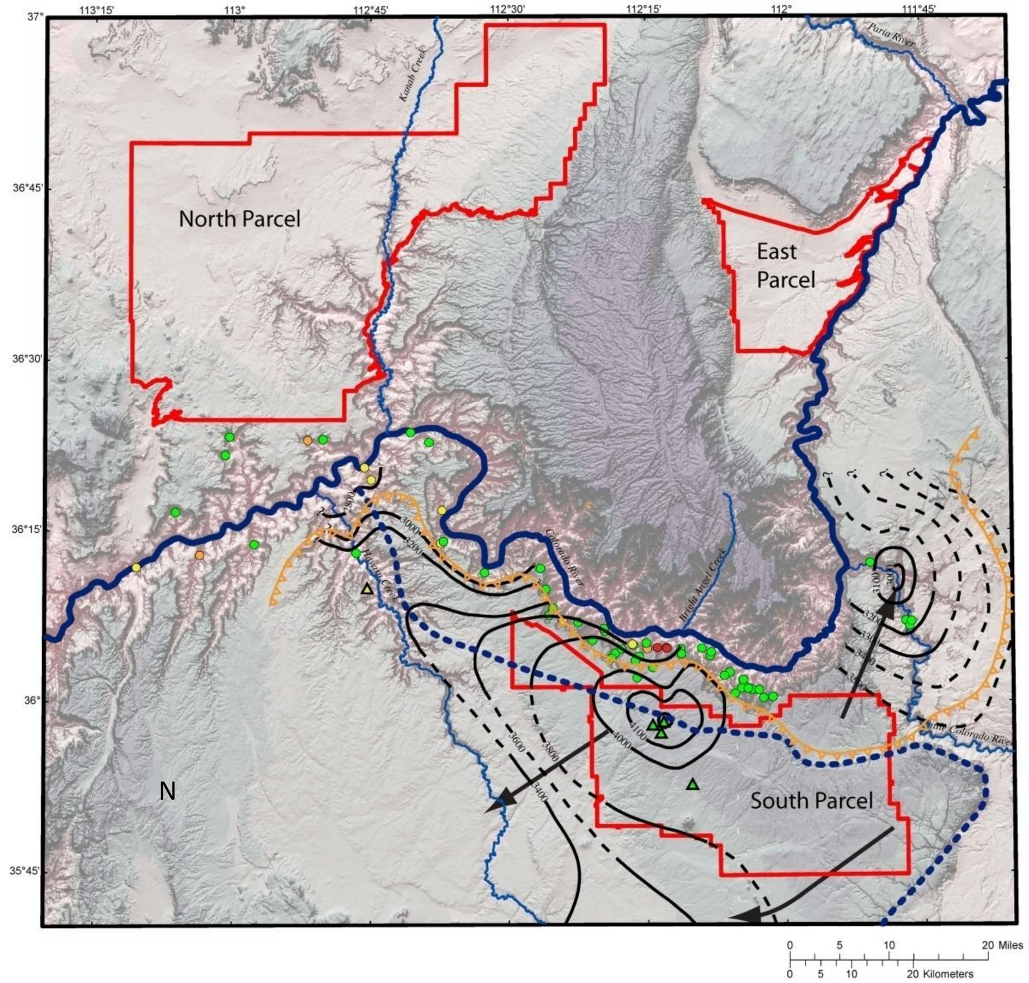

EXPLANATION

3200 Potentiometric contour — Shows altitude at which water level would have stood in a tightly cased well drilled in the Redwall-Muav aquifer prior to about 1990, in feet above mean sea level. Additional well data from 1990 to 2004 used to extend contours in areas not previously developed. Dashed where approximately located, queried where uncertain. Contour intervals 100 and 200 feet.

Ground-water divide

Unconfined / Confined — Approximate boundary between confined and unconfined conditions in the Redwall-Muav aquifer.

Direction of ground-water flow

Springs
- 5µg/L or less dissolved uranium
- 10µg/L or more dissolved uranium
- 30µg/L or more dissolved uranium*
- Gross Alpha and gross Beta emissions at or greater than the MCL of 15 pCi/L and 5 pCi/L, respectively

Water wells in the Redwall-Muav Aquifer
- 5µg/L or less dissolved uranium
- Gross Alpha and Gross Beta emissions at or greater than the MCL of 15 pCi/L and 5 pCi/L, respectively

Area requested for withdrawal from mineral entry

figure 1. Hydrologeology of the Grand Canyon Region with Uranium Mining Withdrawal Areas and selected wells and springs, Coconino and Mohave Counties, Arizona

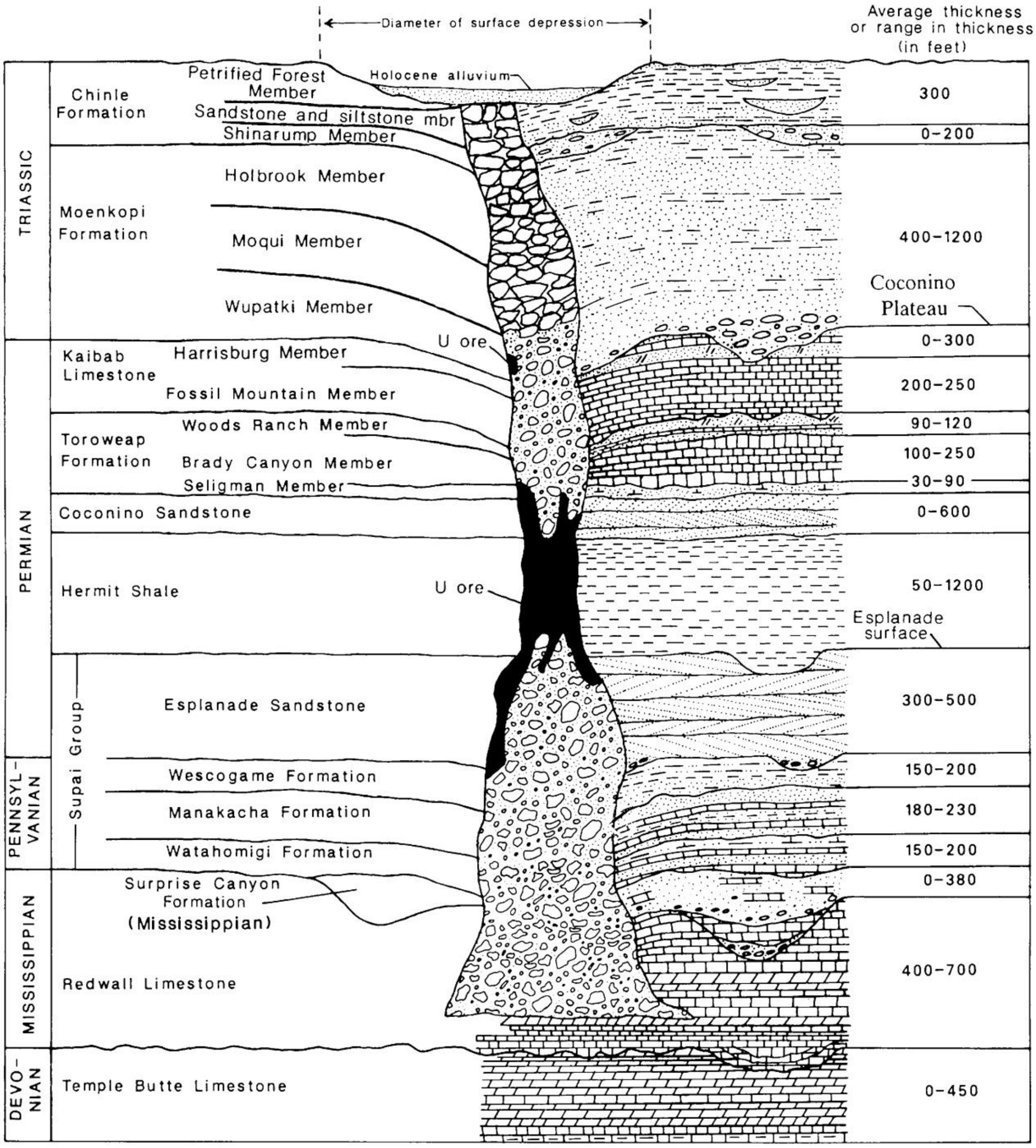

Figure 2. schematic drawing of a breccias pipe (Modified after Finch, 1992).

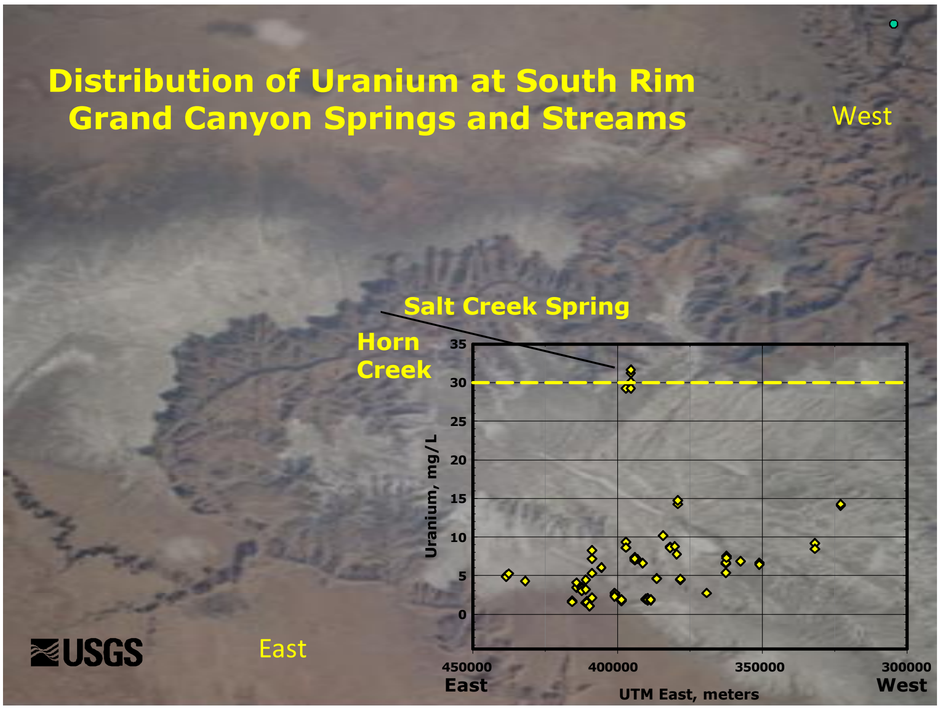

Figure 3, Distribution of dissolved uranium in springs at the South Rim of Grand Canyon (Modified after Monroe and others, 2005). Points on the image represent location of sample sites and points on the plot represent individual spring samples from east to west. View is looking from the northeast.