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Environmental Health Program
Prepared in cooperation with the National Park Service, Bureau of Land Management, and U.S. Department of Agriculture Forest Service

Balancing Natural Resource Use and Extraction of Uranium and Other Elements in the Grand Canyon Region

The Grand Canyon region is an important natural, cultural, and archeological resource known worldwide. The region contains uranium resources that could be used to generate electricity. The U.S. Geological Survey (USGS), in cooperation with the National Park Service, Bureau of Land Management, and U.S. Department of Agriculture Forest Service, is conducting studies to answer questions about the environmental effects of mining uranium and other associated elements in the region.

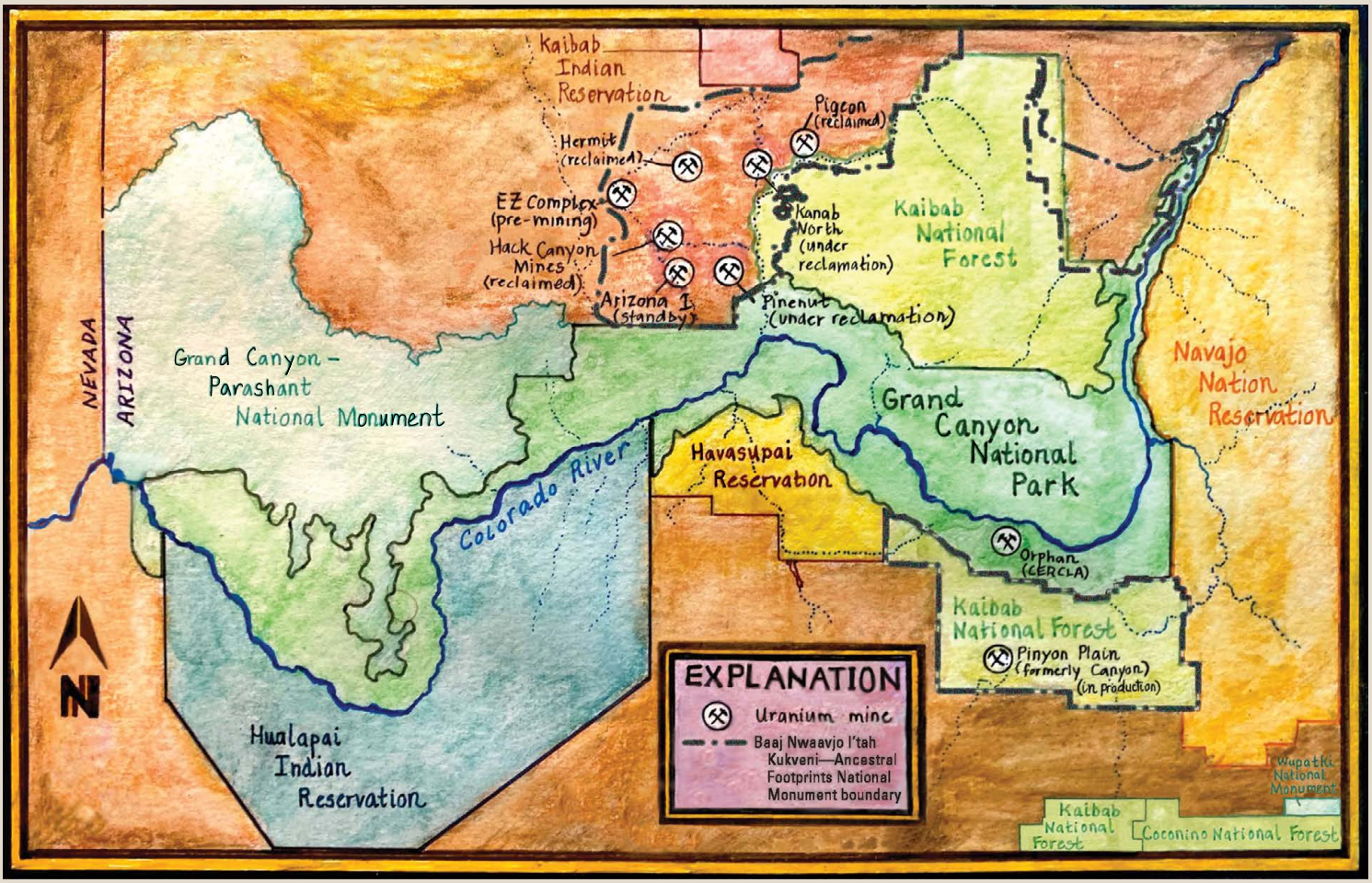


Figure 1. Illustration of the Grand Canyon region in northwestern Arizona showing major land holders and locations of some of the uranium mines in the region. Mine status and Tribal land names current as of March 2024.

Why the Grand Canyon?

The Colorado Plateau, including the Grand Canyon (fig. 1), contains natural sources of uranium and other elements that have been mined for decades. Mining changes the natural landscape and has environmental effects (U.S. Department of the Interior, 2012). The Grand Canyon is of immeasurable importance to local indigenous people who have inhabited the region for thousands of years (National Park Service, 2023). The Grand Canyon is also a World Heritage Site visited in 2023 by almost 5 million people (National Park Service, 2024). This area also includes Baaj Nwaavjo I'tah Kukveni–Ancestral Footprints National Monument that was established in 2023 (fig. 1; Biden, 2023).

What are breccia pipes?

The Grand Canyon region contains hundreds of unique geologic breccia pipe features (fig. 2). A few of them contain uranium and other elements about 1,000 feet below ground, and some have been mined (Alpine, 2010). Uranium is used to generate electricity. The breccia pipes in the Grand Canyon region contain some of the highest-grade uranium ores in the Nation (Alpine, 2010). As of August 2023, new mining is not allowed within the Baaj Nwaavjo I'tah Kukveni–Ancestral Footprints National Monument. There are a small number of breccia-pipe mines within the national monument that are permitted to continue (Biden, 2023). Breccia pipes with uranium located outside the national monument could also be mined in the future.

What are the effects of uranium mining?

Scientific data support decisions that could balance uses of natural resources (land, water, plants, and animals). The USGS is a Federal agency that provides scientific data to decision makers and the public (U.S. Geological Survey, 2021). In 2012, the USGS was directed by the Department of the Interior to study the effects of uranium mining in the Grand Canyon region (U.S. Department of the Interior, 2012; Hinck and others, 2014b). Studies designed by the USGS and natural resources managers are underway or completed. Study results are available to everyone, and this document summarizes some of the results of these studies.

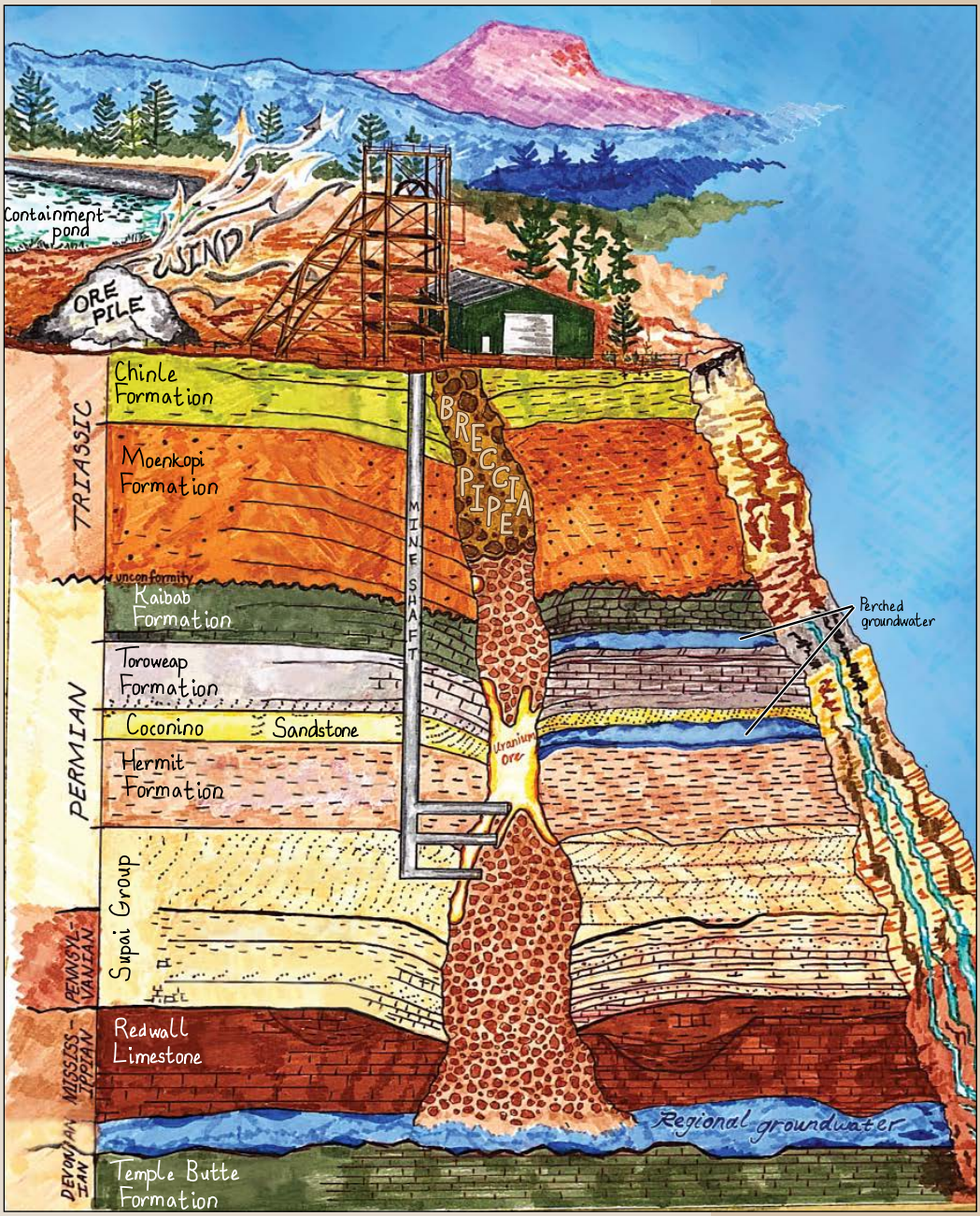


Figure 2. Schematic geologic cross section of a breccia pipe uranium deposit showing uranium ore at depth being accessed by underground workings and a head frame at the surface. The ore occurs primarily in the Coconino Sandstone. Also shown are perched groundwater aquifers that support springs in the area and the regional groundwater aquifer at the bottom of the breccia pipe. Modified from Alpine (2010).

What have we learned about how mining affects resources that humans use?

Uranium is important, but it is not only about the uranium.

- Uranium ore in breccia pipes contains large amounts of many elements including arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, sulfur, uranium, and zinc (fig. 3*A*; Bern and others, 2019; Van Gosen and others, 2020a, b, c).
- Mining increases levels of uranium and some of these ore-related elements in soil around the mine sites (fig. 3*B*; Naftz and Walton-Day, 2016; Walton-Day and others, 2019).
- Wind can move dust containing ore-related elements to areas around the mine (fig. 2) (Bern and others, 2019; Hinck and others, 2017).
- Uranium ore piles produce greater radon gas levels than the mine vent during active mining. Wind and rain reduce radon accumulation in air around the mine. Radon is known to be hazardous to human health. Outdoor radon risk thresholds for humans are not available (Naftz and others, 2020; Walton-Day and others, 2021).

Exposure to uranium is not always the cause of greatest concern (risk) to animals at breccia-pipe uranium mines. Other ore-related elements are also important.

- Traditional and new study tools (fig. 3*C*) were used to understand how mining activities can affect local food webs. Elements can enter animals (fig. 3*D–F*) by ingestion, inhalation, absorption, and dietary transfer (Hinck and others, 2014a, 2017; Klymus and others, 2017; Mann and Duniway, 2020; Albers and others, 2021; Cleveland and others, 2021; Valdez and others, 2021).
- Health risks from elements found in uranium ore were low for terrestrial animals studied (fig. 3*D*). Arsenic, cadmium, copper, and zinc cause the greatest risk to animals that eat ants and other terrestrial invertebrates at breccia-pipe mine sites. Health risks to aquatic animals are unknown (Hinck and others, 2021).

Adverse effects to plants and terrestrial animals from uranium ore-related elements are unlikely even with long-term (30 year) exposure at breccia-pipe uranium mines in the Grand Canyon region.

- Radiation levels in plants and animals were low (fig. 3*D, G*). Radiation enters rodents through soil interactions (for example, burrowing, incidental ingestion, and bathing) or their diet. Amounts of radium-226 were below harmful levels. This radioactive element (radionuclide) is of most concern for rodent health (Hinck and others, 2017; Cleveland and others, 2019; Minter and others, 2019).
- Plants and animals (fig. 3*D, G*) take up mining-related radionuclides, uranium, and other elements, but direct effects such as death and reduced growth were not found (Hinck and others, 2017; Cleveland and others, 2019, 2021). Amounts of arsenic and selenium in water at mine sites may be harmful to aquatic animals like tadpoles (Hinck and others, 2017) (fig. 3*C*).

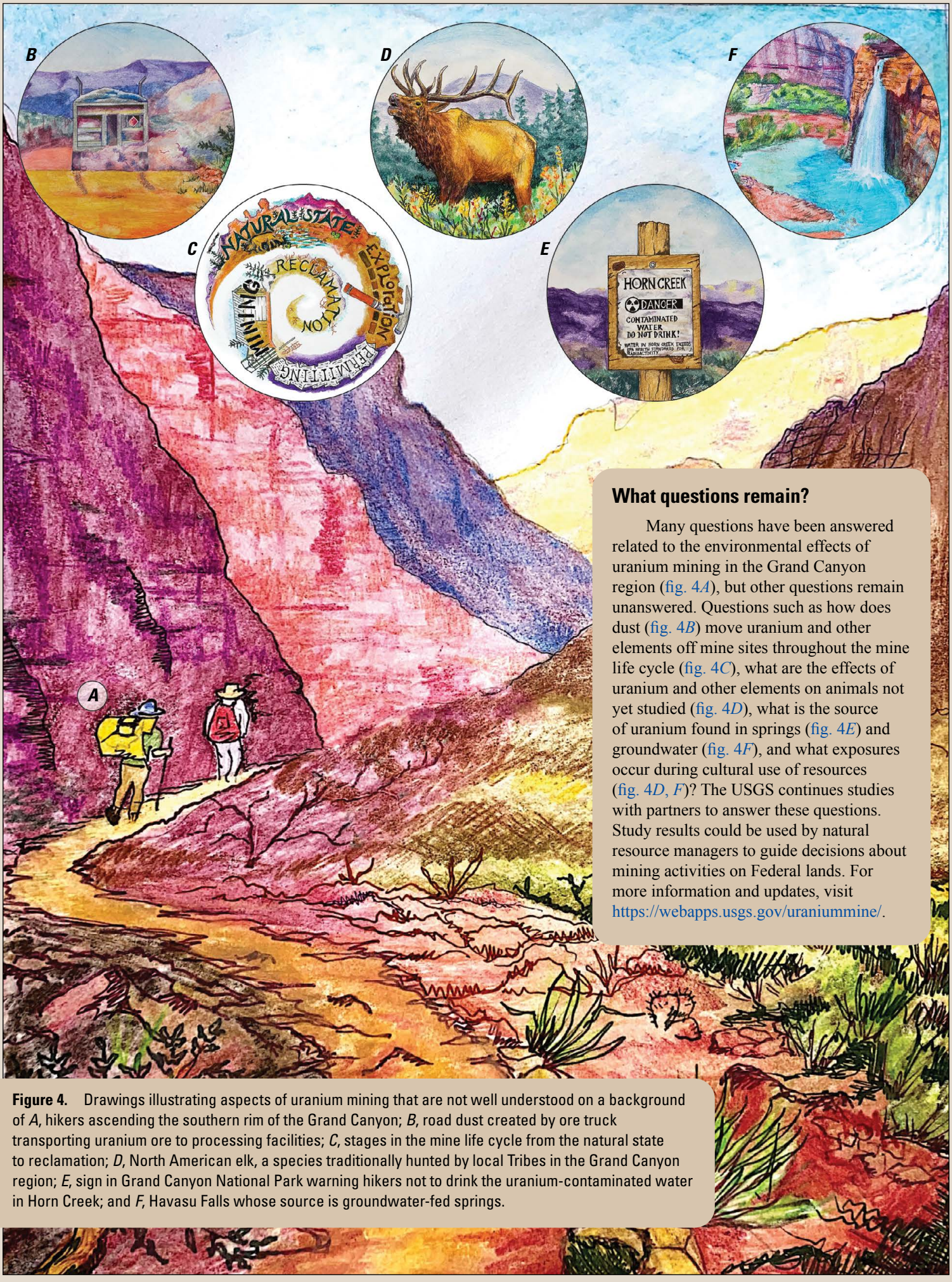
Mines are not the only source of uranium in water.

- Natural sources of uranium are in groundwater and springs fed by groundwater (fig. 3*H, I*; Beisner and others, 2017a, b, 2020; Tillman and others, 2021). Uranium is associated with bicarbonate in some Grand Canyon spring water (fig. 3*H, I*). This form of uranium is not generally taken up by invertebrates living in water (fig. 3*J, K*; Croteau and others, 2016).
- Amounts of uranium and other ore-related elements in Colorado River water in the Grand Canyon region are low (fig. 3*L*). Sometimes amounts are higher in tributaries where mining has or could occur. These tributaries usually contribute very small amounts of uranium and other ore-related elements to the Colorado River (Tillman and others, 2020).
- Groundwater age helps us understand why contaminants might be in groundwater. Old groundwater is mostly cut off from human activities and contamination at the Earth's surface. Deep groundwater feeding most of the springs on the Grand Canyon southern rim (fig. 3*H*) is mostly old. Some of the springs contain a portion of relatively young water. Young groundwater is more easily contaminated by human activities, because it has recently had contact with the Earth's surface (U.S. Geological Survey, 2019; Solder and Beisner, 2020; Solder and others, 2020).

Figure 3. Illustration of U.S. Geological Survey science at breccia pipe mines in the Grand Canyon region. *A*, The upper left portion shows a cross section of a breccia pipe and rock layers (far upper left) in a panoramic view of the Grand Canyon with upper right depicting rock pinnacles the Havasupai Tribe call Wi'i Gileeva (Tilousi and Hinck, 2024). *B*, A typical breccia pipe uranium mine site where soil is sampled. *C*–*G*, Local plant and animal species studied. *H*, A spring area with *I*, scientists measuring water quality and *J* and *K*, collecting aquatic invertebrates. *L*, The Colorado River bisects the illustration.

Aquatic insects are unlikely to transport uranium to terrestrial environments.

- Aquatic invertebrates (fig. 3*J*, *K*), including insect larvae such as mayflies, take up little uranium (Fuller and others, 2019), partly because they generally do not take in the forms of uranium present in the water where they live. Uranium also is in food eaten by invertebrates. Only a limited amount stays in their bodies with most passing through (Croteau and others, 2016; Henry and others, 2020).
- Uranium that does end up in mayfly tissues is rapidly removed, which reduces the amount of uranium in their bodies (Henry and others, 2020).



What questions remain?

Many questions have been answered related to the environmental effects of uranium mining in the Grand Canyon region (fig. 4*A*), but other questions remain unanswered. Questions such as how does dust (fig. 4*B*) move uranium and other elements off mine sites throughout the mine life cycle (fig. 4*C*), what are the effects of uranium and other elements on animals not yet studied (fig. 4*D*), what is the source of uranium found in springs (fig. 4*E*) and groundwater (fig. 4*F*), and what exposures occur during cultural use of resources (fig. 4*D*, *F*)? The USGS continues studies with partners to answer these questions. Study results could be used by natural resource managers to guide decisions about mining activities on Federal lands. For more information and updates, visit https://webapps.usgs.gov/uraniummine/.

Figure 4. Drawings illustrating aspects of uranium mining that are not well understood on a background of *A*, hikers ascending the southern rim of the Grand Canyon; *B*, road dust created by ore truck transporting uranium ore to processing facilities; *C*, stages in the mine life cycle from the natural state to reclamation; *D*, North American elk, a species traditionally hunted by local Tribes in the Grand Canyon region; *E*, sign in Grand Canyon National Park warning hikers not to drink the uranium-contaminated water in Horn Creek; and *F*, Havasu Falls whose source is groundwater-fed springs.

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