

Supplemental Information

for

Geoenvironmental Model for Roll-Type Uranium Deposits in the Texas Gulf Coast

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1. Processing of Data from Existing Datasets

1.1. Background and Deposit Trace Element Content Section

1.1.1. National Uranium Resource Evaluation Stream Sediment Samples and U.S. Geological Survey Soil Samples

NURE data [1] [2] on Figure 5 were processed as follows. Geographic information was used to plot the data in a geographic information system [3], clipping by permissive tract. Values of “0” were removed from the dataset. If negative values were listed, we assumed the value was below laboratory detection limit and replaced the value with half the absolute value of the negative value. Negative values in the dataset were: As, none; Mo = -4, -2; Se = -0.1; U none; V = -10, -2.

USGS data from [4] [5] on Figure 5 were processed as follows. Geographic information was used to plot the data in a geographic information system, clipping by permissive tract and sorting the data by sample type: from 0-5 cm, A horizon, and C horizon. There were no “0” values reported. Values censored with less than (<) were assumed to be less than the laboratory detection limit and were replaced with half the absolute value of the negative value. Only Se had < values, where <0.2 was replaced with 0.1.

1.2. Tailings samples from different uranium deposit types (Figures 5 and 7)

1.2.1. Source of samples and data

Six samples and data from sandstone-hosted uranium deposits were used. One sample was provided for analysis by the U.S. Department of Energy from their Moab, Utah uranium mill tailings remedial action project (UTMCB-1). Analyses for five other sandstone uranium deposit mill tailings are available from [6] from the Slick Rock (Colorado), Durango (Colorado), and Monticello (Utah) mill sites; these sites include tailings that were processed using acid-leached or alkaline-leached hydrometallurgical methods.

The samples of tailings from unconformity deposits, pegmatitic deposits, and quartz-pebble conglomerate deposits are all standard reference materials distributed by Natural Resources Canada (<https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/mining-resources/uts-1-uts-4-certificate-analysis/8127>). Unconformity deposit tailings include Eldorado Nuclear/Beaverlodge, Saskatchewan, Canada (UTS-3) and Eldorado Mines, Rabbit Lake, Saskatchewan, Canada (UTS-4). The tailings from a pegmatitic deposit are from Madawaska Mines, Bancroft, Ontario, Canada (UTS-1), and tailings for the quartz-pebble conglomerate deposits are from Elliot Lake, Ontario (UTS-2). The two samples of tailings from metasomatic deposits were derived from metallurgical test material from the Coles Hill deposit, Virginia. Ore crushed and ground by Virginia Uranium, Inc. (VUI) as part of their metallurgical testing was used in leaching tests at the USGS to mimic their acid leaching (CH-ACD; sulfuric acid) and alkaline leaching (CH-ALK; sodium carbonate + sodium bicarbonate). For the acid leach, a solution containing 37 g/L H₂SO₄ + 0.9 g/L NaClO₃ was leached mixing equal masses of solution and sample for 18 hours. For

the alkaline leach, a solution of 60 g/L Na₂CO₃ + 12g/L NaHCO₃ was leached mixing equal masses of solution and sample for 18 hours. Leaching was a pretreatment process only; no analysis was performed on the leach solutions. Additional details are in [7].

1.2.2. Analytical methods

Bulk geochemistry of the samples (the Moab sample, UTMCB-1, and the samples from non-sandstone U deposits) were determined using a variety of techniques, including X-ray fluorescence, inductively coupled plasma- atomic emission spectroscopy (ICP-AES), and inductively coupled plasma-mass spectrometry (ICP-MS). Methods and results are provided in [7].

1.3. Water Resources and Water-Quality Section

NURE data [1] on Figure 7 were processed as follows. Geographic information was used to plot the data in a geographic information system, clipping by permissive tract. Values of "0" were removed from the dataset. If negative values were listed, we assumed the value was below laboratory detection limit and replaced the value with half the absolute value of the negative value. Negative values in the dataset were: As = -0.5; Mo = -4, -2; Se = -0.1, -0.2; U = -0.2; V = -10, -2).

Texas Water Development Board Data [8] on Figure 7 were processed as follows. Geographic information was used to plot the data in a geographic information system clipping by permissive tract. Values of "0" were removed from the dataset. Values censored with < were assumed to be below the laboratory detection limit and were replaced with half the absolute value of the negative value. All five analytes had multiple detection limits: As, <0.002, <0.01, <0.2, <1, <1.5, <2, <2.04, <3, <4, <4.5, <5, <7.5, <8, <10, <16, and <20; Mo, <0.4, <1, <1.02, <2, <3, <20, <50; Se, <0.08, <0.4, <1, <1.02, <2, <4, <4.08, <5, <10, <12, <18, <30, <60; U, <0.0003, <0.3, <1; and V, <0.1, <0.14, <1, <1.02, <1.58, <2, <2.04, <4, <5, <6, <9.36, <10, <17.4, <20. The Ra-226 data from the Texas Water Development Board also had multiple detection limits (provided in becquerel per liter with picocuries per liter in parentheses): <0.0074 (0.2); <0.0222 (0.6); <0.0259 (0.7); <0.0296 (0.8); <0.03626 (0.98); <0.037 (1); <0.074 (2). Because this was an exploratory exercise where only the range of data was plotted, we did not employ methods for analyzing data having multiple detection limits.

Uranium mill tailings samples (except those from [6]) were leached using the United States Environmental Protection Agencies Synthetic Precipitation Leaching Procedure (EPA method 1312) [9]. The EPA Method 1312 reacts a 1:20 solid to solution mixture for 18 hours with end over end agitation. The solution is a dilute mixture of sulfuric and nitric acids adjusted to pH 5.0. The resulting leachates are characterized after filtration (0.45 micrometer (μm)) for chemical analysis using ICP-AES and ICP-MS. Results for leachate chemistry are published separately [7].

2. Waste Types Produced During In Situ Recovery Mining

This section contains information on waste produced during the different processes that occur during ISR mining. All information comes from [10].

Activities that generate waste during uranium extraction at mines or remote processing facilities include operation of ion exchange (IX) columns to recover uranium from lixiviant solutions; elution of IX columns that includes stripping accumulated uranium from the resin and preparing the resin and columns for reuse; recovering yellowcake; and restoring the aquifer. Elution removes and recovers uranium from exchange sites on the IX resin and returns chloride ions to the exchange sites. The uranium-rich solution is discharged to a holding tank until quantity is sufficient to begin yellowcake recovery. Yellowcake recovery includes precipitation of uranium out of the uranium-rich eluent solution and drying the resulting slurry to produce the final yellowcake concentrate. Aquifer restoration may involve groundwater sweeps where groundwater is pumped from the well field drawing native water into the well field to flush the area; reverse osmosis with permeate injection where pumped groundwater is purified using reverse osmosis creating "clean" water that is reinjected to the well field and brine that is disposed in deep injection

wells, or evapo-concentrated in ponds prior to disposal; and recirculation of well field water involving pumping and reinjecting pumped water using the original well field injection and production wells.

Wet, dry, and airborne wastes are produced at all stages of uranium recovery. The ion exchange process includes the intentional bleed of one to three percent of the solution after lixiviant flows through the IX column. This bleed ensures that the amount (of lixiviant that is barren and regenerated after passing through the IX columns) injected into the well field is less than the amount being pumped from the well field (pregnant lixiviant) ensuring a gradient in the well field toward the extraction wells. This gradient minimizes excursions of lixiviant and groundwater from the well field into surrounding unmined areas. Other liquid wastes are produced during backwash of sand filters used in some processing steps, from resin wash solutions, and from washing operations in the plant. Waste management includes evaporation ponds, deep injection wells, land application, or surface discharge under a National Pollution Discharge Elimination System permit. Solid wastes include spent resin, empty chemical containers, pipes and fittings, sludge in ponds, and tank sediments. These wastes are either characterized as contaminated or noncontaminated according to their radiological characteristics. Noncontaminated wastes are considered ordinary trash. Contaminated wastes are disposed in a Nuclear Regulatory Commission-licensed facility. Gaseous and airborne emissions from ISR facilities include radon and airborne particulates from lixiviant circulation and yellowcake drying.

References

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