Gamma-Ray Characterization of Soil Samples at the Peña Blanca Natural Analog, Chihuahua, Mexico

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Location of Peña Blanca

(Pearcy et al., 1994)

Tertiary Volcanic Rocks

California

Arizona

New Mexico

Texas

San Antonio

Mexico City

Chihuahua

Yucca Mountain

Peña Blanca Study Area
Location of Prior High Grade Stockpile Relative to Nopal 1 Mine

Prior High Grade Stockpile (PHGS):

- Ore transported to site during mining in the 1980's, then removed from site in 1990's. Some ore boulders rolled down slope from site. Maximum residence time for boulders studied: 25 years.
The purpose of this study is to characterize intermediate daughters of the uranium decay chain in the soil below high-grade boulders.

U-series disequilibria documents mobilization of uranium and other radionuclides.
Sample Area

PST (Potential Scientific Target)

#110

The boulder is located just downslope from the (PHGS) site.

Samples were collected from the boulder itself, and from beneath and adjacent to the boulder.
Sample Area After Boulder Moved
Samples analyzed thus far: B1, B3, B7, and a boulder sample (PointE, not on figure).

B3 and B7 have higher gamma-ray activities than B1, reflecting active transport from the boulder; boulder shielded B1 site.
Samples

Large samples necessary for analytical precision because activities are low.
Gamma ray spectra yield peaks of $^{210}\text{Pb}$, $^{234}\text{U}$, $^{234}\text{Th}$, $^{230}\text{Th}$, $^{226}\text{Ra}$, $^{214}\text{Pb}$, $^{214}\text{Bi}$, and $^{234}\text{Pa}$.

Half-lives of daughters shown in yellow are appropriate for this study.
The standard used for this study is BL-5, uraninite from the Beaver Lodge deposit. BL-5 is used for a standard because it is certified to be in secular equilibrium.

BL-5 is cast in a resin disk and counted in the same fashion as the samples.

Samples counted from anywhere between three days to a week and a half.

Error analysis is done on each daughter/parent (D/P) pair using peak areas generated by Canberra GENIE 2000 software.
Analytical Procedure

- Self-attenuation corrections are propagated for all D/P pairs.

- Formula used to calculate attenuation factor:

\[ A/O = \ln \left( \frac{T/I}{(T/I)} - 1 \right) \]

- \( I \) = unattenuated counts per second (empty container)
- \( T \) = attenuation counts per second (full sample container)
- \( A/O \) = attenuation correction as dependent on energy (keV)

(Cutshall et al. 1983)
Results for

Graph showing D/P of sample/D/P of BL-5 for various isotopes:
- Th-230/U-234
- Ra-226/Th-230
- Pb-214/Ra-226
- Pb-214/Pb-214
- Bi-214/Pb-214
- Bi-214/Bi-214
- Pb-210/Bi-214

Data points for:
- BL-5
- PointE
- 110-B1-1
- 110-B1-2
- 110-B1-3
- 110-B3-1
- 110-B3-2
- 110-B3-3
- 110-B7-1
- 110-B7-2
- 110-B7-3
- 110-B4-1
- 110-B4-2
- 110-B4-3
$^{226}\text{Ra}/^{230}\text{Th}$
Spectra produced with GENIE 2000 software – BL-5 (above) and organic sample (below). In the organic fraction a $^{230}\text{Th}$ peak was not resolved, indicating a very low activity of $^{230}\text{Th}$ in the organic fraction relative to BL-5.
Scientists at the Southwest Research Institute (SWRI) found mobilization of U, Th, and Ra within the last million years adjacent to the breccia pipe. This study documents mobilization in the last 20-30 years.

Wong et al. in 1999 also found U, Th, and Ra disequilibria. The most pronounced mobility was in veins and fractures with oxidized alteration minerals, e.g. hematite.

Murrell and others (2002) found deficiencies of $^{226}$Ra using Thermal Ion Mass Spectroscopy (TIMS), similar to our study and the SWRI results. They did not find disequilibria for the other isotopes.

Leslie et al. in 1999 documented that plants fix $^{226}$Ra. We are also finding large $^{226}$Ra excesses in organic material from PST 110.
Conclusions

- Secular disequilibrium: $^{230}\text{Th}/^{234}\text{U}>1$, $^{226}\text{Ra}/^{230}\text{Th} >1$, and $^{210}\text{Pb}/^{214}\text{Bi} <1$. These patterns agree with previous work.

- The $^{234}\text{U}$ deficiency suggests mechanical weathering of the boulder, then in situ chemical weathering i.e. leaching, in the soil where U is more mobile than Th.

- $^{226}\text{Ra}$ excess provided by the plants ability to sequester Ra from solution in the soil.

- The $^{210}\text{Pb}$ deficiency provided by Rn loss to environment prior to encapsulation.
Conclusions

- Th-230 > U-234

1. Non aqueous transport of pieces of the boulder spall off (mechanical transport)
2. In situ aqueous transport, i.e. leaching, of mechanically transported pieces
3. $^{234}$U deficiency caused by U mobility relative to Th.

Diagram:
- Boulder
- Mechanical transport
- Uranium leaching
Conclusions

Ra-226 > Th-230

Radium excess requires:

a) Radium transport from the boulder to exceed thorium transport.
b) Efficient fixing of radium by organics.
c) Radium precipitation in organic fraction greater than thorium precipitation.

Boulder

Ra transport > Th transport

Ra fixed by organics
Conclusions

Pb-210 < Bi-214

1. $^{222}$Rn loss to the atmosphere because it is a noble gas.
2. Rn in atmosphere decays to $^{210}$Pb.
3. $^{210}$Pb deficiency caused by insufficient rain to cycle it back to the surface.

Rn-222 $\rightarrow$ Pb-210

Insufficient rain to cycle Pb-210 to soil
Conclusions

- Contribution of this study: short residence time of ore at the PHGS, time span for mobility decades rather than previous minimum estimate of thousands of years.
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