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

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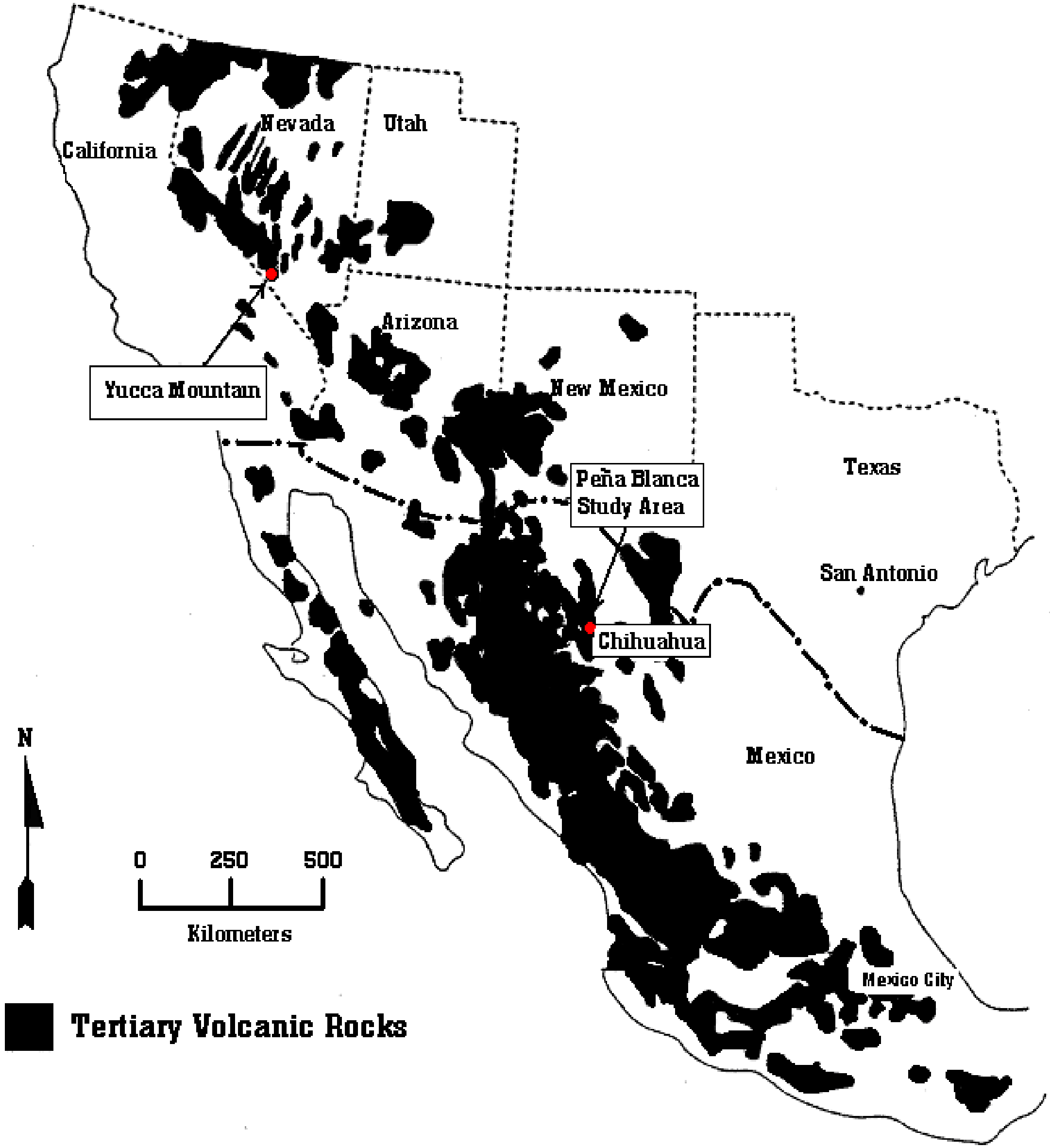
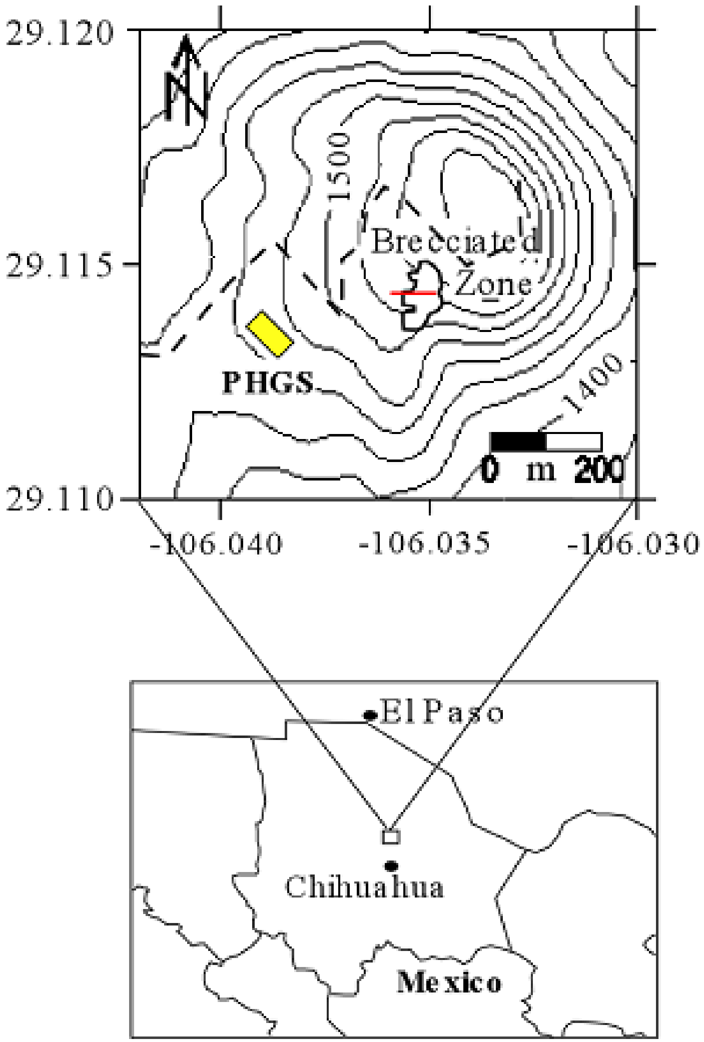
Location of Peña Blanca



(Pearcy et al., 1994)

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.**

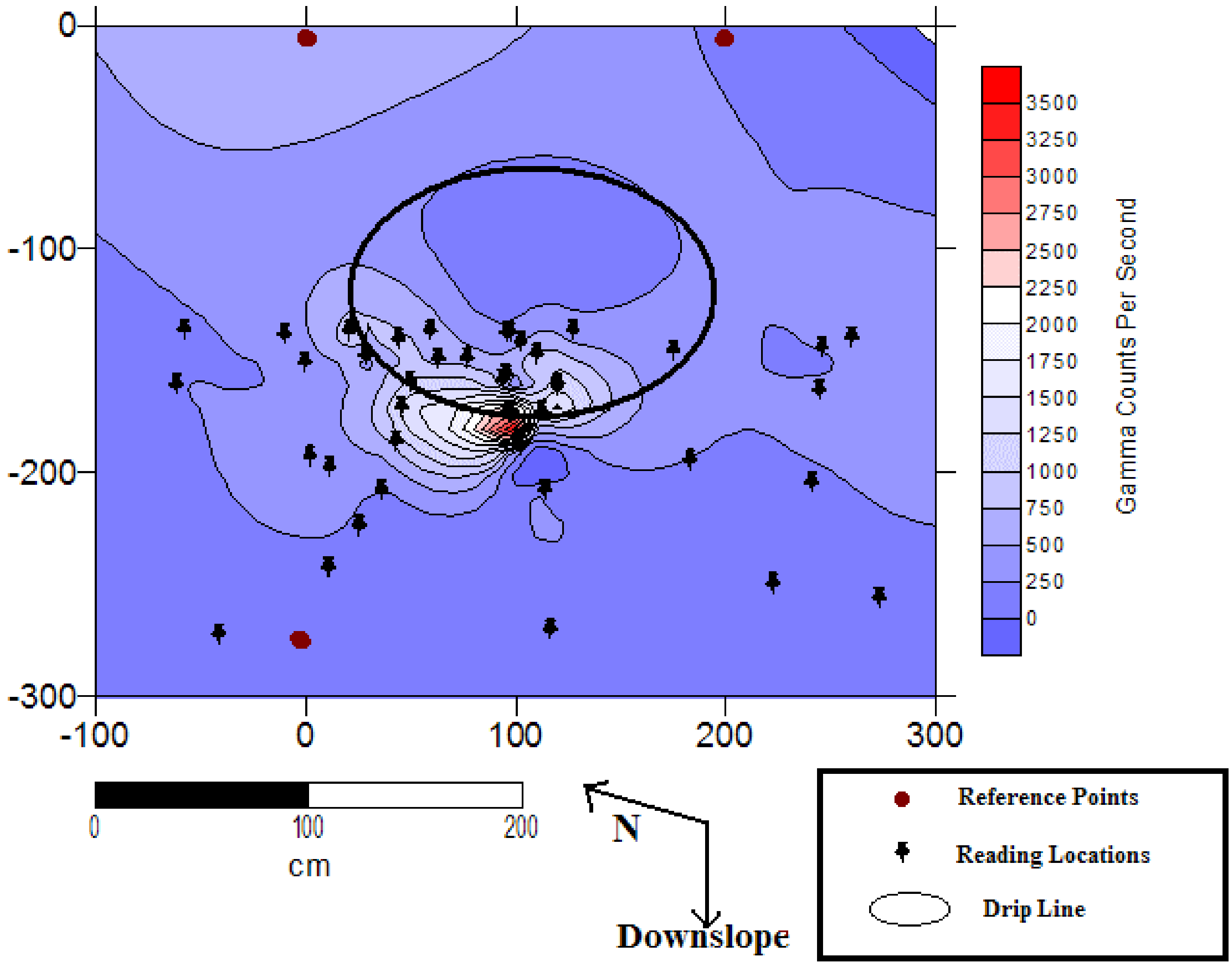
Purpose of Study: Gamma-Ray Characterization at Prior High Grade Stockpile

- **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

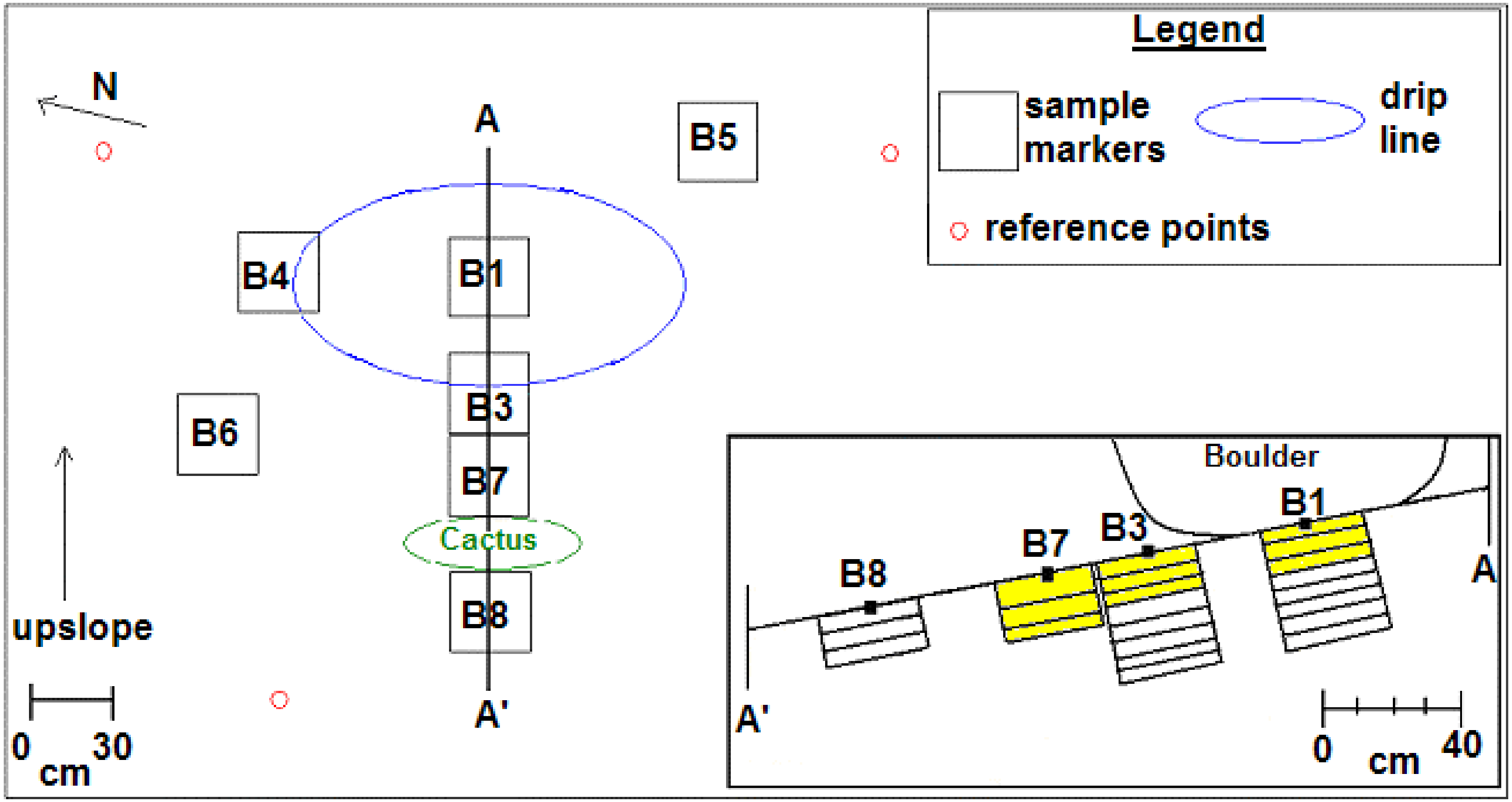
- PST (Potential Scientific Target) #110
- The boulder is located just downslope from the (PHGS) site
- Samples were collected from the boulder itself, and from beneath and adjacent to the boulder

Field Radiometric Survey



Sample Area After Boulder Moved

Sketch of Sample Locations

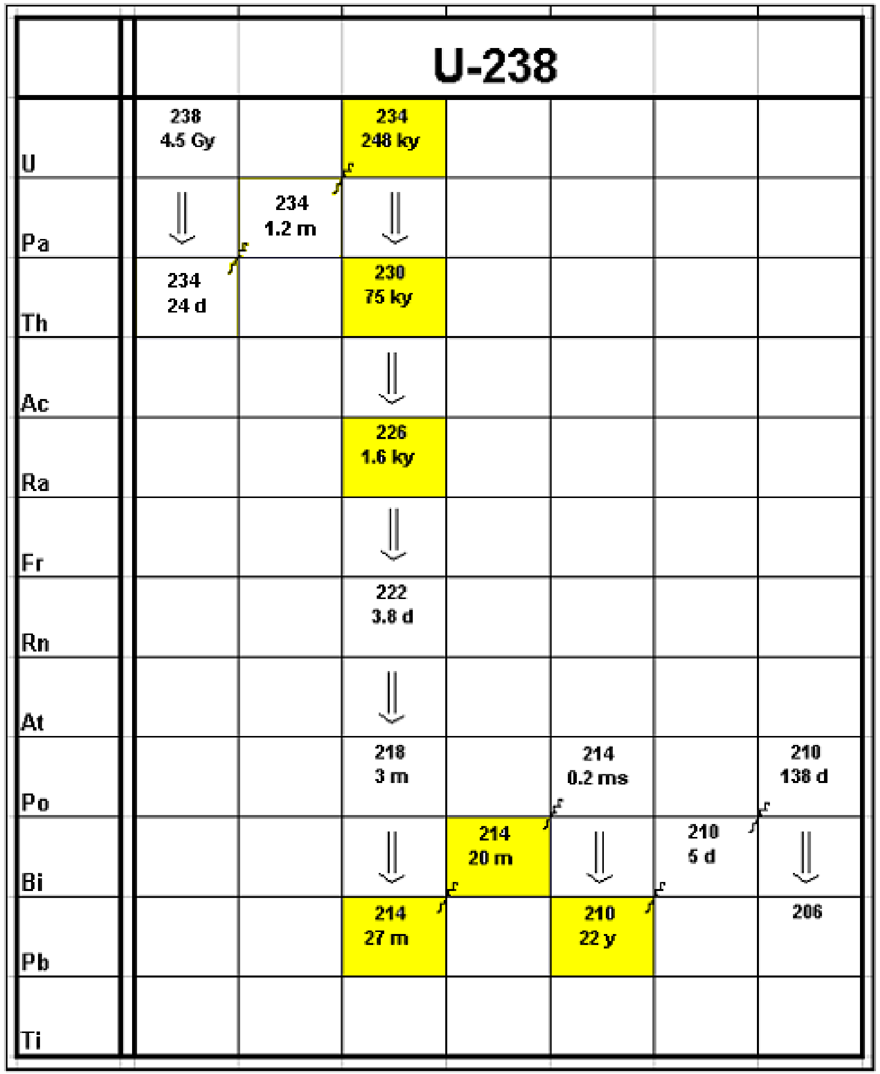


- Samples analyzed thus far: B1, B3, B7, and a boulder sample (PointE, not on figure).
- B3 and B7 have higher gamma-ray activities than B1, reflecting active transport from the boulder; boulder shielded B1 site.

Samples

- Large samples necessary for analytical precision because activities are low.

Uranium Disequilibria



- Gamma ray spectra yield peaks of ^{210}Pb, ^{234}U, ^{234}Th, ^{230}Th, ^{226}Ra, ^{214}Pb, ^{214}Bi, and ^{234}Pa.
- Half-lives of daughters shown in yellow are appropriate for this study.

Analytical Procedure

- **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:**

$$A/O = Ln\,(T/I)/(T/I)-1$$

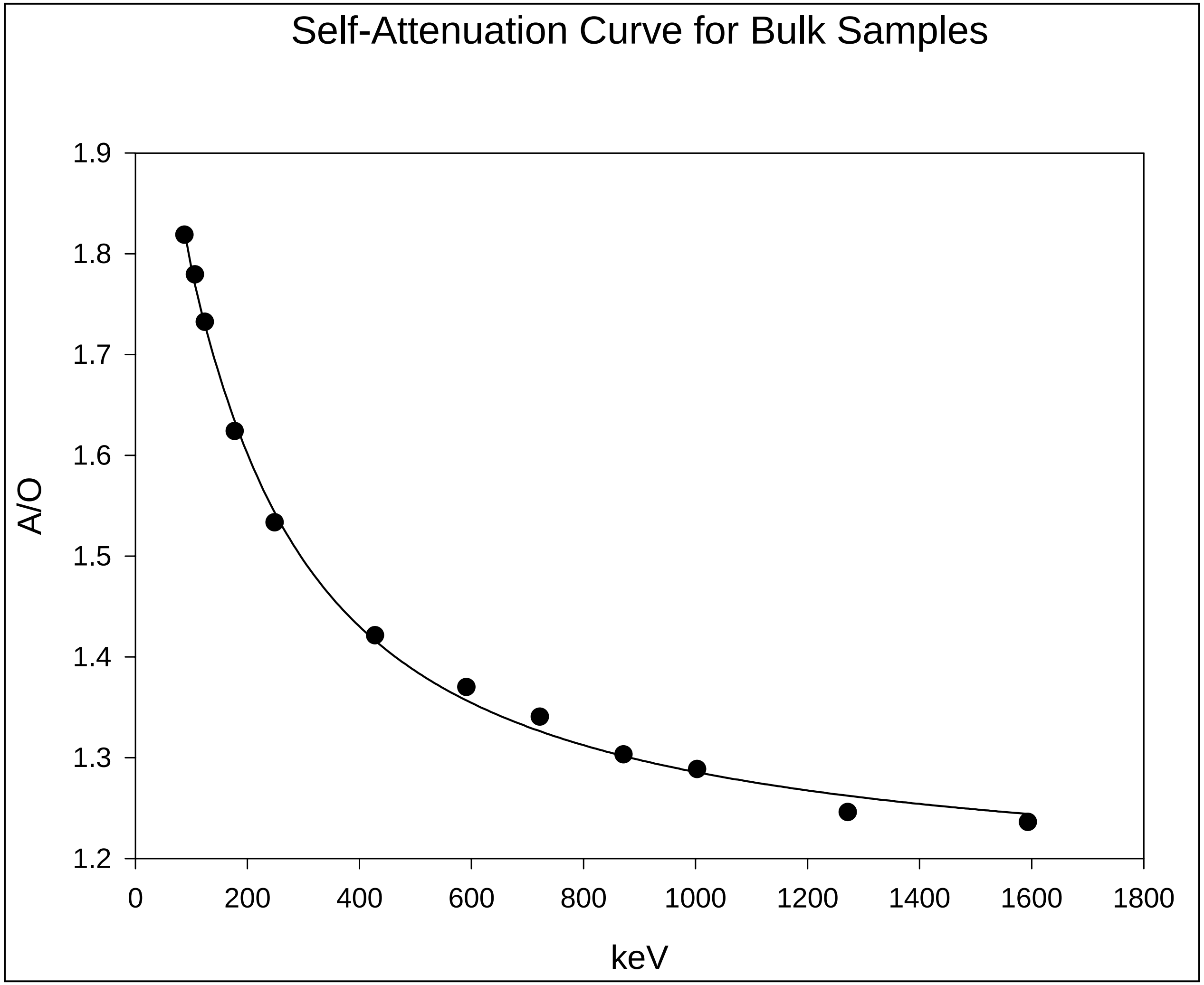
I= unattenuated counts per second (empty container)

T=attenuation counts per second (full sample container)

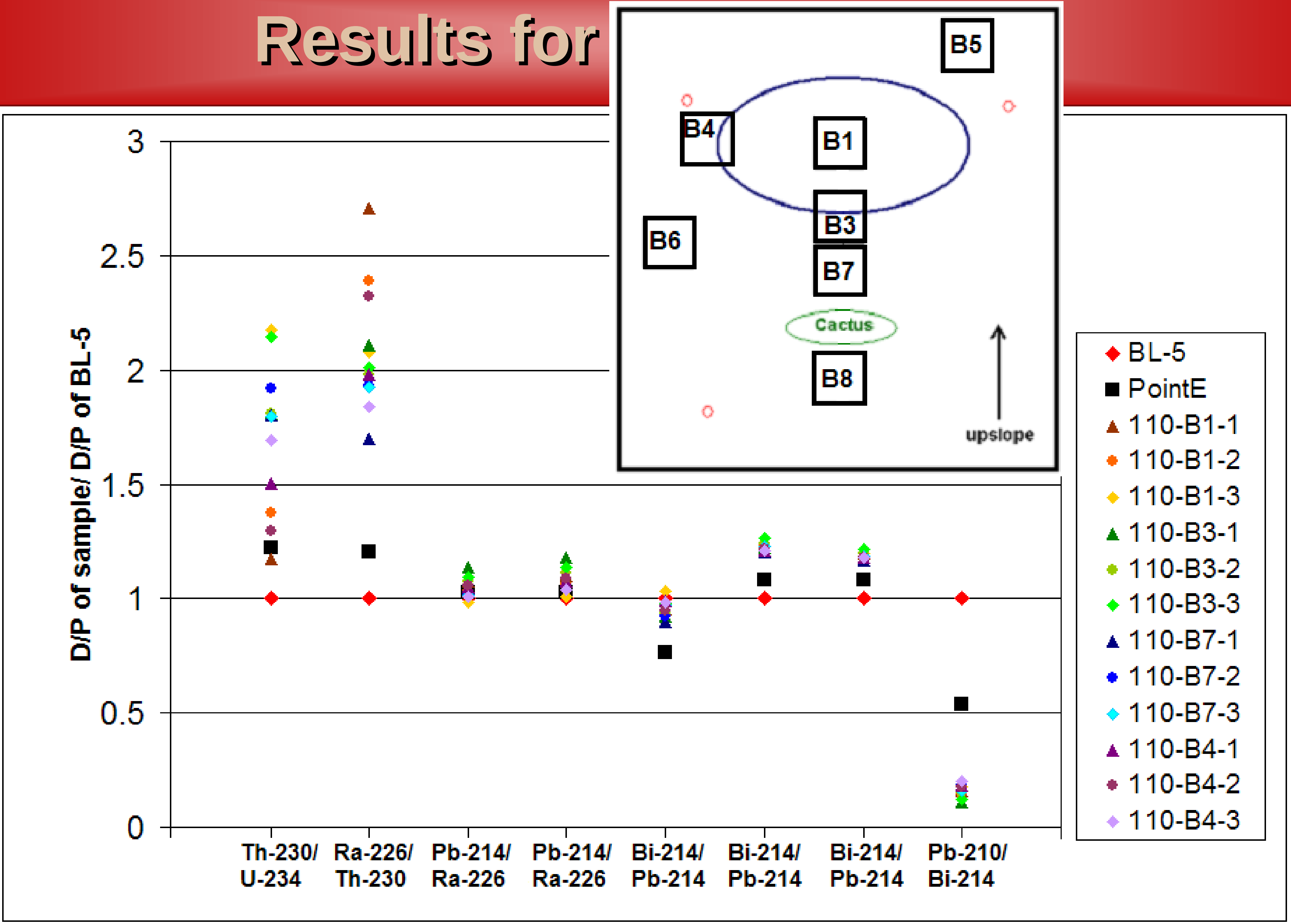
A/O=attenuation correction as dependent on energy (keV)

(Cutshall et al. 1983)

Self-attenuation Corrections

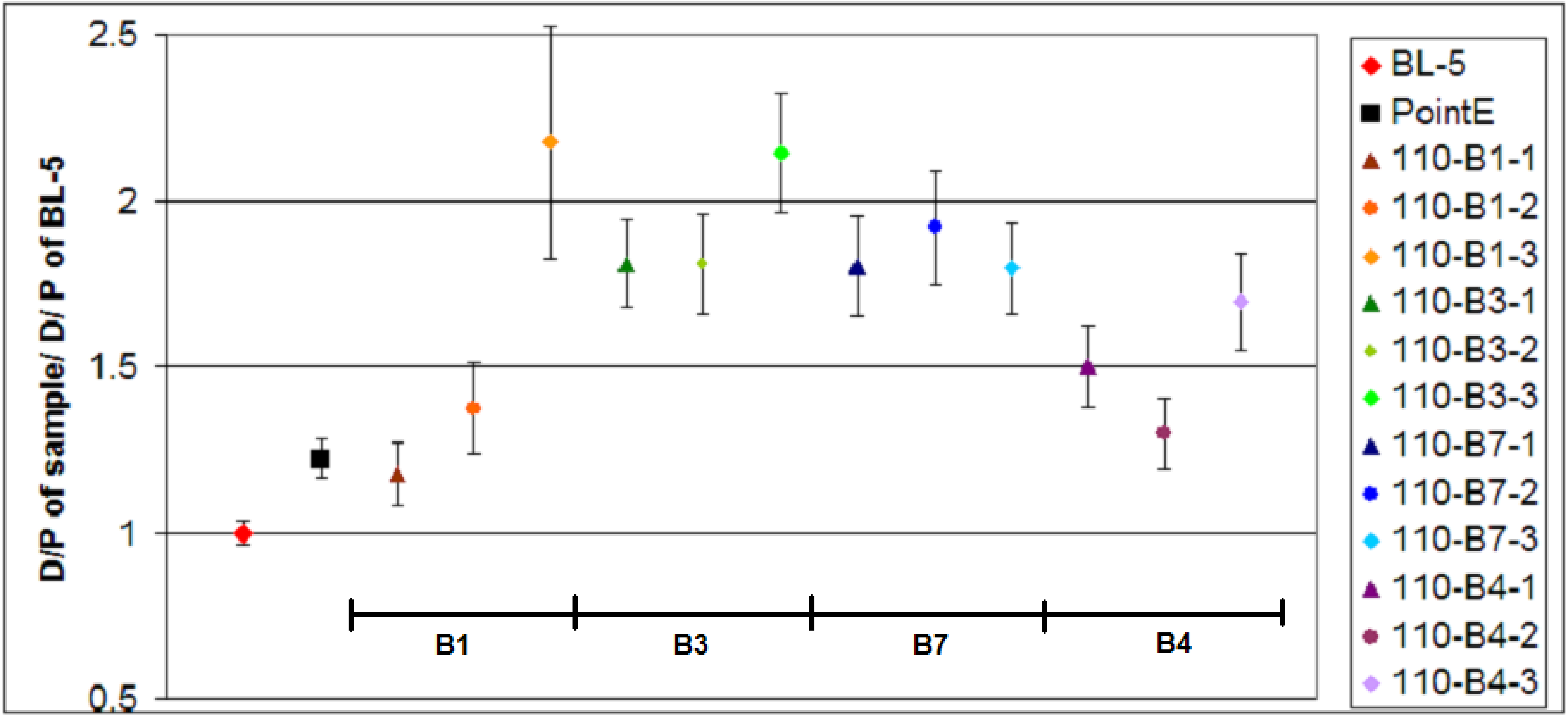


Results for



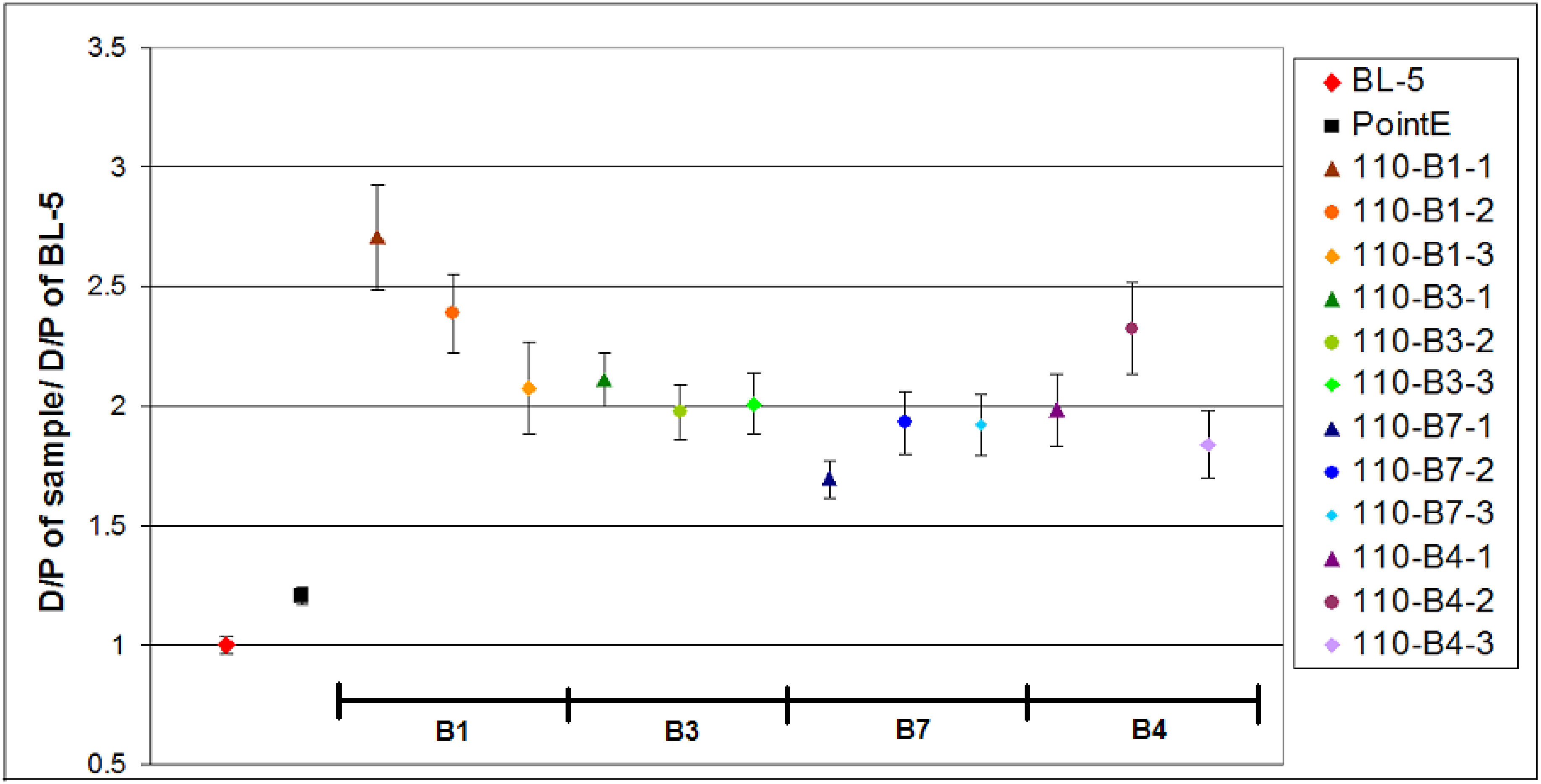
B5
B4
B1
B3
B6
B7
Cactus
B8
upslope
3
2.5
2
1.5
1
0.5
0
D/P of sample/ D/P of BL-5
Th-230/ U-234
Ra-226/ Th-230
Pb-214/ Ra-226
Pb-214/ Ra-226
Bi-214/ Pb-214
Bi-214/ Pb-214
Bi-214/ Pb-214
Pb-210/ Bi-214
BL-5
PointE
110-B1-1
110-B1-2
110-B1-3
110-B3-1
110-B3-2
110-B3-3
110-B7-1
110-B7-2
110-B7-3
110-B4-1
110-B4-2
110-B4-3

$^{230}Th/^{234}U$



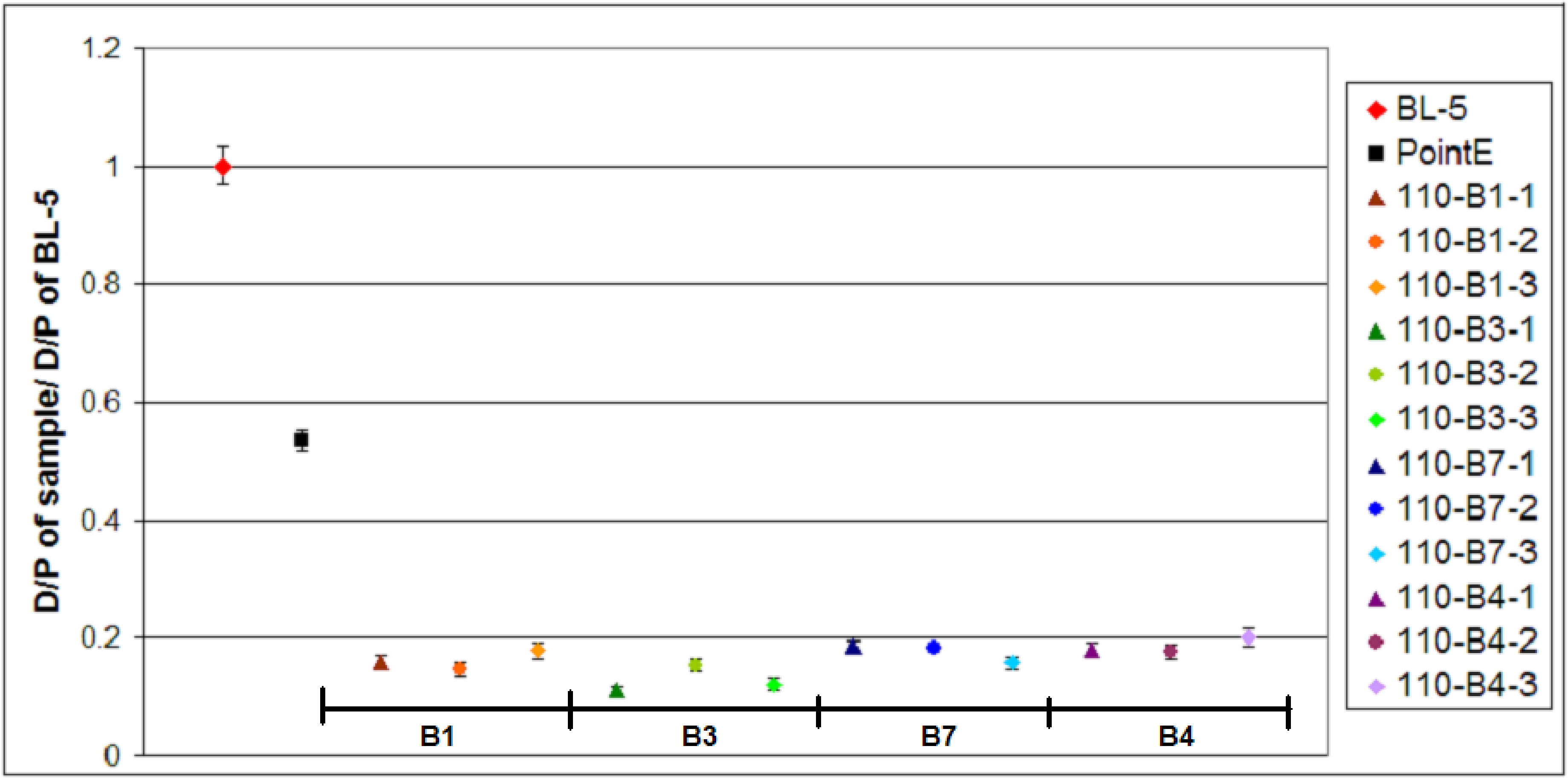
2.5
2
1.5
1
0.5
D/P of sample/ D/ P of BL-5
B1
B3
B7
B4
BL-5
PointE
110-B1-1
110-B1-2
110-B1-3
110-B3-1
110-B3-2
110-B3-3
110-B7-1
110-B7-2
110-B7-3
110-B4-1
110-B4-2
110-B4-3

$^{226}Ra/^{230}Th$

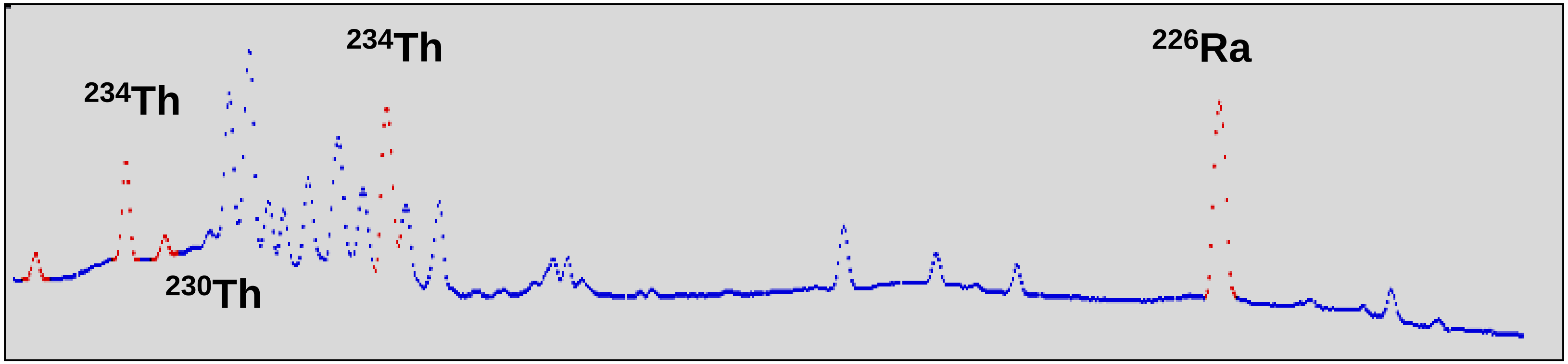


D/P of sample/ D/P of BL-5
3.5
3
2.5
2
1.5
1
0.5
B1
B3
B7
B4
BL-5
PointE
110-B1-1
110-B1-2
110-B1-3
110-B3-1
110-B3-2
110-B3-3
110-B7-1
110-B7-2
110-B7-3
110-B4-1
110-B4-2
110-B4-3

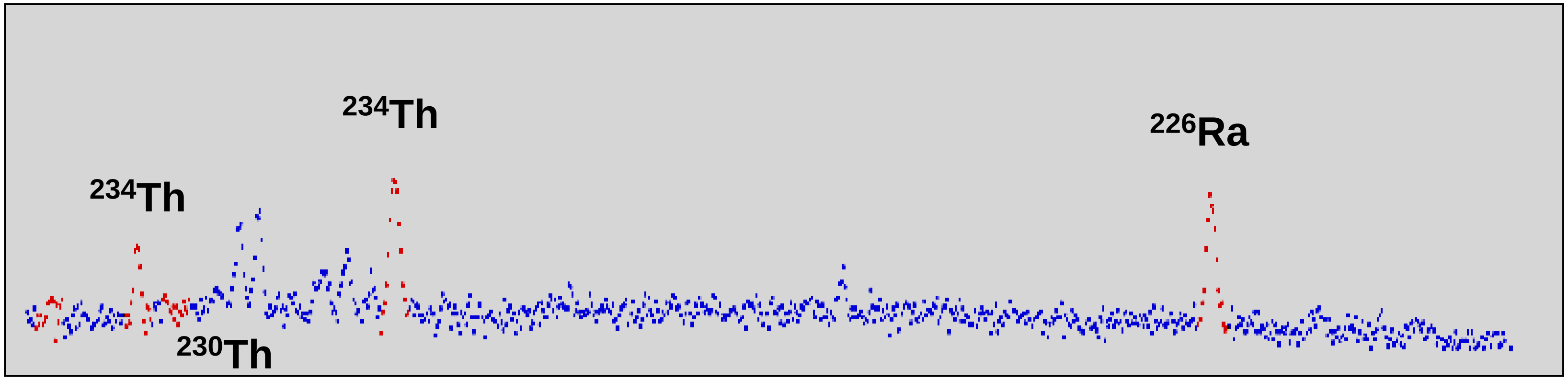
$^{210}Pb/^{214}Bi$


1.2
1
0.8
0.6
0.4
0.2
0
D/P of sample/ D/P of BL-5
B1
B3
B7
B4
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

Results for Organics



- **Spectra produced with GENIE 2000 software – BL-5 (above) and organic sample (below). In the organic fraction a ^{230}Th peak was not resolved, indicating a very low activity of ^{230}Th in the organic fraction relative to BL-5.**



Comparison of current results to those of previous studies

- 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.

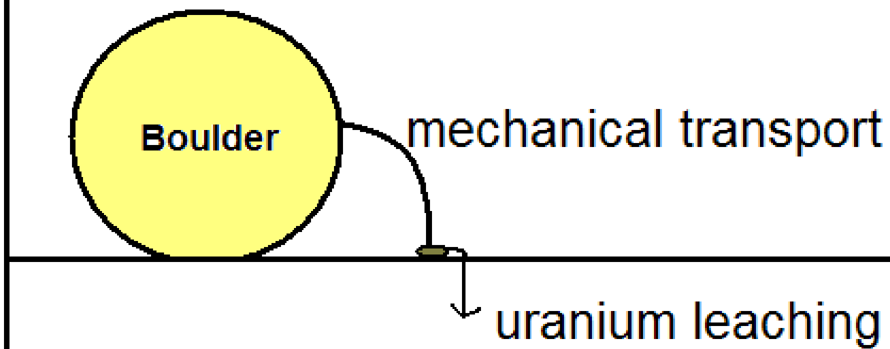
Conclusions

- Secular disequilibrium: $^{230}Th/^{234}U>1$, $^{226}Ra/^{230}Th>1$, and $^{210}Pb/^{214}Bi<1$. These patterns agree with previous work.
- The ^{234}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}Ra excess provided by the plants ability to sequester Ra from solution in the soil.
- The ^{210}Pb deficiency provided by Rn loss to environment prior to encapsulation.

Conclusions

Th-230 > U-234

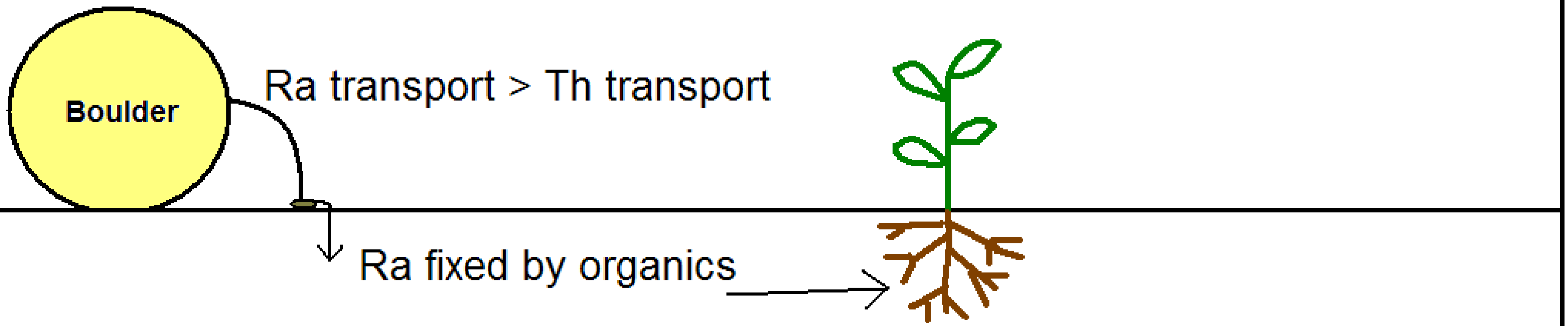
1. Non aqueous transport of pieces of the boulder spall off (mechanical transport)
2. In situ aqueous transport, i.e. leaching, of mechanically transported pieces
3. ^{234}U deficiency caused by U mobility relative to Th.



Conclusions

Ra-226 > Th-230

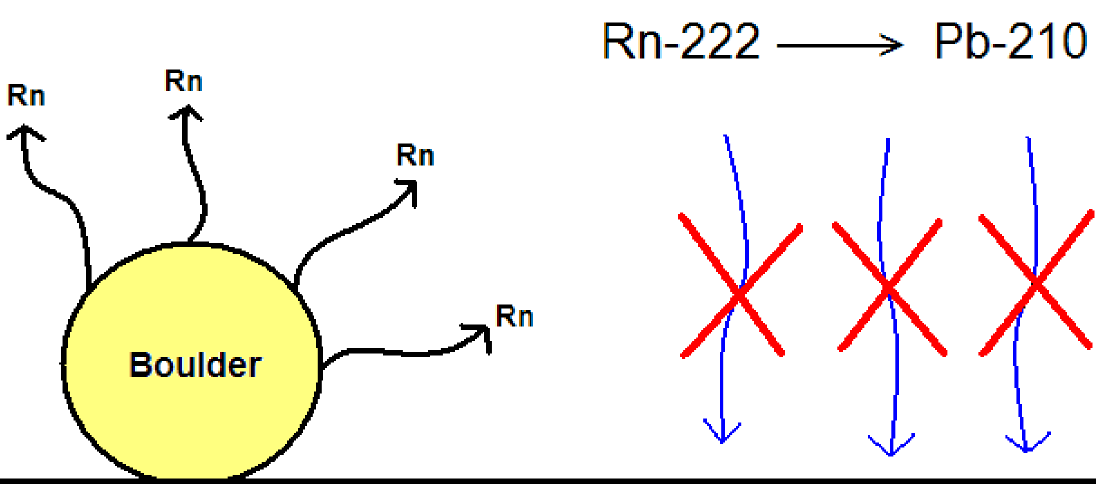
- Radium excess requires:
  a) Radium transport from the boulder to exceed thorium transport.
  b) Efficient fixing of radium by organics.
  c) Radium precipitation in organic fraction greater than thorium precipitation.



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



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**

Acknowledgements

- **John Walton, Aaron Kelts, and Charles Beshears - for assistance in sample collection and discussions of data**
- **Minghua Ren - for assistance in the gamma-ray laboratory and with sample preparation**
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Questions?

Drawing by: June Walton