Sediment Generation Rates in the Potomac River Basin

A Thesis Progress Report Presented

by

Charles David Trodick Jr.

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The Following Members of the Thesis Committee have

read and approved this document before it was circulated

to the faculty:

____________________________Dr. Paul Bierman (Advisor)

____________________________Dr. Donna Rizzo

____________________________Dr. Laura Webb

Date Accepted:____________________

Abstract

My research is determining sediment generation rates in the Potomac River Basin. I have made significant progress since my proposal. First, I went to the field for several weeks and collected 71 riverine samples from the Potomac River and its tributaries. I have done initial processing of all samples, including, drying, sieving and magnetically separating. I purified the quartz for nearly all of my samples and ground all of my samples for meteoric extraction. I learned the meteoric extraction technique and gotten my first set of data back from Lawrence Livermore National Laboratory. I also have presented my initial data at the annual Geologic Society of America Meeting. To analyze my data I synthesized all of the relevant studies on sediment generation and sediment yield that have been done in the study area. I will also do a comparison of the rates I find between basins of differing size and relief. Then, I will compare the meteoric and the in situ data to determine how land use affects the concentration of meteoric ^{10}Be in river sediment.

1.0 Introduction

"The Potomac River has long been viewed as the Nation's River because of its pivotal role in the development of the United States and as the seat of our national government (US EPA, 2001)."

Today, the Potomac River (37995 km^2) contributes a significant amount of sediment to the Chesapeake Bay (Stanton, 1993). Because the Bay is a valuable natural resource and because large amounts of money, time and energy are being spent protecting it (US EPA, 2001), responsible management requires good estimates not only of current rates of sediment delivery to the bay but also background (pre-disturbance) rates of sediment generation from major river basins feeding the Bay. The Potomac River is one of two major rivers, the other being the

Susquehanna that feed sediment to the bay (Figure 1). The Potomac provides 44% of the riverine sediment to the Bay while the Susquehanna provides 27% (Gellis et al., 2004). Both the current sediment yield (Gellis, et al., 2004) and background rate of sediment generation (Reuter et al., 2006) have been determined for the Susquehanna River Basin. My Masters research is determining long-term sediment generation rates for the Potomac River Basin, which I will then compare with contemporary sediment yields (Gellis, et al., 2004). This comparison will allow me to infer how the sediment generation rates have changed since western settlement of the Potomac Watershed. I will test for differences in sediment generation rates among basins of different size, relief, and in different physiographic provinces within the Potomac River Basin. In addition, I will compare results of meteoric ^{10}Be and in situ ^{10}Be analysis to determine how land use affects the concentration of meteoric ^{10}Be adhered to sediments. Lastly, I will compare the Potomac River Basin sediment generation rates with others in the southern Appalachians including those in the Susquehanna River Basin (Reuter, et al., 2006), the Shenandoah River Basin (Duxbury et al., accepted), the Blue Ridge (Sullivan et al., accepted), and the Great Smokey Mountains (Matmon et al., 2003).

2.0 Progress to Date

2.1 Sample Collection

During the fall of 2008, I collected ten riverine samples from gaging stations on the Potomac River and its tributaries (Figure 2) along with one sample from a small basin. During this past summer (2009), I collected an additional 60 samples from small river basins in each of the five physiographic provinces of the Potomac Watershed (Figure 3). Each sample I sieved on site to between 850 and 250 microns, and I collected between 0.5 kg to 2 kg of sample from each site, depending on the amount of quartz that could be seen in hand specimen.

2.2 Lab Work

After collection, all samples were brought to UVM for processing. Currently, I am extracting and purifying quartz from each sample so that we can measure in situ ^{10}Be (link). So far, I have dried, sieved and magnetically separated all samples. In addition, each sample has been repeatedly etched in HCl and dilute HF/HNO_3, which dissolves most minerals except quartz (Kohl and Nishiizumi, 1992). I have also done a burn to remove all organic material including coal and I have completed density separations to remove all heavy minerals on 43 of my samples. Soon I will be testing the samples for quartz purity, using standard lab procedures (link).

Meteoric ^{10}Be, which is adhered to the surface of sediment and soil grains, is extracted using a flux method (Stone, 1998) described here link. A quick outline of what is done includes powdering the sediment and spiking it with ^{9}Be. I have completed powdering all my samples. Then KHF_2 and NA_2SO_4 are added to the sample and it is fused with a flame. Then K is removed from the sample using $HClO_4$ and B is removed through fuming with HF. Finally, $Be(OH)_2$ is formed with NH_4OH and burned to form BeO. I have done these steps with 35 samples. Finally, the ^{10}Be is measured on an accelerator mass spectrometer (AMS) at the Lawrence Livermore Laboratory. Fifteen of my samples have been analyzed isotopically. The next set will be measured in early December.

2.3 National GSA Meeting

I presented data from my initial 15 meteoric ^{10}Be samples at the National Geologic Society of America meeting in Portland, OR. I created a poster detailing my initial results and the conclusions that I was able to reach from the data.

3.0 Data

So far, we have measured meteoric ^{10}Be in sand collected from three sites on the main-stem Poto mac River (basin areas of 18616, 15528, and 1411 km^2) and from 12 tributaries (16 km^2 to 2642 km^2). Ten samples came from USGS gaging station sites where suspended sediment data are available. Meteoric ^{10}Be concentration are uncorrelated with both basin area (R^2 = 0.11, P=1.00) and sediment load (R^2 =0.31, P=0.17). Our meteoric ^{10}Be concentrations range from 0.6 to 5.5*10^8 atoms/g with an average of 2.5+/-1.3*10^8 atoms/g. Small basins (16 to 34 km^2), one in the Coastal Plain and 3 in the Piedmont, near Washington, DC have the lowest meteoric ^{10}Be concentrations (0.6 to 1.5*10^8 atoms/g). The highest concentration of ^{10}Be (5.5*10^8 atoms/g) is found on Conococheague Creek, (basin area 796 km^2), the northernmost tributary of the Potomac. There is a decreasing downstream trend in ^{10}Be concentrations on the Potomac (4.3*10^8, 2.6*10^8 and 2.0*10^8 atoms/g). This data can be used to determine erosion rates, if you assume a steady state condition. At the gaging sites, we can compare the ^{10}Be concentrations with sediment yield (Gellis et al., 2004). In addition, we can calculate erosion indexes (EI) at the gaging station sites (Brown et al. 1988).

4.0 Results

Table 1 shows the meteoric ^{10}Be concentrations and other relevant data from the first 15 meteoric samples. The sample taken from the mouth of the Potomac River has a meteoric ^{10}Be concentration of 2.0 * 10^8 atoms/g. The other two main branch samples have concentrations of 2.6 and 4.3 * 10^8 atoms/g. The South Fork of the Shenandoah has a concentration of 3.7 * 10^8 atoms/g. Other medium sized basins with areas ranging from 278-796 km^2 have concentrations from 1.6 to 5.5 * 10^8 atoms/g. The small basins, with areas ranging from 6-34 km^2, have concentrations ranging from 6.3 * 10^7 to 3.1 *10^8 atoms/g.

5.0 Discussion

The initial analyses of meteoric ^{10}Be in 15 samples, has produced interesting results and has shown the importance of generating more data. First, meteoric ^{10}Be concentrations are uncorrelated with basin area (Figure 4). In addition, meteoric ^{10}Be concentrations are uncorrelated with sediment load (Figure 5). The measured meteoric ^{10}Be concentrations range from 0.6 to 5.5*10^8 atoms/g with an average of 2.5+/-1.3*10^8 atoms/g. Small basins (16 to 34 km^2), one in the Coastal Plain and three in the Piedmont near Washington, DC have the lowest meteoric ^{10}Be concentrations (0.6 to 1.5*10^8 atoms/g). The highest concentration of ^{10}Be (5.5*10^8 atoms/g) is found on Conococheague Creek, (basin area 796 km^2), the northernmost tributary of the Potomac River. There is a decreasing downstream trend in ^{10}Be concentrations on the Potomac River (4.3*10^8, 2.6*10^8 and 2.0*10^8 atoms/g). This trend is most likely caused by a downstream increasing in density of agriculture and construction on the Potomac River.

Erosion indexes (EI) are calculated by multiplying the annual sediment load of a basin by the meteoric ^{10}Be of the sediment leaving the basin. This is divided by the basin area and the atmospheric deposition rate of ^{10}Be (1.3* 10^6 $cm^{-2}yr^{-1}$ (Monaghan et al., 1986)) (Brown et al., 1988). If the erosion index is greater than one, then sediment and ^{10}Be are leaving the basin faster than it is being generated. If the erosion index is less than one, sediment and ^{10}Be are being retained in the basin. Brown et al. 1988 measured an erosion index of 0.77 at gaging station 01638500. I calculated an EI of 1.3 at the same station. The increase in EI was caused by an increase in sediment. The erosion index at each of the gaging stations indicates that most of the

Potomac Watershed is exporting sediment and 10Be more quickly than it is being generated and delivered (Table 1). Only two EI values are below one, 01647740 and 01656120, with EIs of 0.25 and 0.28. EIs at the remainder of the gaging stations range from 1.3 to 3.3. The high EIs are most likely caused by large amounts of disturbance, construction and agriculture in the Potomac River Basin.

If we assume steady state, we can calculate erosion rates for each of the basins. Our meteoric ^{10}Be concentrations indicate erosion rates of 9 m/My-77 m/My, which are similar to past erosion rate calculations of 3.8-54 m/My for the Appalachians (Table 2).

6.0 Future Work

6.1 GIS

First, I need to redraw all of my sampled basins in GIS. Then, I can do detailed analyses of each basin and start looking for variables that could be affecting sediment generation rates. I will determine, slope, relief, average elevation, basin area, bedrock type, and dominant land use of the basin. I will then export this data so that I can compare it with meteoric and in-situ ^{10}Be concentrations and calculated erosion rates.

6.2 Lab Work

For in-situ ^{10}Be, I need to finish doing density separations on my last 30 samples. Then, I will do quartz purity testing on all of my samples, following the methods here (link). Then I need to extract ^{10}Be by using a multi-acid dissolution an anion and cation exchange and pH-specific precipitation to separate and purify ^{10}Be. The detailed methods are here (link). For meteoric ^{10}Be, I am waiting for 20 samples to be run at Lawrence Livermore Laboratory. After these samples are run, I will process remaining samples.

6.3 Core

I am waiting for Dr. Milan Pavich to send me 15 samples taken from a core near the mouth of the Potomac River. Each one of these samples will be tested for meteoric ^{10}Be; six will be tested for in-situ ^{10}Be.

7.0 Timeline

See Table 3 for detailed timeline.

Figures and Tables

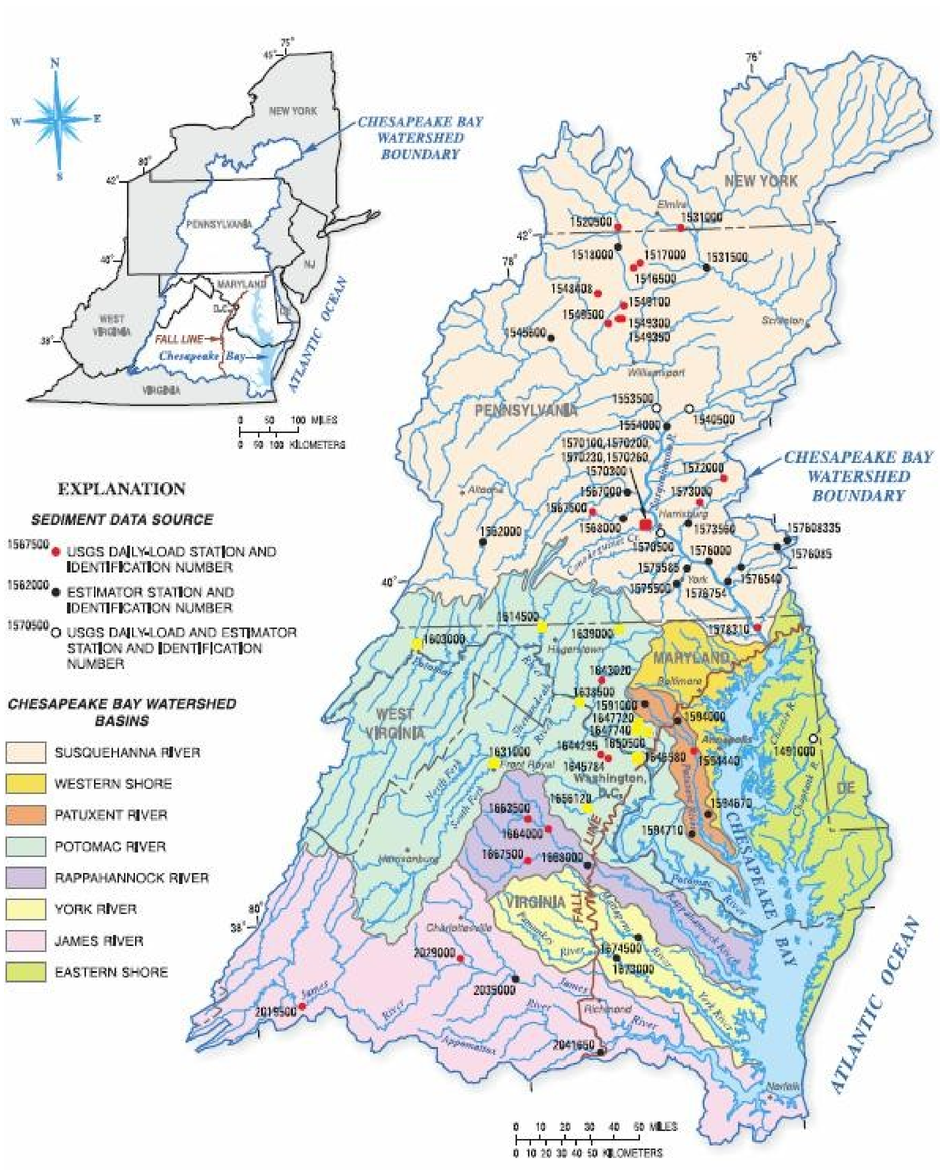

Figure 1
This figure shows the Chesapeake Bay Watershed. The tan Northern section is the watershed of the Susquehanna River, while the light green section is the Potomac Watershed. The red, white and black dots are USGS gauging stations or former gauging stations.

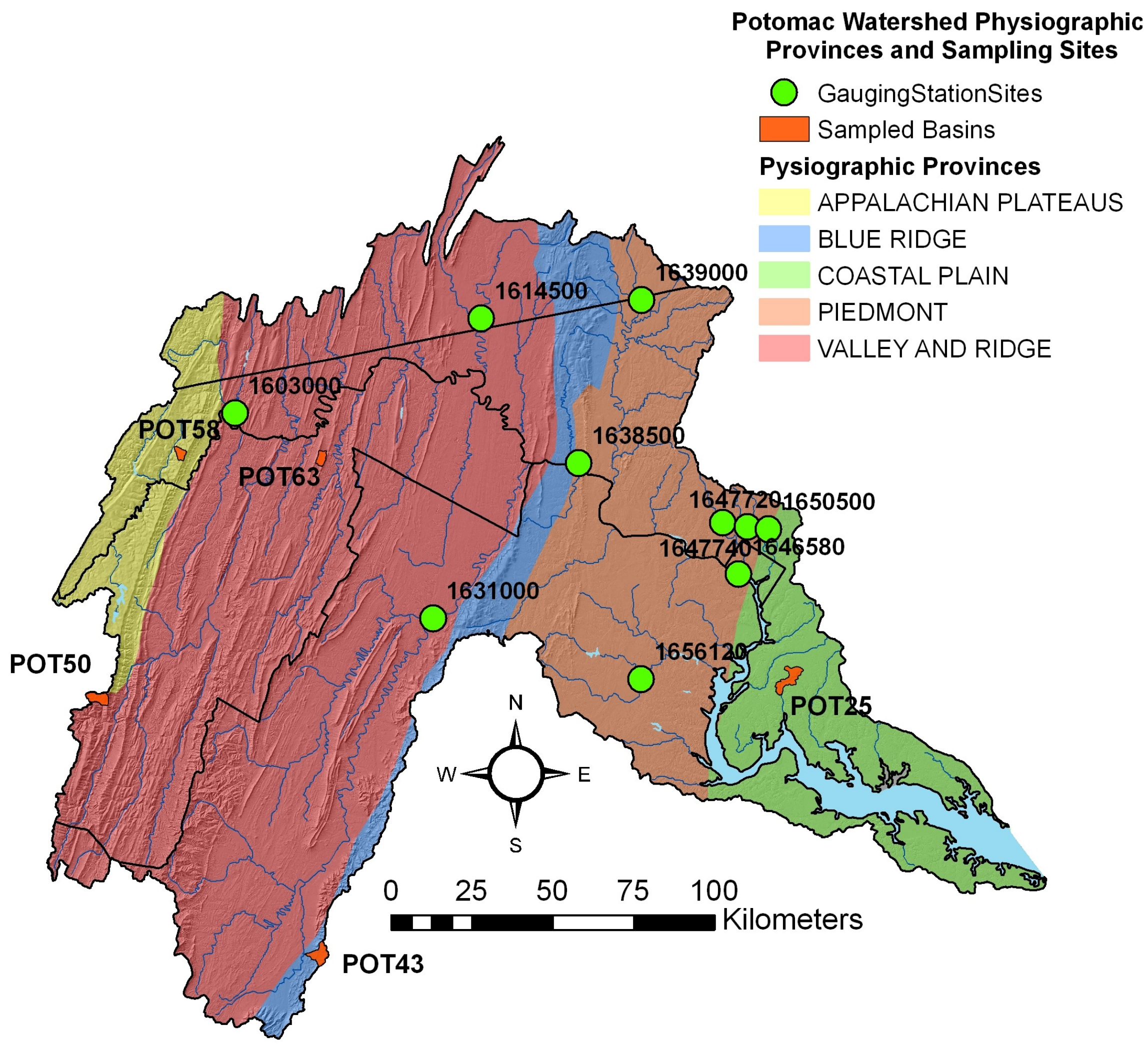

Figure 2
This figure shows the physiographic provinces and the states, that the Potomac River runs through along with my desired sampling sites. The Physiographic Province from West to East are the Appalachian Plateau (Yellow), Valley and Ridge (Red), Blue Ridge (Blue), Piedmont (Orange) and Coastal Plain (Green). Pennsylvania is to the north, West Virginia is to the west, Virginia is to the south, Maryland is in the center and east and DC is where the river starts to widen. Each green dot is the location of a USGS gaging station that I sampled. The orange polygons are basins that I have sampled and have meteoric ^{10}Be data available.

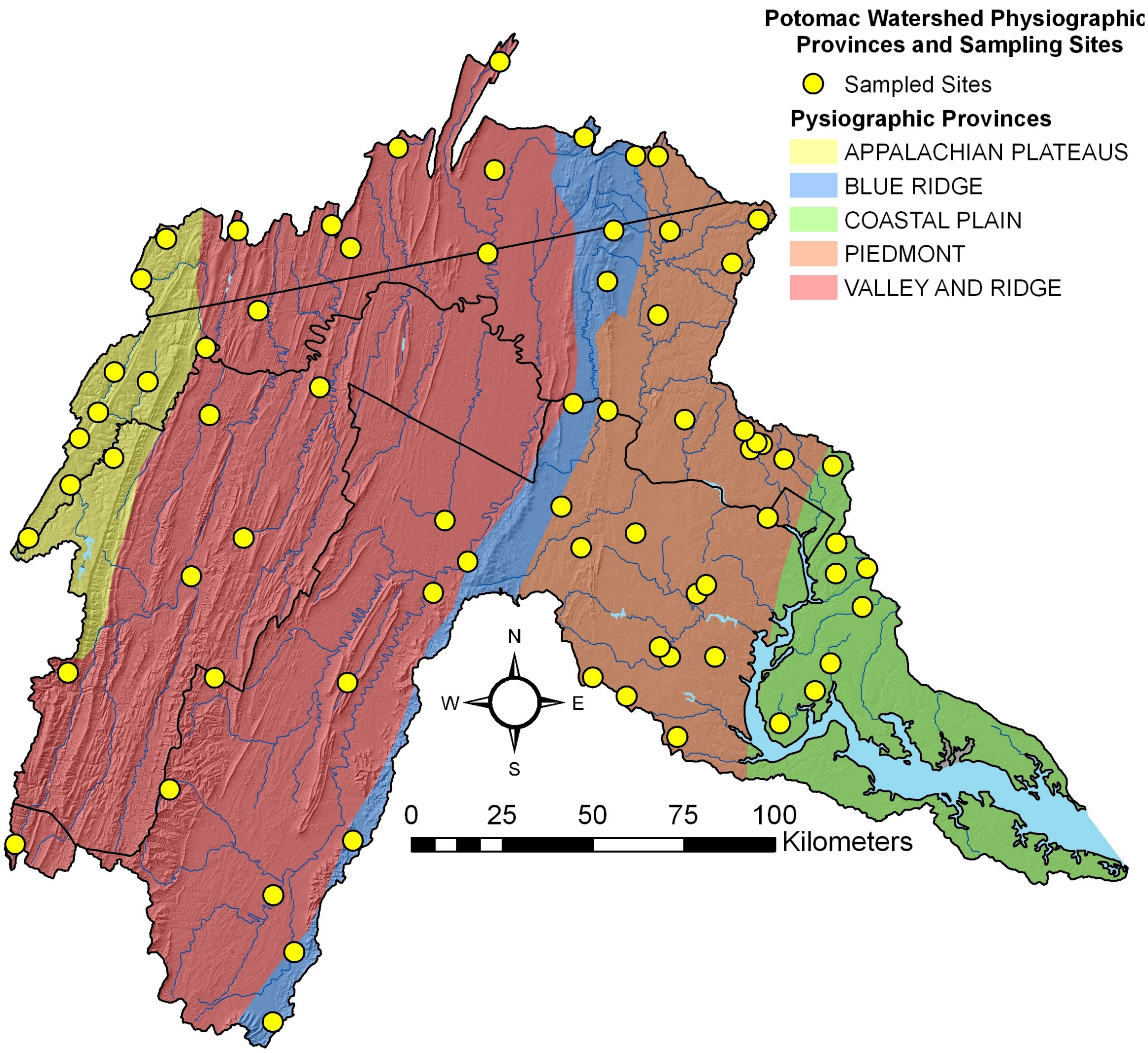

Figure 3

This figure shows the physiographic provinces and the states, that the Potomac River runs through along with my desired sampling sites. The Physiographic Province from West to East are the Appalachian Plateau (Yellow), Valley and Ridge (Red), Blue Ridge (Blue), Piedmont (Orange) and Coastal Plain (Green). Pennsylvania is to the north, West Virginia is to the west, Virginia is to the south, Maryland is in the center and east and DC is where the river starts to widen. Each yellow dot is a site from which I collected a sample.

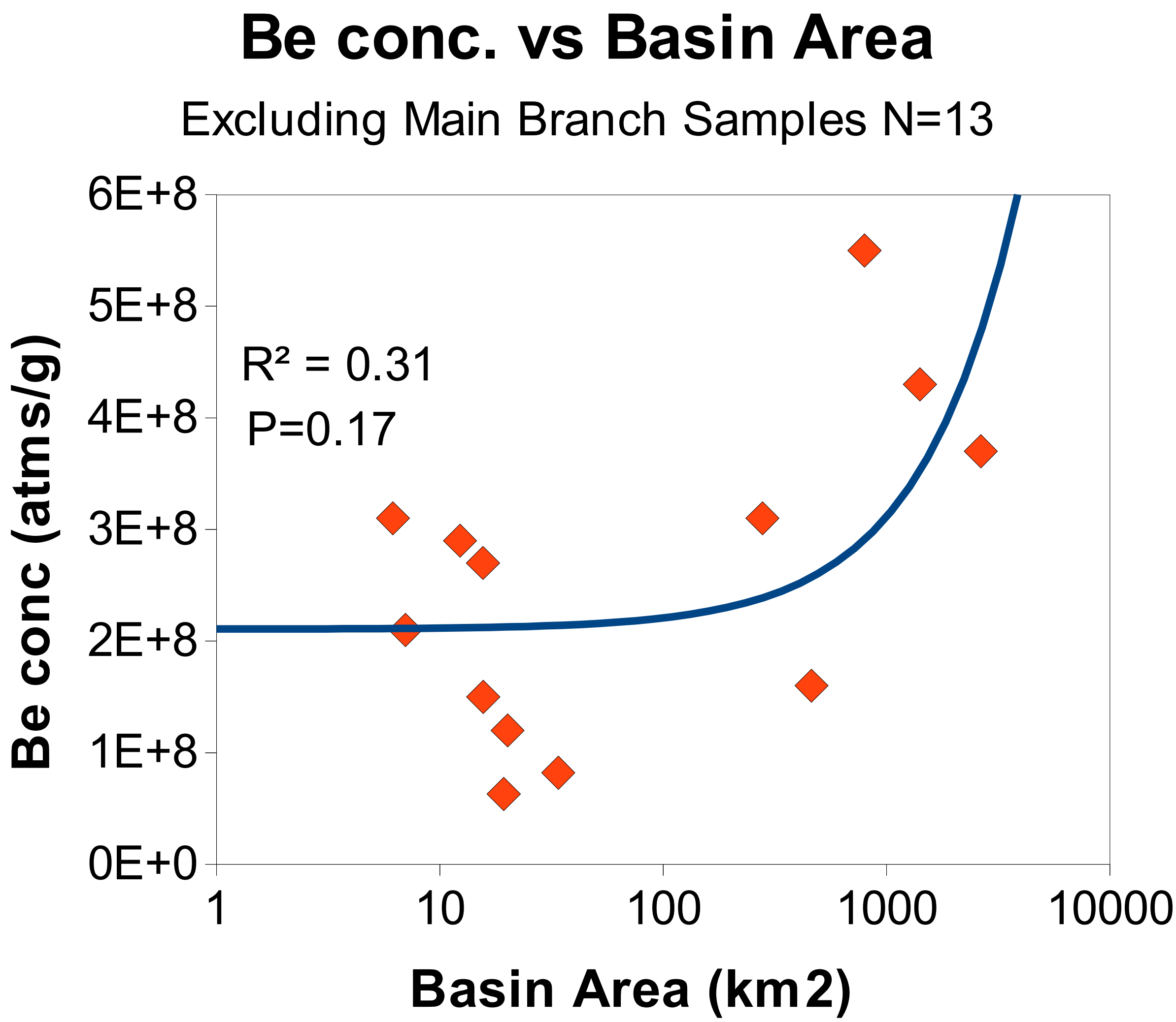

Figure 4
This graph shows the correlation between ^{10}Be concentration and basin area. While the data is still random, a P-Value of 0.17 indicates a much better fit. Small basins (16 to 34 km^2), one in the Coastal Plain and three in the Piedmont near Washington DC, have the lowest meteoric ^{10}Be concentrations (0.6 to 1.5*10^8 atoms/g). The highest concentration of ^{10}Be (5.5*108 atoms/g) is found on the Conococheague Creek, (basin area 796 km^2), the northernmost tributary of the Potomac.

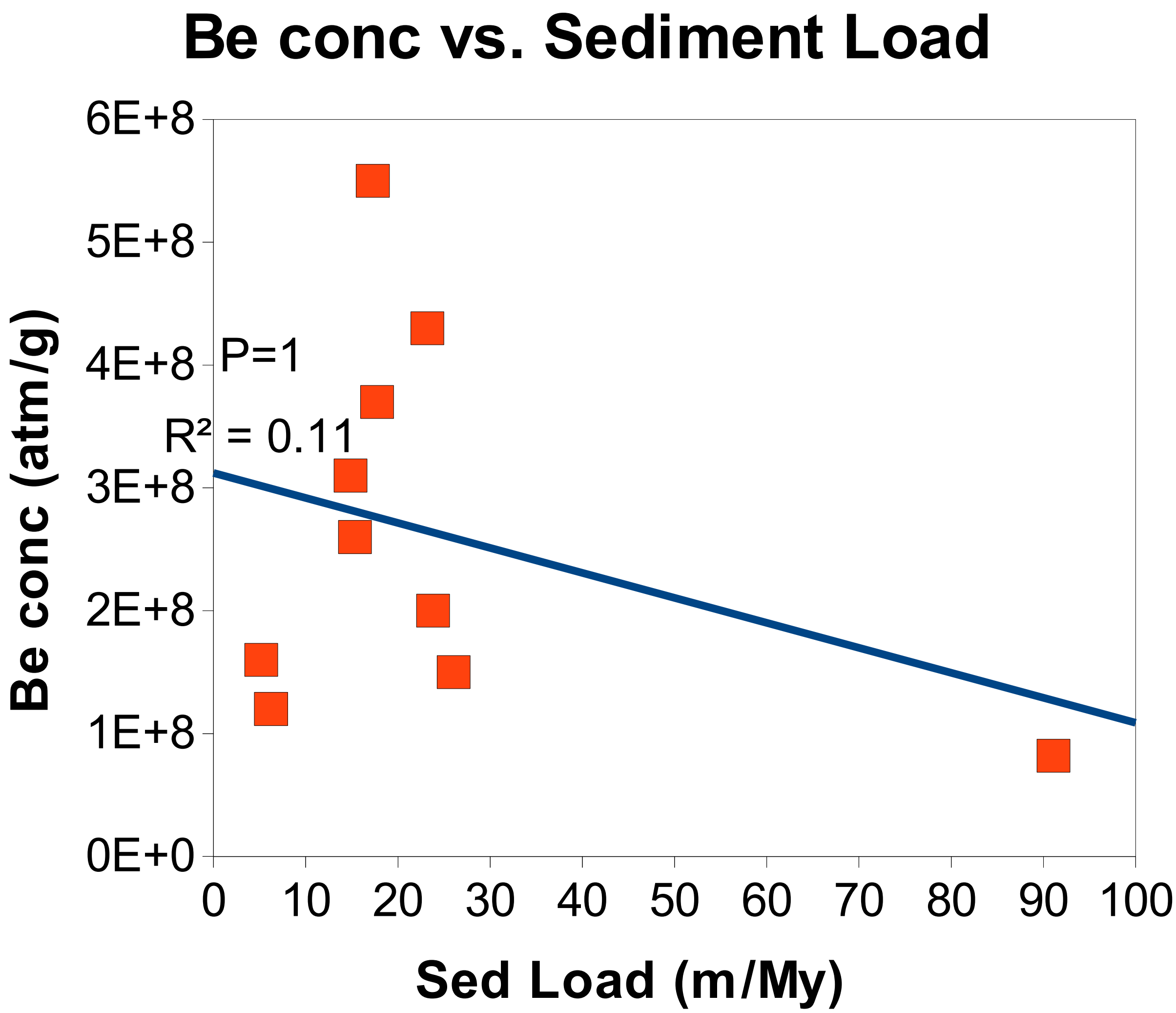

Figure 5
This graph shows the lack of correlation between sediment load and ^{10}Be concentration. The points are completely random, shown by the P-Value of 1.00. This means that the amount of sediment leaving a basin has nothing to do with how much meteoric ^{10}Be is leaving the basin.

Location	Be Conc (atms/g)	Erosion (m/My)	Basin Area (km2)	Sed. Load (m/My)	Calc. Index
1646580	2E+8	24	19000	24	1.59
1650500	8E+7	59	34	91	2.5
1647740	1E+8	41	20	6	0.25
1647720	2E+8	33	16	26	1.31
1638500	3E+8	19	16000	15	1.33
1656120	2E+8	29	460	5	0.28
1631000	4E+8	13	2600	18	2.19
1603000	4E+8	11	1400	23	3.33
1614500	6E+8	9	800	17	3.18
1639000	3E+8	16	280	15	1.54
POT25	6E+7	77	19		
POT43	3E+8	18	16		
POT50	3E+8	17	12		
POT58	3E+8	15	6		
POT63	2E+8	23	7		

Table 1

The first column is the gaging station number or the sample site number; refer to figure two for locations. The second column is the meteoric ^{10}Be concentration at measured at each location. The third column is the erosion rate at each site assuming steady state. The fourth column is the basin area for each site. The fifth column is the amount of sediment leaving each basin in meter per million years; this is calculated from modern sediment loads. The final column is the erosion index for each site.

Region	Rate	Type	Author
Great Smokey	25-30 m/My	10Be	Matmon et al. (2003)
Susquehanna	4-54 m/My	10Be	Reuter et al. (2006)
Shenandoah	3.8-24 m/My	10Be	Duxbury et al. (accepted)
Blue Ridge	6.5-38 m/My	10Be	Sullivan et al. (accepted)
Appalachians	29 m/My	Thermochronology	Pazzaglia and Brandon (1996)
Southern Apps	16-36 m/My	Thermochronology	Roden (1990)
Blue Ridge	20 m/My	Thermochronology	Naeser et al. (2004)
Blue Ridge	9-29 m/My	Thermochronology	Spotila et al. (2003)
New Hampshire	32 m/My	Thermochronology	Doherty and Lyons (1980)

Table 2
This table shows erosion rate measurements from many different places in the Appalachians. Column 1 is the regions for which the erosion rates were calculated. Column 2 is the range of erosion rates for each location. Column 3 is what was used to determine the erosion rate.

Current	Final Density Separations GIS Work Powdering Samples
Winter 2009	Finish Etching Quartz Purity Testing Clean Any Dirty Sample Powder Core Sample Mineral Seperation of four core samples Finish Meteoric Chemistry
Start of 2010	In situ Chemistry Get All Meteoric Data
Spring 2010	Finish All Lab Work All Data Should Be Back From LLNL Data Analysis Start Thesis
Summer 2010	Finish Thesis Prepare Papers for Journal Submissions
Fall 2010	Present Thesis Defence Present Final Work at GSA Annual Meeting

Table 3

References

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