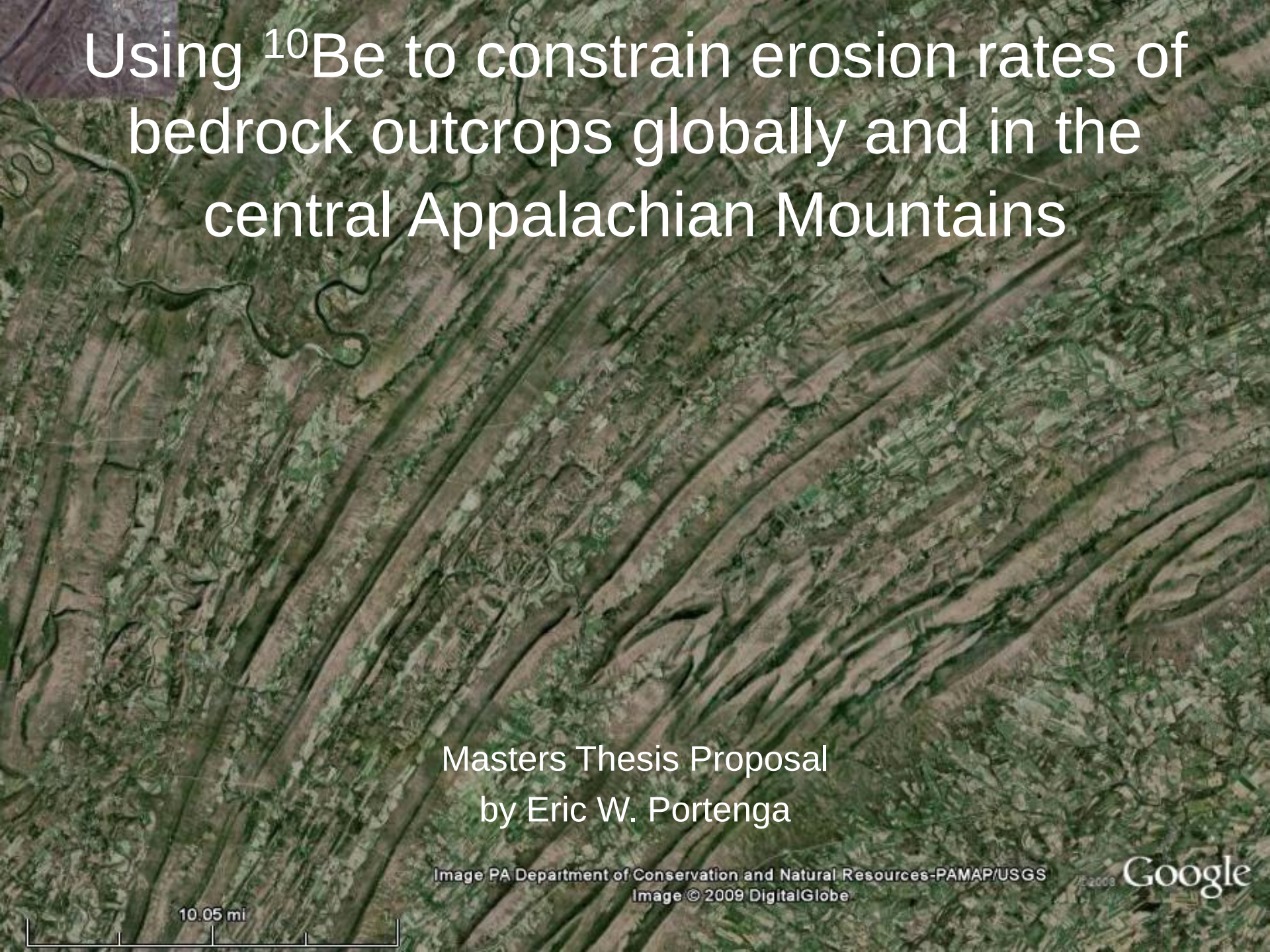
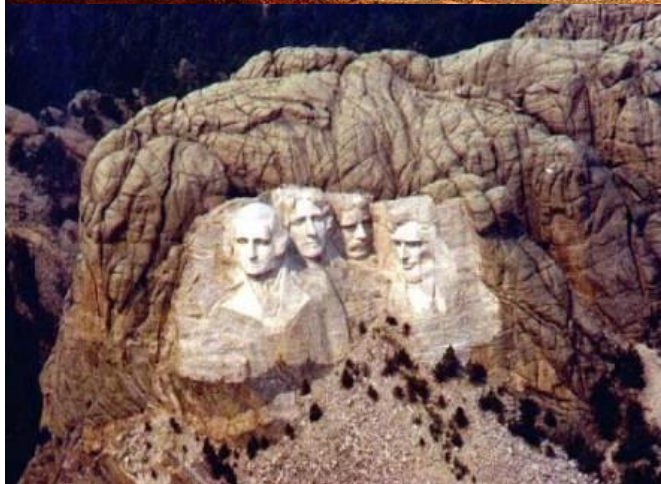
Using ^{10}Be to constrain erosion rates of bedrock outcrops globally and in the central Appalachian Mountains

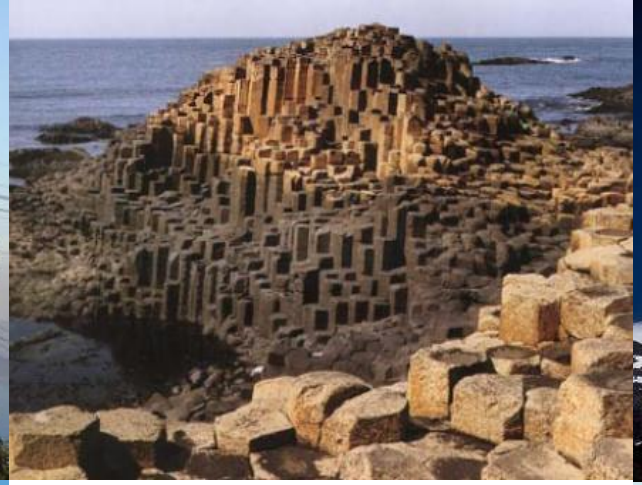
Masters Thesis Proposal
by Eric W. Portenga



Outline

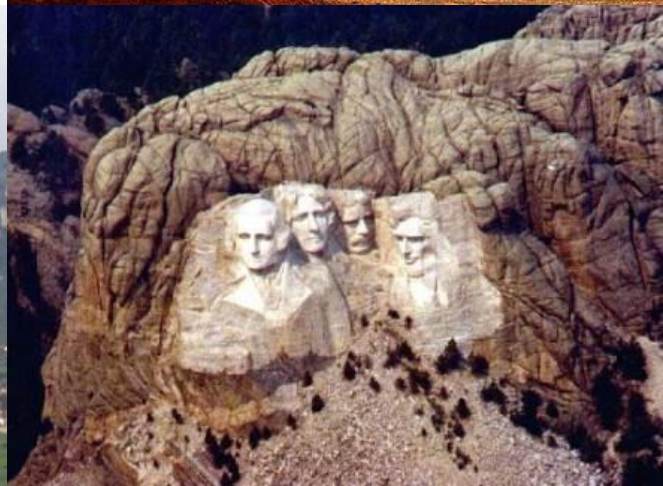
- Background
- Questions
- Objectives
- Cosmogenic ^{10}Be methods
- Global outcrop erosion
- Field methods
- Lab methods
- Timeline



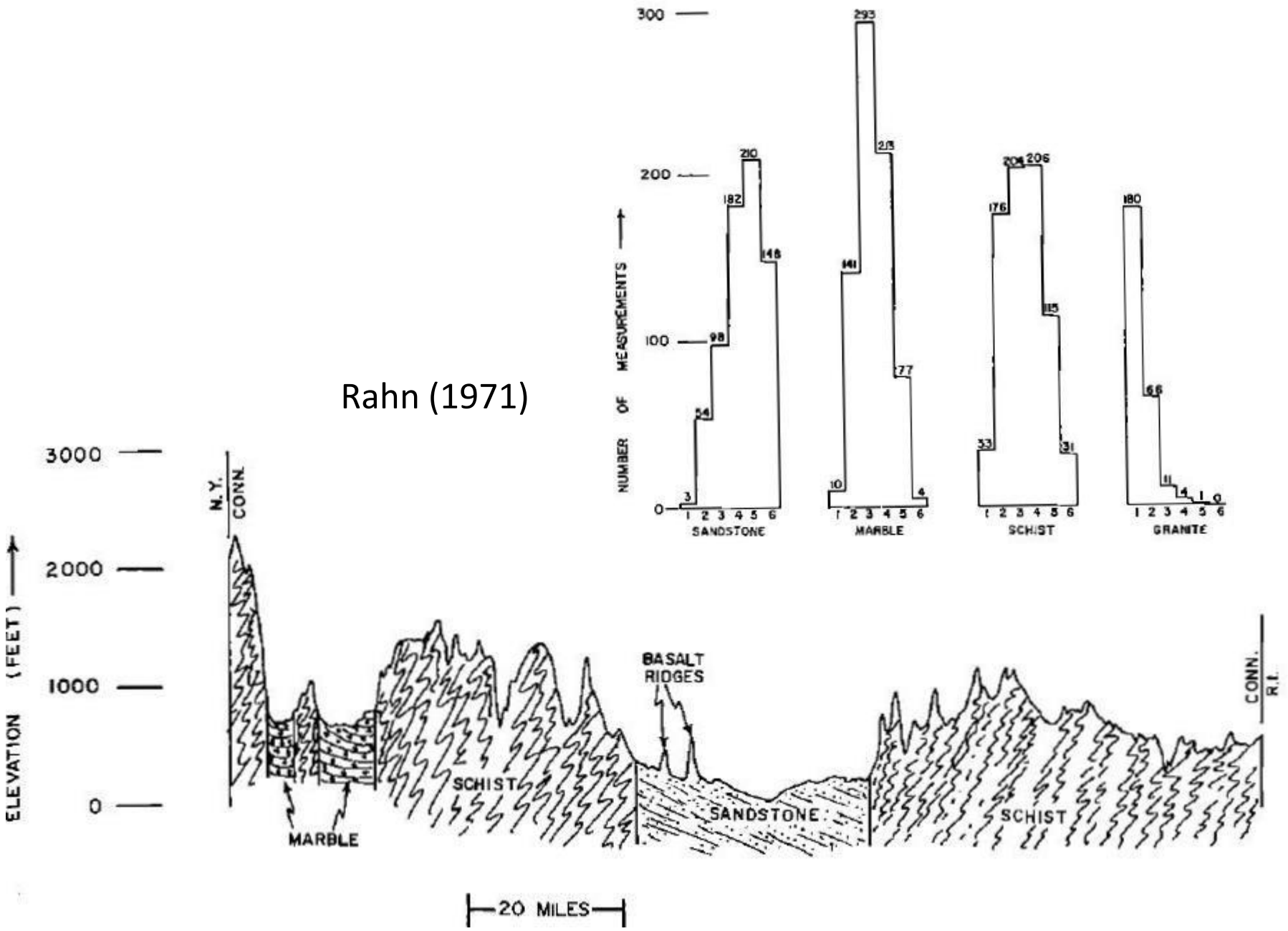
Why?



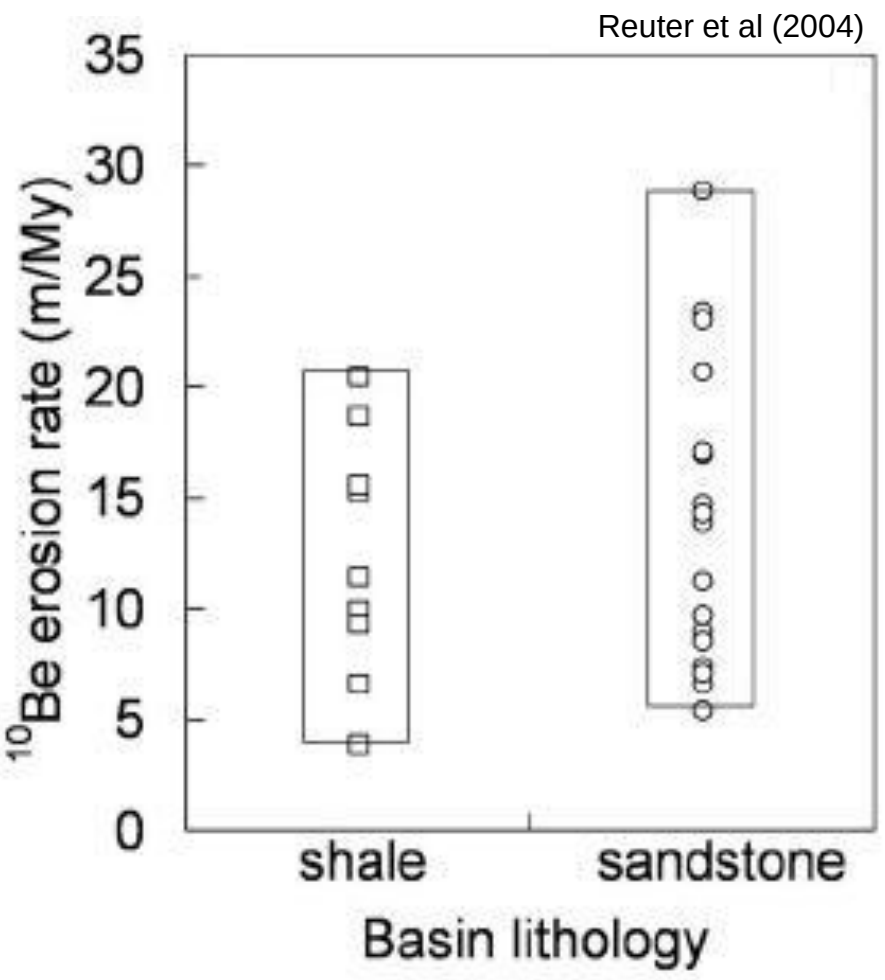



Outcrop Erosion Rate Difficulties

- Tends to be slow and unnoticeable over the span of a human's lifetime
- Tombstone studies
  - Matthias (1967)
  - Judson (1968)
  - Rahn (1971)


Rahn (1971)
NUMBER OF MEASUREMENTS
300
200
100
0
SANDSTONE
MARBLE
SCHIST
GRANITE
ELEVATION (FEET)
3000
2000
1000
0
N.Y.
CONN.
MARBLE
SCHIST
BASALT RIDGES
SANDSTONE
SCHIST
CONN.
R.I.
20 MILES

- Hack (1960) suggests that topography of landscapes is heavily influenced by lithology
  - Granite → resistant → large positive relief
  - Shale → not resistant → low relief
- Reuter et al. (2004) discovered that lithology does not play as important a role in controlling erosion rates

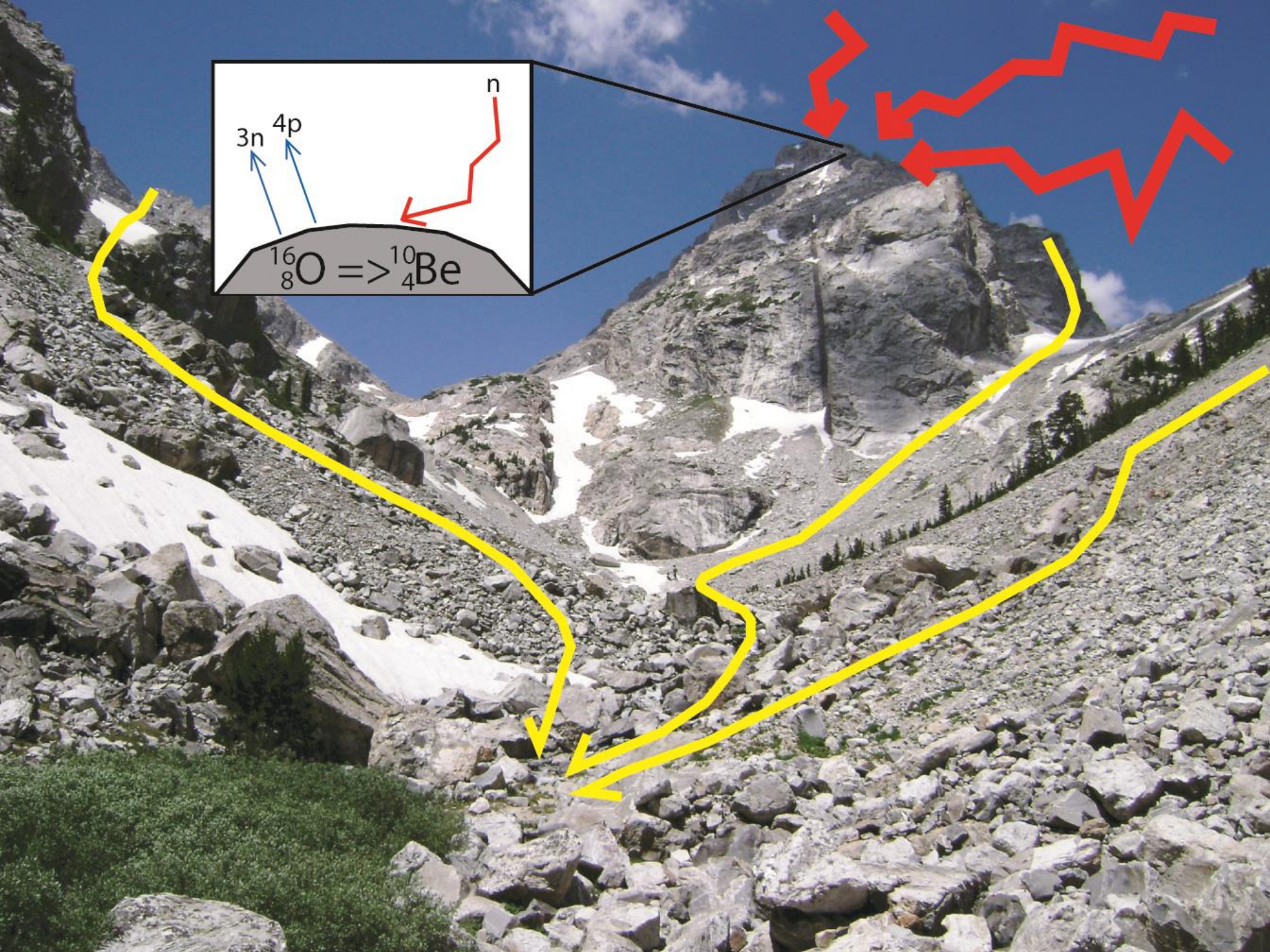


Questions

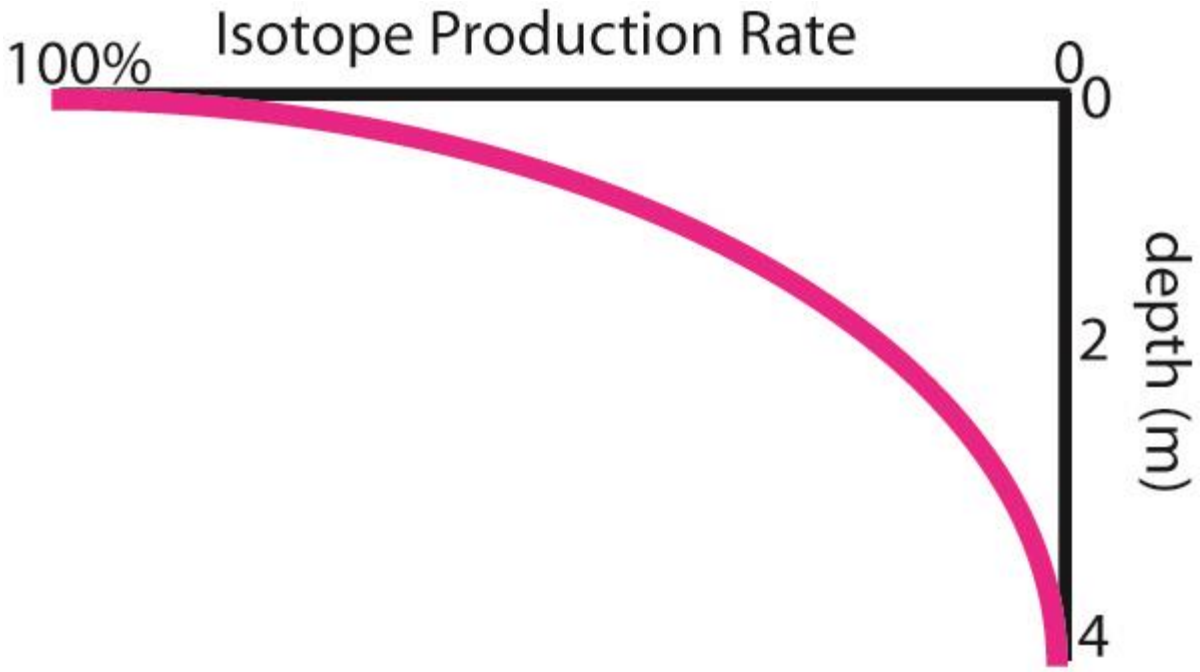
- How quickly does exposed bedrock erode?
- What physical parameters hold control over erosion rates?
- Are there patterns in global exposed bedrock erosion rates?
- How do erosion rates determined by cosmogenic radionuclide methods compare to other methods?

Objectives

- Determine erosion rates from exposed bedrock samples in the Appalachian Mountains using the ^{10}Be method (n≈40)
- Compile ^{10}Be exposed bedrock erosion rates from the current literature and look for spatial patterns
- Compare exposed bedrock erosion rates with those determined by the basin-scale approach
- Compare ^{10}Be exposed bedrock erosion rates with other thermochronometers
  - Apatite Fission Track Thermochronology
  - (U-Th)/He


n
3n
4p
$^{16}_{8}O$ => $^{10}_{4}Be$

^{10}Be Production Rates



Adapted from Bierman & Nichols (2004)

Quartz is most commonly used mineral for ^{10}Be erosion rates

- –Ubiquitous mineral phase
- –Easy to separate atmospheric ^{10}Be from *in-situ* ^{10}Be
- –Easy to separate quartz from other mineral phases

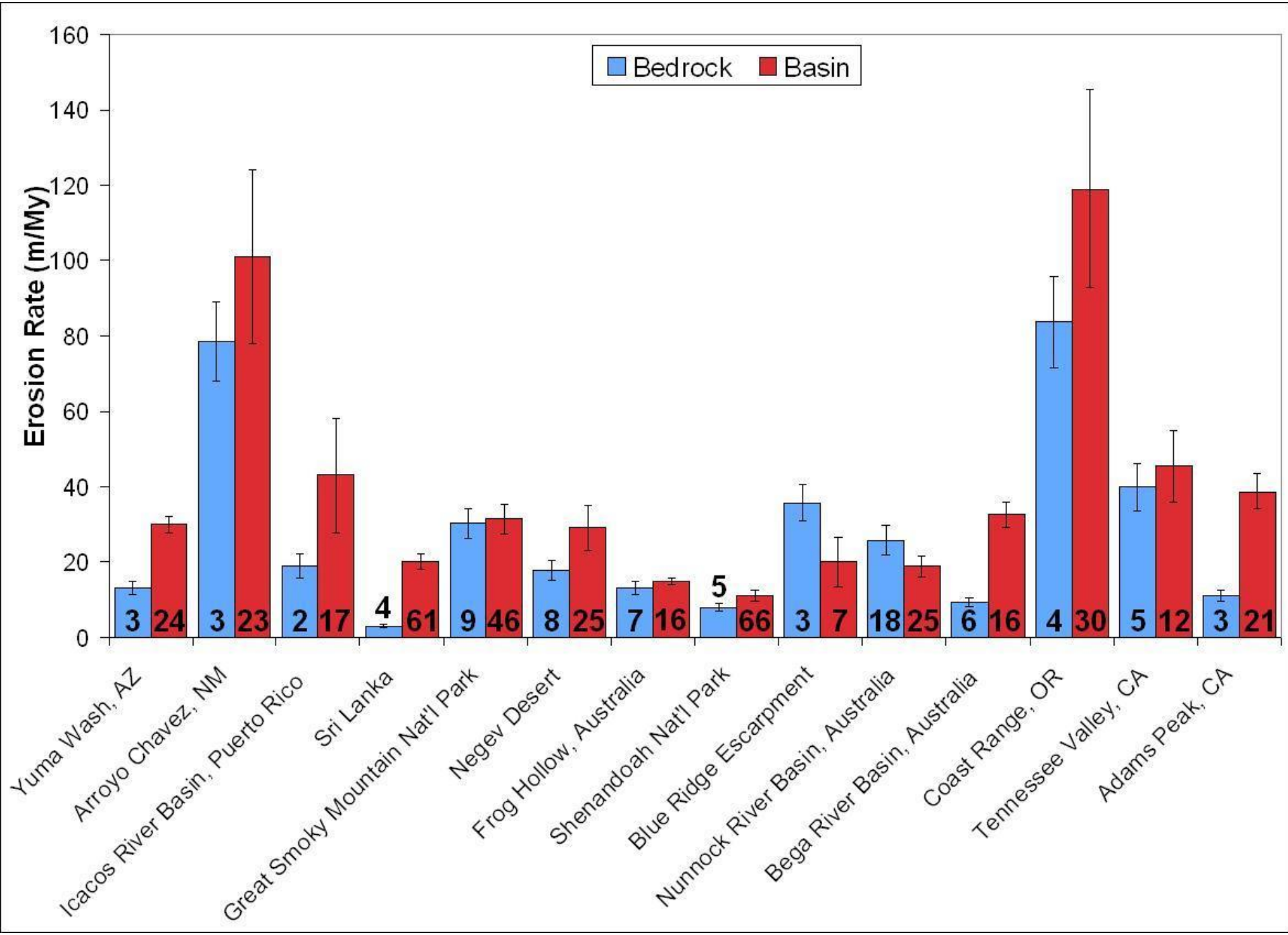
Global Exposed Bedrock Analysis

- Many cosmogenic radionuclide erosion studies utilize the basin-wide average ^{10}Be method
- Very few look only at exposed bedrock

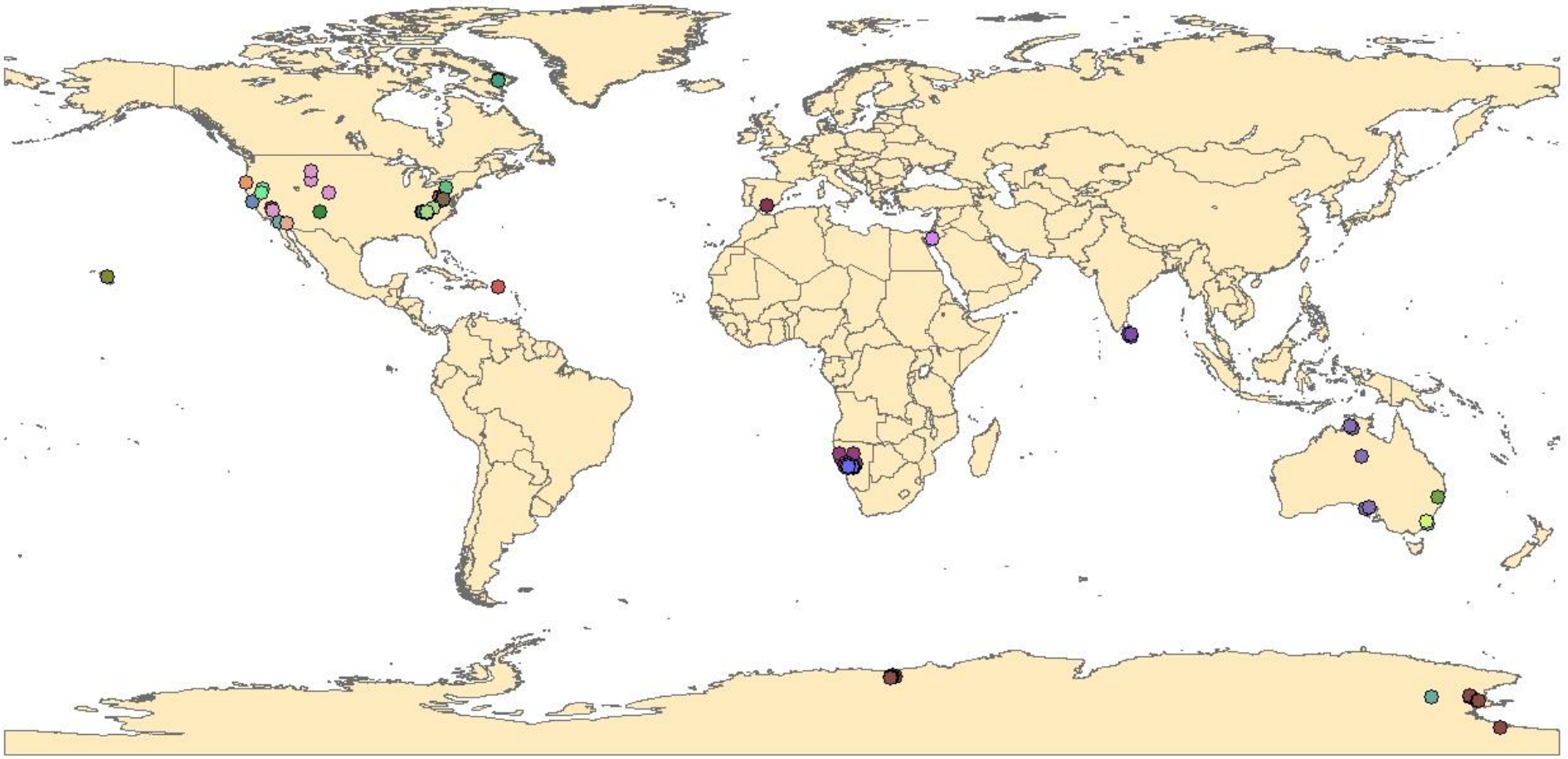
Bedrock Outcrop Erosion Summary Table

Study No.	Study Location	No. of Samples	Focus*	Reference
1	Namib Desert and Escarpment, Namibia	48	O	Bierman and Caffee (2001)
2	Eyre Peninsula, Australia	75	O	Bierman and Caffee (2002)
	Northern Territory, Australia	18		
3	Cumberland Peninsula, Baffin Island, Canada	7	O	Bierman et al. (1999)
4	Luquillo Experimental Forest, Puerto Rico	2	B	Brown et al. (1995)
5	Negev Desert, Israel	8	B	Clapp et al. (2000)
6	Arroyo Chavez Basin, NM, USA	3	S	Clapp et al. (2001)
7	Yuma Wash, AZ, USA	3	S	Clapp et al. (2002)
8	Namib Desert, Namibia	20	O	Cockburn (2000)
9	Shenandoah National Park, VA, USA	5	B	Duxbury (2008)
10	Adams Peak, CA, USA	3	B	Granger et al. (2001)
11	Dolly Sods, WV, USA	9	O	Hancock and Kirwin (2007)
12	Tennessee Valley, CA, USA	5	S	Heimsath et al. (1997)
13	Southeast Australian Escarpment, Australia	6	S	Heimsath et al. (2000)
14	Frog Hollow, Souteast Australia	7	B	Heimsath et al. (2001)
15	Coast Range, OR, USA	4	S	Heimsath et al. (2001)
16	Southeast Australian Escarpment, Australia	18	S	Heimsath et al. (2006)
17	Laurely Fork, PA, USA	2	B	Jungers et al. (2006)
18	Great Smoky Mountains, TN & NC, USA	10	B	Matmon et al. (2003b)
19	Alabama Hills, CA, USA	20	O	Nichols et al. (2006)
20	Allan Hills, Antarctica	1	O	Nishiizumi et al. (1986)
	Anza Borrego, CA, USA	2		
21	Haleakala Volcano, HI, USA	1	O	Nishiizumi et al. (1990)
22	Allan Hills, Antarctica	9	O	Nishiizumi et al. (1991)
	Reckling Peak, Antarctica	2		
	Sör Rondane, Antarctica	8		
	Tillite Glacier, Antarctica	4		
	Wright Valley, Antarctica	4		
23	Torrente Catchment, Sierra Nevada, Spain	8	B	Reinhardt et al. (2007)
24	Wind River Range, WY, USA	7	O	Small et al. (1997)
	Beartooth Mountains, MT, USA	5		
	Front Range, CO, USA	4		
	Sierra Nevada, CA, USA	3		
25	Blue Ridge Escarpment, USA	3	B	Sullivan (2007)
26	Sri Lanka	4	B	Von Blanckenburg et al. (2004)
27	Baker's Creek, southeastern Australia	1	O	Weissel and Seidl (1998)

*O=Bedrock Outcrops, B=Basin-wide, S=Sediment, Soil or Boulder shielding


Bedrock
Basin
Erosion Rate (m/My)
0
20
40
60
80
100
120
140
160
3
24
3
23
2
17
4
61
9
46
8
25
7
16
5
66
3
7
18
25
6
16
4
30
5
12
3
21
Yuma Wash, AZ
Arroyo Chavez, NM
Icacos River Basin, Puerto Rico
Sri Lanka
Great Smoky Mountain Nat'l Park
Negev Desert
Frog Hollow, Australia
Shenandoah Nat'l Park
Blue Ridge Escarpment
Nunnock River Basin, Australia
Bega River Basin, Australia
Coast Range, OR
Tennessee Valley, CA
Adams Peak, CA

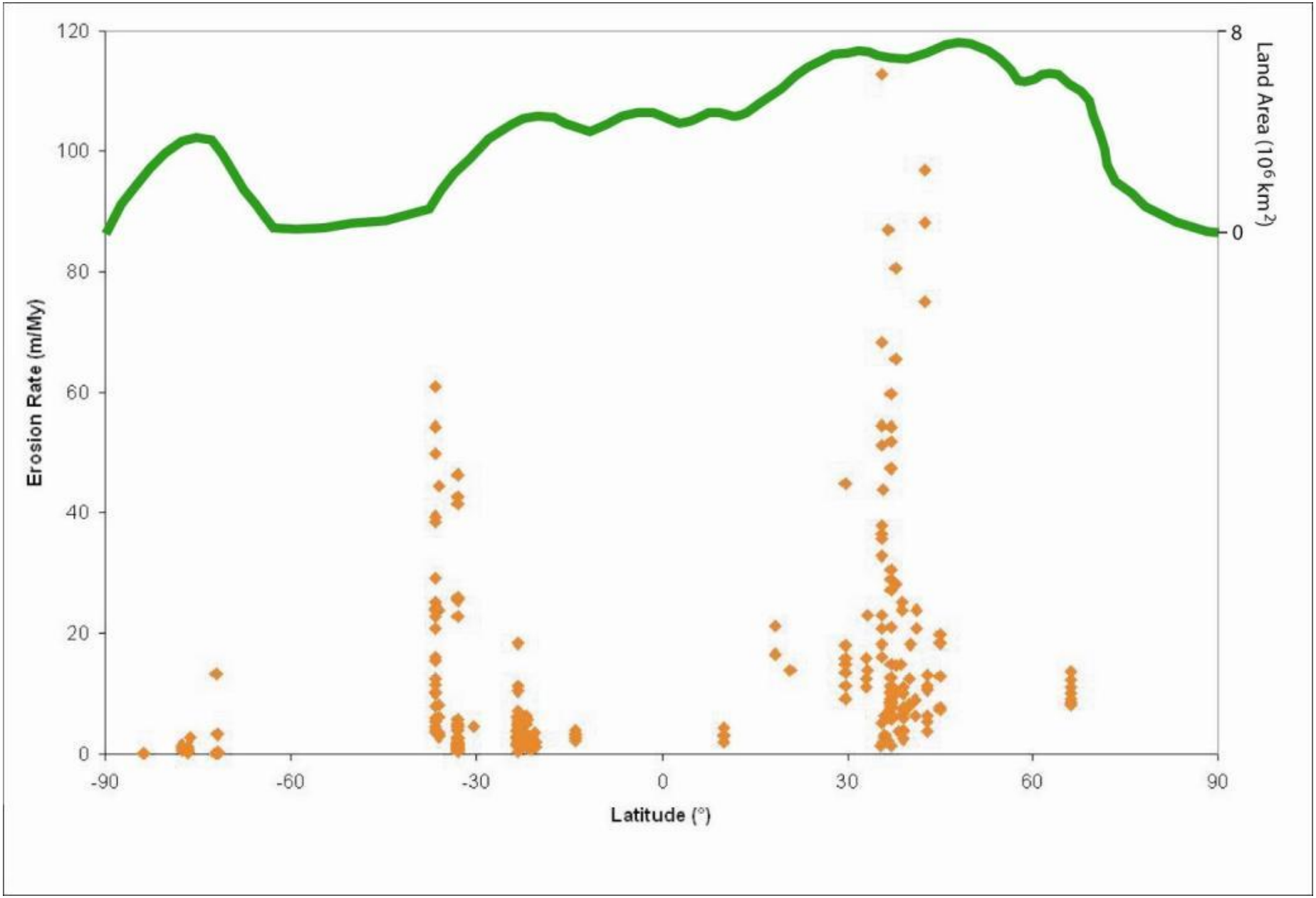
Global ^{10}Be Erosion Data



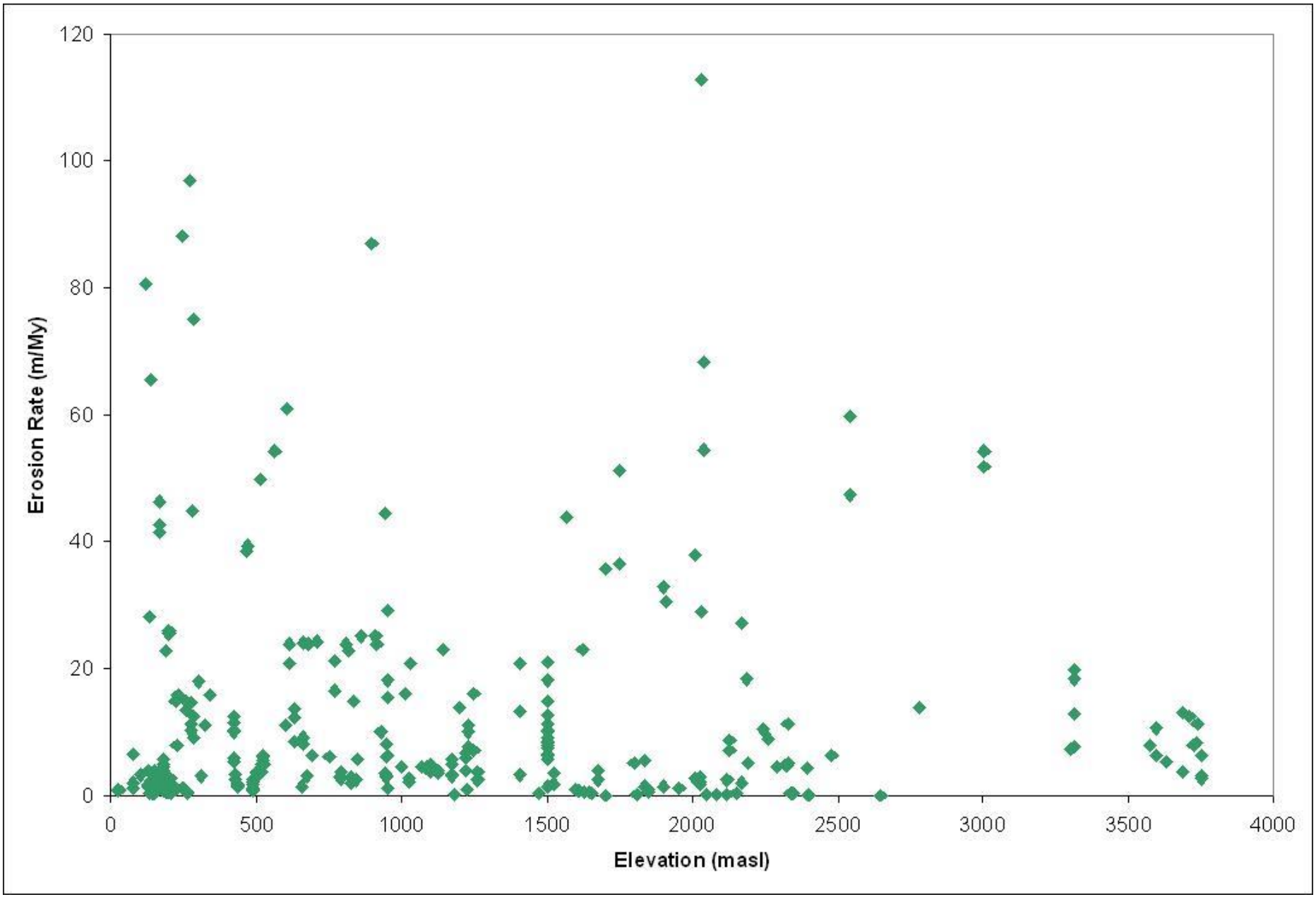
Physical Parameters

- Latitude
- Elevation
- Lithology
- Mean annual precipitation
- Mean annual air temperature

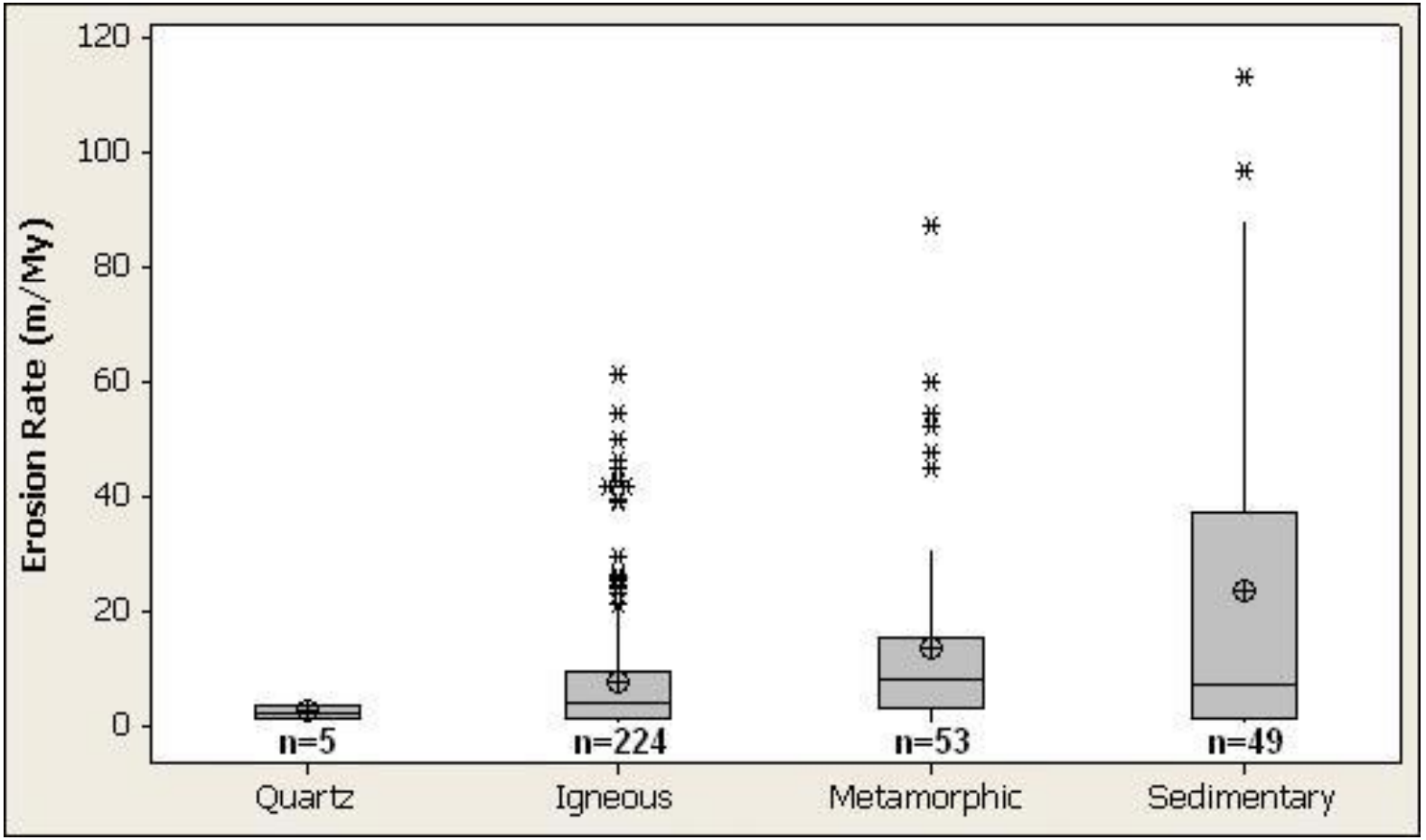
Latitude


120
100
80
60
40
20
0
Erosion Rate (m/My)
8
0
Land Area (10^6 km^2)
-90
-60
-30
0
30
60
90
Latitude (°)

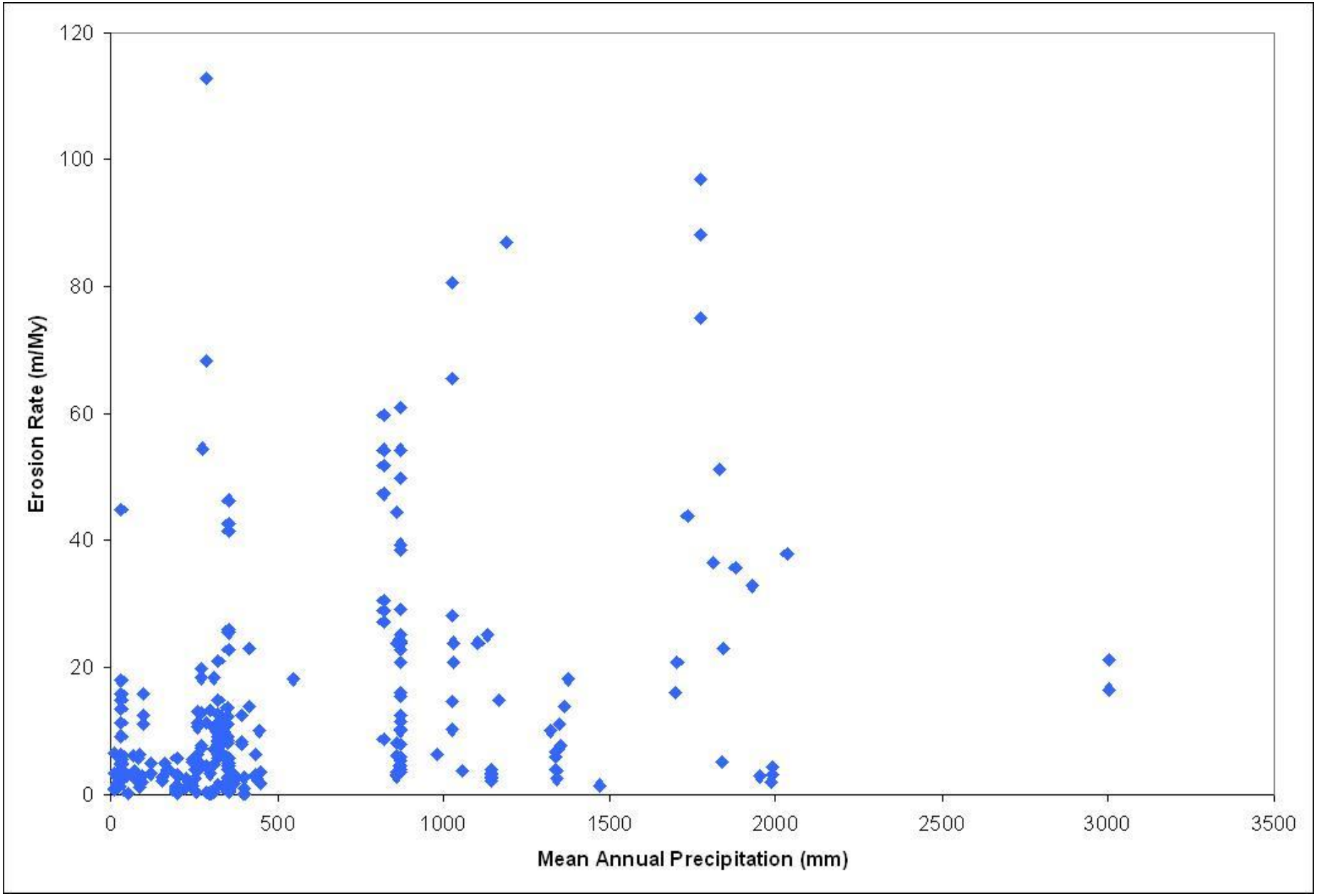
Elevation


120
100
80
60
40
20
0
Erosion Rate (m/My)
0
500
1000
1500
2000
2500
3000
3500
4000
Elevation (masl)

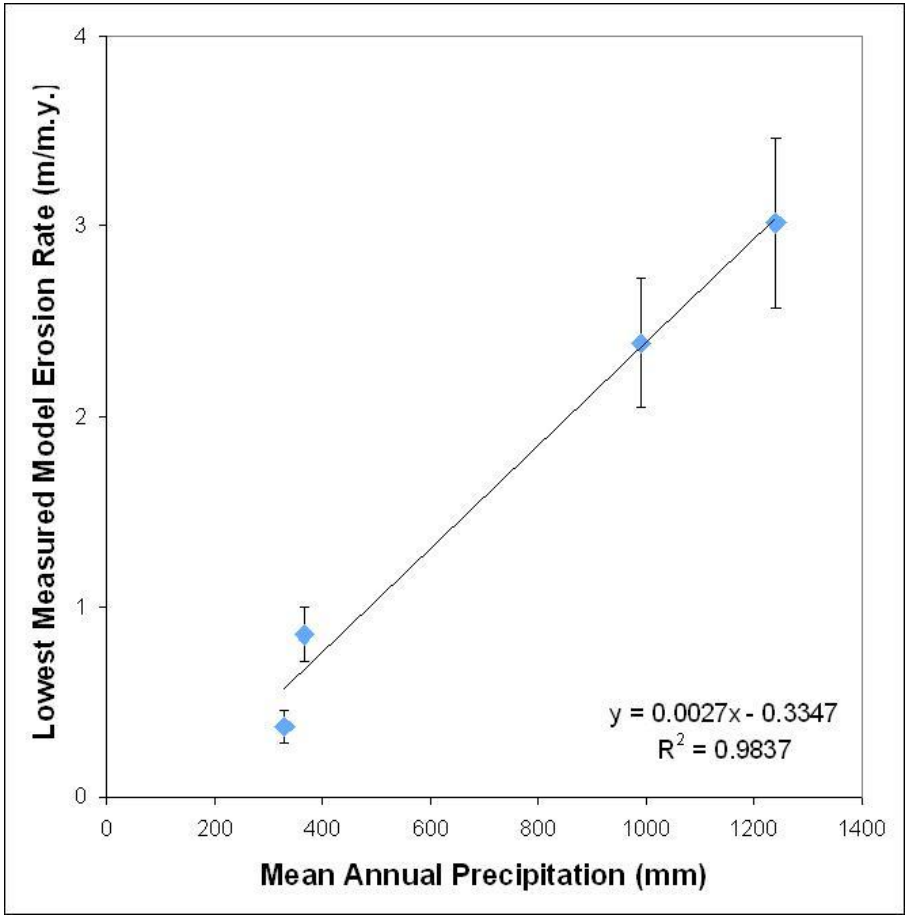
Lithology


Erosion Rate (m/My)
120
100
80
60
40
20
0
n=5
n=224
n=53
n=49
Quartz
Igneous
Metamorphic
Sedimentary

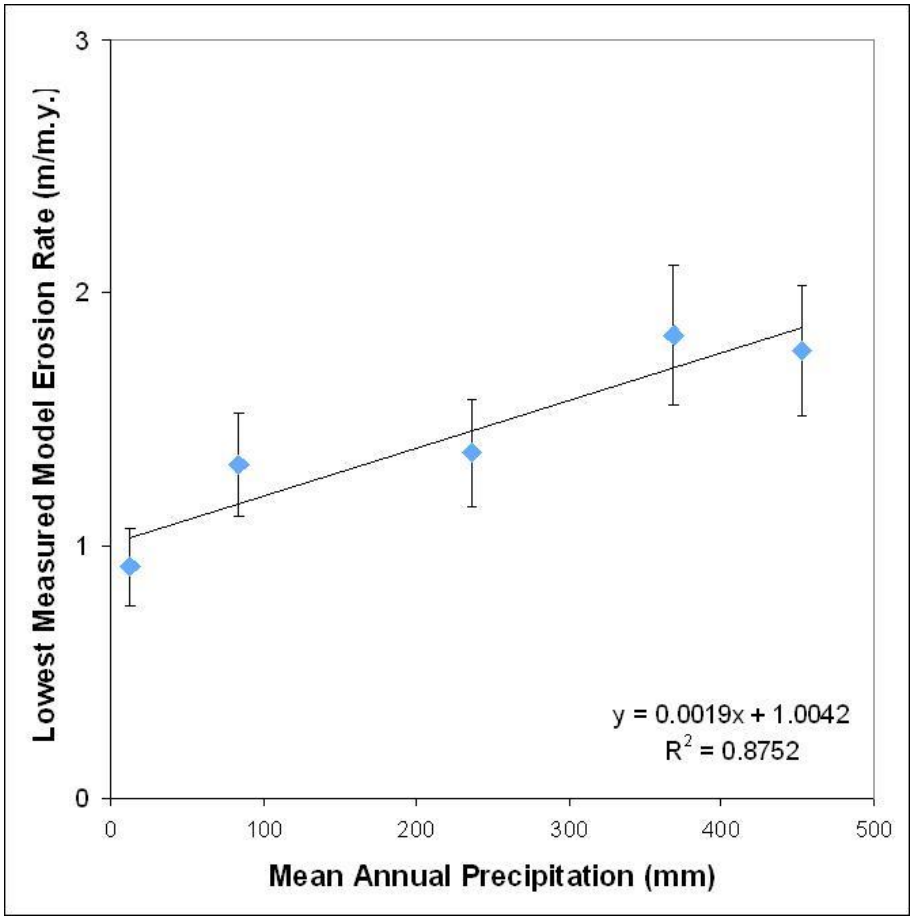
Mean Annual Precipitation



Correlations in MAP

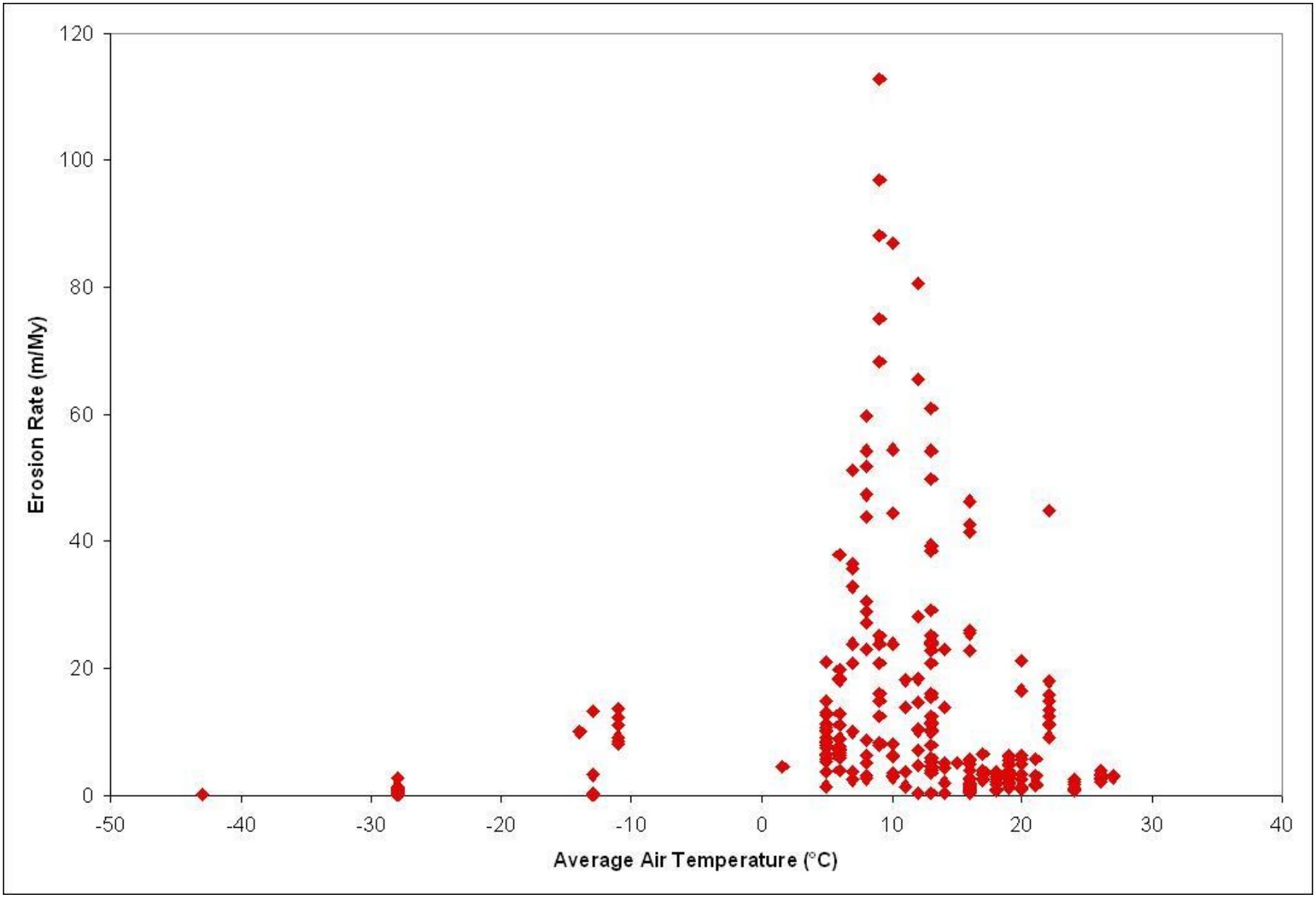


Australia data from Bierman & Caffee (2002)



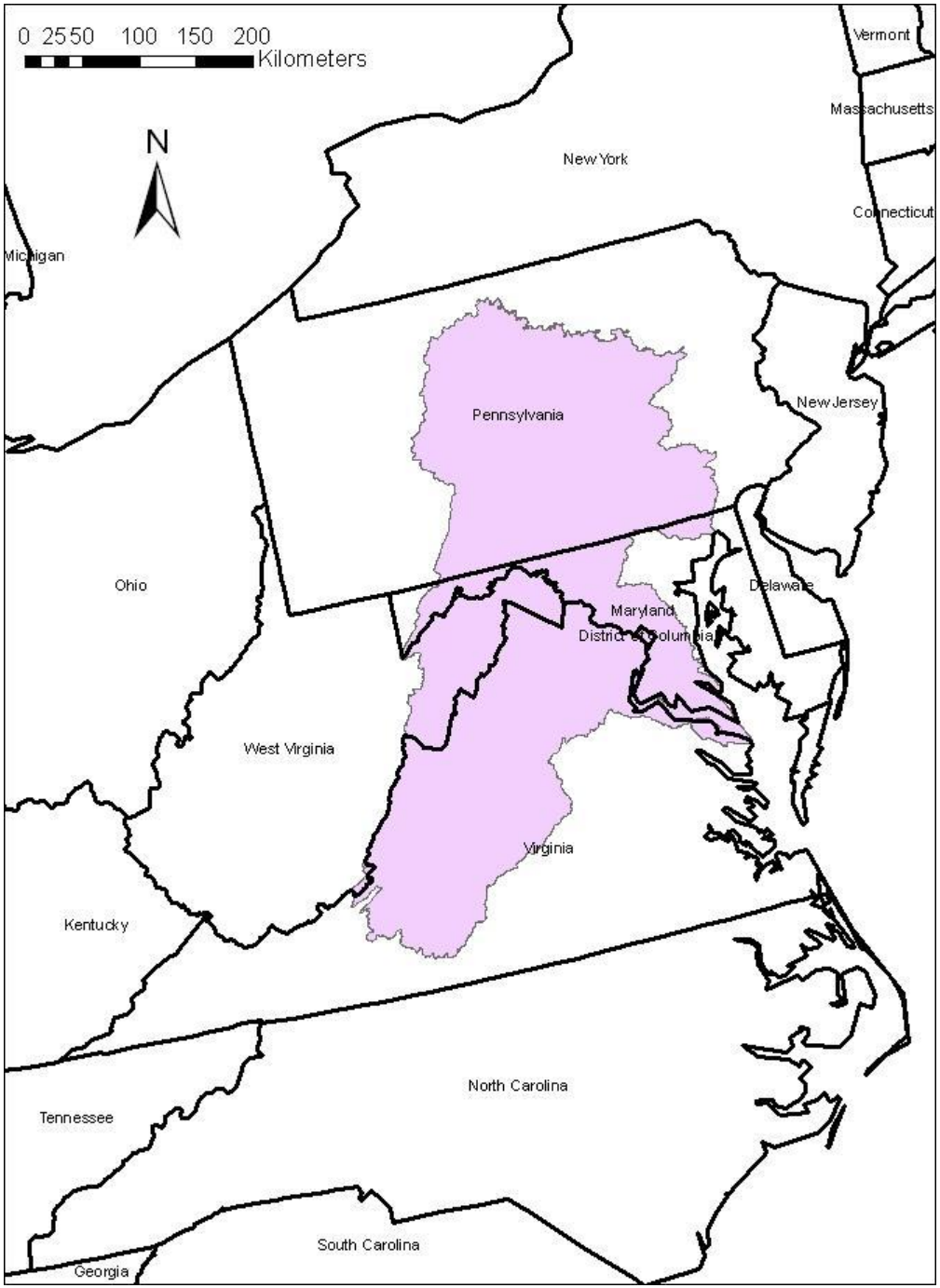
Namibia data from Bierman & Caffee (2001)

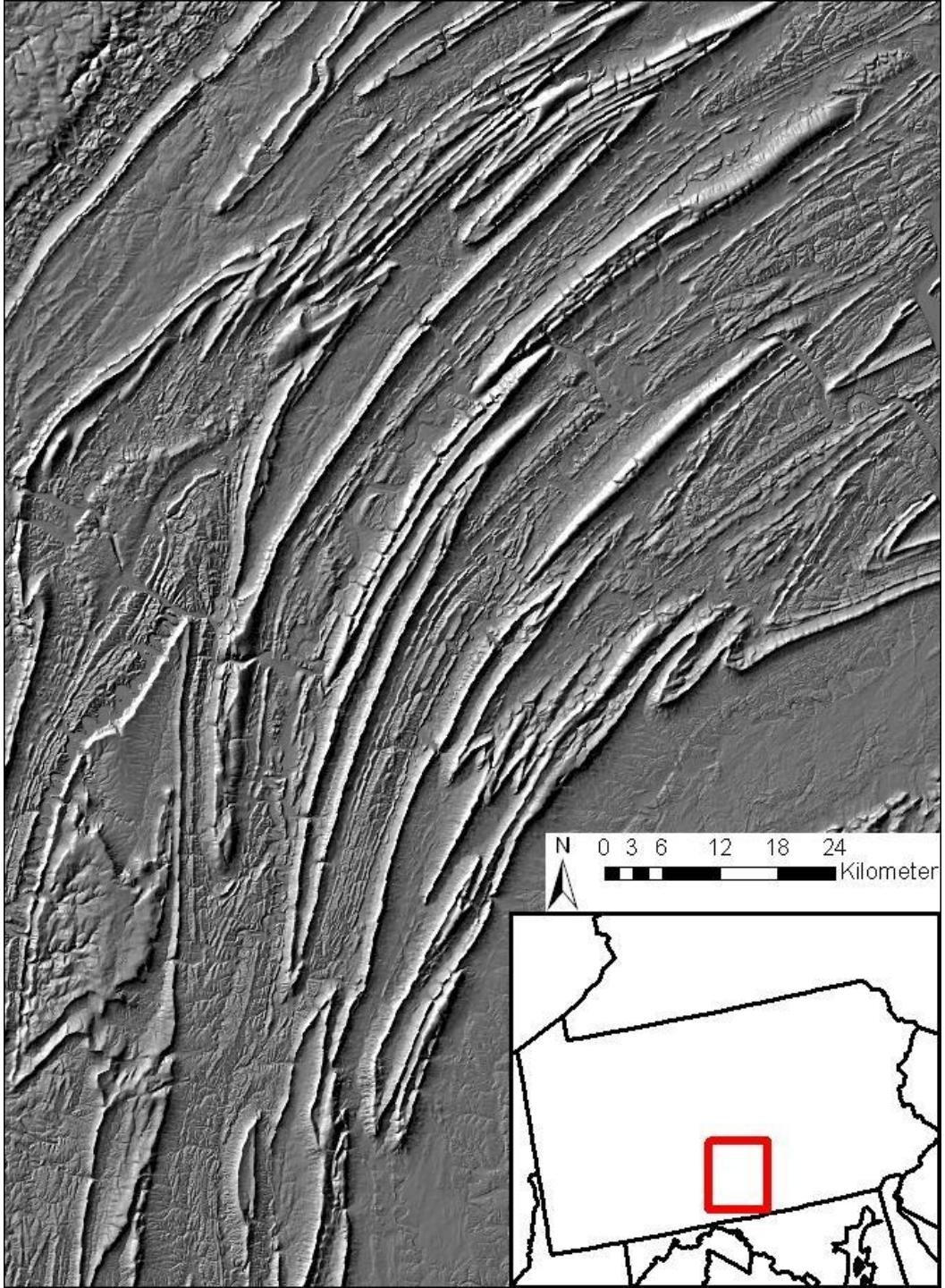
Average Air Temperature

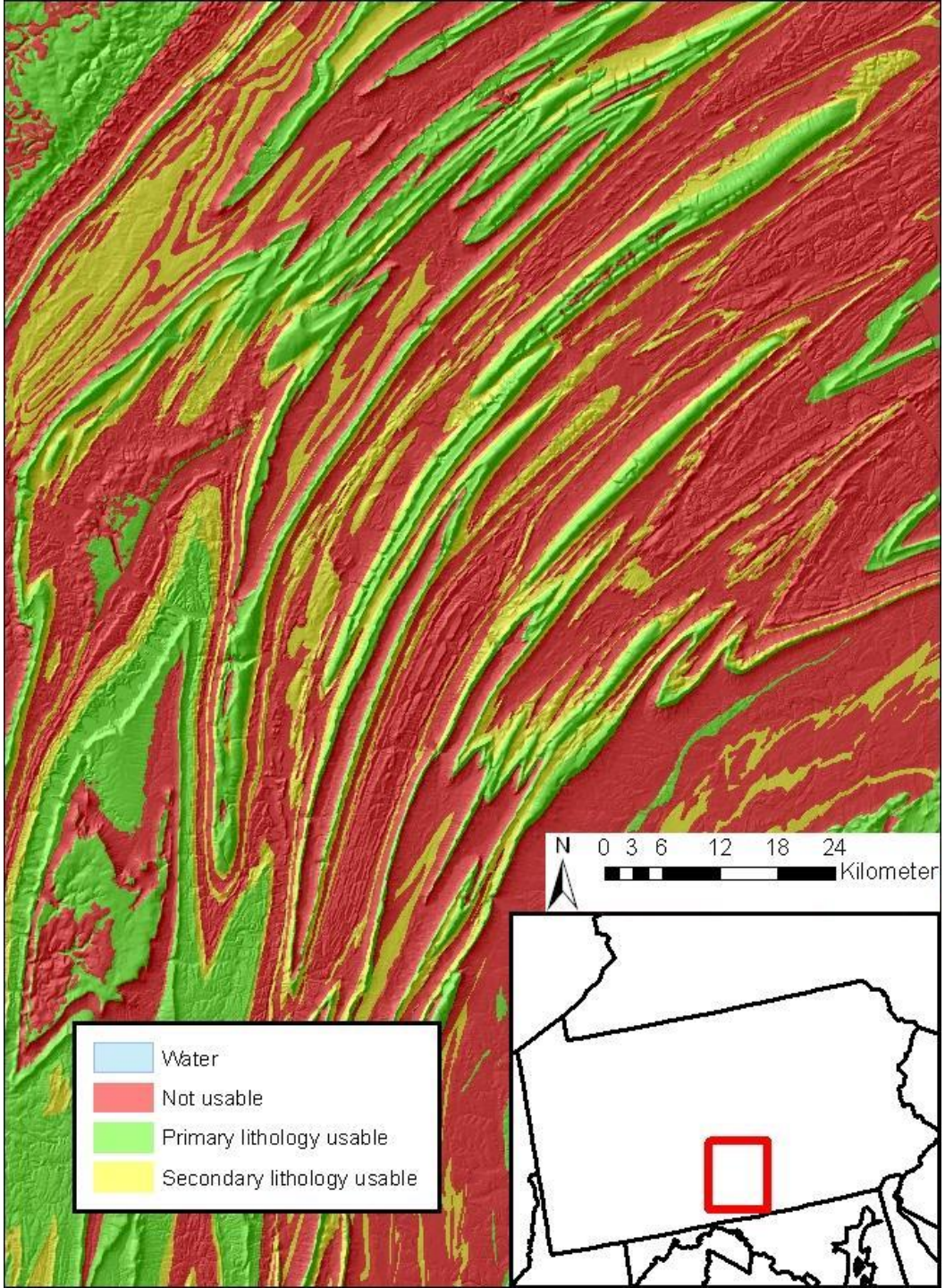


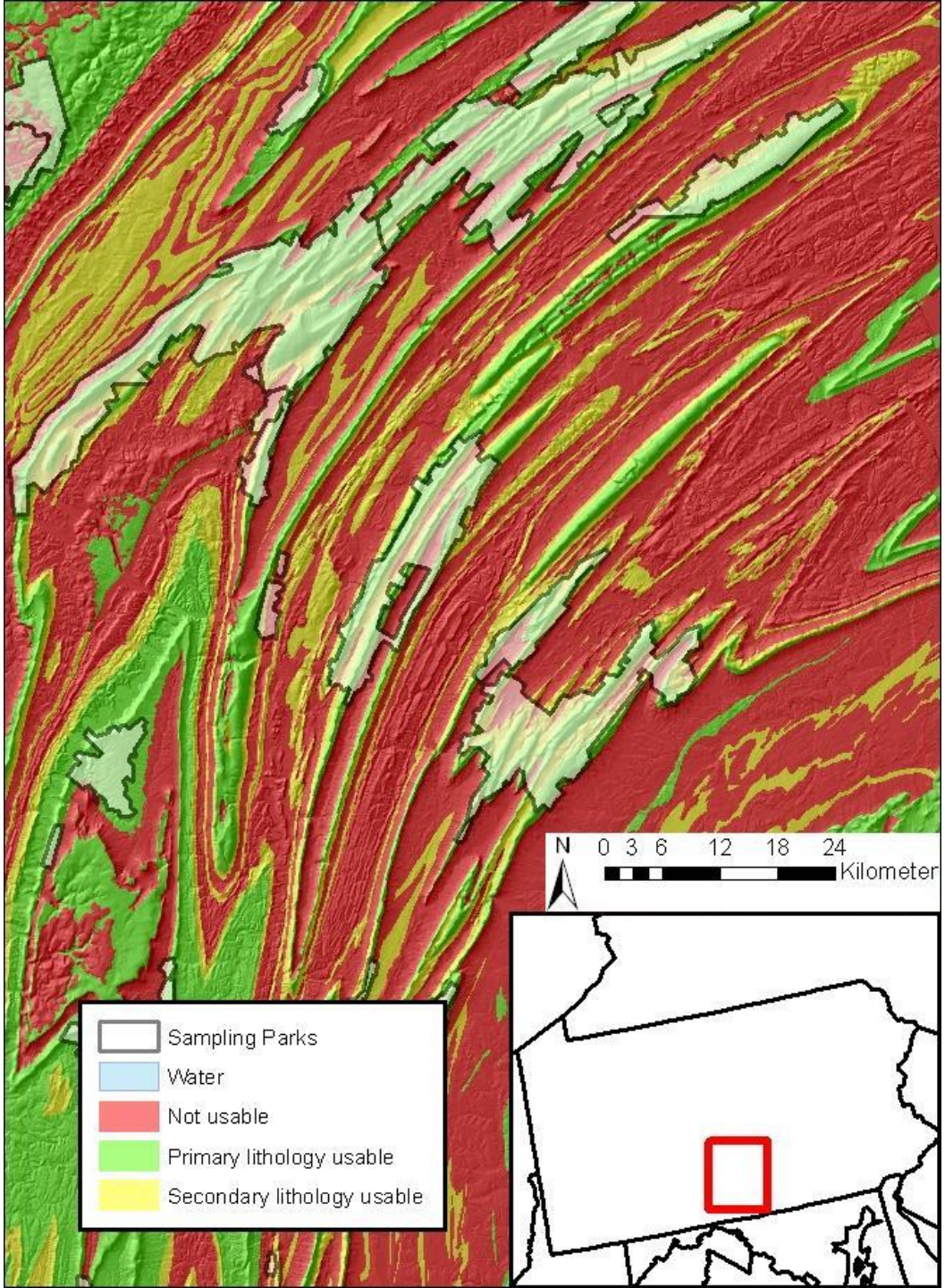
Field Methods

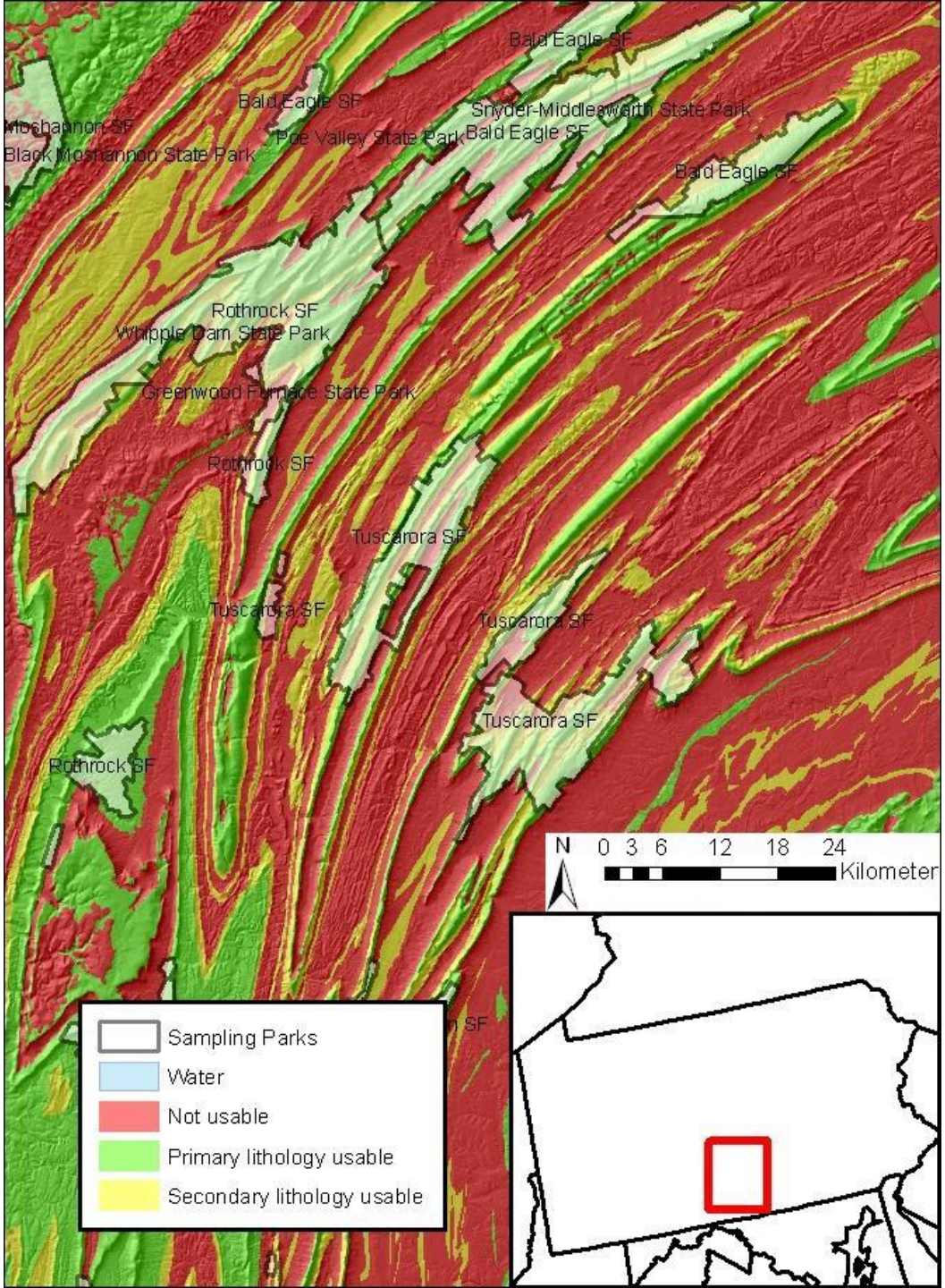
- Collect ~40 samples from the Appalachian Mountains
- Areas already sampled and analyzed for the basin-wide method
- GIS analysis to narrow areas of outcropping bedrock

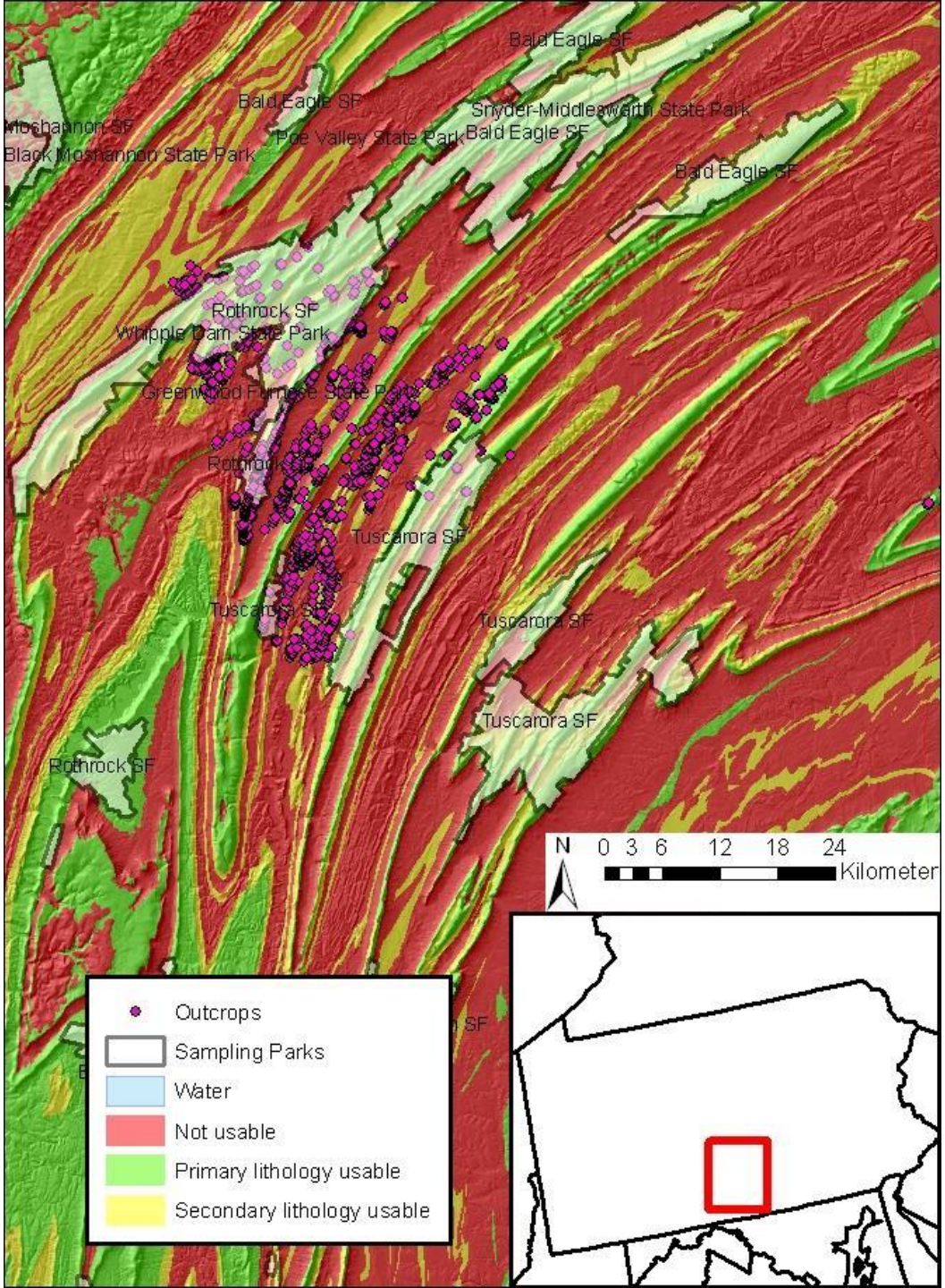



N
0 3 6 12 18 24
Kilometer


N
0 3 6 12 18 24
Kilometer
Water
Not usable
Primary lithology usable
Secondary lithology usable


N
0 3 6 12 18 24
Kilometer
Sampling Parks
Water
Not usable
Primary lithology usable
Secondary lithology usable


Bald Eagle SF
Bald Eagle SF
Snyder-Middleswarth State Park
Bald Eagle SF
Moshannon SF
Black Moshannon State Park
Poe Valley State Park
Bald Eagle SF
Rothrock SF
Whipple Dam State Park
Greenwood Furnace State Park
Rothrock SF
Tuscarora SF
Tuscarora SF
Tuscarora SF
Tuscarora SF
Rothrock SF
N
0 3 6 12 18 24
Kilometer
Sampling Parks
Water
Not usable
Primary lithology usable
Secondary lithology usable


Bald Eagle SF
Bald Eagle SF
Snyder-Middleswarth State Park
Moshannon SF
Black Moshannon State Park
Poe Valley State Park
Bald Eagle SF
Bald Eagle SF
Rothrock SF
Whipple Dam State Park
Greenwood Furnace State Park
Rothrock SF
Tuscarora SF
Tuscarora SF
Tuscarora SF
Tuscarora SF
Rothrock SF
N
0 3 6 12 18 24
Kilometer
Outcrops
Sampling Parks
Water
Not usable
Primary lithology usable
Secondary lithology usable

Laboratory Methods

- Rock crushing to produce monomineralic grains
- Mineral Separation
- Acid baths (HF/HNO_3)
- ICP-OES analysis, testing quartz purity
- Cation exchange to separate Al from Be
- AMS analysis at Lawrence Livermore NL

Timeline

May 2009	•Field Work
Summer 2009	•Sample Prep •Lab work •Prepare abstract for GSA
Fall 2009	•Progress Report •Sample Analysis at LLNL •Attend GSA •Start writing thesis •Take statistics course
Winter 2009/2010	•Continue writing thesis
Spring 2010	•Defend thesis •Joint NE/SE GSA