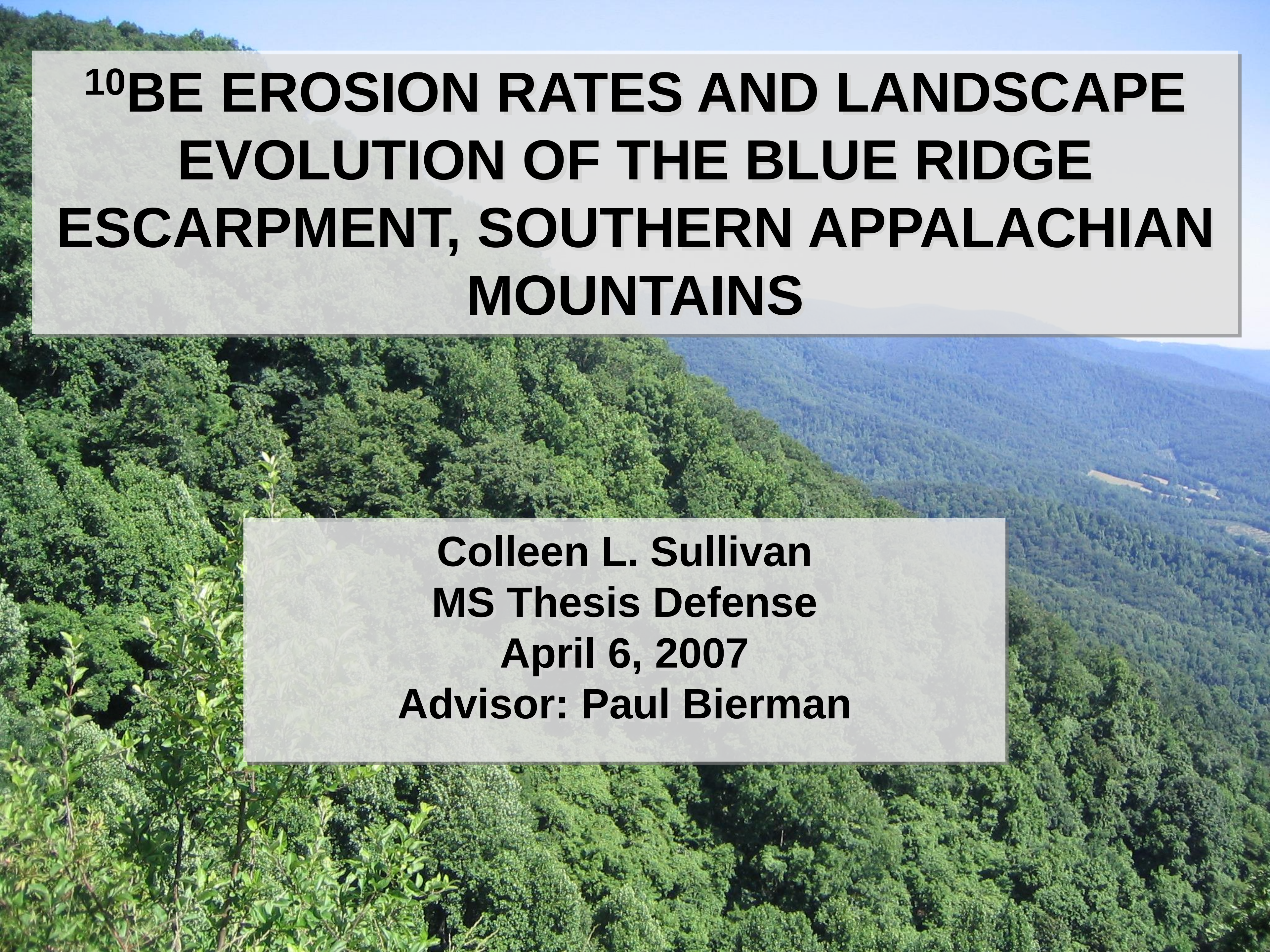
^{10}BE EROSION RATES AND LANDSCAPE EVOLUTION OF THE BLUE RIDGE ESCARPMENT, SOUTHERN APPALACHIAN MOUNTAINS



Colleen L. Sullivan

MS Thesis Defense

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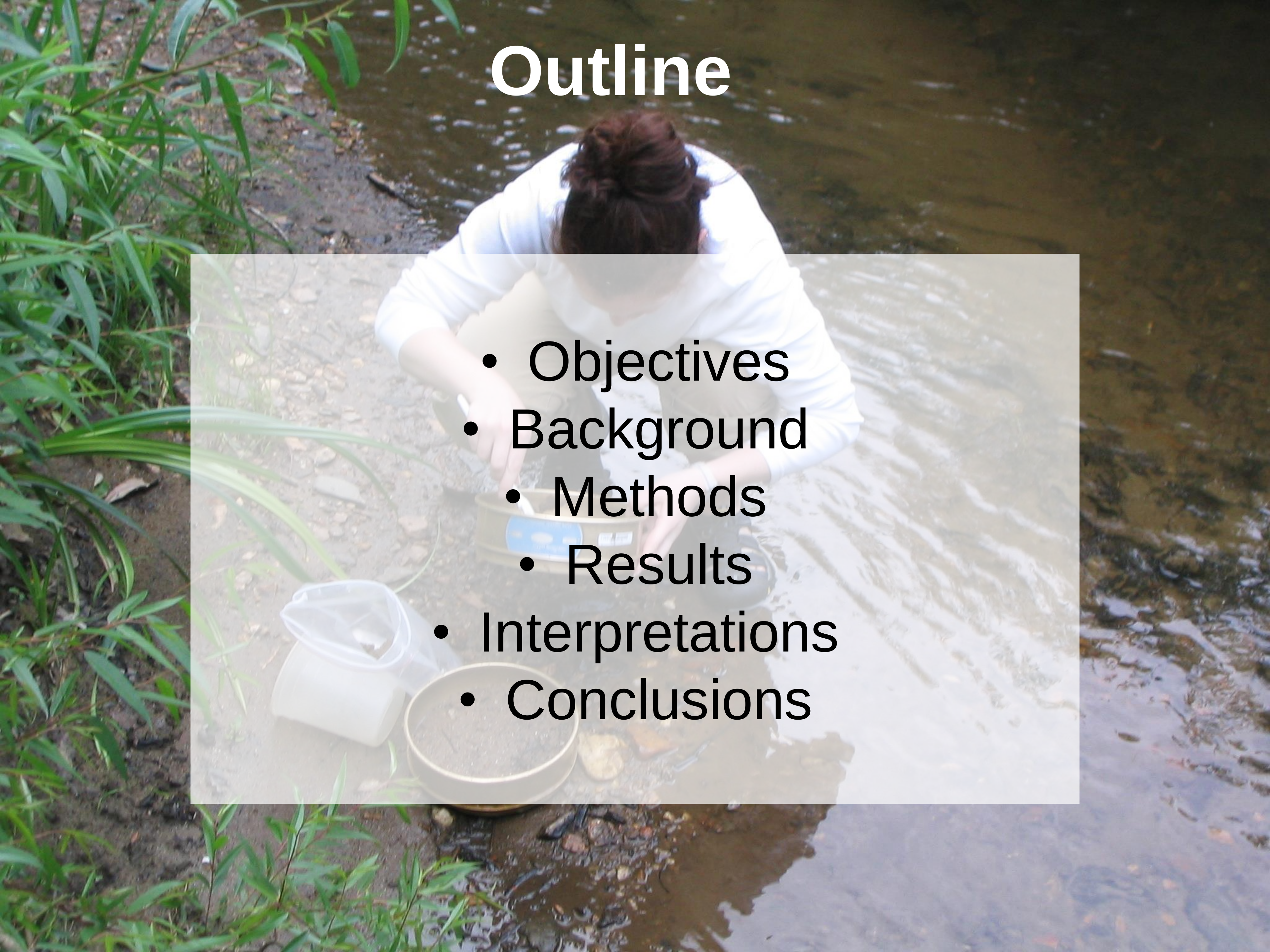
Advisor: Paul Bierman



Outline

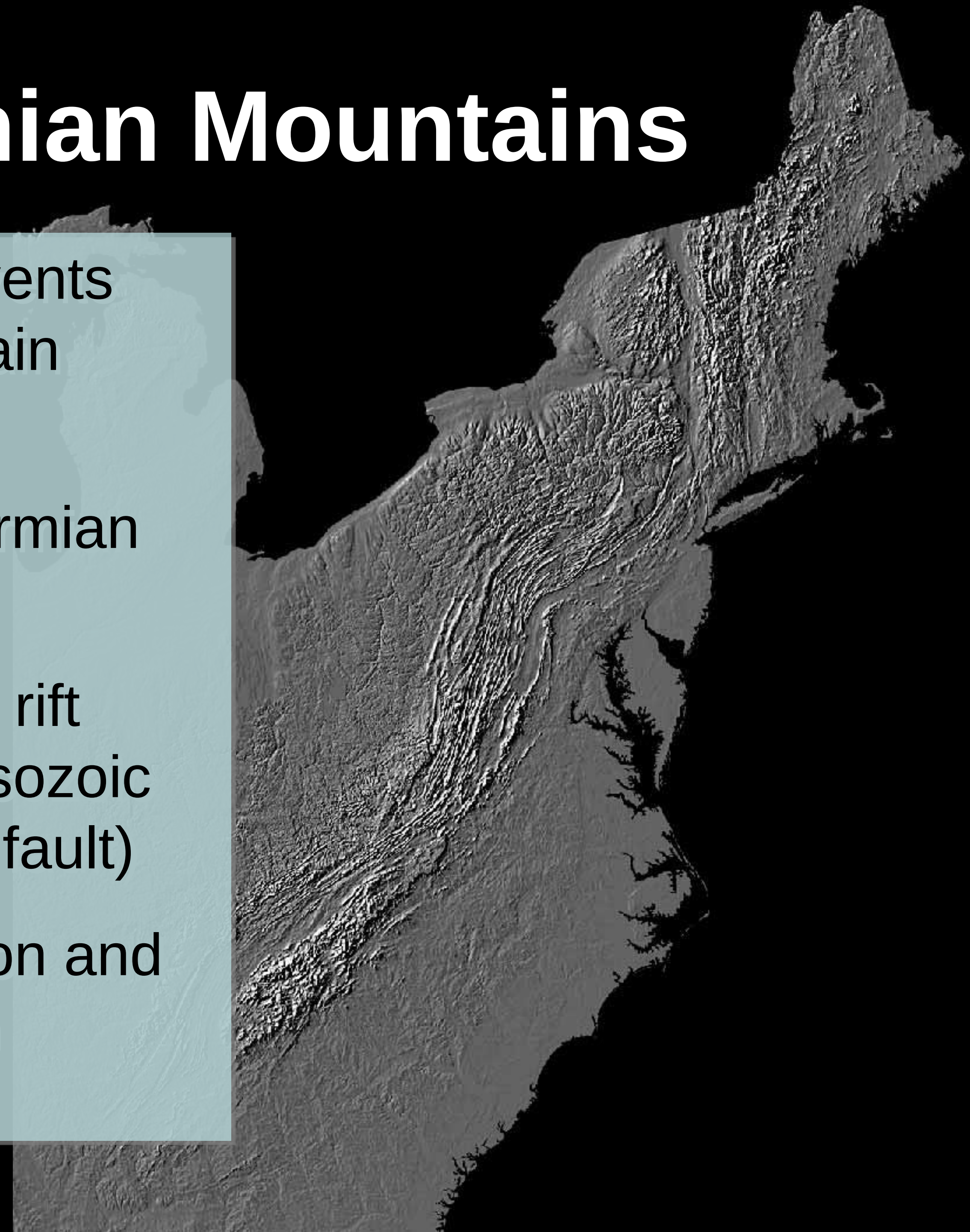
- Objectives
- Background
- Methods
- Results
- Interpretations
- Conclusions

Objectives

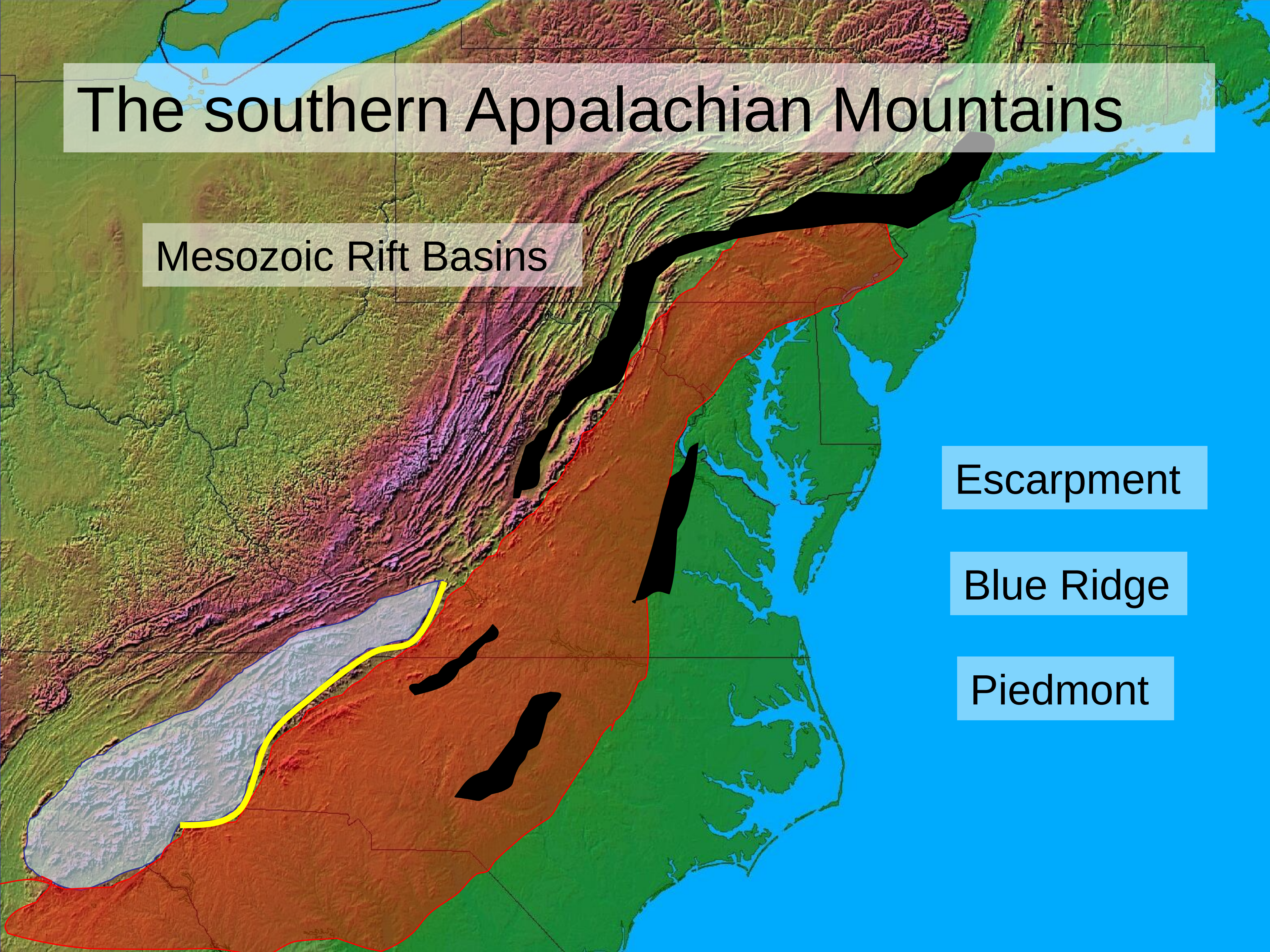
- to determine whether grain size influences ^{10}Be concentration in fluvial sediment on and near the Blue Ridge escarpment (BRE);
- to quantify basin-scale ^{10}Be erosion rates for the BRE and the surrounding provinces;
- to test for relationships between ^{10}Be erosion rates and specific landscape characteristics;
- to determine whether the BRE has evolved according to a model of ongoing & parallel retreat or by a model of rapid erosion following rifting and subsequent landscape stability.

Appalachian Mountains

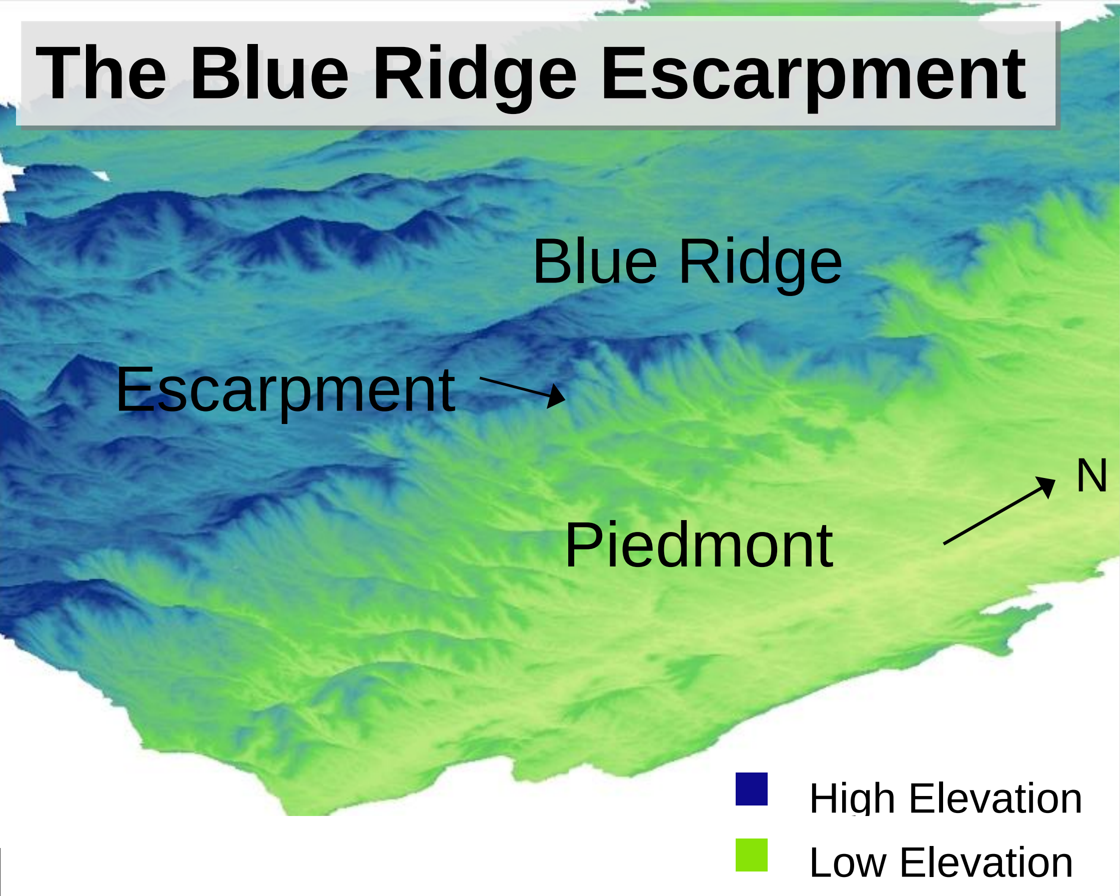
- Paleozoic orogenic events created rugged mountain range
- Erosion during the Permian and Triassic
- Continental rifting and rift margin uplift in the Mesozoic (origin of BRE from rift fault)
- Followed by denudation and isostatic compensation



The southern Appalachian Mountains



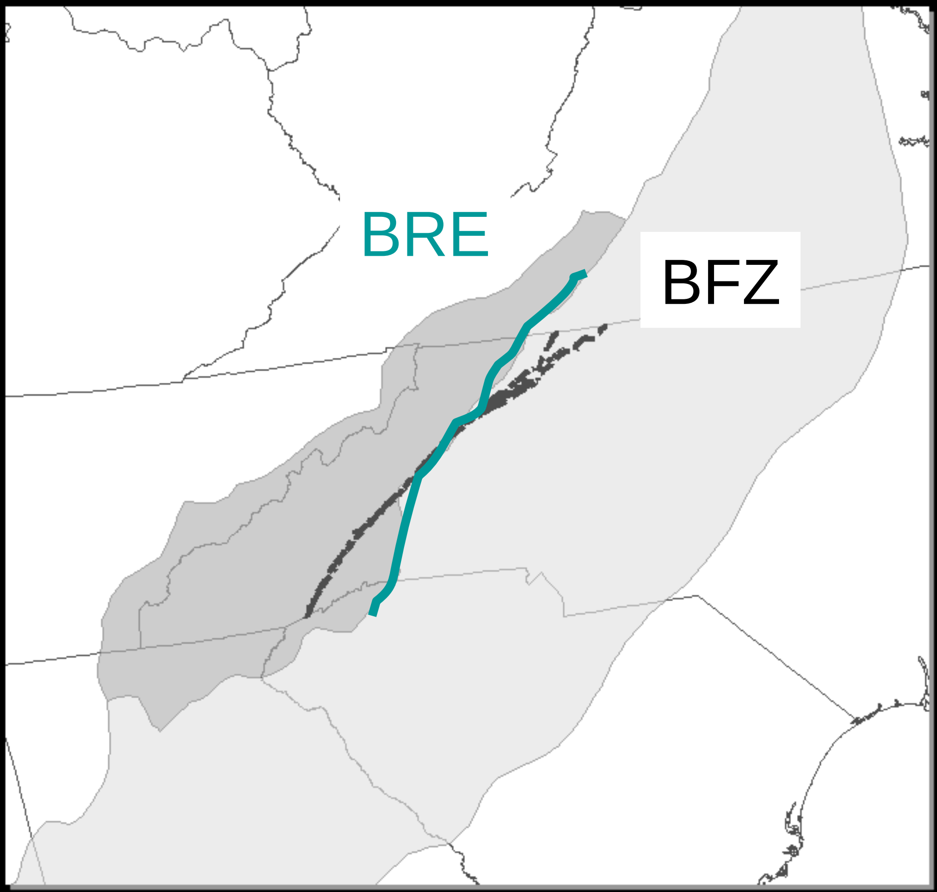
The Blue Ridge Escarpment



- Distinct boundary between less rugged Blue Ridge and Piedmont
- >450 km long
- Can be >500 m high
- Slopes up to 20-30˚
- Asymmetric drainage divide
- Generally within lithology of micaceous schist and gneiss; thus morphology cannot be attributed to differences in bedrock erodability

Brevard fault zone

- Oriented SW-NE
- Extends ~600 km from AL to VA
- Activated during all Appalachian orogenies, well before the rifting events that formed the BRE
- The BFZ only coincides with the BRE for 50-60 km

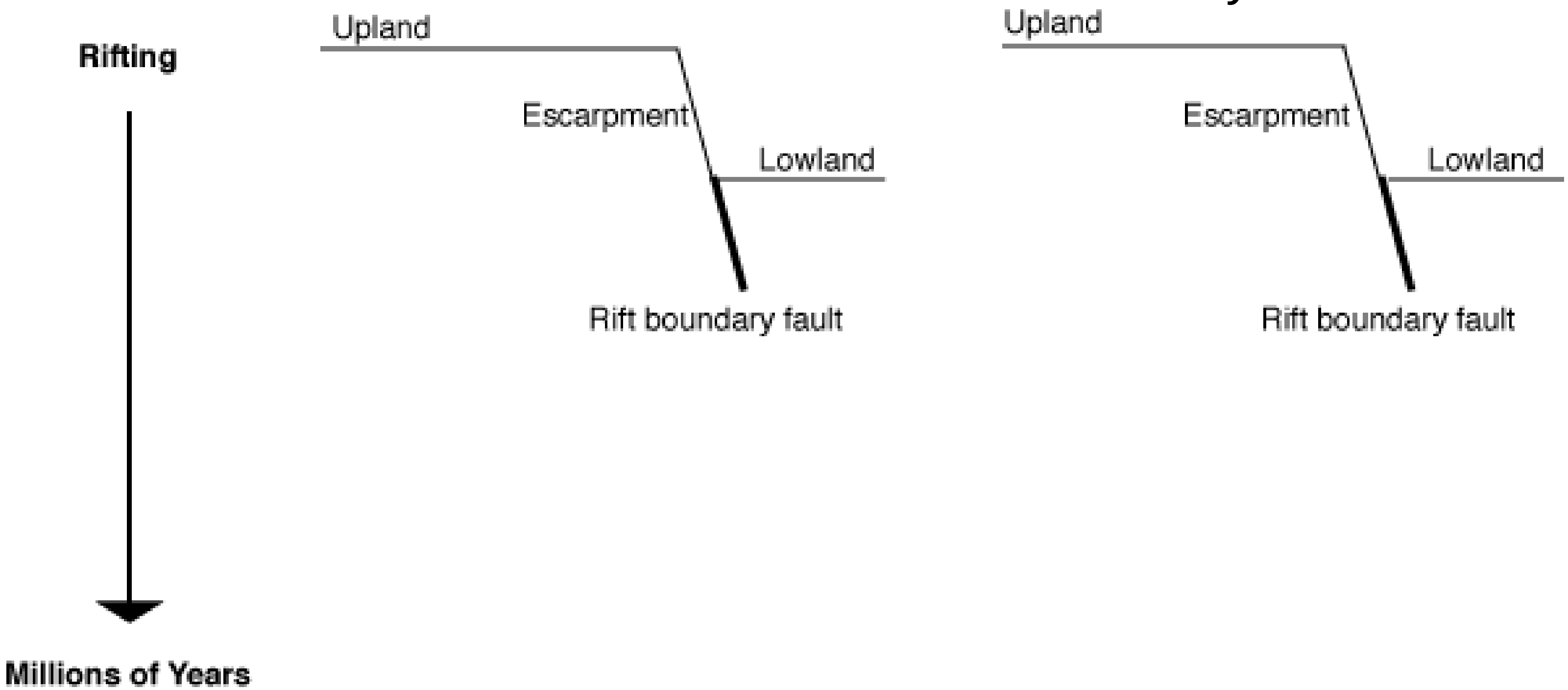


Great escarpments

Escarpment evolution

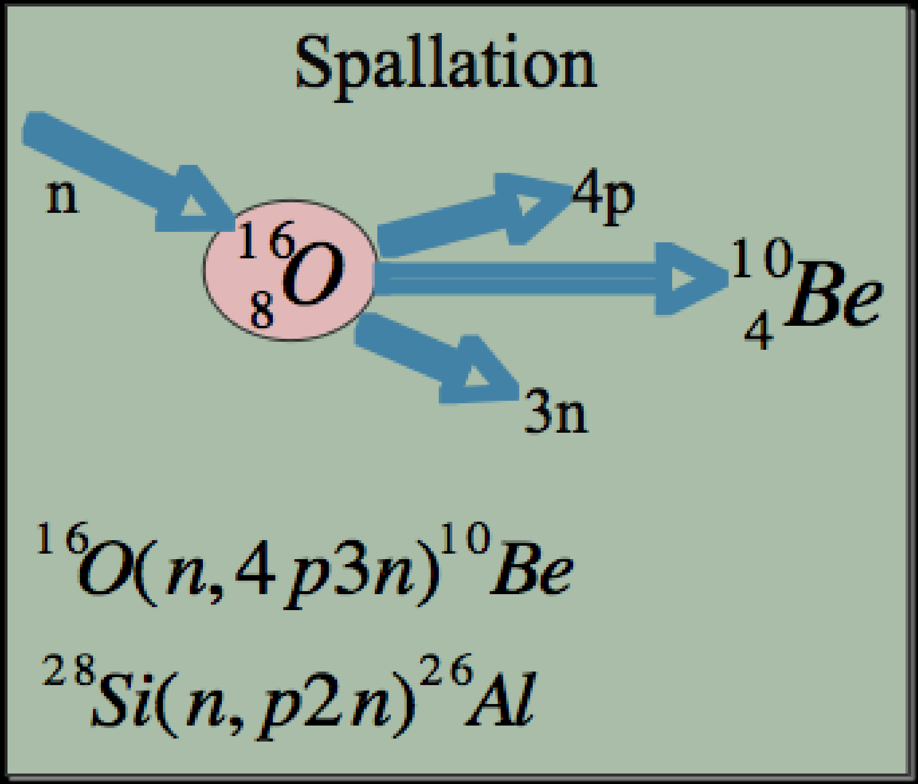
A) Ongoing & steady retreat

B) Significant retreat following rifting, then stability



What is ^{10}Be?

- ^{10}Be accumulates within rock that becomes sediment as it approaches surface
- Time scale of 10^4-10^5 years



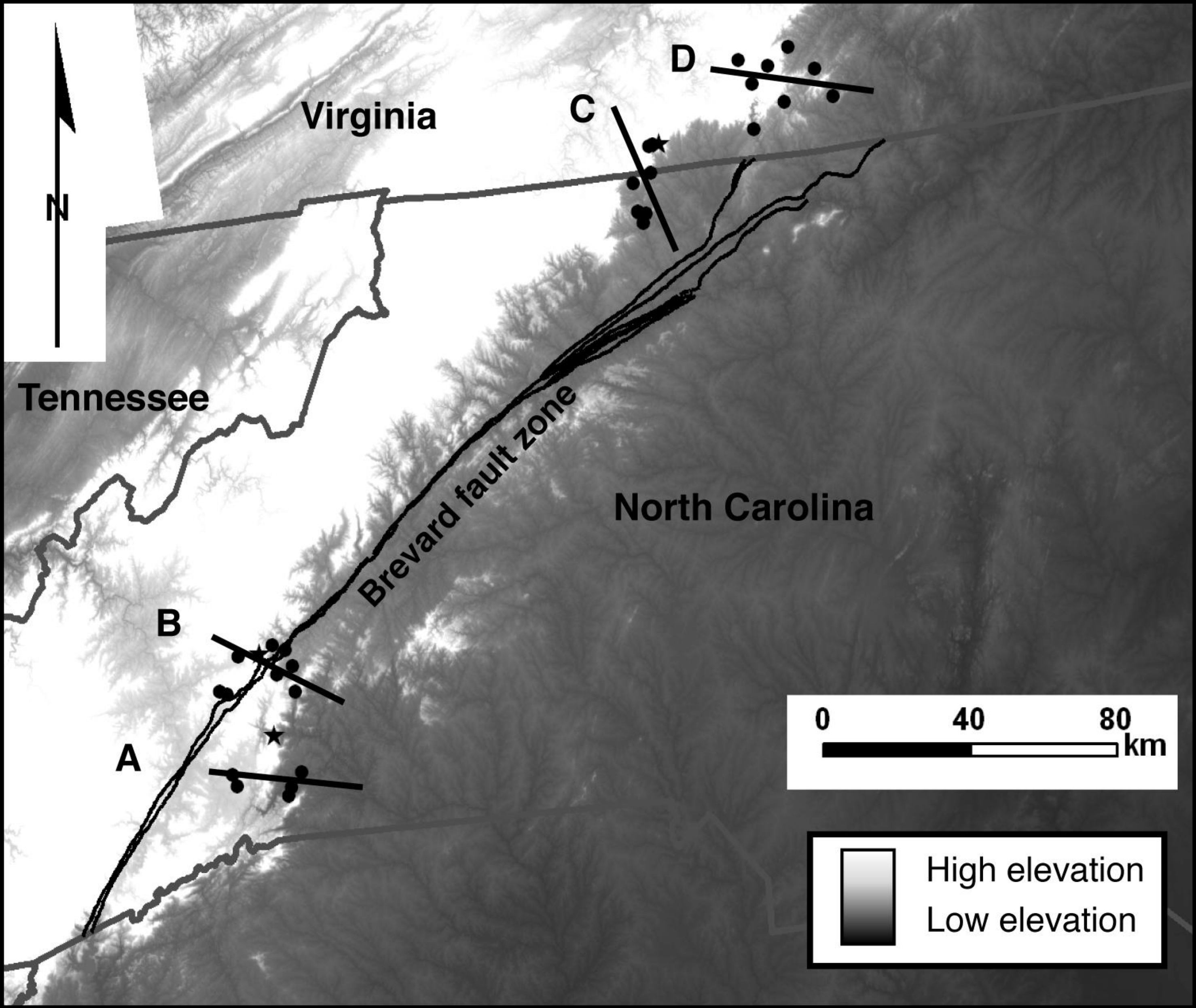
Inferring erosion rates with ^{10}Be

- Rivers mix sediment moving out of drainage basins, thus the concentration of ^{10}Be in fluvial sediment indicates sediment production rates on basin hillslopes.
- Cosmic ray dosing as bedrock is exposed can be used to model bedrock lowering rates.

Assumptions

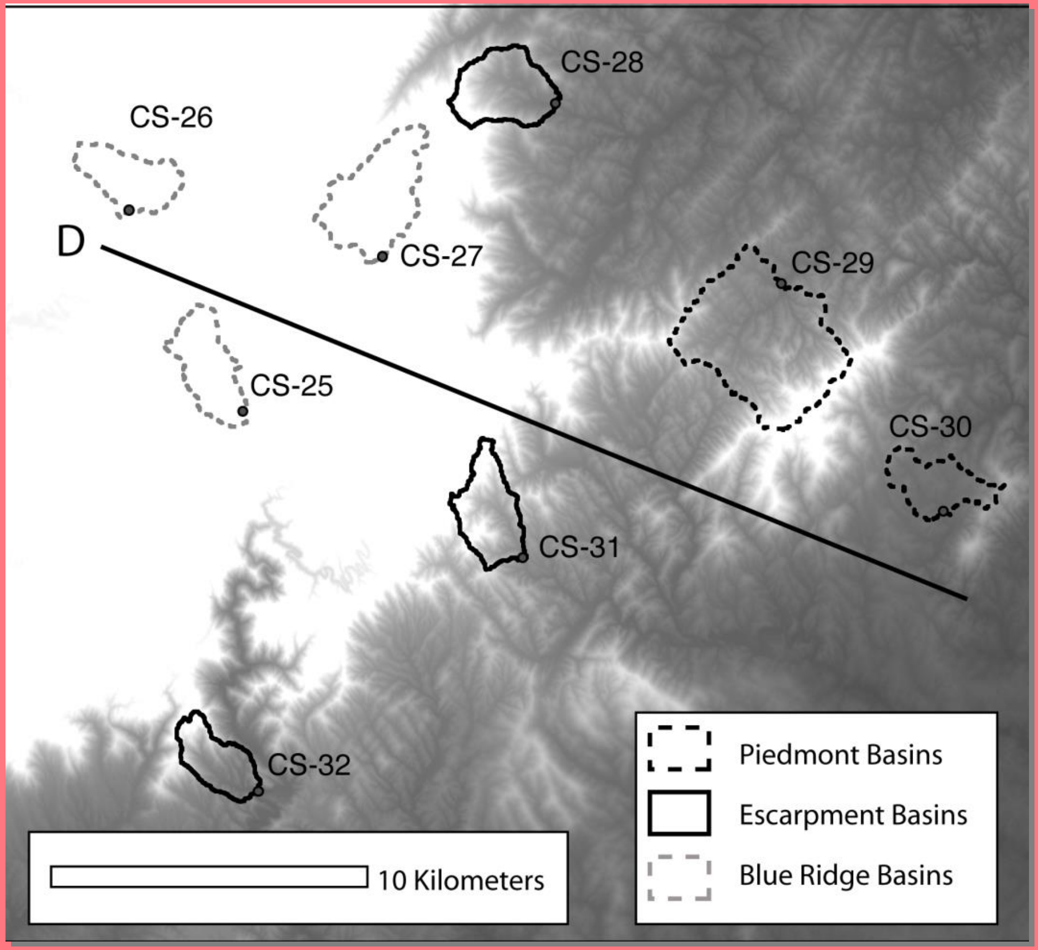
- Well mixed sediment
- No inheritance from prior period of near-surface irradiation
- Sediment transport and production are in steady state

Transect Locations



Basin Selection

- Selected basins based on:
  - size
  - slope
  - province
- I used a GIS database to select basins for Transects B & D
- Manually selected basins from topo maps for Transects A & C



Field methods

- Collected fluvial sediment from 32 basins:
  - Transects B & D field sieved (0.25-0.85 mm)
  - Transects A & C collected mixed grain sizes and sieved in the lab
- Collected 3 bedrock samples from escarpment

Lab methods

- Purified quartz for 53 samples:
  - 32 basins
  - 6 grain size splits
  - 3 bedrock
- Jennifer Larsen isolated ^{10}Be from all samples

AMS at Lawrence Livermore National Laboratory

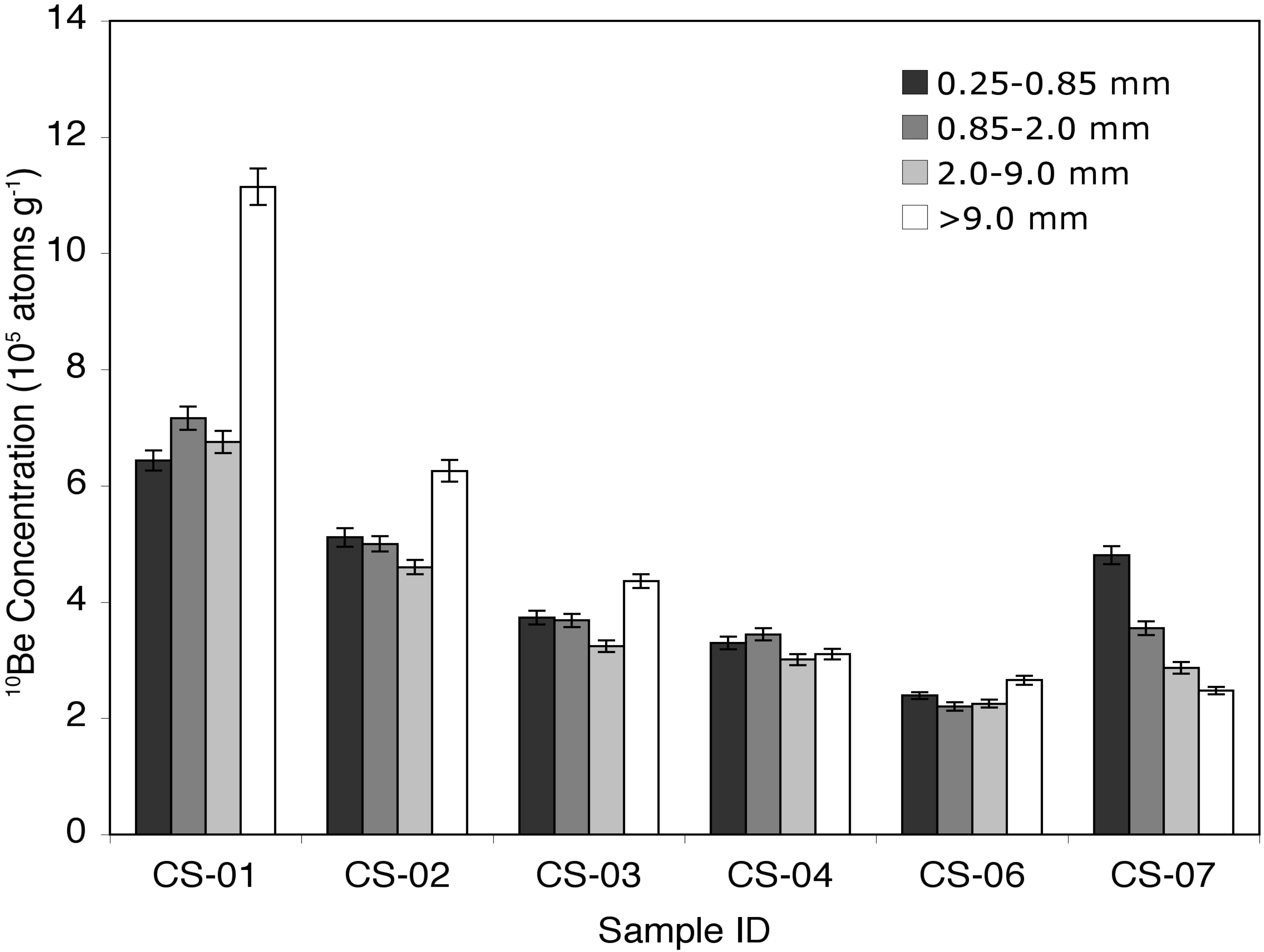
Photo: https://cams.llnl.gov/aboutus.php

Objective

- to determine whether grain size influences ^{10}Be concentration in fluvial sediment on and near the BRE;

Grain Size… Who Cares?

- Brown et al. (1995) suggested that lower ^{10}Be concentrations in larger grain sizes could result from mass wasting events that excavate and carry previously shielded coarse material rapidly down slope.
- Matmon et al. (2003) suggested that the systematic difference in ^{10}Be concentrations between small and large grains in the Great Smoky Mountains results from source area elevation and clast transport distance.



0.25-0.85 mm
0.85-2.0 mm
2.0-9.0 mm
>9.0 mm
14
12
10
8
6
4
2
0
^{10}Be Concentration (10^5 atoms g^{-1})
CS-01
CS-02
CS-03
CS-04
CS-06
CS-07
Sample ID

Grain Size Doesn’t Matter for the Blue Ridge escarpment

- 4 samples largest grain size has most ^{10}Be;
- 1 sample from the escarpment has a monotonic decrease in ^{10}Be with increasing grain size. Escarpment is most likely to be affected by debris flows due to steep slopes, high relief, and precipitation;
- Differences from Matmon (2003) may be due to varying lithologic properties of study areas.

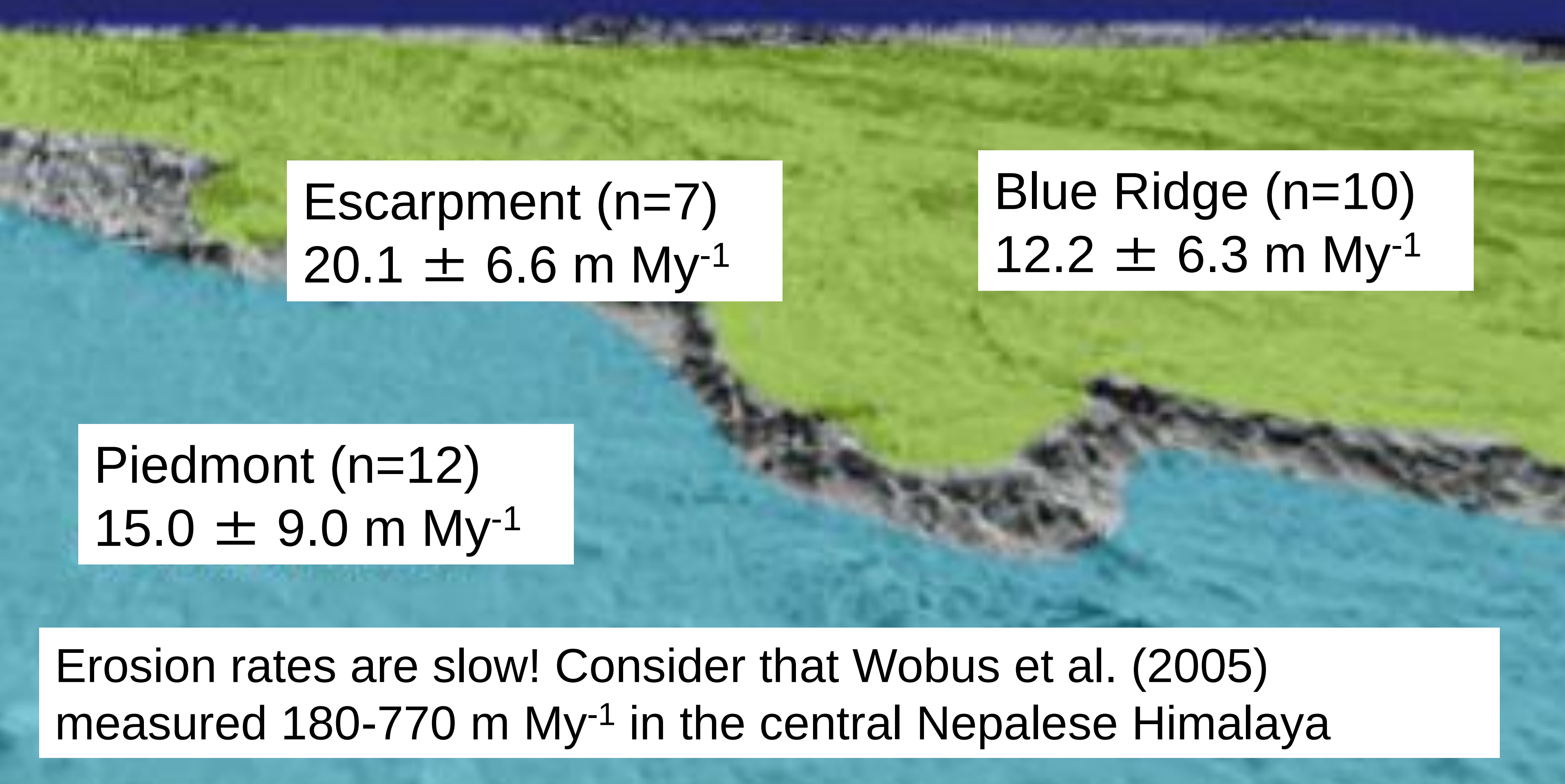
Objective

- to quantify basin-scale ^{10}Be erosion rates for the BRE and the surrounding provinces;

Bedrock samples

- Heavy vegetation in June
- 3 sample sites along escarpment
- Highly variable results
  - CSB-1 (gneiss) 56.8 m My^{-1}
  - CSB-2 (gneiss) 1.7 m My^{-1}
  - CSB-3 (mica schist) 17.4 m My^{-1}
- Lack of natural amalgamation

Basin-Scale Erosion Rates



Escarpment (n=7)
20.1 ± 6.6 m My^{-1}

Blue Ridge (n=10)
12.2 ± 6.3 m My^{-1}

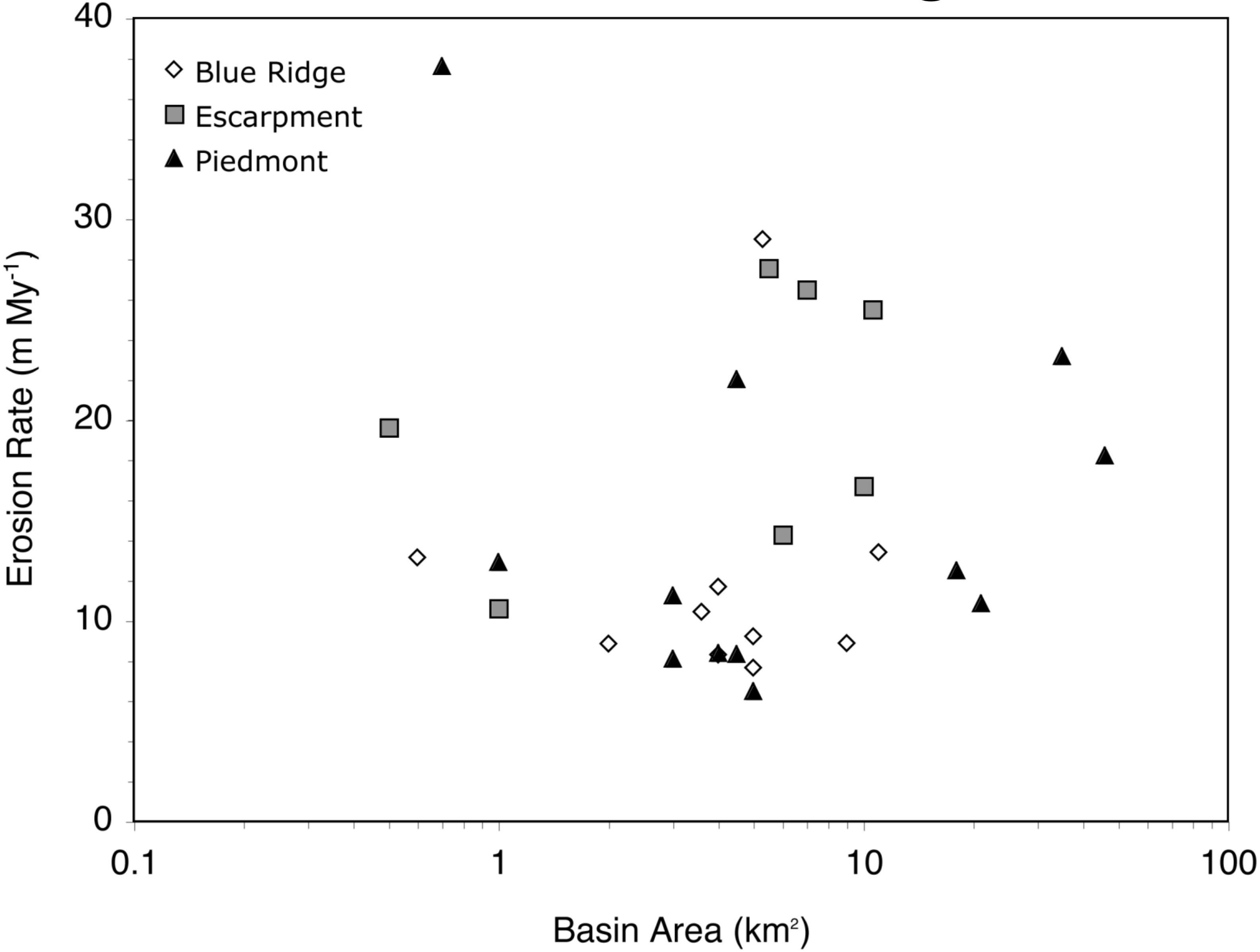
Piedmont (n=12)
15.0 ± 9.0 m My^{-1}

Erosion rates are slow! Consider that Wobus et al. (2005) measured 180-770 m My^{-1} in the central Nepalese Himalaya

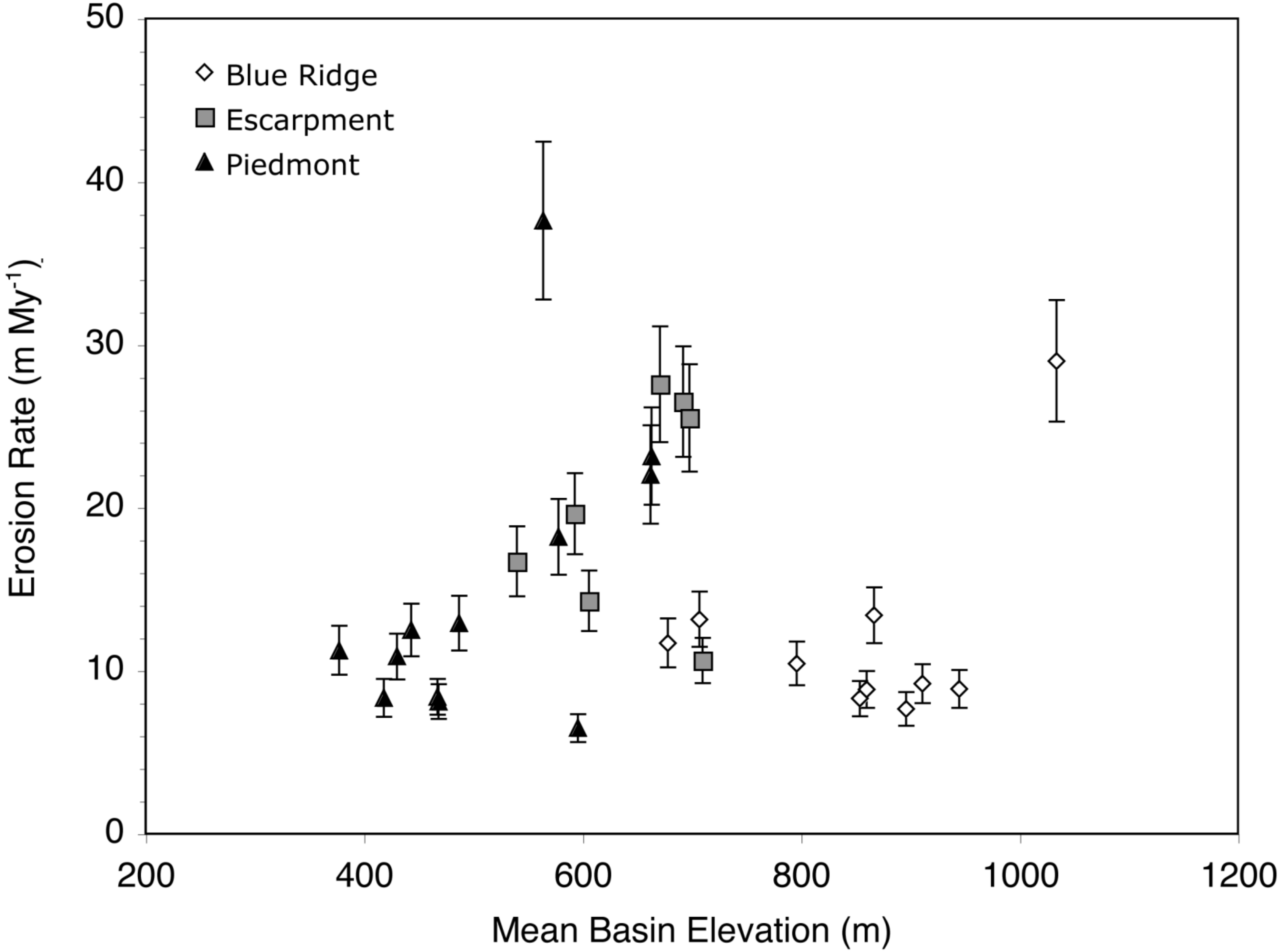
Objective

- to test for relationships between ^{10}Be erosion rates and specific landscape characteristics;

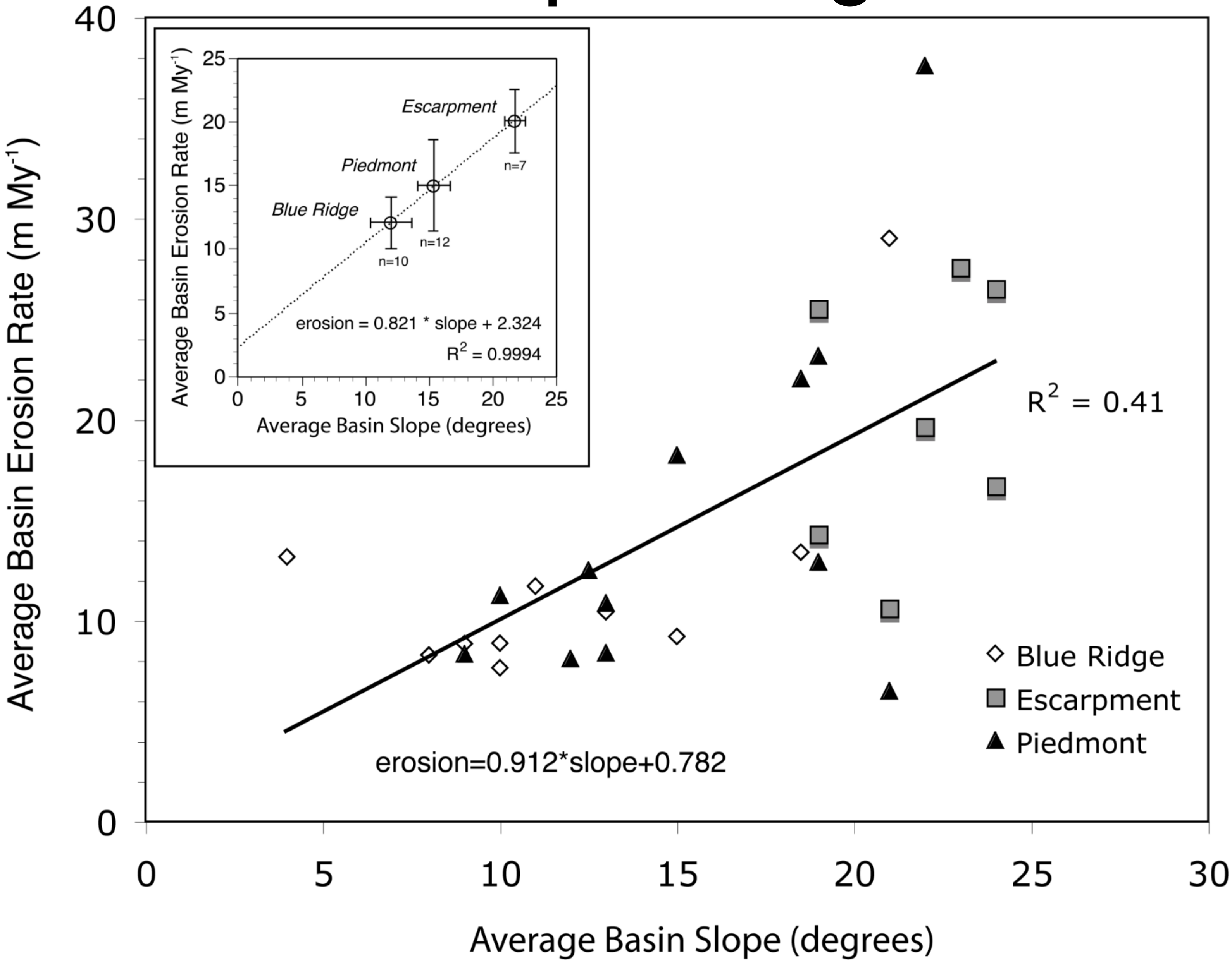
Basin size is not significant



Physiographic province shows slight relationship with erosion, not statistically separable



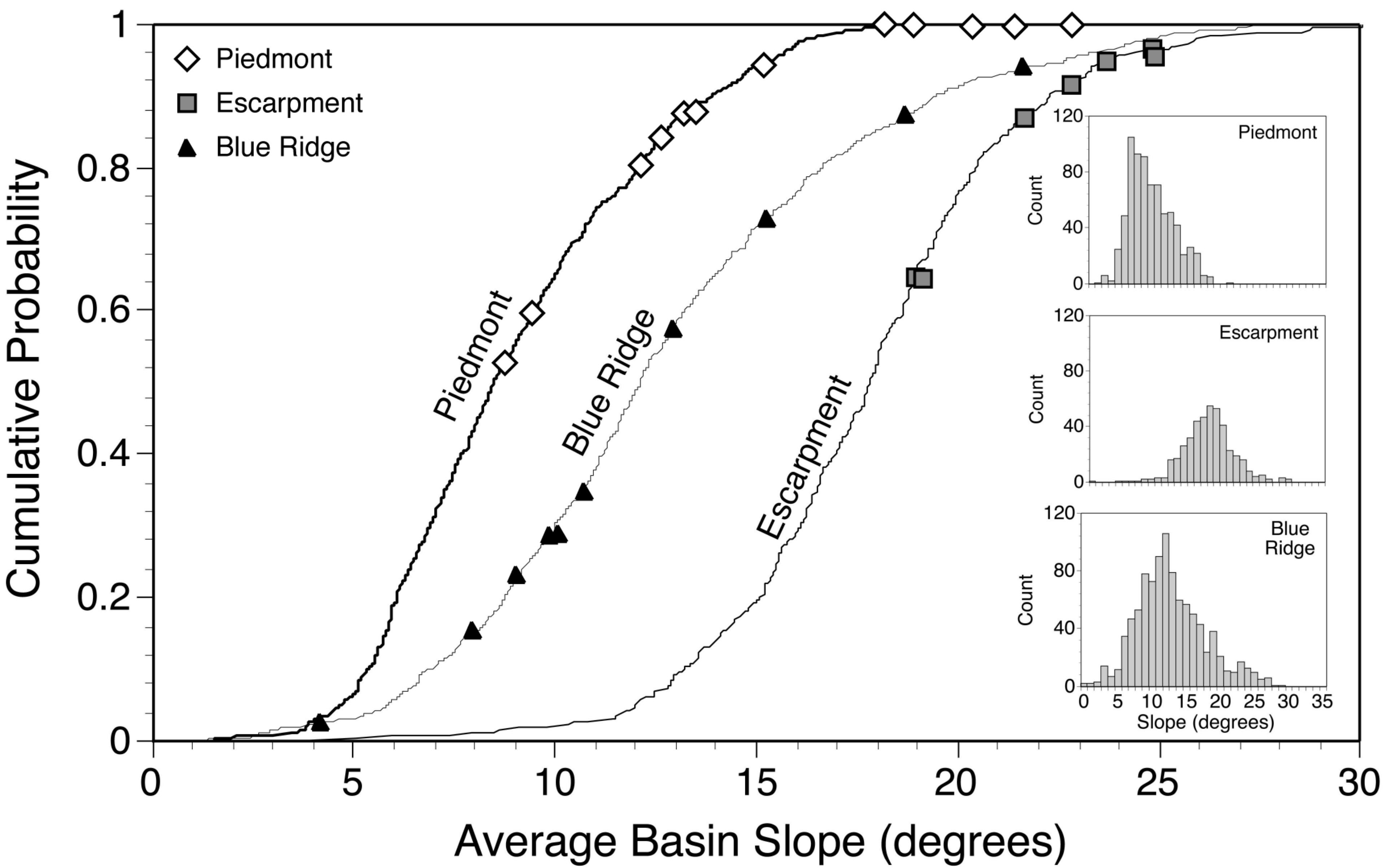
Basin slope is significant



Used GIS to assess average basin slope for the entire population of basins

	Population Slope	Sample Slope
Blue Ridge	12.8˚ n=968	12.0˚ n=10
Escarpment	17.7˚ n=428	21.7˚ n=7
Piedmont	9.0˚ n=738	15.3˚ n=12
Mean	5.6 km^2	8.1 km^2
Median	4.6 km^2	5.0 km^2

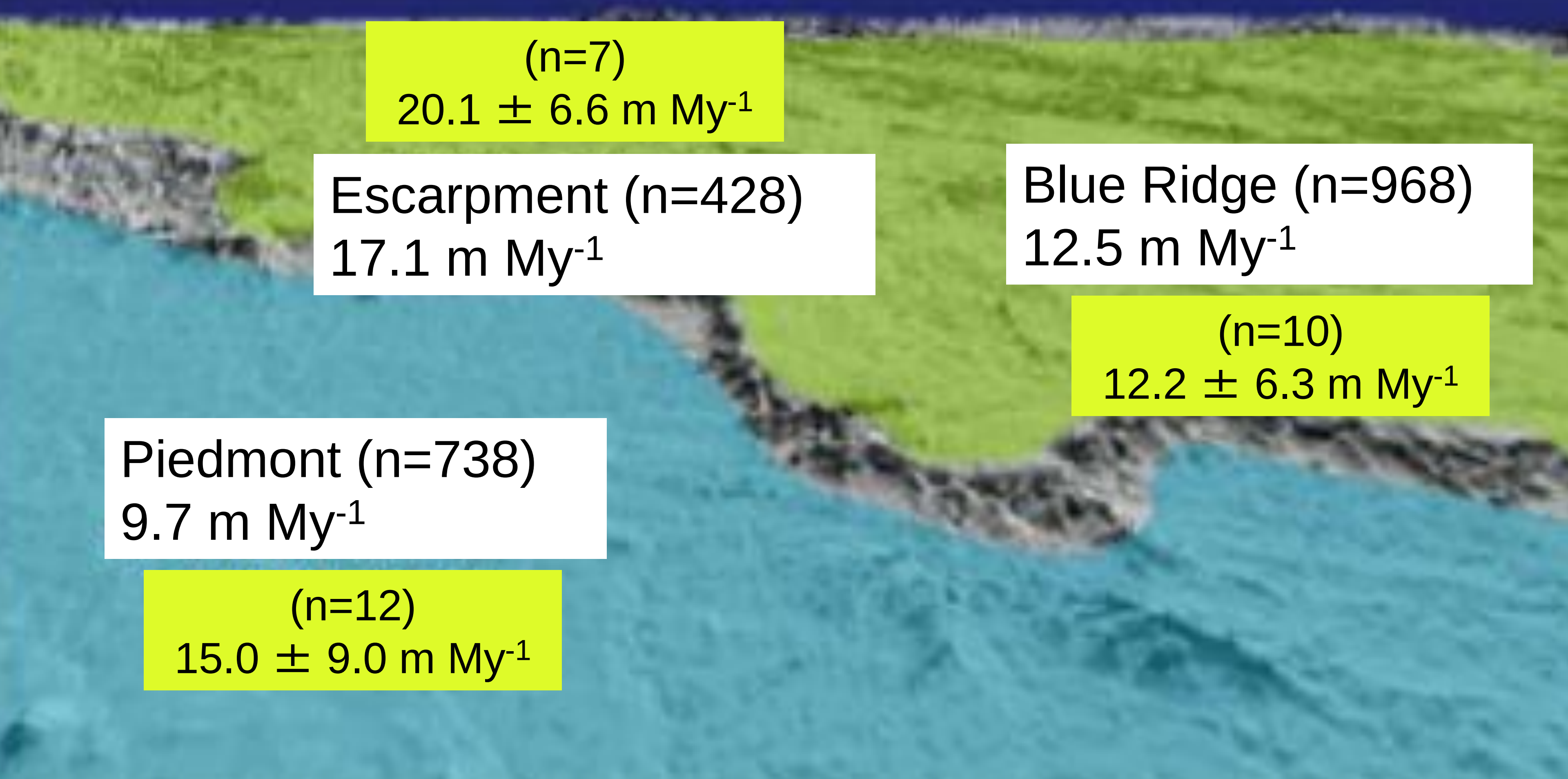
Probability Density Function



How can I model representative erosion rates?

- Erosion rate is dependant on slope:
  - Erosion rate = (° slope) * (0.912) + 0.78
- I calculated a model erosion rate for each province based on the average basin slope of the population.

Integrated Model Erosion Rates



Objective

- to determine whether the BRE has evolved according to a model of ongoing & parallel retreat or by a model of rapid erosion following rifting and subsequent landscape stability.

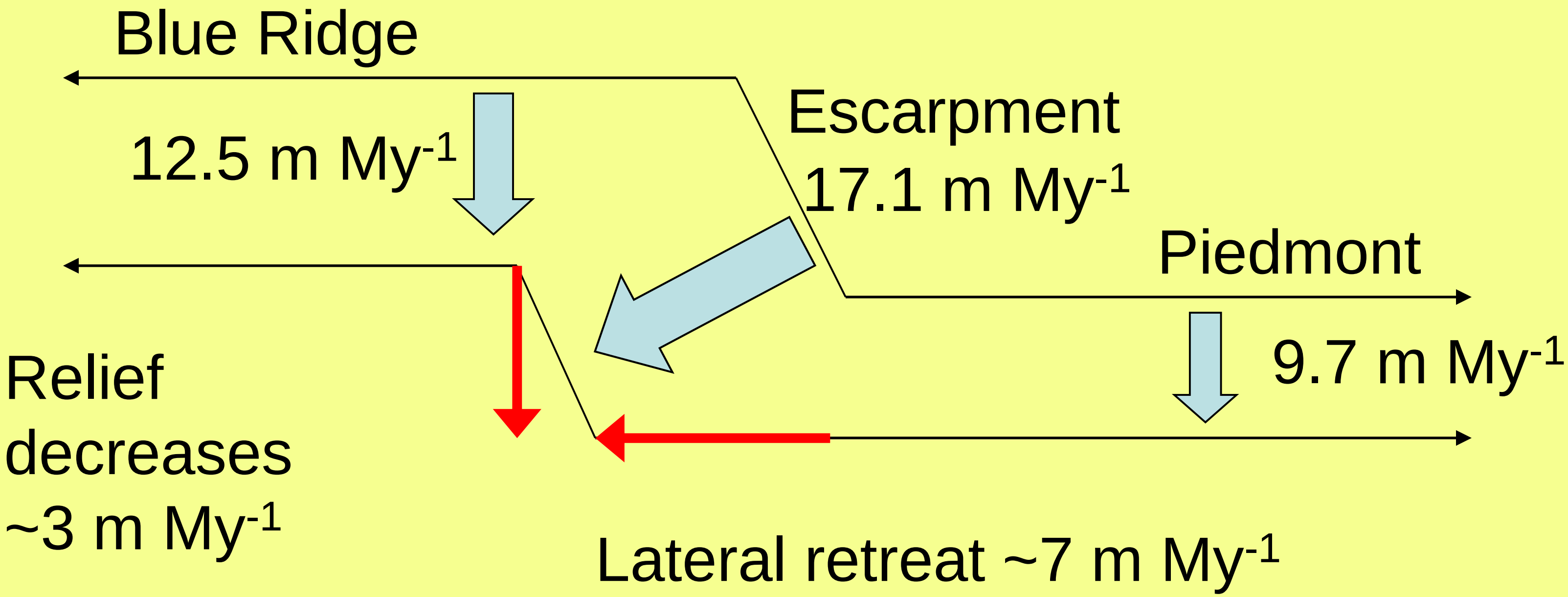
Comparing Cosmogenic and Thermochronologic Erosion Rates

- ^{10}Be erosion rates are integrated over 10^4-10^5 years
- Thermochronologic erosion rates are integrated over 10^8 years.
- Erosion Rate=**Depth** (integrated geothermal gradient and closure temp)/**Age** (U-Th)/He or # fission tracks.
  - AHE- (U-Th)/He closure temp 40-90°C
  - AFT- fission tracks closure temp 60-110°C

Thermochronologic data consistent with Cosmogenic data

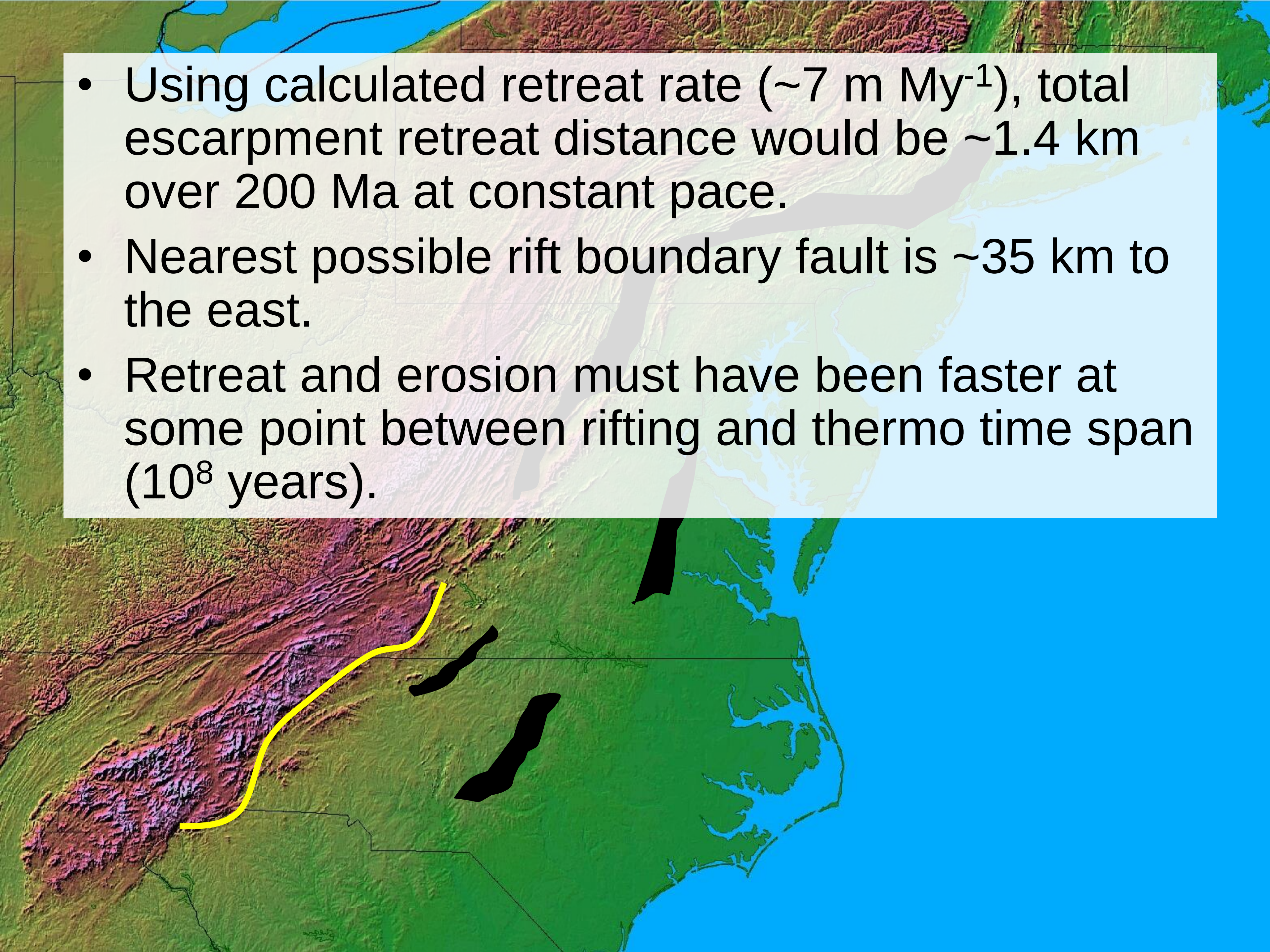
The picture can't be displayed.

Both datasets are relatively slow



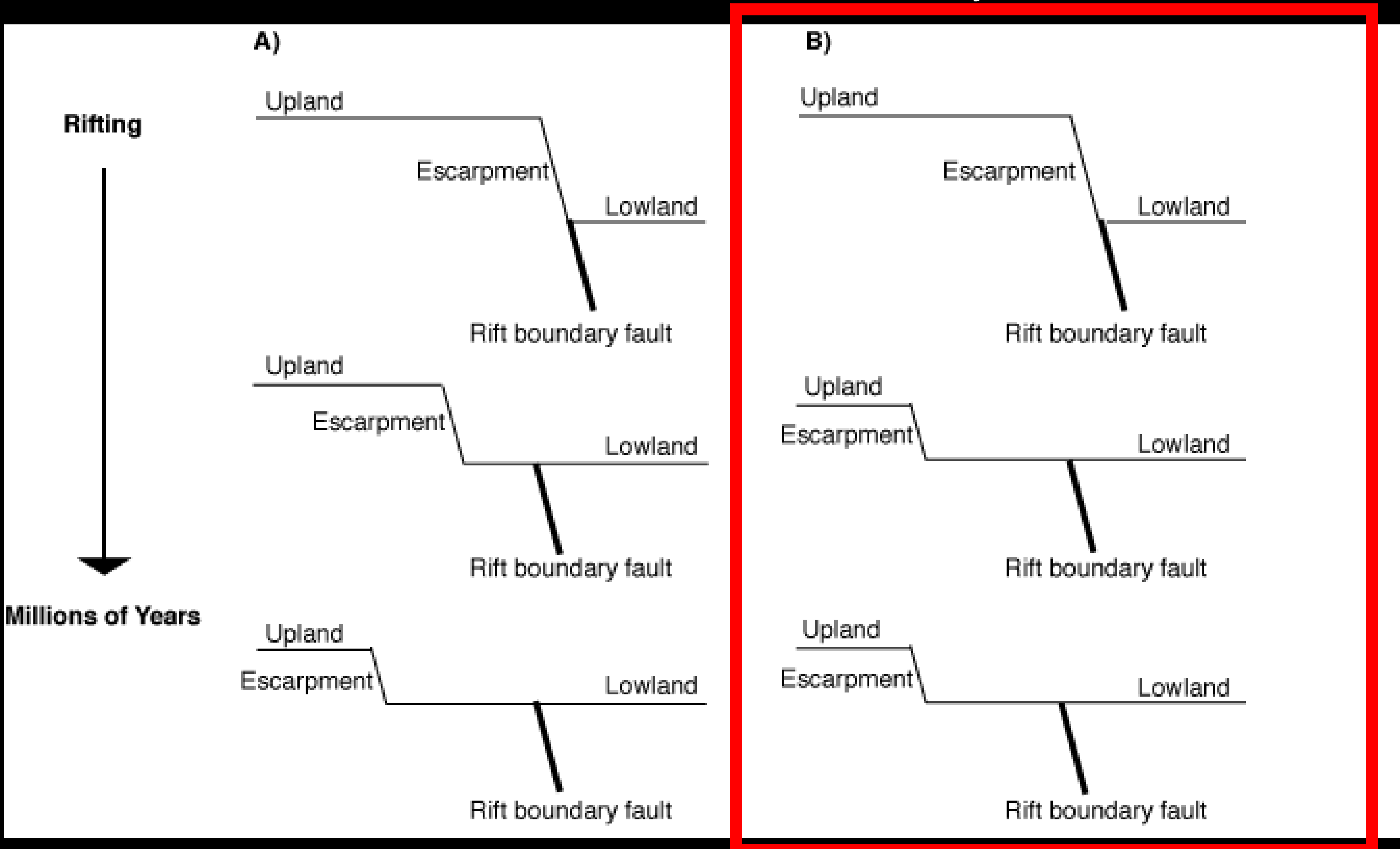
- Base level for the escarpment is set by the Piedmont therefore the difference in lowering rates can be taken as the retreat rate
- Piedmont is eroding more slowly than the Blue Ridge therefore relief is decreasing

- Using calculated retreat rate (~7 m My^{-1}), total escarpment retreat distance would be ~1.4 km over 200 Ma at constant pace.
- Nearest possible rift boundary fault is ~35 km to the east.
- Retreat and erosion must have been faster at some point between rifting and thermo time span (10^8 years).



Ongoing & steady retreat

Significant retreat following rifting, then stability



Other escarpments

- These results agree with studies from other passive margin escarpments such as:
  - **Namibia** (Bierman and Caffee, 2001; Brown et al., 2000)
  - **South Africa** (Fleming et al., 1999; Summerfield et al., 1997)
  - **Southeastern Australia** (Heimsath et al., 2006; Persano et al., 2002)
  - **Sri Lanka** (Vanacker et al., 2007)

Conclusions

- Grain size does not affect ^{10}Be concentration on and near the BRE
- Overall the BRE is lowering and retreating very slowly
- Average slope is the only basin characteristic that influences erosion on and near the BRE
- The BRE appears to have evolved through a period of significant and rapid erosion immediately following rifting and has remained a fairly stable feature of the landscape since that time.

Acknowledgments

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- Corey Coutu
- Dave Linari


Rocks Older Than Dinosaurs?
FANCY GAP HWY
VIRGILINA CIR
CS-14

Cosmogenic isotope production with depth

$$P_x = P_o e^{-(x\rho/\Lambda)}$$

Variables:

P_x= nuclide production rate at depth x

P_o= sediment production rate (5.17 atoms g^{-1} y^{-1})

ρ = density of material (2.7 g cm^{-3} for rock)

Λ = attenuation factor (165 g cm^{-2})

Erosion rate calcs...

$$m/\rho=\varepsilon=\Lambda(P-N)/\rho N$$

Variables:

ε = erosion rate

P = basin effective production rate

ρ = density of material (2.7 g cm^{-3} for rock)

Λ = attenuation factor (165 g cm^{-2})