


Determining long-term erosion rates in Panama

An application of ^{10}Be

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Defense Presentation

Outline

- Background
- Introduction
- Methods
- Results and Interpretations
- Conclusion
- Final remarks

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Objectives

- Determine long-term erosion rates in Panama, using ^{10}Be measured in river sediments

- Effect of physiographic controls on erosion

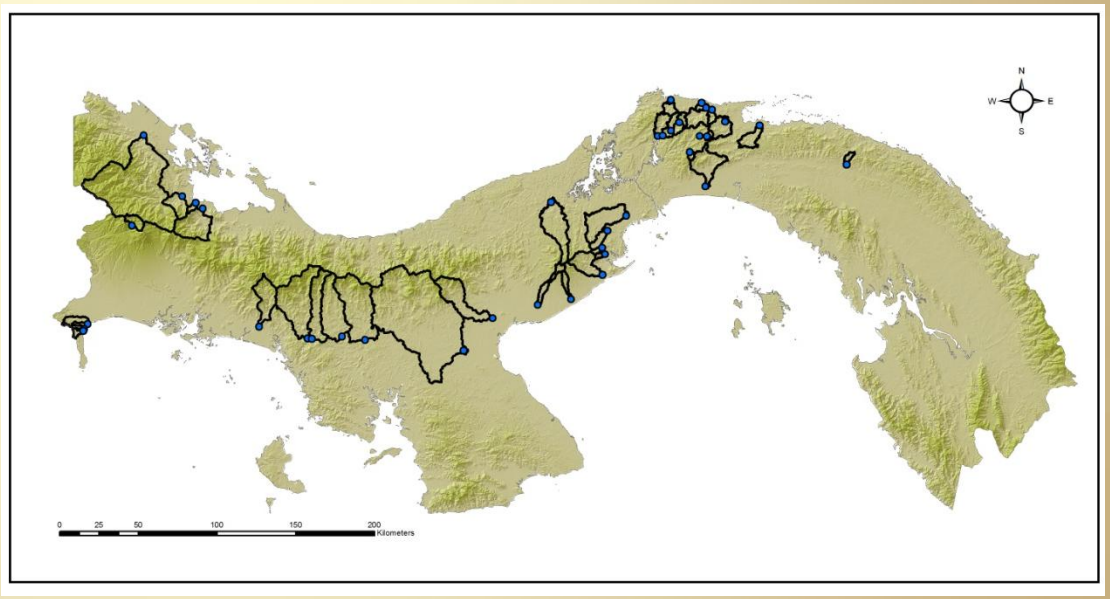
- Assess sediment delivery to rivers by landslide events, by way of grain-size analysis

Panama

- Location
  - 7° - 9° N
  - 77 ° - 83 ° W

Location of Panama

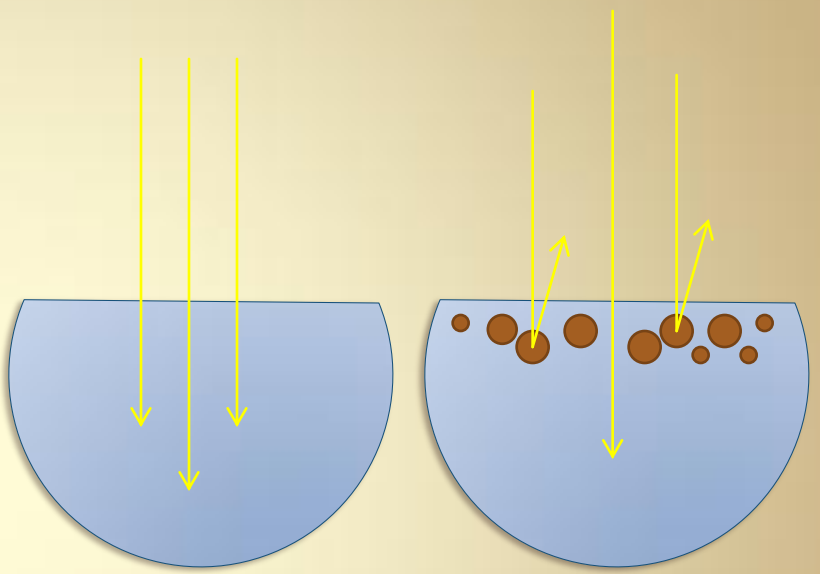
- Climate
  - 24 – 28 °C
  - 1,500 – 3,000 mm Pacific slope
  - 4,000 mm Caribbean slope



Panama relief

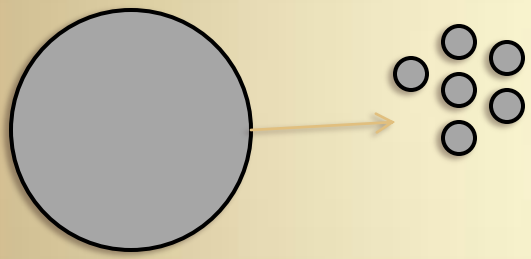
Sediments

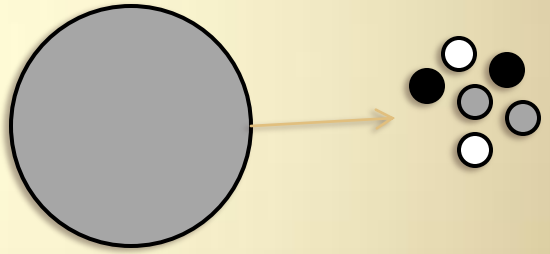
- Aquatic biota
  - Temperature
  - Dissolved oxygen
  - Primary producers activity
- Water treatment
- Reservoir lifetime



Concepts

- Erosion
  - Physical weathering
- Denudation
  - Chemical and physical weathering

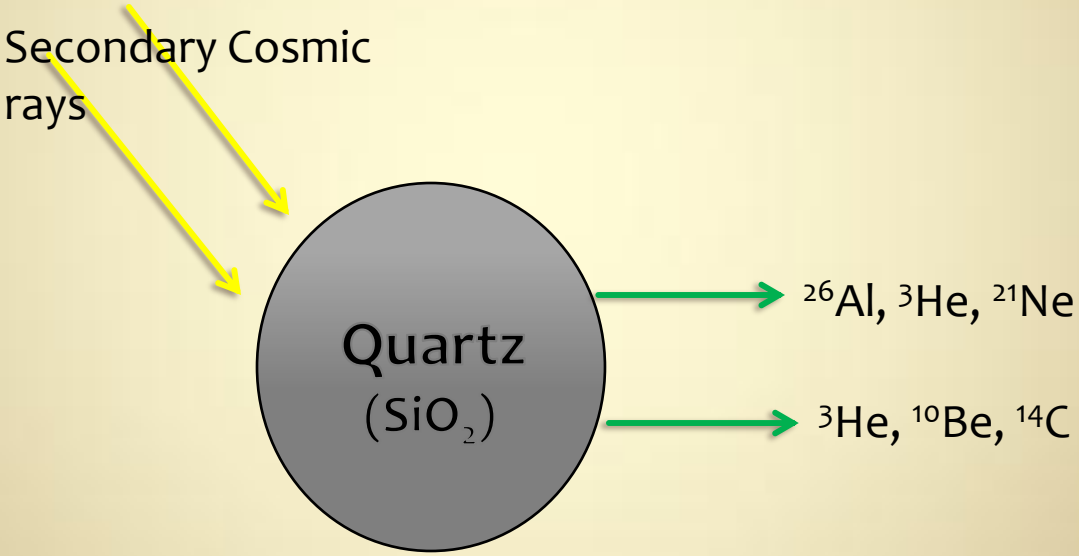




  - Erosion rate: the pace at which material is removed from the basin
  - Sediment yield: Sediment discharged from the basin

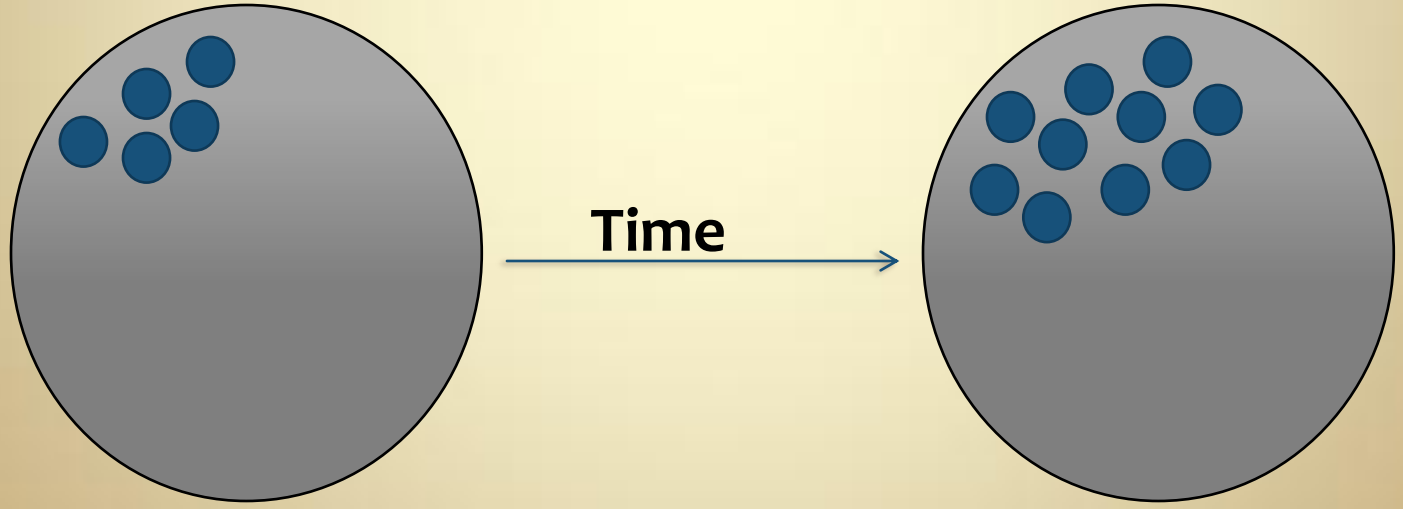
Cosmogenic isotopes- ^{10}Be

- Isotopic formation



Cosmogenic isotopes- ^{10}Be

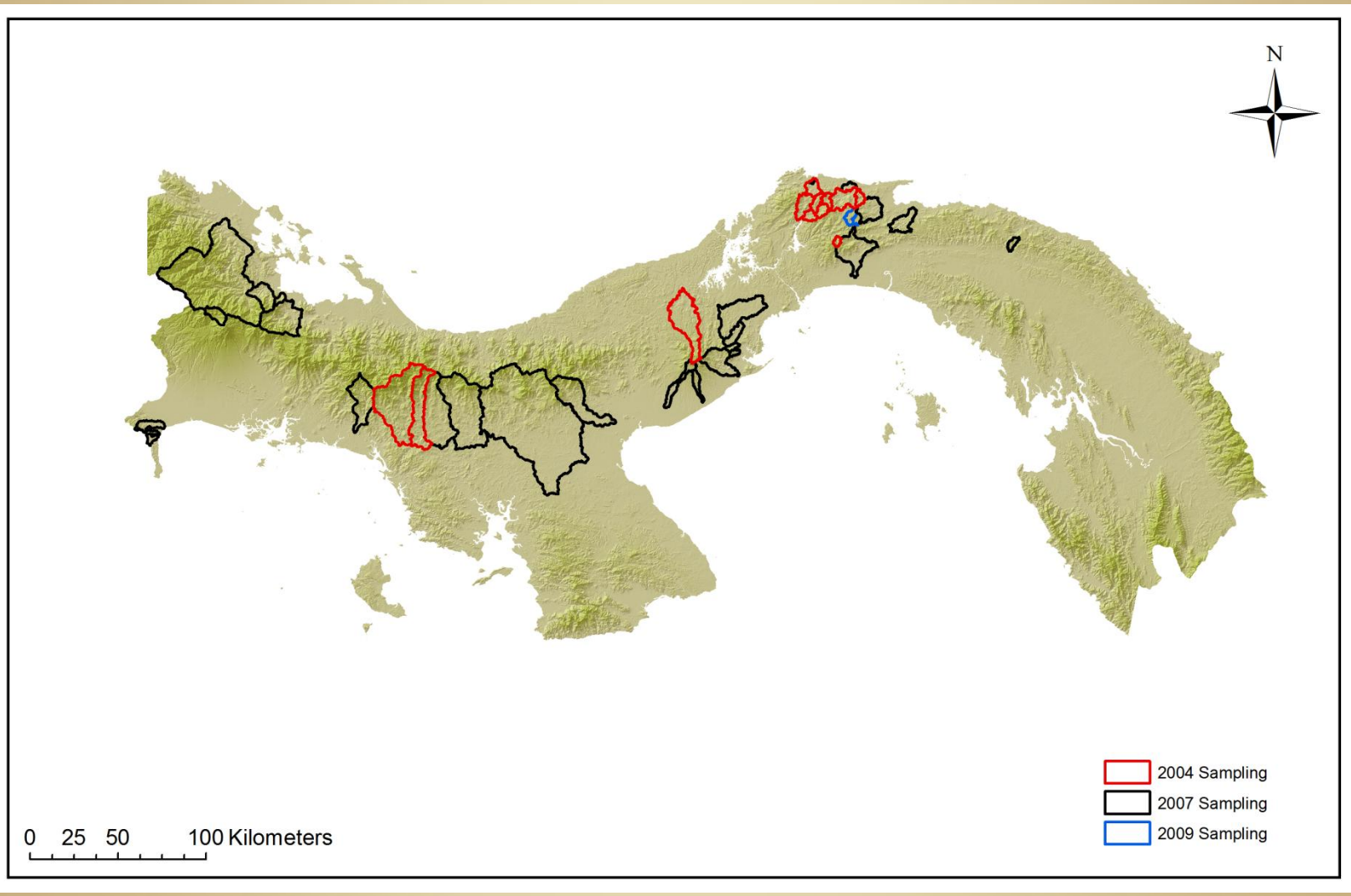
- Isotopic formation



Cosmogenic isotopes-^{10}Be

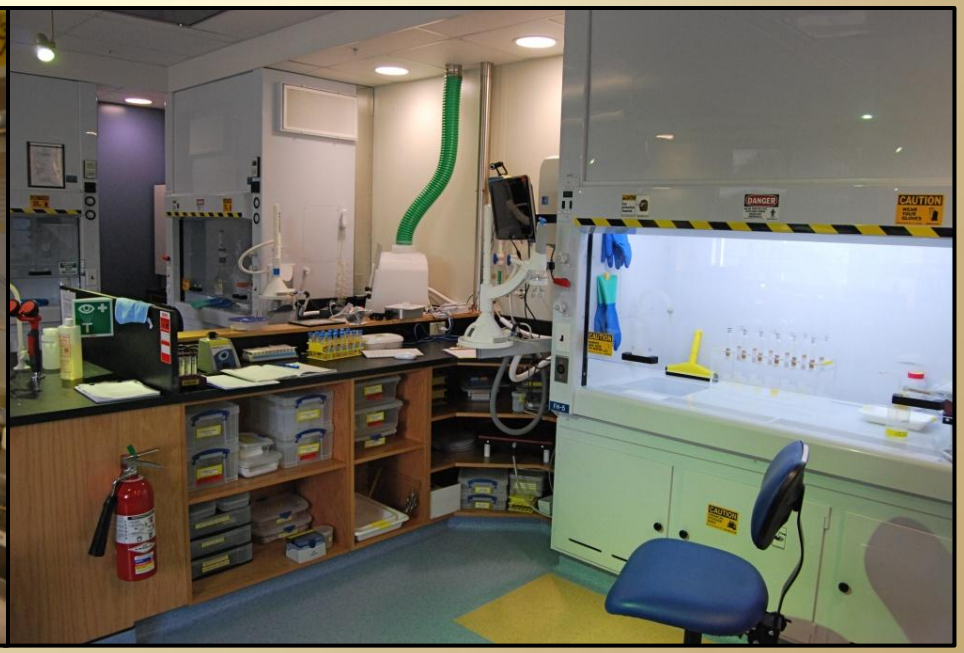
- Benefits of the method
  - Integrate enough time to even out extremes
  - Serves as benchmarks
- Assumes steady state
- Depends on quartz distribution in the watershed's bedrock

Sampling


N
2004 Sampling
2007 Sampling
2009 Sampling
0 25 50 100 Kilometers

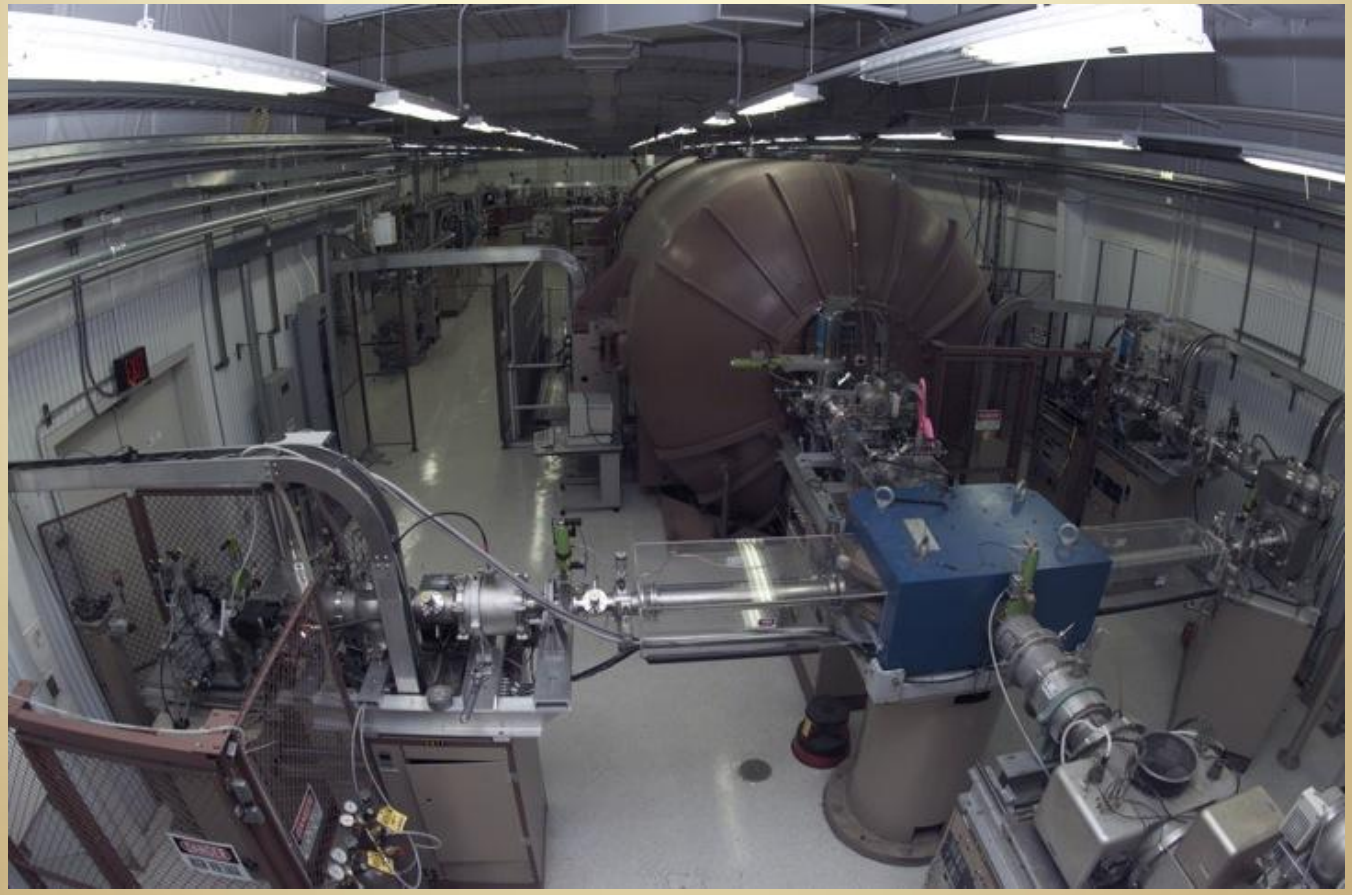
Laboratory Methods

Grinding → Quartz Isolation → ^{10}Be extraction

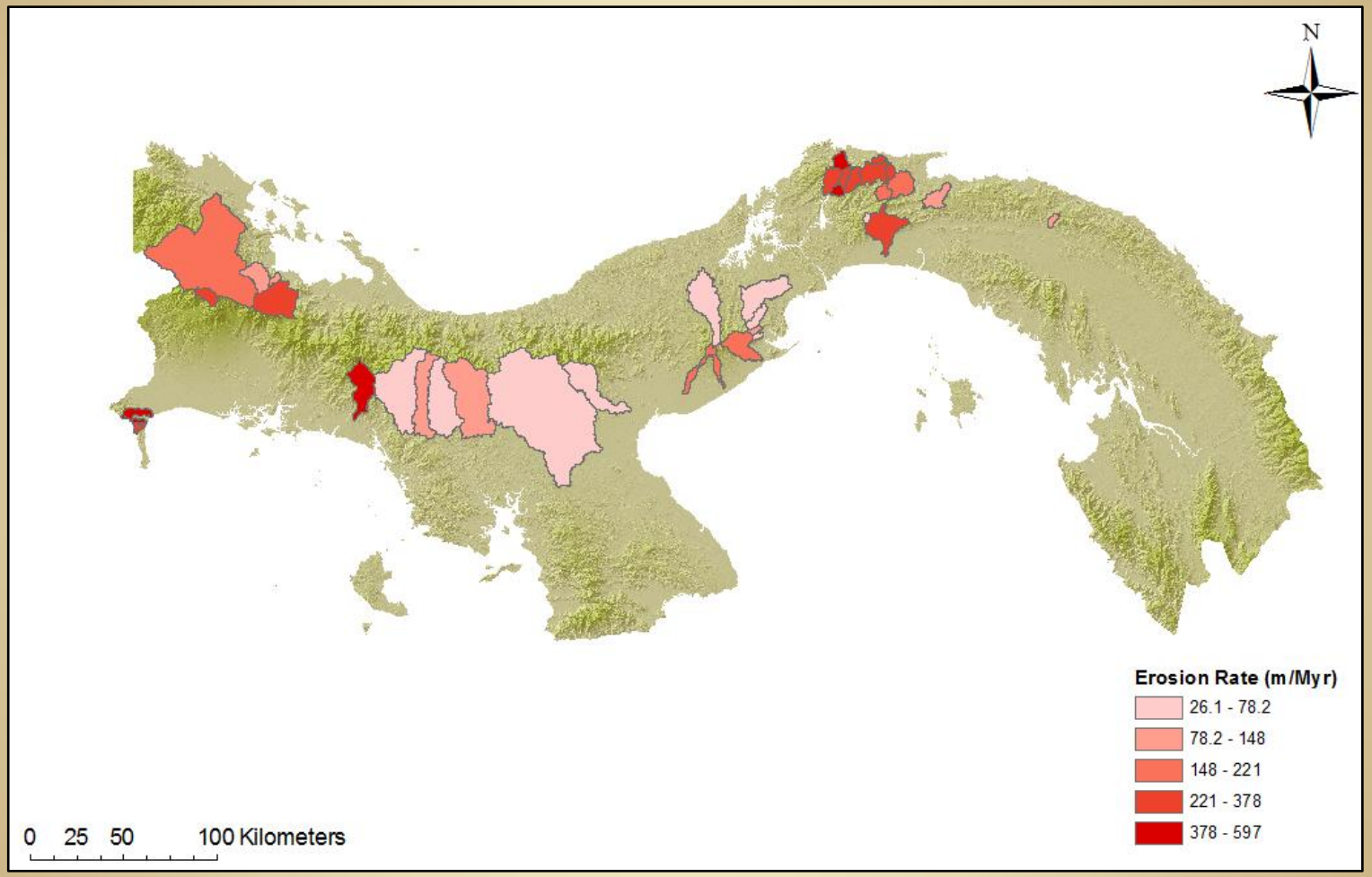


Isotopic content and erosion rates

- Accelerator Mass Spectrometry –LLNL
- CRONUS Earth

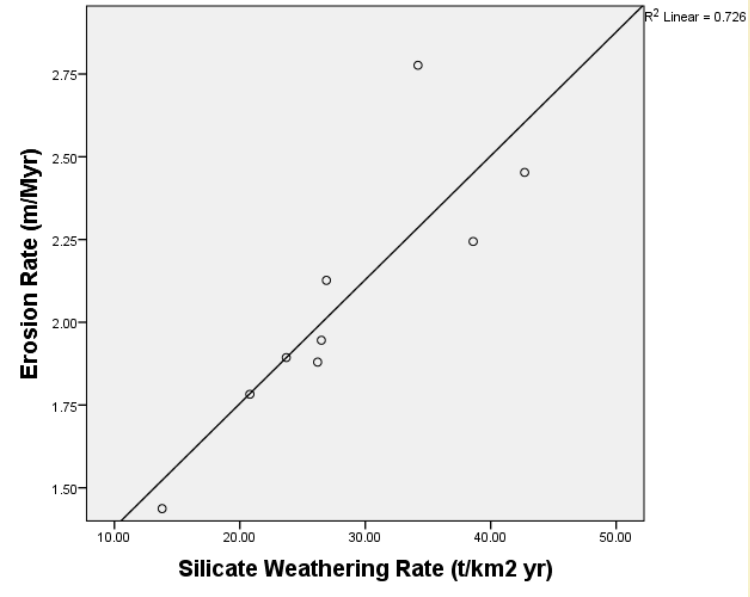


Results



Erosion rates: 26.1 m/Myr to 597 m/Myr
Average: 218 m/Myr
Area weighted average: 150 m/Myr

Silicate weathering



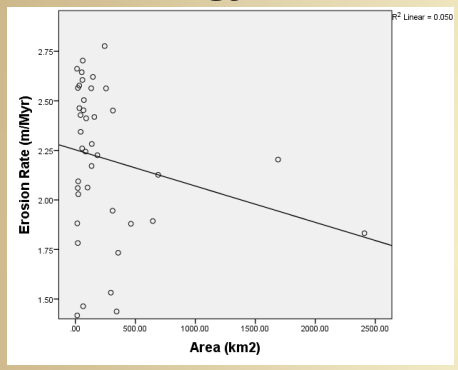
R^2=0.726; p = 0.004

River (sample ID)	Chemical weathering rate (t km^{-2} yr^{-1})	Total weathering rate (t km^{-2} yr^{-1})	Percent of chemical weathering in total
Anton (ANT)	38.6	512.2	7.5
Chagres (CHAG2009)	20.8	184.5	11.3
Chiriqui Viejo (CHVIEH)	42.7	808.3	5.3
Chico (C-NATA)	13.8	87.7	15.7
Cobre (COBRE)	26.2	230.9	11.3
Felix (FELIX)	34.2	1647.4	2.1
San Pablo (SANPAB)	26.9	388.4	6.9
Tabasara (TABA)	23.7	235.0	10.1
Vigui (VIGUI)	26.5	265.0	10.0

Topographic controls

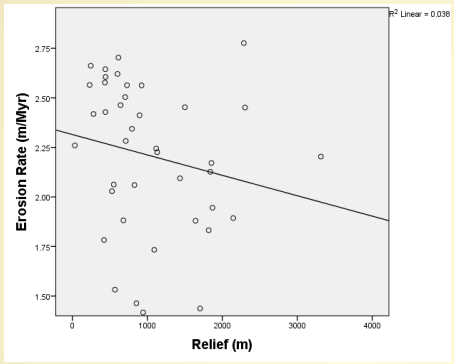
- No relationship found between area, slope, relief, elevation

Area



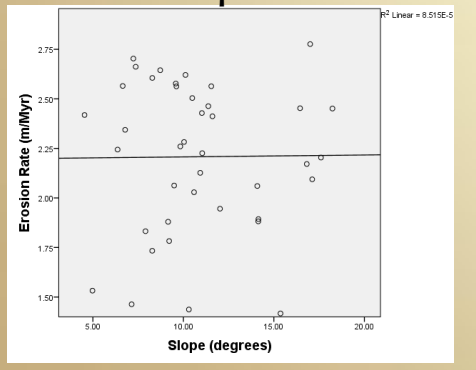
R^2=0.223; p = 0.166

Relief



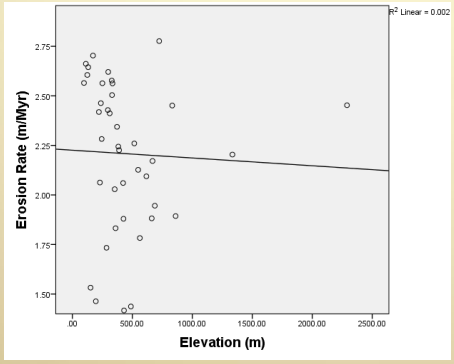
R^2=0.196; p = 0.226

Slope

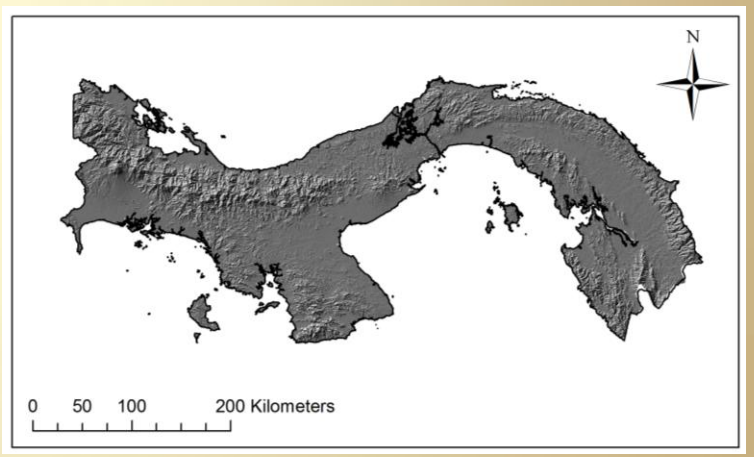


R^2=0.099; p = 0.955

Elevation



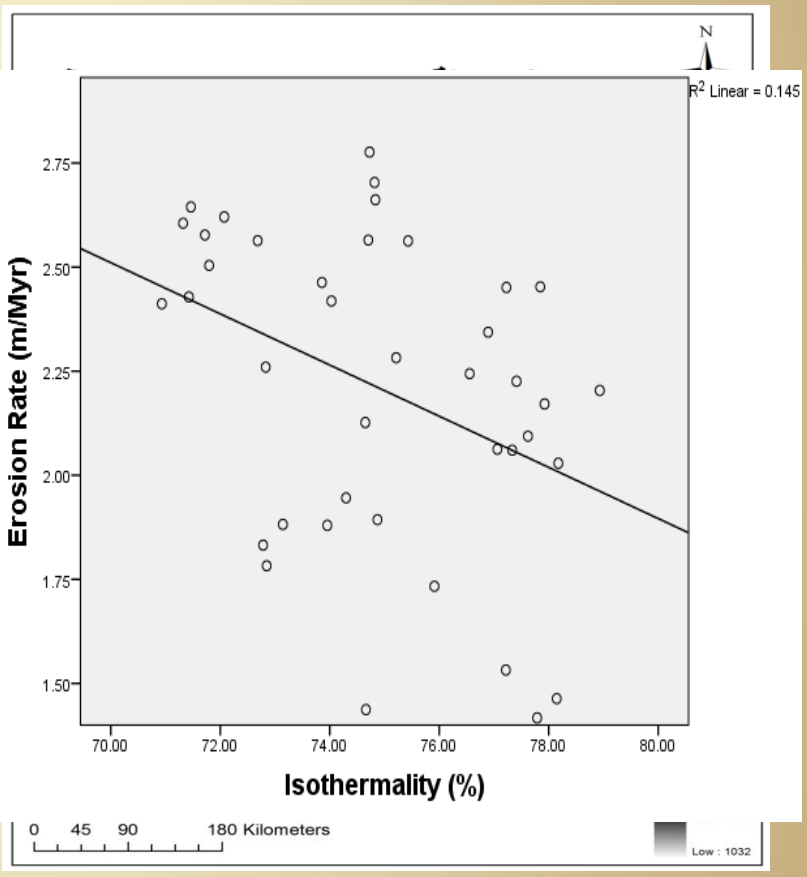
R^2=0.040; p = 0.805



Shaded relief map of Panama

Climatic controls

- Temperature seasonality
  - R^2=0.445, p =0.004
- Precipitation dry month
  - R^2=0.319, p =0.045
- Precipitation seasonality
  - R^2=0.394, p =0.012
- Precipitation dry quart
  - R^2=0.376, p =0.017
- Isothermality
  - R^2=0.145, p =0.015
- Precipitation
  - *R^2=0.307, p =0.054*



Annual precipitation (mm) in Panama

Climatic controls

- Temperature seasonality
  - R^2=0.445, p =0.004
- Precipitation dry month
  - R^2=0.319, p =0.045
- Precipitation seasonality
  - R^2=0.394, p =0.012
- Precipitation dry quart
  - R^2=0.376, p =0.017
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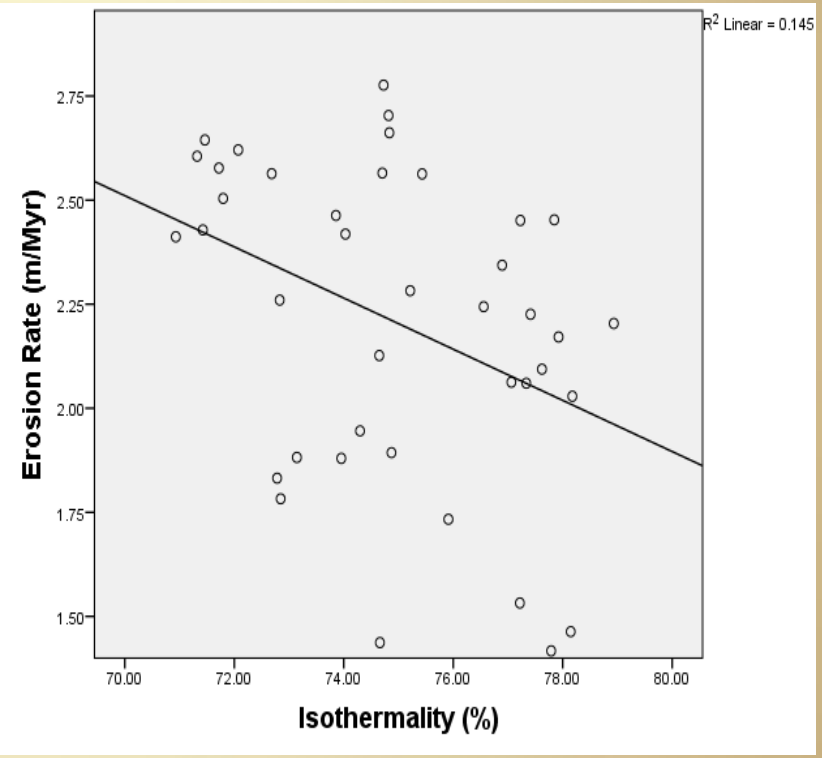
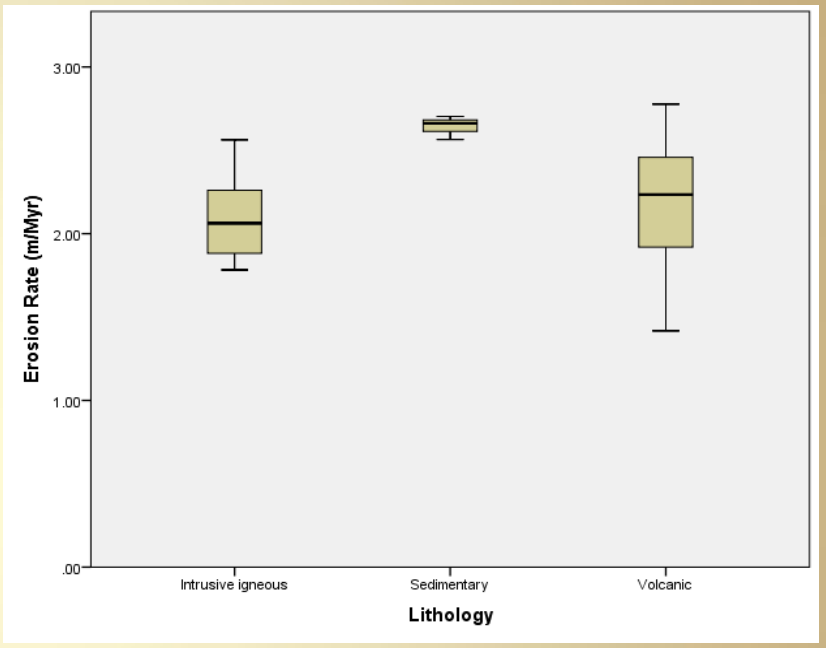
- Precipitation
  - *R^2=0.307, p =0.054*

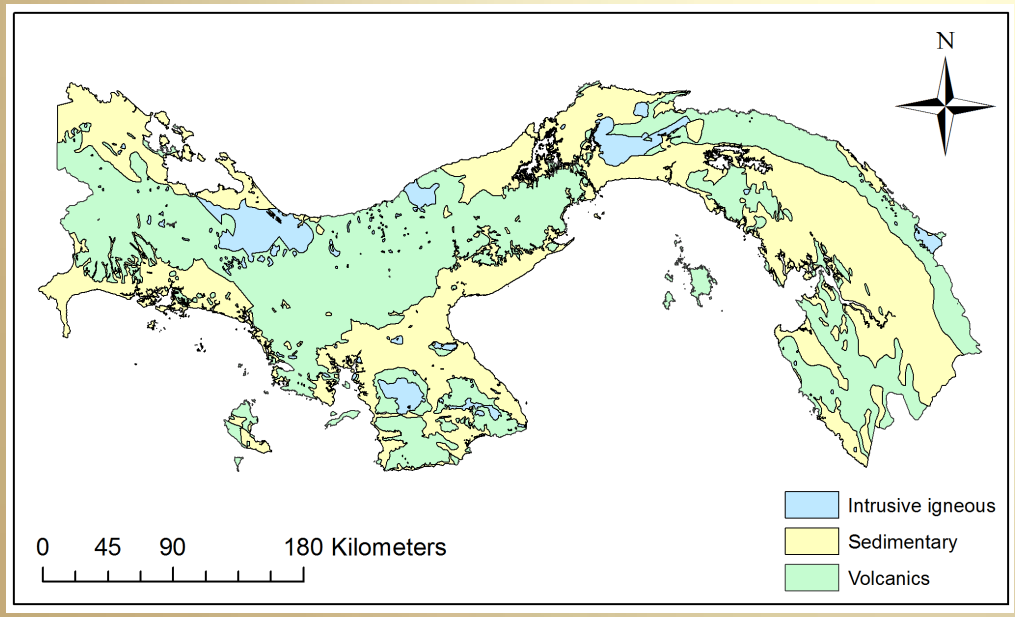


Lithology

- Tertiary volcanic rocks (n=32)
- Sedimentary rocks (n=3)
- Igneous intrusive rocks (n=5)



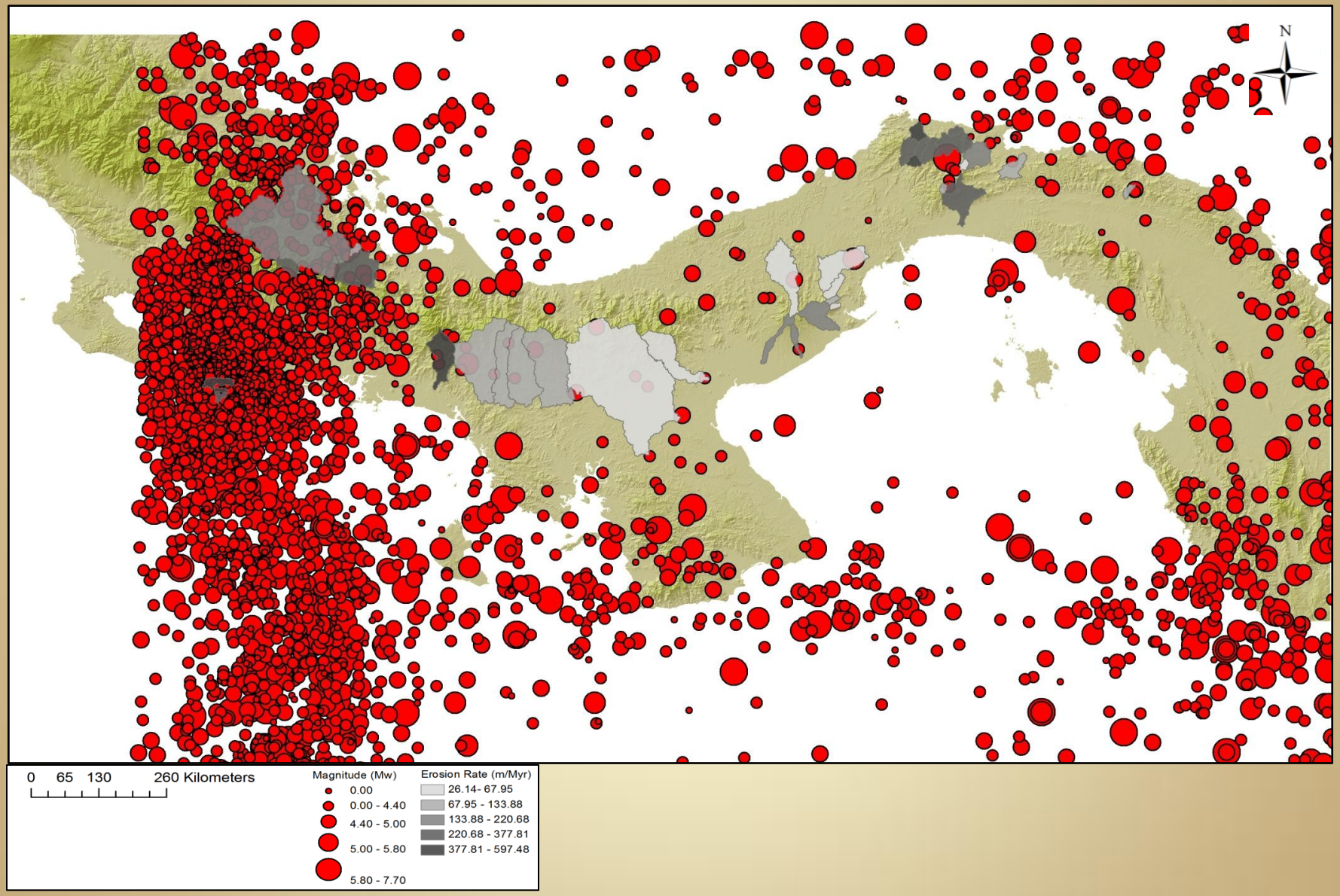
F = 2.4247; p = 0.102



Simplified geology of Panama

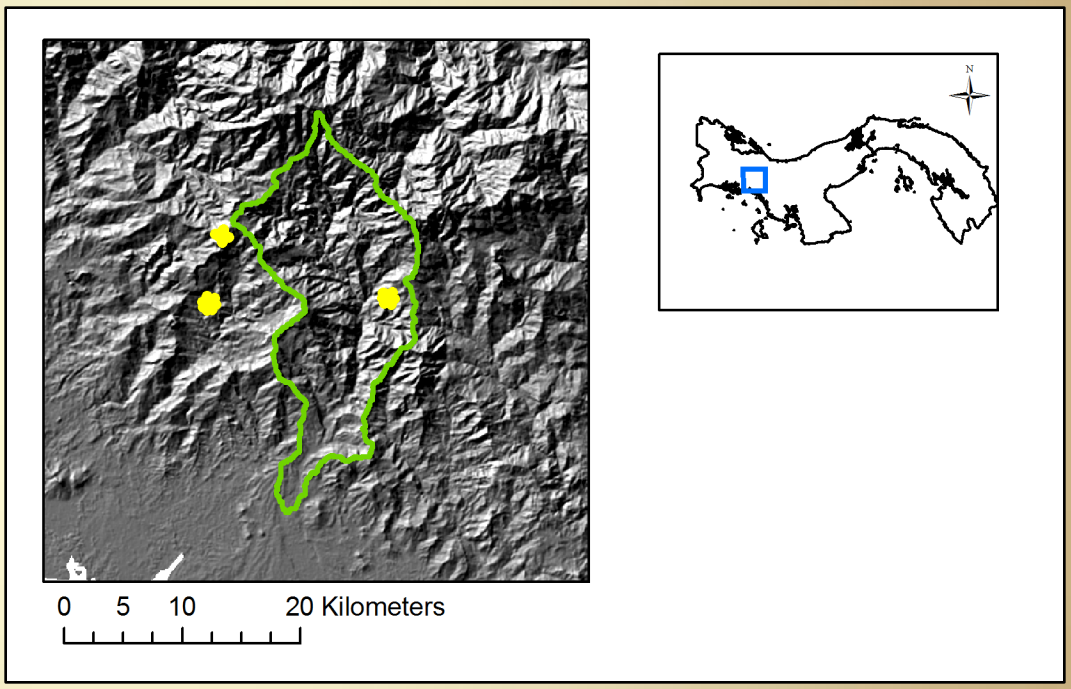
Seismicity

Variable	R^2	p	Slope
Events 10km	0.338	0.033	+
Events 25km	0.350	0.027	+
Depth 25km	0.334	0.035	-
Magnitude 25km	0.431	0.005	-
Events 50km	0.363	0.021	+
Depth 50km	0.466	0.002	-
Magnitude 50km	0.368	0.019	-
Events 75km	0.348	0.028	+
Depth 75km	0.420	0.007	-
Magnitude 75km	0.550	0.000	-
Events 100km	0.316	0.047	+


N
0 65 130 260 Kilometers
Magnitude (Mw)
0.00
0.00 - 4.40
4.40 - 5.00
5.00 - 5.80
5.80 - 7.70
Erosion Rate (m/Myr)
26.14- 67.95
67.95 - 133.88
133.88 - 220.68
220.68 - 377.81
377.81 - 597.48

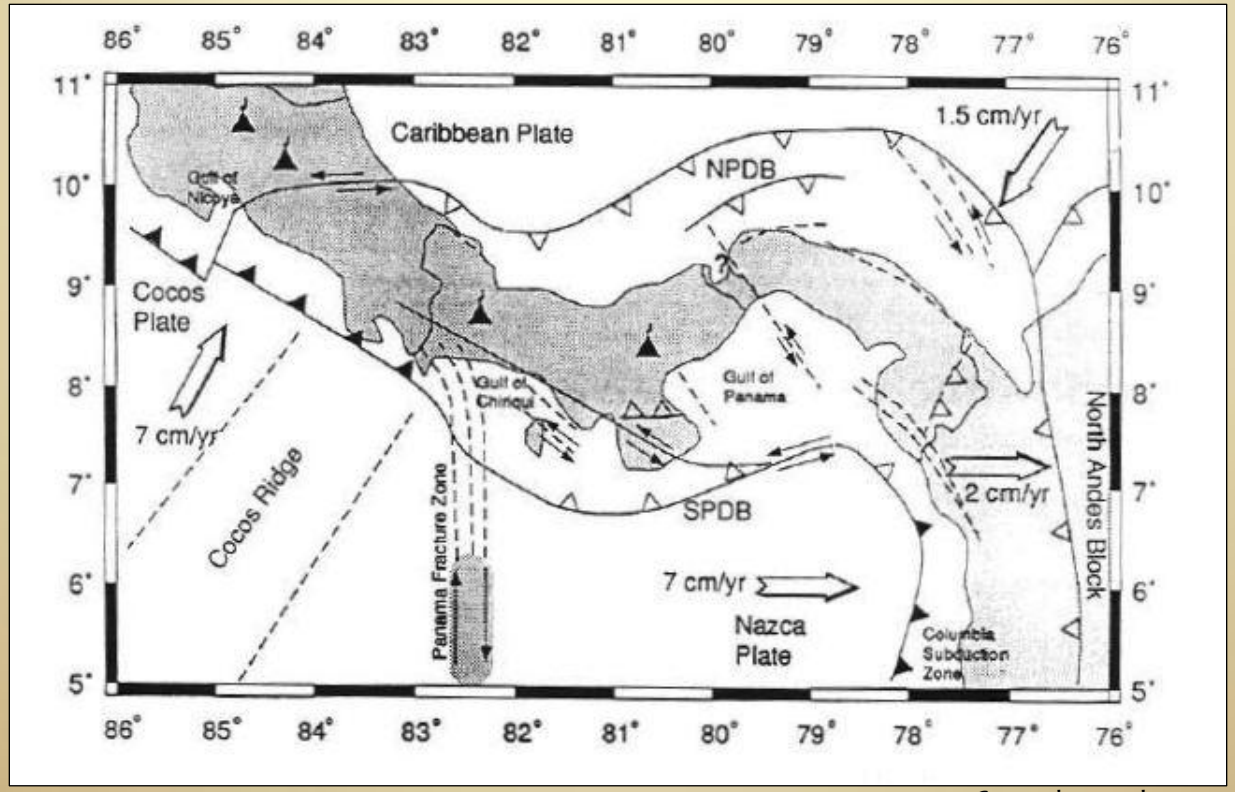
Rio Felix

- Highest eroding basin of my study
  - 597 m/Myr
- It is the only watershed that includes a volcanic structure (of the three in Panama)



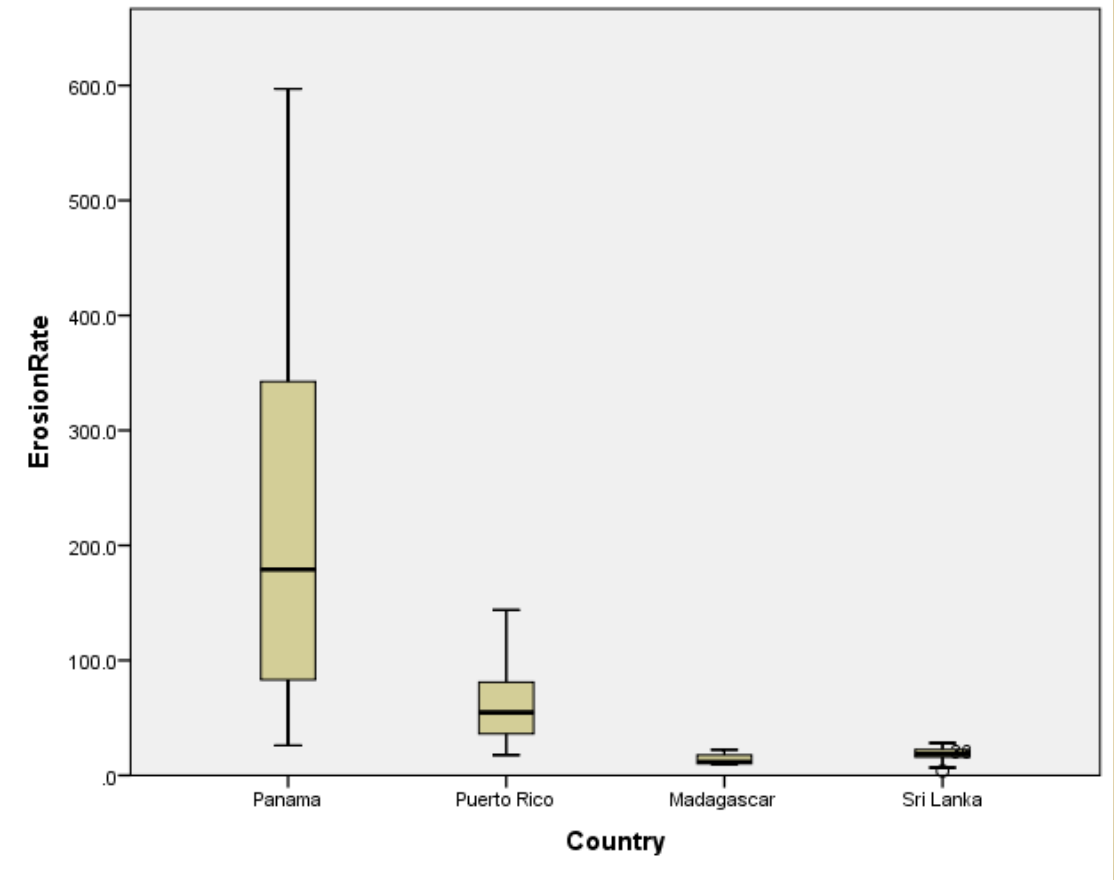
Tectonics

- Landslide frequency increases with seismic events, thus increasing erosion
- Rock uplift induced by tectonics
  - Burica Peninsula uplifts at a rate of ~55mm/yr



Camacho et al., 1997

Tropical cosmogenic studies

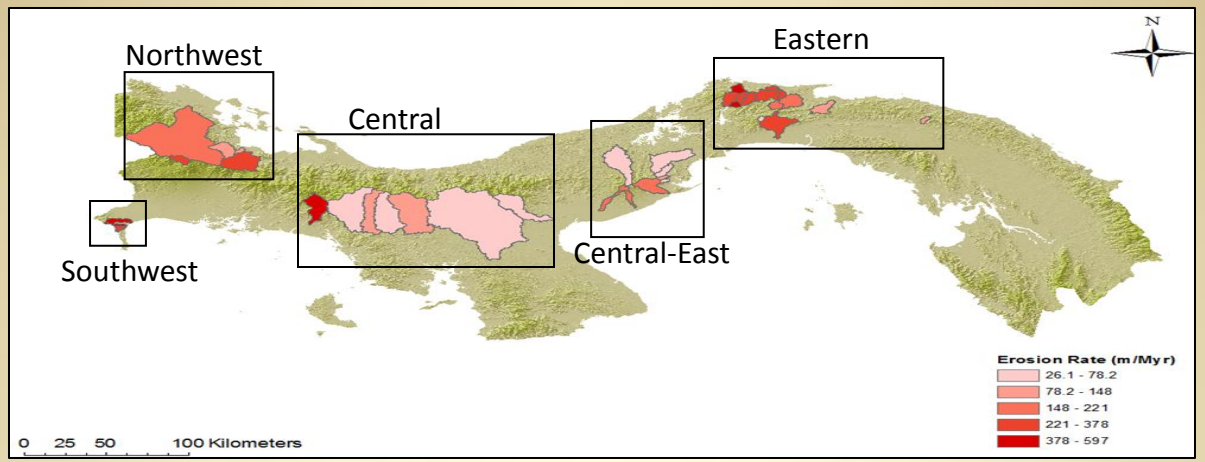


F=19.767, p<0.005

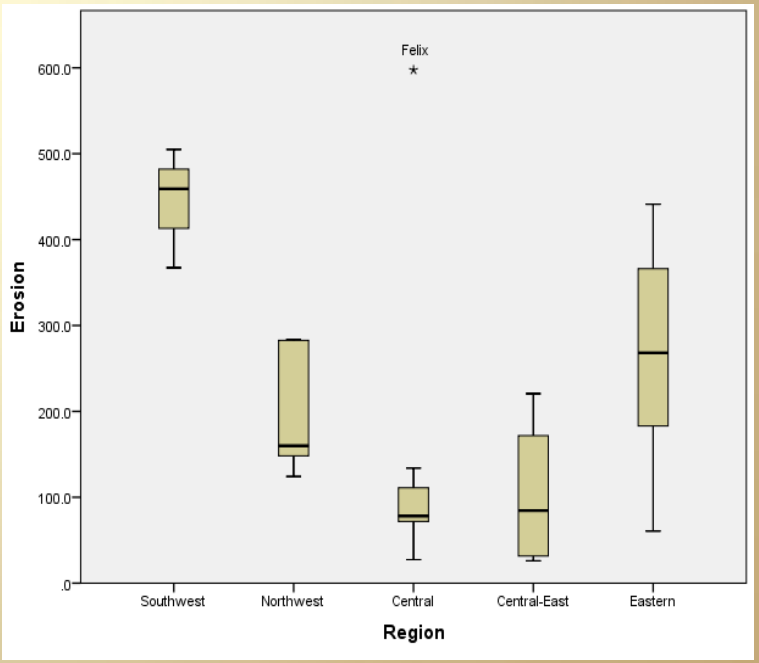
Tropical cosmogenic studies

Country	Average Erosion rates (m/Myr)	Peak Ground Acceleration (g)	Temperature (°C)	Precipitation (mm)
Panama (n=40)	218	2.29	24.4	2796
Puerto Rico (n= 24)	60.9	1.88	21.2	2733
Madagascar (n=4)	18.1	0.36	20.2	1135
Sri Lanka (n=16)	13.9	0.06	19.2	2480

Regional scale analysis

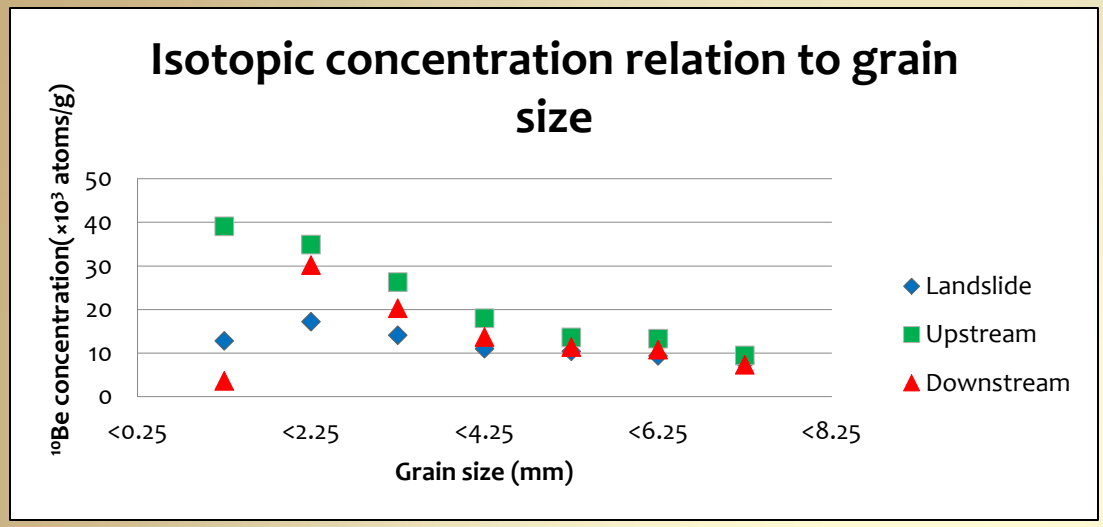


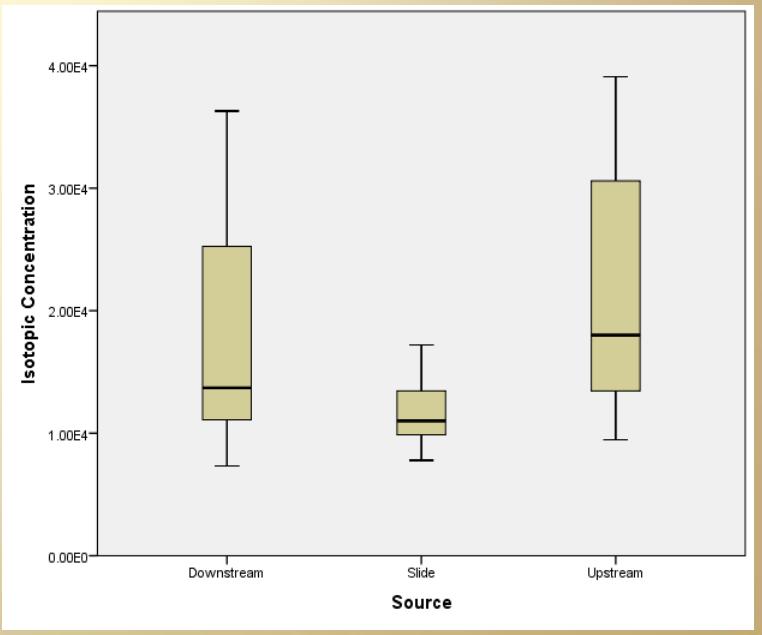
Region	Average erosion rate (m/Myr)	Average area (km^2)
Southwestern (n= 3)	444 ± 70	34.2 ± 27.8
Northwestern (n= 5)	200 ± 77	476 ± 752
Central (n= 7)	153 ± 199	783 ± 815
Central-eastern (n= 8)	103 ± 77	142 ± 141
Eastern (n= 17)	264 ± 151	84 ± 64



Parameter	R^2 (n=40)	R^2 (n=5)
Slope	0.009 (p=0.955)	0.192 (p=0.460)
Average Temperature	0.041 (p= 0.800)	0.071 (p=0.666)
Isothermality	0.381 (p= 0.015)	0.164 (p=0.499)
Mean annual precipitation	0.307 (p= 0.054)	0.000 (p=0.973)
Peak Ground Acceleration	0.307 (p= 0.054)	0.589 (p=0.130)
Seismic Magnitude 75km	0.550 (p = 0.000)	0.407 (p=0.247)
Seismic Events 10km	**0.338 (p= 0.033)**	**0.813 (p=0.036)**

Landslide samples





Grain size fraction	Upstream ^{10}Be ($x10^3$ atoms/g)	Landslide ^{10}Be ($x10^3$ atoms/g)	Downstream ^{10}Be ($x10^3$ atoms/g)	% landslide material downstream
<0.25mm	39.1	12.8	36.3	10.65
0.25mm -1 mm	34.9	17.2	30.2	26.55
1mm – 2mm	26.3	14.1	20.3	49.18
2mm – 4mm	18	11	13.7	61.42
4mm – 9mm	13.6	10.4	11.4	68.75
9mm – 12mm	13.3	9.35	10.8	63.29
>12mm	*9.46*	*7.79*	*7.33*	~~*127.54*~~

Conclusions

- First determination of long-term erosion rates in Panama at the country scale

- Highest cosmogenic-derived erosion rate of tropical climates (Portenga and Bierman, 2011)
  - Only exceeded by several studies in California Switzerland, and Italy (Temperate and Polar climates)

- Lack of relationship with topography – complex erosive dynamics

Future work

- Comparison to previously published work on cosmogenic-derived erosion rates in Panama and calculate changes in reservoir storage capacity at redefined erosion rates

- Calculation of modern sediment yields to compare to long-term in our watersheds

- Filling the spatial gaps in our study with both long-term and modern erosion rates data

Acknowledgements

- Committee
  - Dr. Paul Bierman
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  - Dr. Kyle K. Nichols
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Thanks for your attention