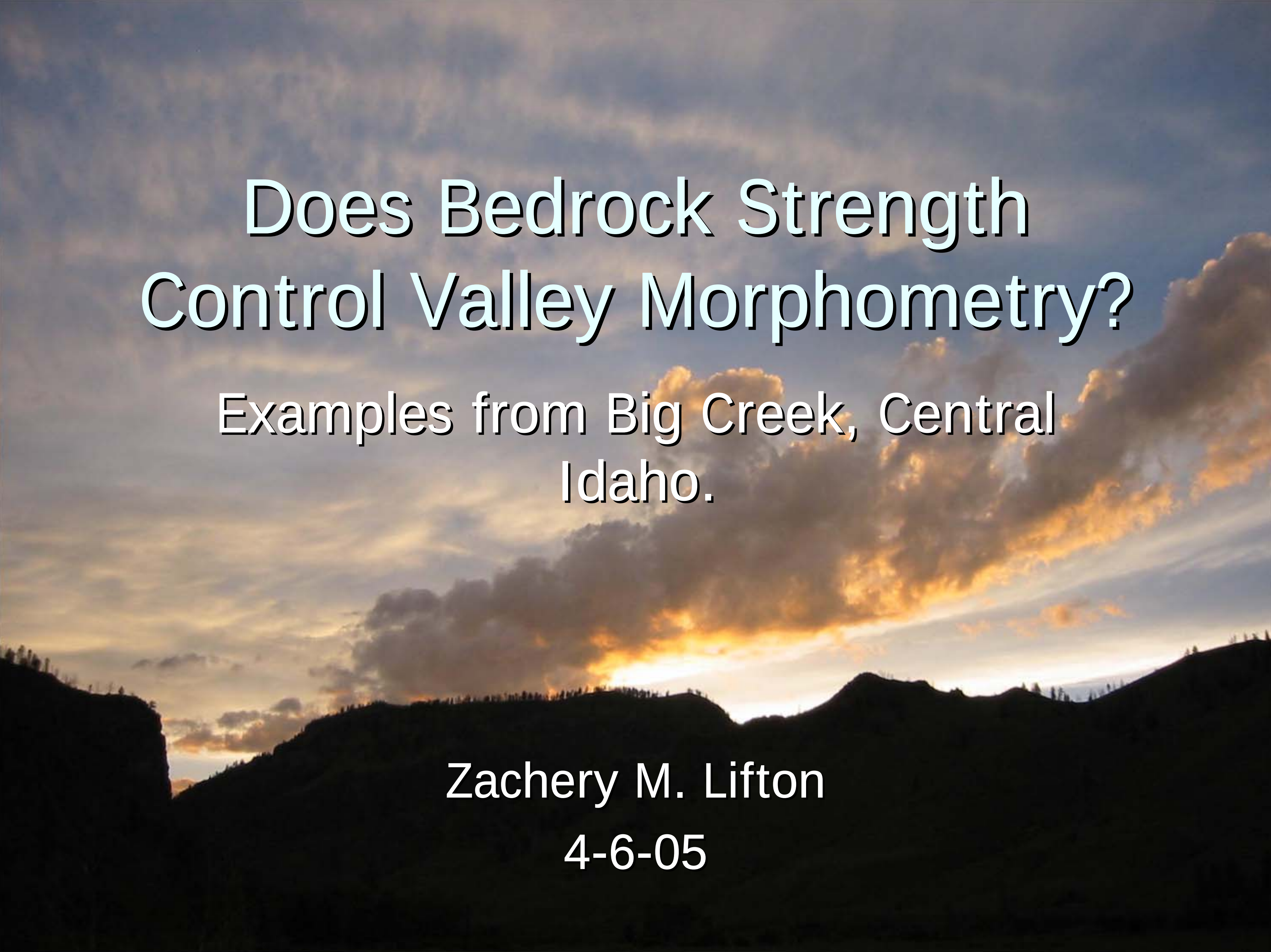

Does Bedrock Strength Control Valley Morphometry?
Examples from Big Creek, Central Idaho.
Zachery M. Lifton
4-6-05

Hypothesis

Bedrock with low strength will produce wide valley floors, low river gradients, and low hillslope gradients.

Bedrock with high strength will produce narrow valley floors, steep river gradients, and steep hillslope gradients.

Approach

In this study, a quantitative measure of bedrock strength is compared to three valley parameters:

1) Valley Floor Width
2) Stream Gradient
3) Hillslope Gradient

Approach

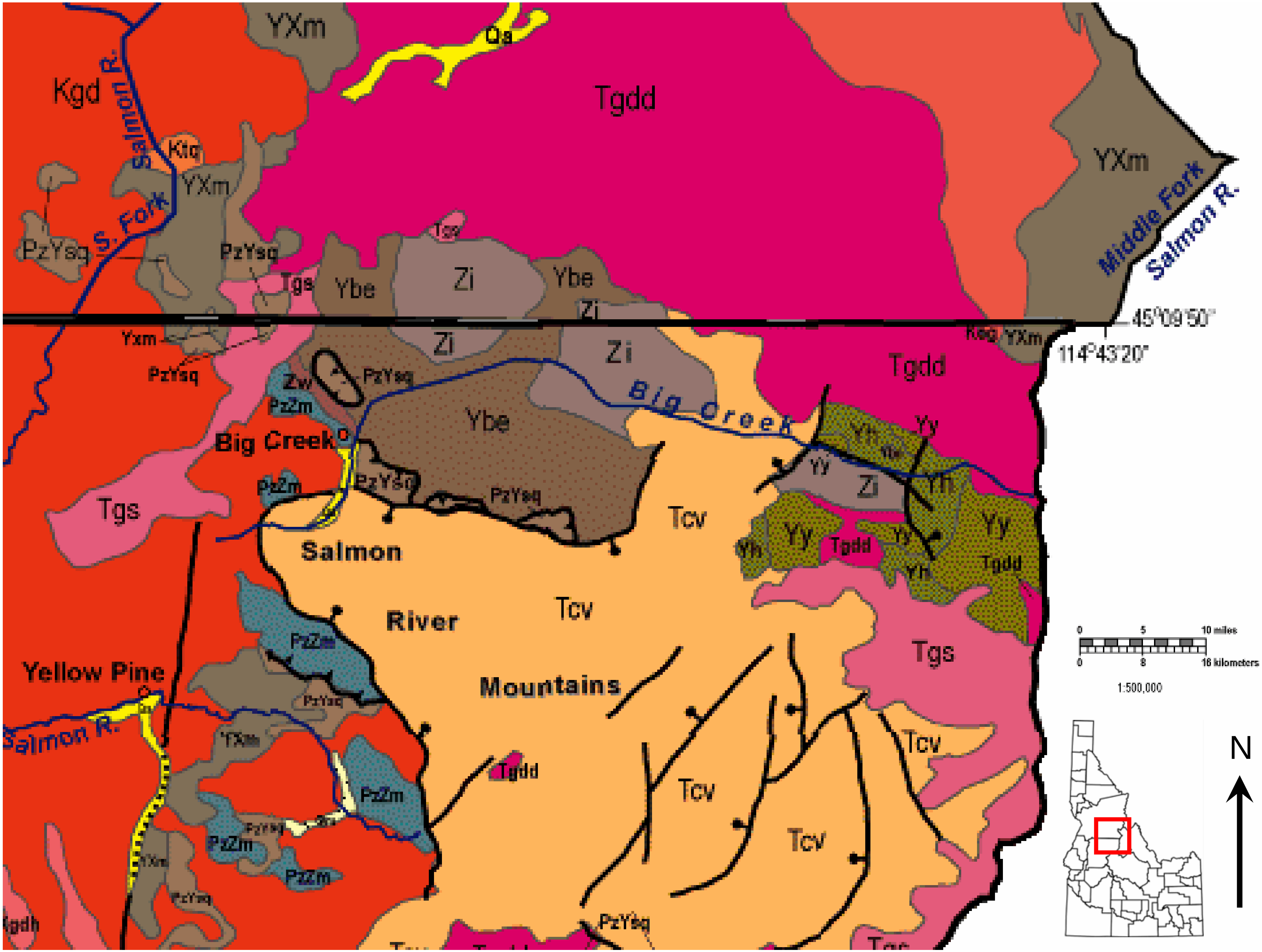
Intuitively, rock type must influence the development of river valleys. “Soft” or “weak” rock erodes more easily than “hard” or “strong” rock.

But what do “soft”, “hard”, “strong”, or “weak” mean?

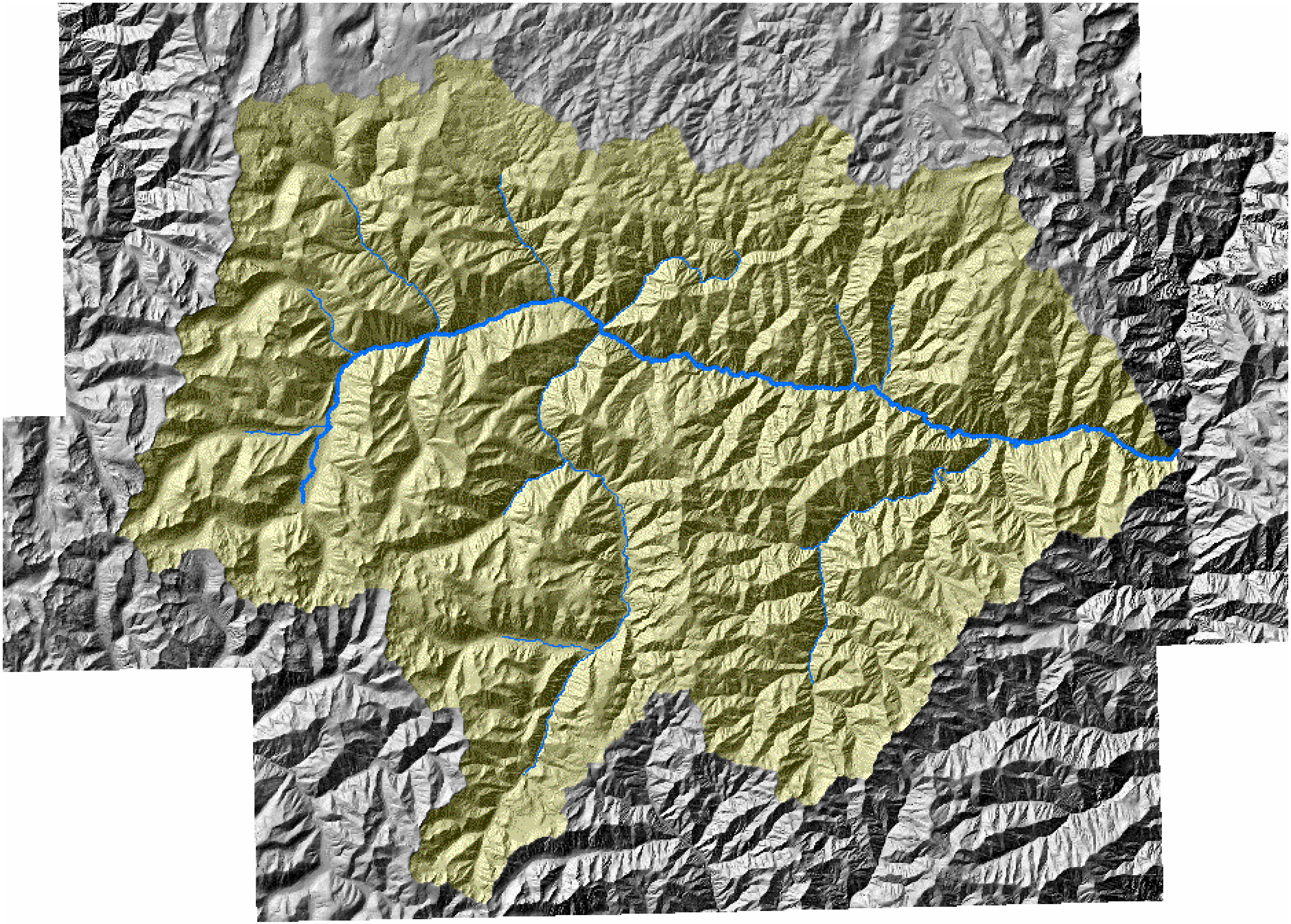
Approach

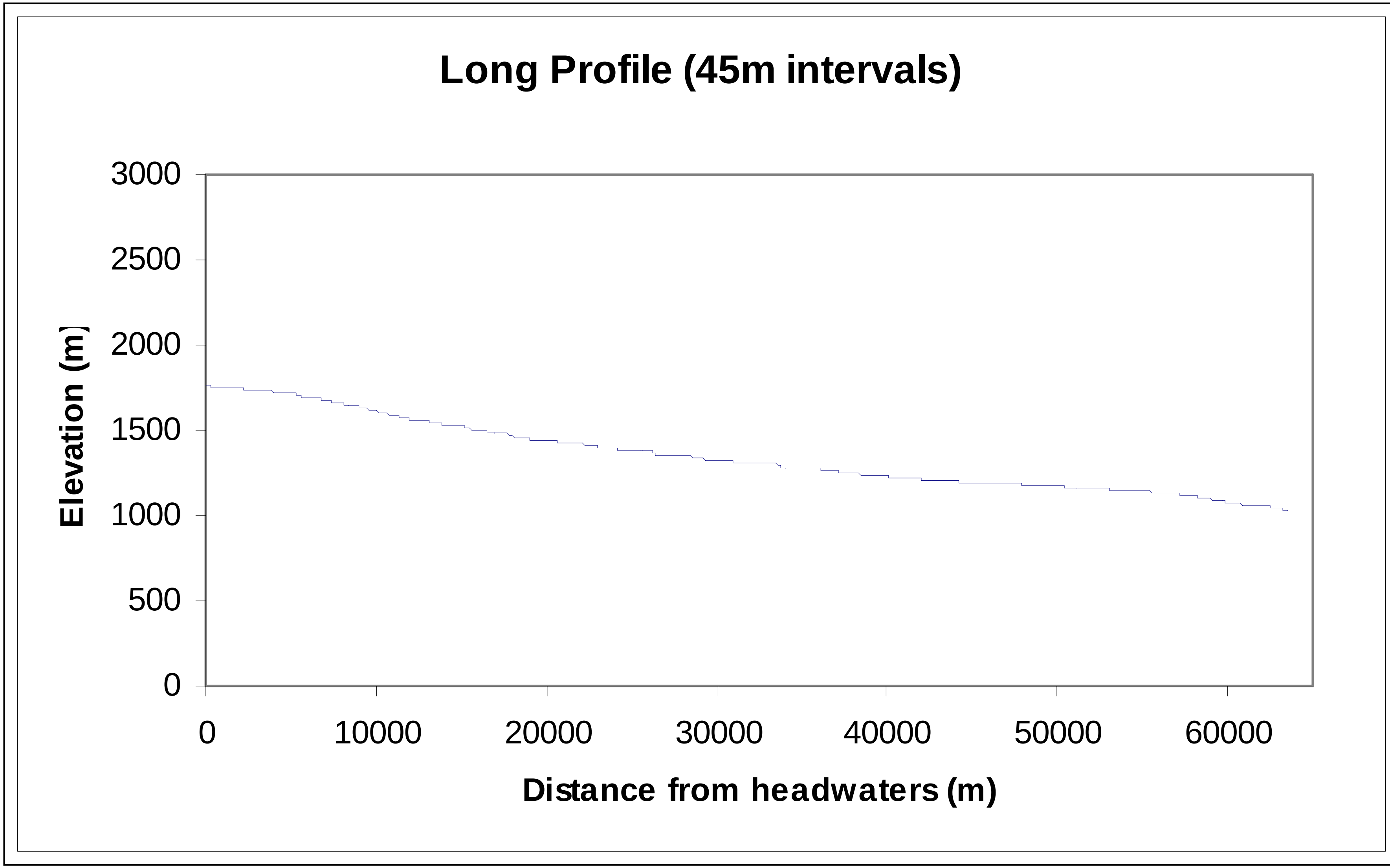
Additionally, rock type or lithology alone does not provide enough information for classifying, explaining, or predicting valley morphometry.

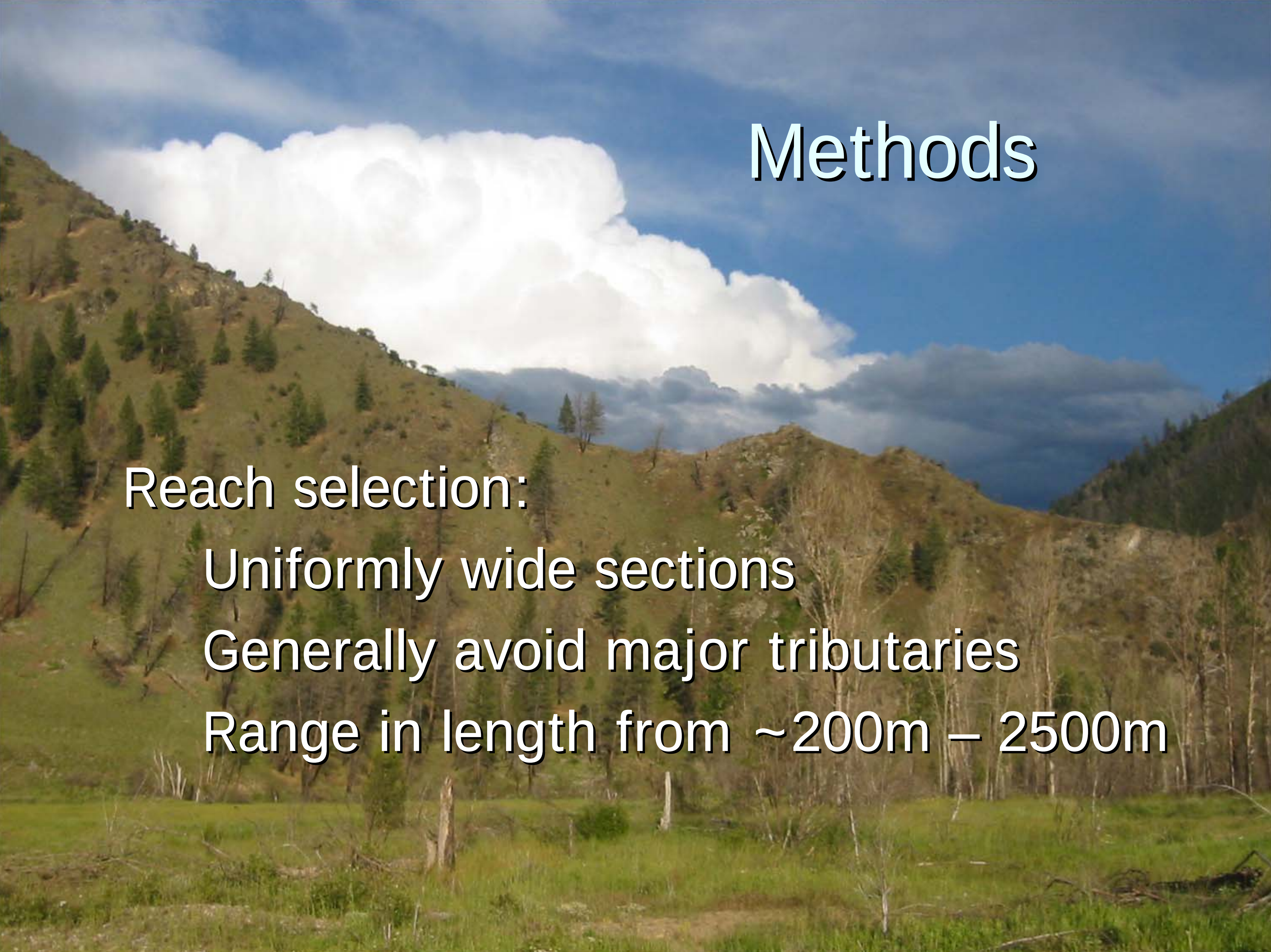
Something else is needed...



YXm
Qs
Kgd
Salmon R.
Tgdd
Ktg
YXm
S. Fork
PzYsq
PzYsq
Tgs
Ybe
Zi
Ybe
Zi
Middle Fork
Salmon R.
45°09'50"
114°43'20"
Yxm
PzYsq
Zi
Zi
Kgg
YXm
Tgdd
Zw
PzYsq
PzZm
Big Creek
Ybe
Big Creek
Yy
Yh
Yy
Zi
Yh
PzZm
PzYsq
PzYsq
Tcv
Tgs
Salmon
Yy
Tgdd
Yy
Yh
Yy
Tgdd
Yh
River
Tcv
PzZm
Tgs
0
5
10 miles
0
8
16 kilometers
1:500,000
Yellow Pine
Mountains
PzYsq
Salmon R.
YXm
Tcv
Tgdd
PzZm
Tcv
N
PzZm
Tcv
PzZm
PzYsq
PzYsq



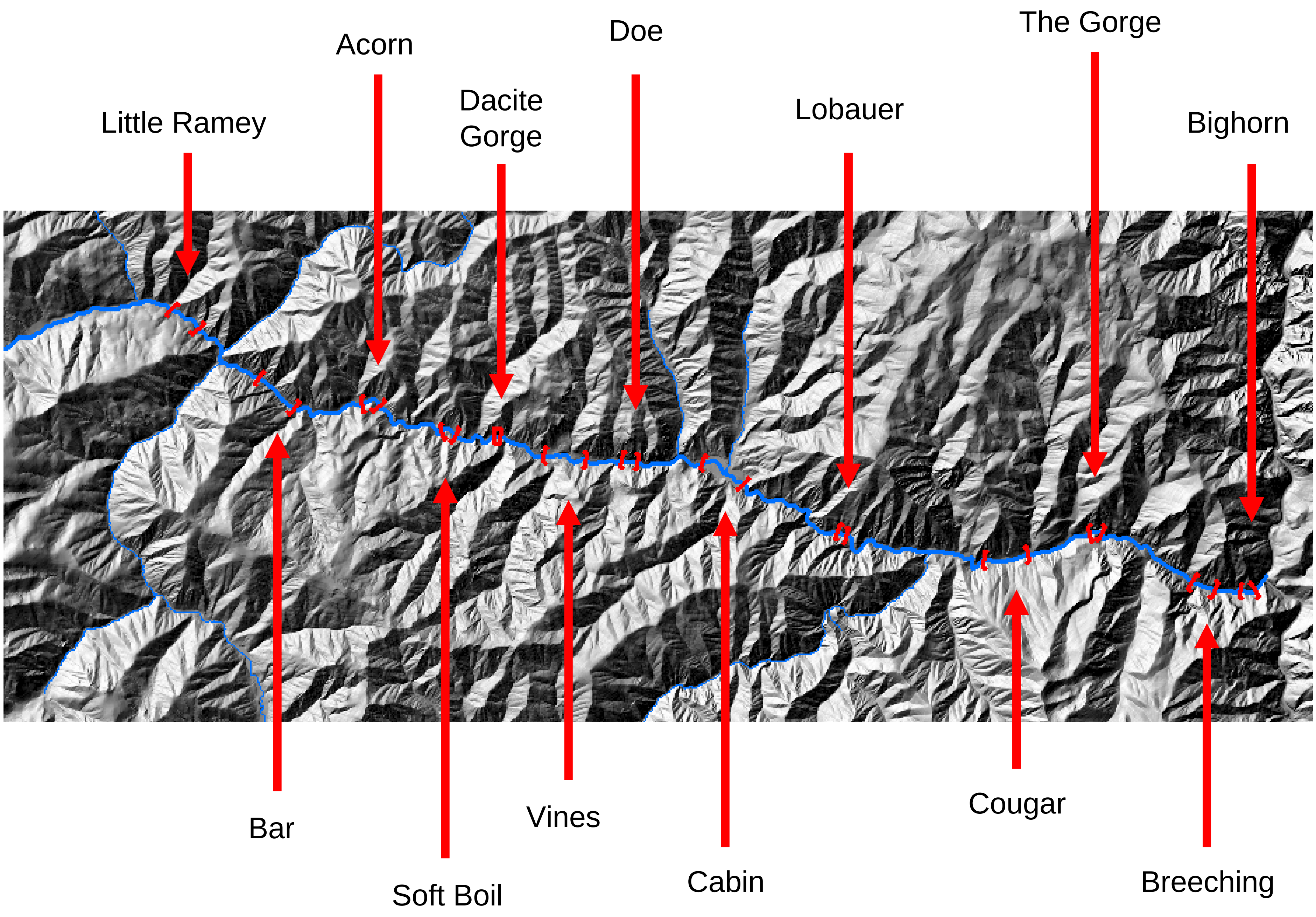

Long Profile (45m intervals)
Elevation (m)
3000
2500
2000
1500
1000
500
0
0
10000
20000
30000
40000
50000
60000
Distance from headwaters (m)



Methods

Reach selection:

- Uniformly wide sections
- Generally avoid major tributaries
- Range in length from ~200m – 2500m


Little Ramey
Acorn
Dacite Gorge
Doe
Lobauer
The Gorge
Bighorn
Bar
Soft Boil
Vines
Cabin
Cougar
Breeching

Methods

- Rock strength measured with a Schmidt Hammer.
- Valley floor width measured with a laser rangefinder.
- Stream gradient measured from DEM in ArcMap and RiverTools.
- Hillslope gradient measured from DEM in ArcMap.

Methods

The Schmidt Hammer "measures the distance of rebound of a controlled impact on a rock surface" (Day, 1980).

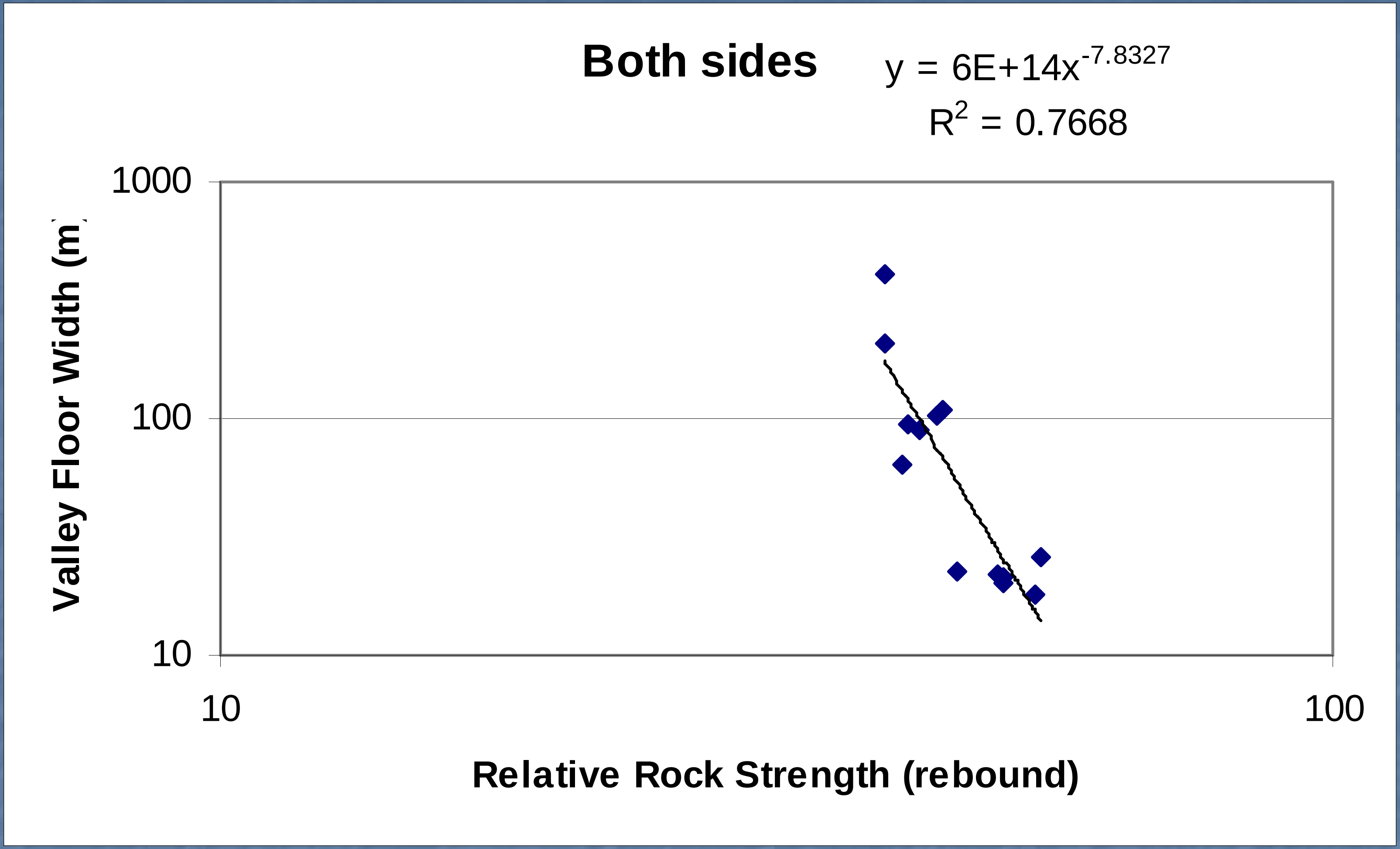
Methods

"Elastic recovery depends on surface hardness, and hardness is related to mechanical strength" (Day, 1980), therefore rebound measures relative hardness and may be thought of as a proxy for overall mechanical strength.

Methods

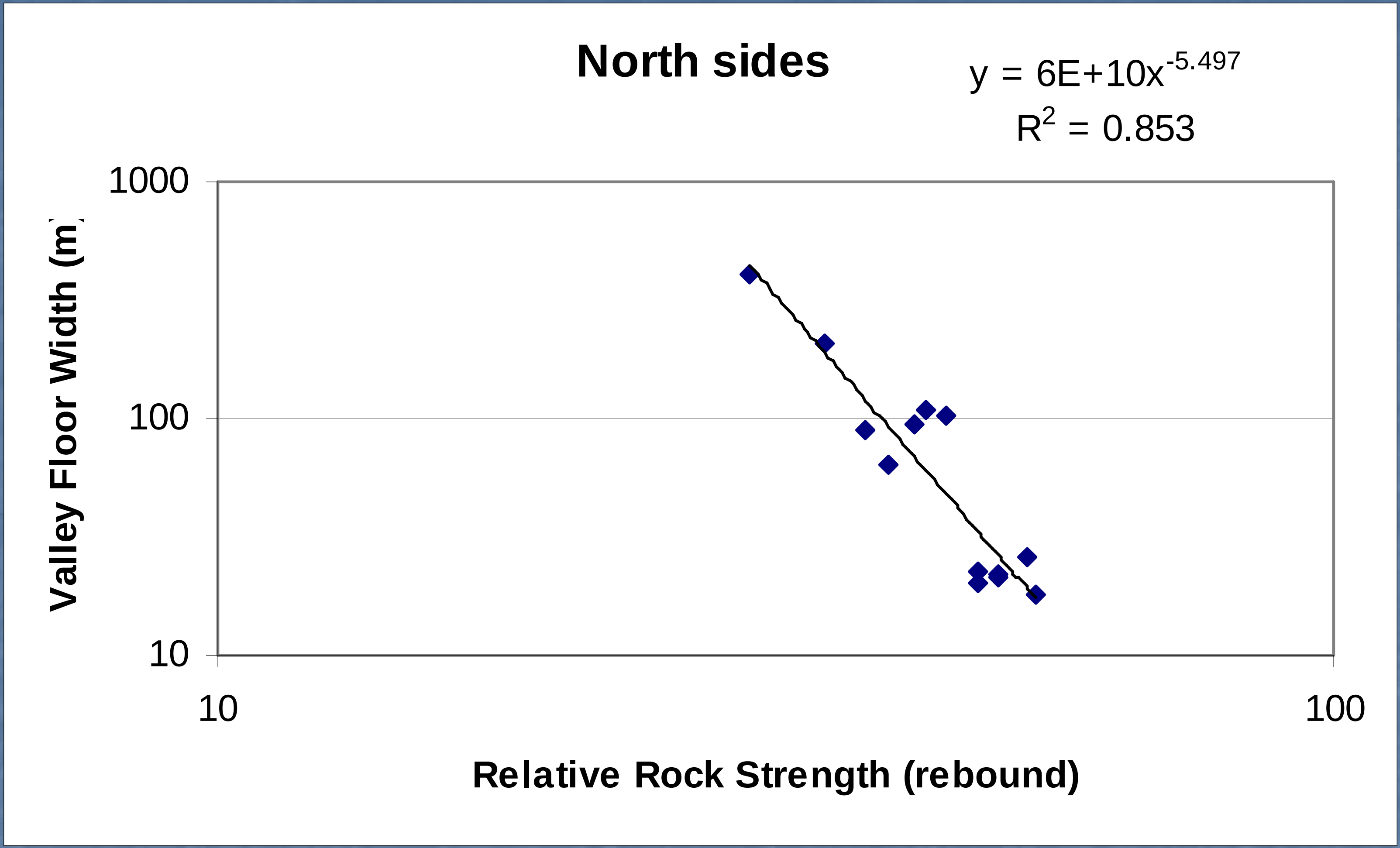
Furthermore, “surface hardness [...] may be a better measure of resistance to erosion than the bulk compressive strength” (Day, 1980).

Variance analysis shows that the mean of rebound readings at each reach are distinct: the variance between reaches is higher than the variance within the reaches.

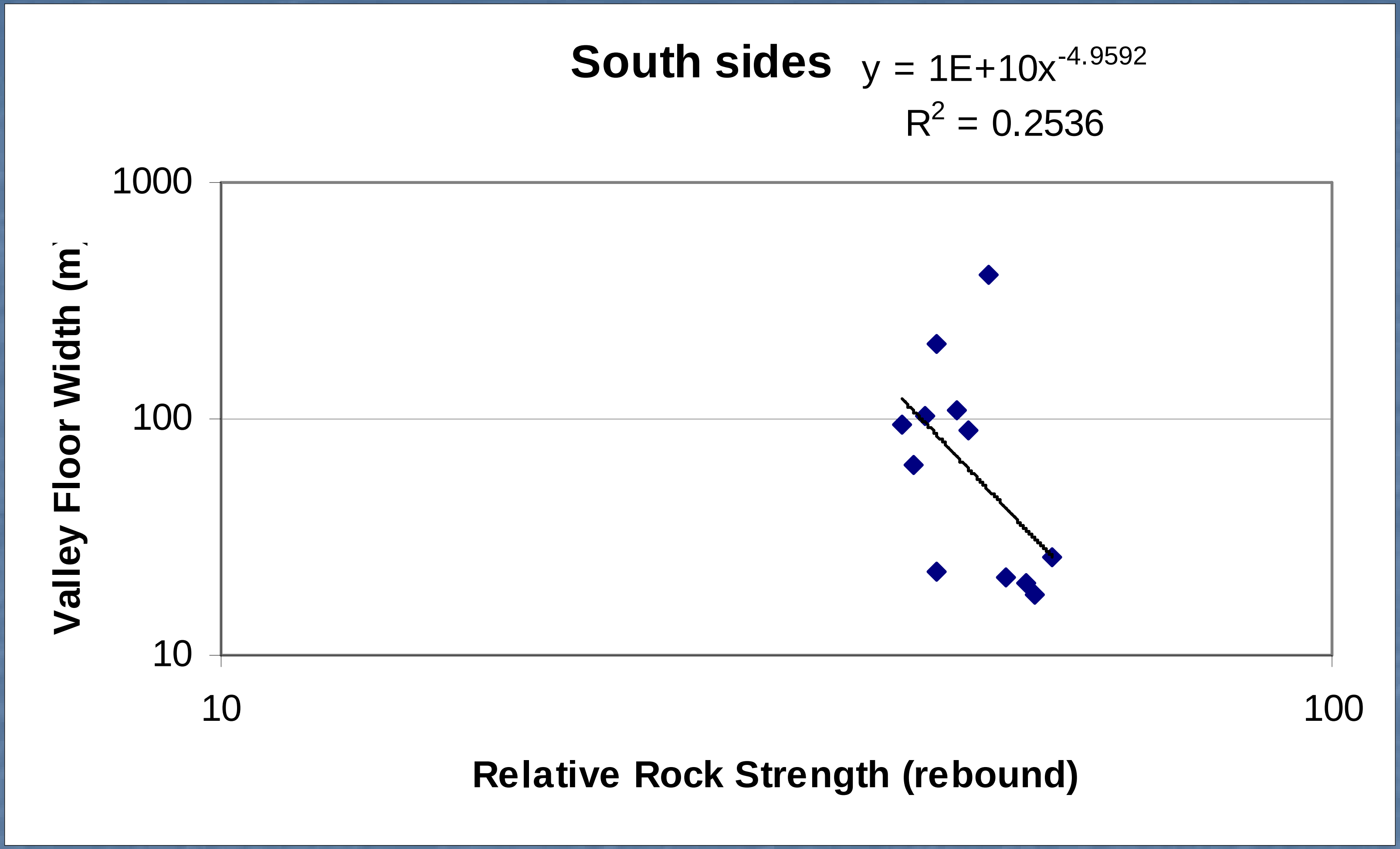


Both sides
y = 6E+14x-7.8327
R2 = 0.7668
1000
100
10
10
100
Valley Floor Width (m)
Relative Rock Strength (rebound)

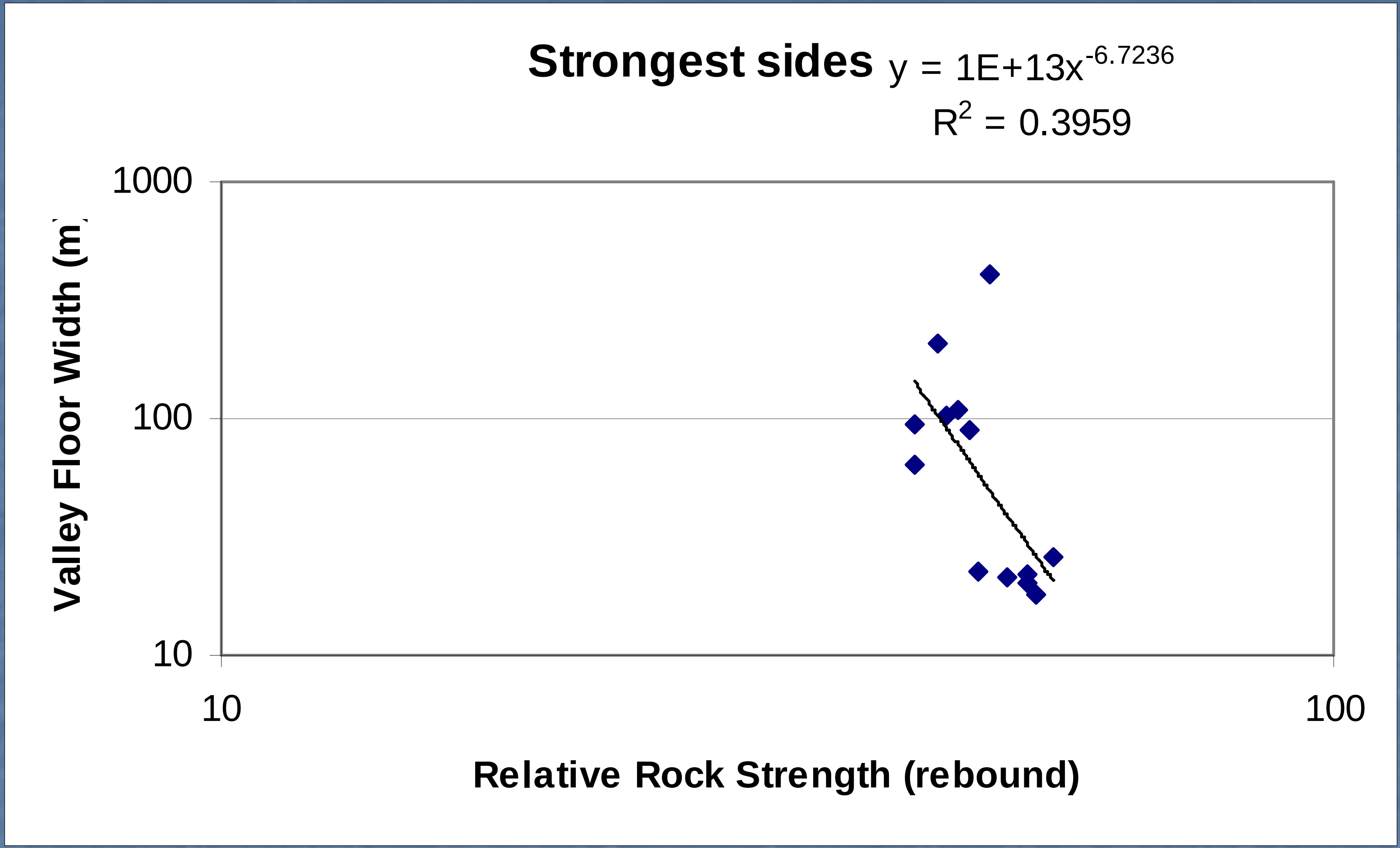
P = 7.859 E-05


North sides
y = 6E+10x-5.497
R2 = 0.853
1000
100
10
10
100
Valley Floor Width (m)
Relative Rock Strength (rebound)

P = 6.612 E-06

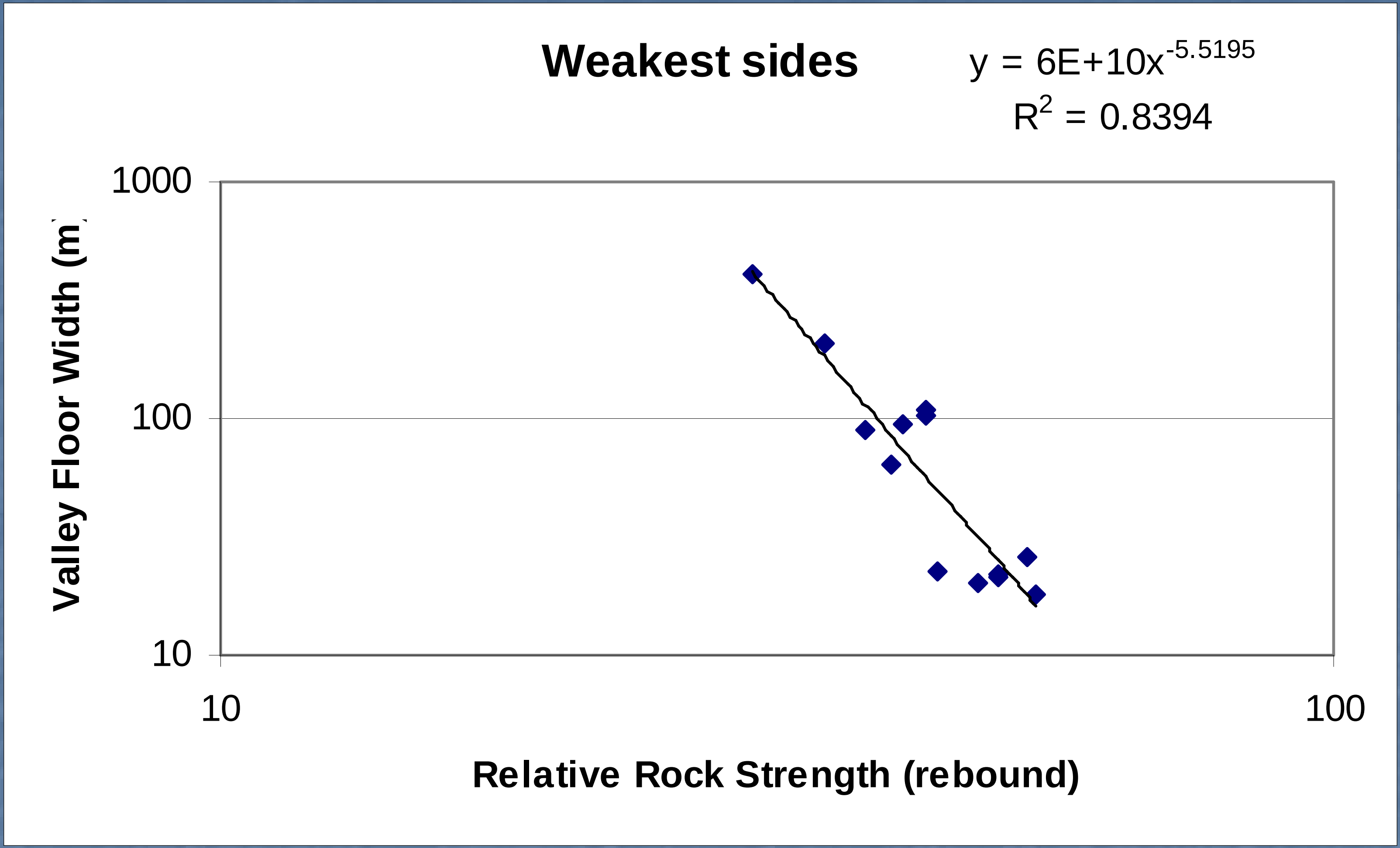

South sides
y = 1E+10x-4.9592
R2 = 0.2536
1000
100
10
Valley Floor Width (m)
10
100
Relative Rock Strength (rebound)

P = 0.0547

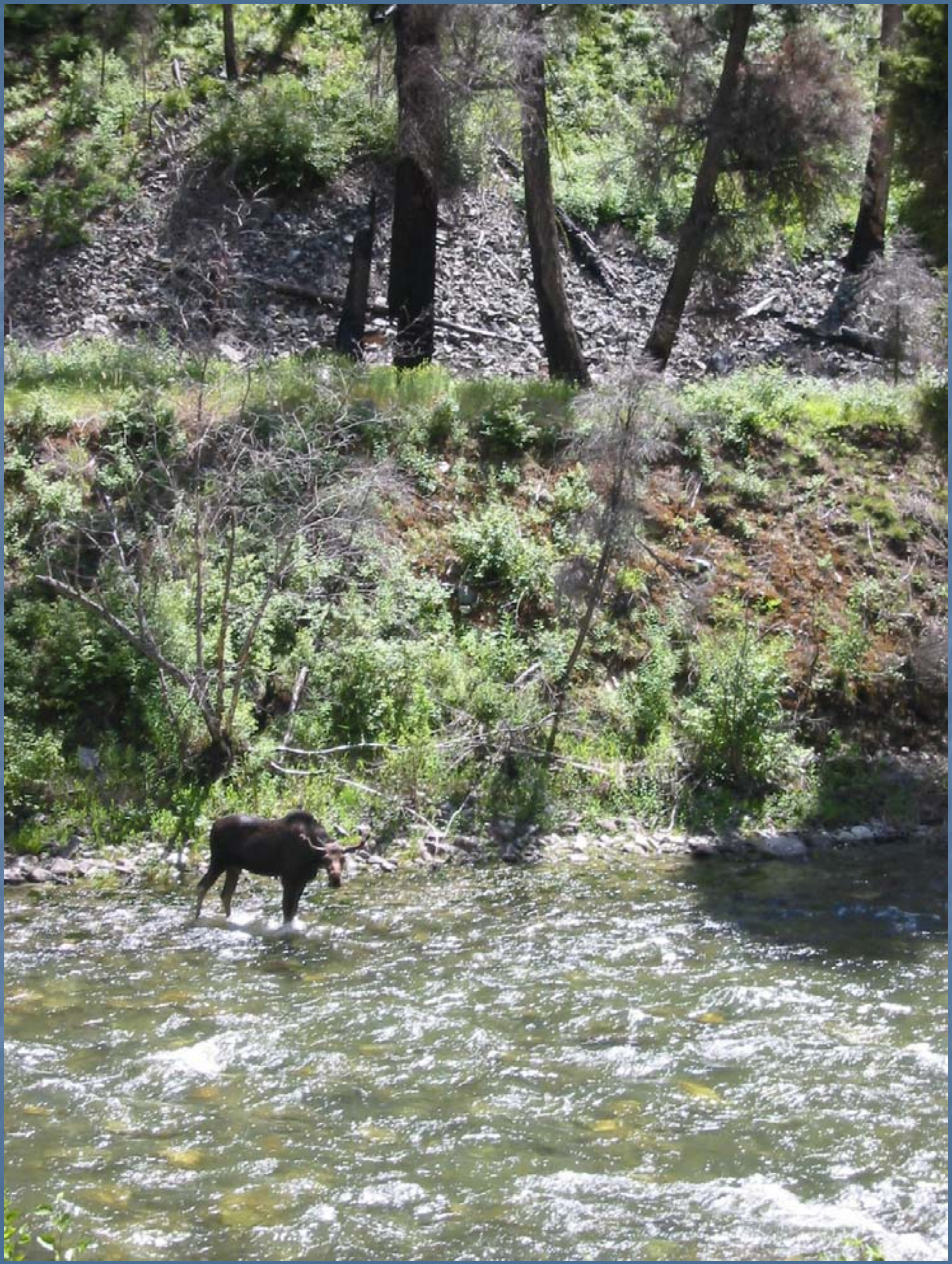


Strongest sides
y = 1E+13x-6.7236
R2 = 0.3959
1000
100
10
10
100
Valley Floor Width (m)
Relative Rock Strength (rebound)

P = 0.0212


Weakest sides
y = 6E+10x-5.5195
R2 = 0.8394
1000
100
10
10
100
Valley Floor Width (m)
Relative Rock Strength (rebound)

P = 1.082 E-05



The relationship between relative rock strength (as measured by the Schmidt Hammer) and valley floor width is described by a power law function. Sklar and Dietrich (2001) found a similar relationship in an abrasion study.

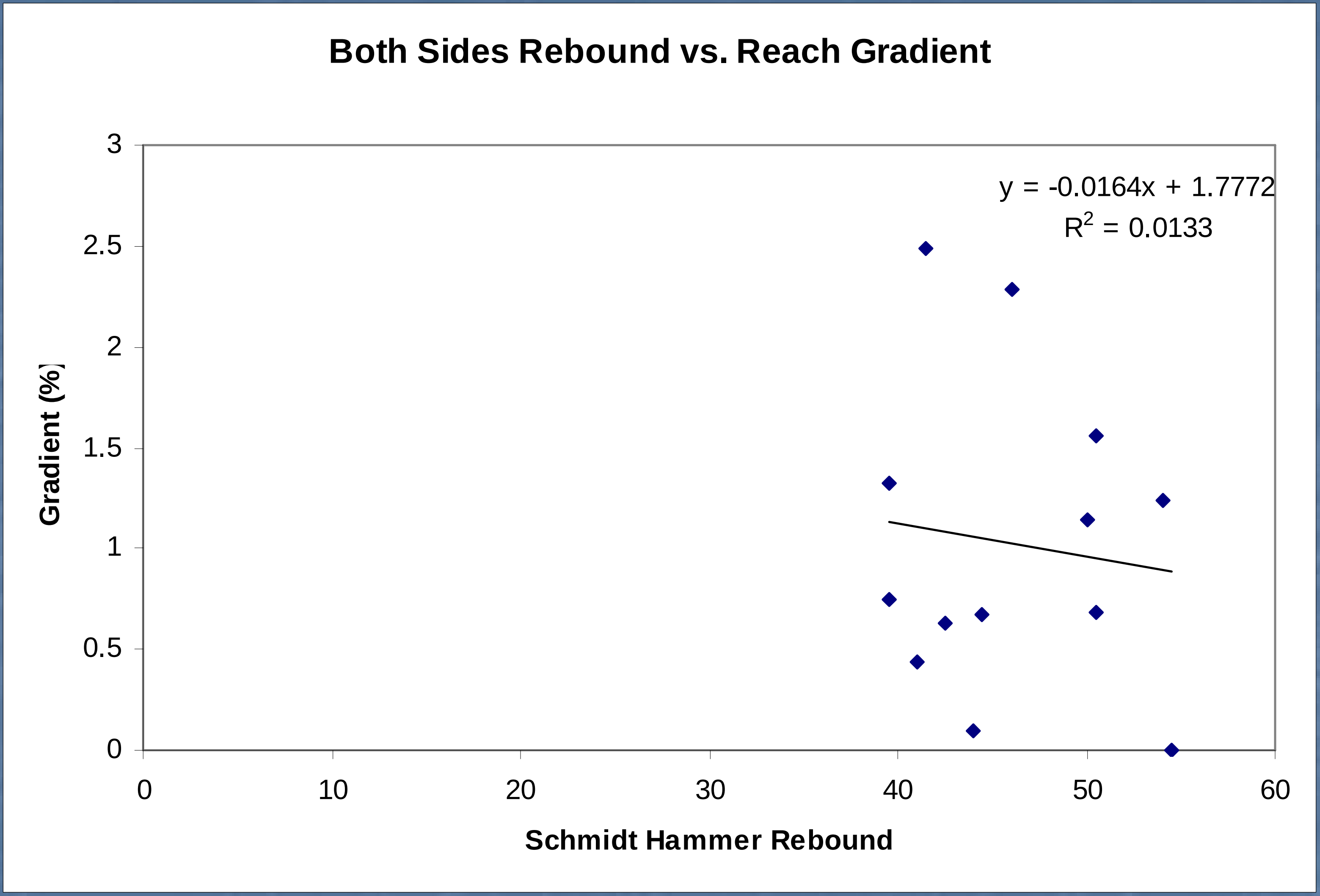
There also appears to be an aspect effect on rock strength: the south side of the valley (north facing slopes) generally has higher rock strength.

t-test of all North data vs. all South data

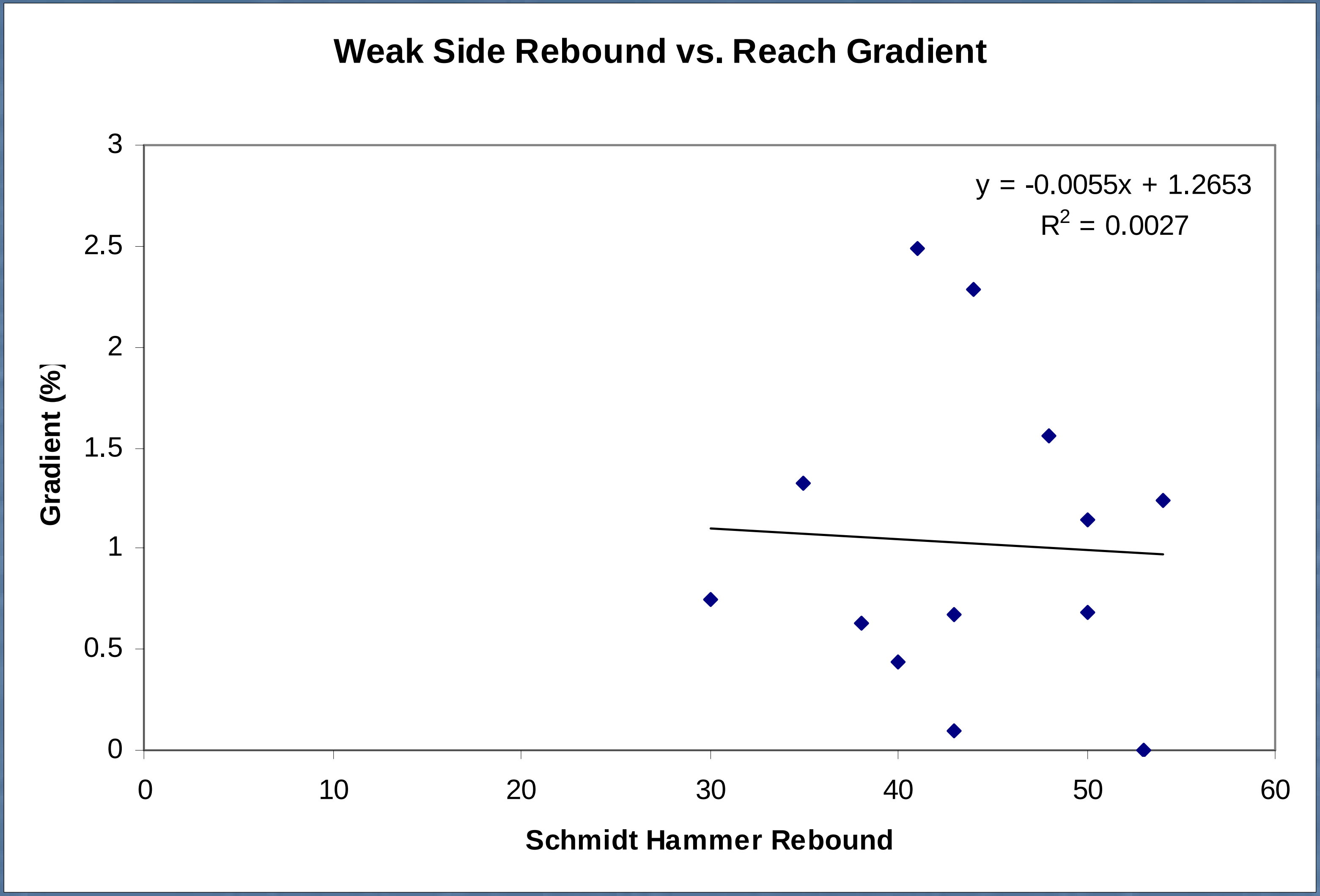
N/S compared by ALL DATA

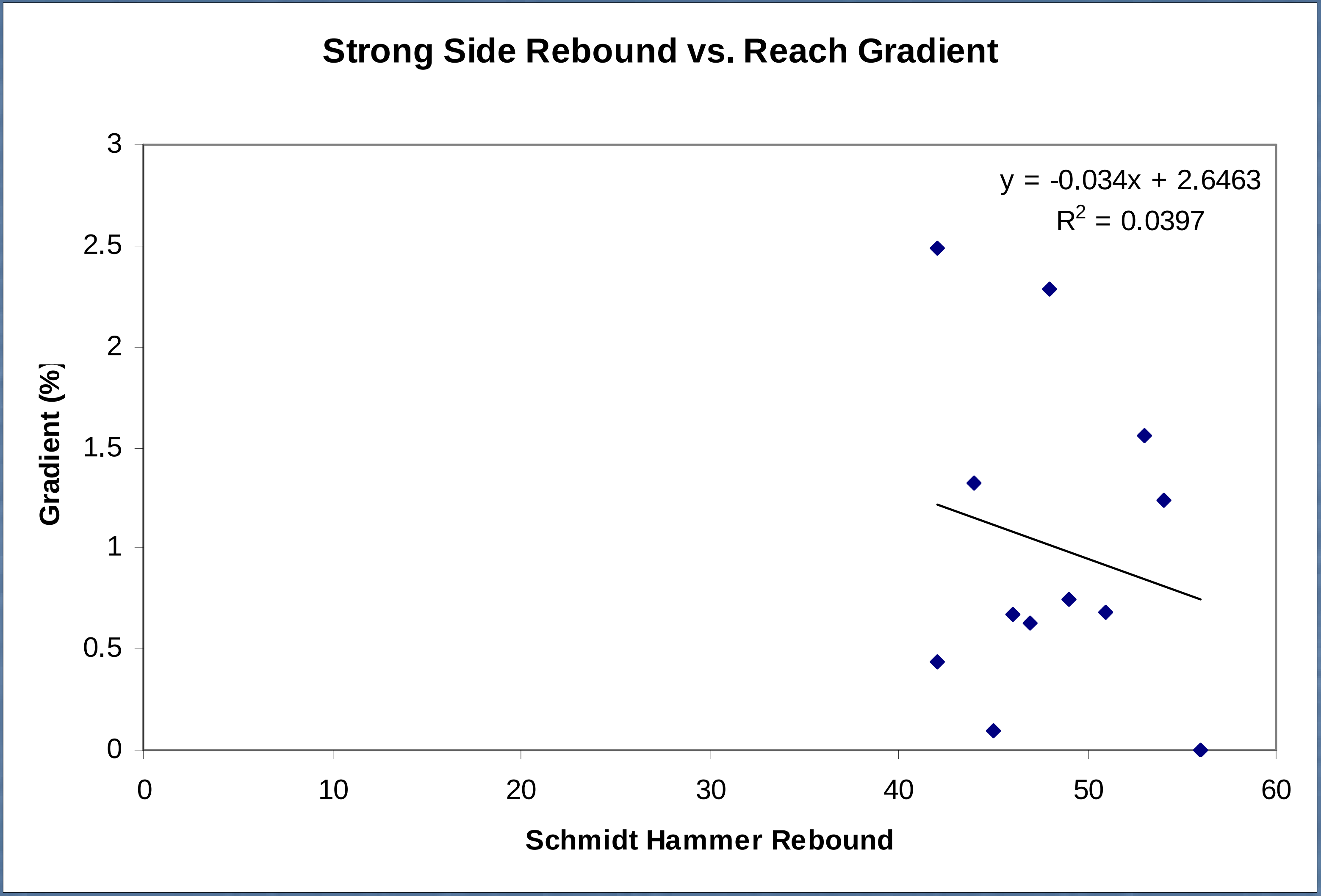
t-Test: Two-Sample Assuming Unequal Variances

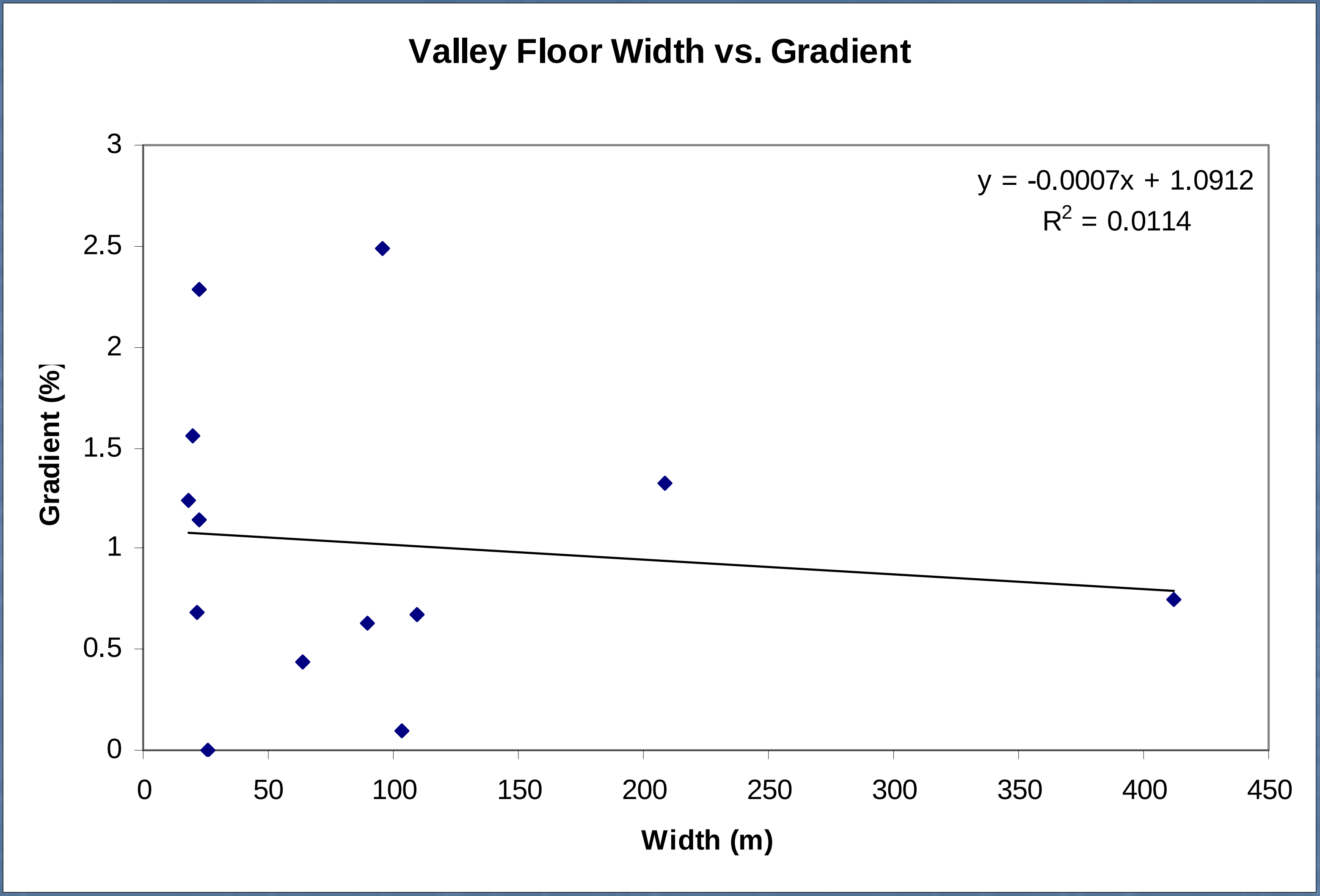
	All North	*All South*
Mean	1.620513	1.654133
Variance	0.029982	0.015141
Observations	1078	1231
Hypothesized Mean Difference	0	
df	1913	
t Stat	-5.30824	
P(T<=t) one-tail	6.18E-08	
t Critical one-tail	1.645651	
P(T<=t) two-tail	1.24E-07	
t Critical two-tail	1.961207	



Both Sides Rebound vs. Reach Gradient
y = -0.0164x + 1.7772
R2 = 0.0133
Gradient (%)
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
Schmidt Hammer Rebound


Weak Side Rebound vs. Reach Gradient
y = -0.0055x + 1.2653
R2 = 0.0027
Gradient (%)
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
Schmidt Hammer Rebound


Strong Side Rebound vs. Reach Gradient
y = -0.034x + 2.6463
R2 = 0.0397
Gradient (%)
Schmidt Hammer Rebound
0
0.5
1
1.5
2
2.5
3
0
10
20
30
40
50
60


Valley Floor Width vs. Gradient
y = -0.0007x + 1.0912
R^2 = 0.0114
Gradient (%)
Width (m)
0
0.5
1
1.5
2
2.5
3
0
50
100
150
200
250
300
350
400
450

Local stream gradient doesn’t seem to be controlled by rock strength, probably because Big Creek is an alluvial stream.

Conclusions

- Rock strength is related to valley floor width by a power-law relationship.
- Stream gradient does not seem to be affected by rock strength (in an alluvial river).
- Rock strength is influenced by aspect. North-facing slopes have higher strength than south-facing slopes. Melton (1960) offers some explanations, but this study did not address that question directly.
- Hillslope analysis is in progress.

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Why not Selby's (1980) Rock Mass Strength Index?

- RMS is primarily a hillslope index.
- It estimates the total strength of a mass of rock; this is useful for engineering applications, but "seldom relevant to geomorphic study" (Selby, 1980).
- I am interested in fluvial processes where strength at a smaller scale is needed.
- RMS index takes semi-quantitative measures and turns them back into a qualitative index!

Variance analysis by lithology

Groups	Count	Sum	Average	Variance
Yh/Yaq	246	402.5816	1.636511	0.019658
Zdi-sy	722	1170.633	1.621376	0.024695
Tdq/Tss	935	1521.702	1.627488	0.023102
Tgd/Tgdf	170	287.6142	1.691848	0.012589

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.714262	3	0.238087	10.63337	6.16E-07	2.609205
Within Groups	46.3261	2069	0.022391			
Total	47.04036	2072				