The influence of sandstone caprock material on channel steepness in the Buffalo National River Basin, AR

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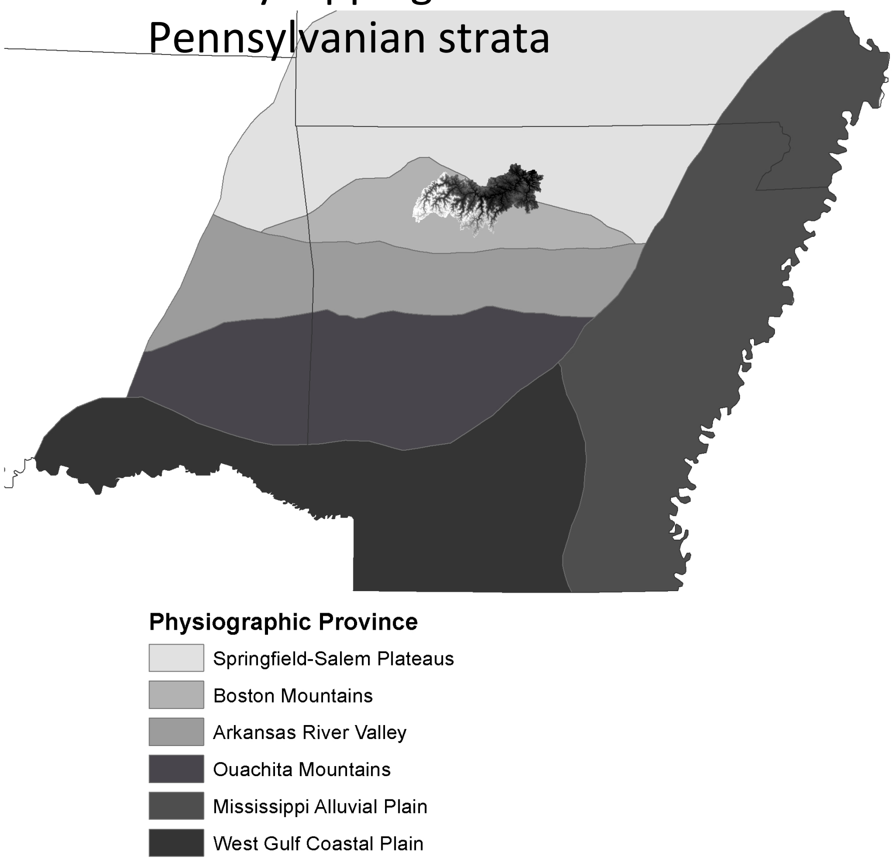
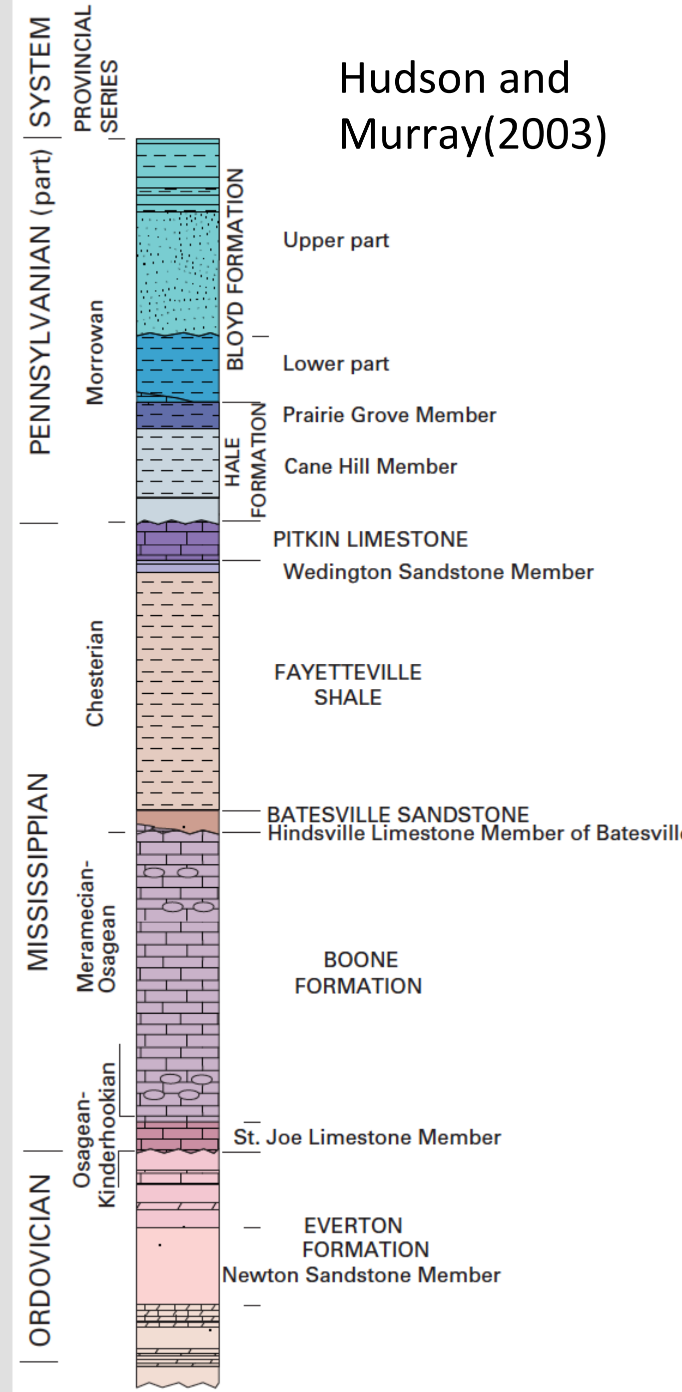
Buffalo National River Basin
Ozark and Boston Mountains Region

- Uplift coincident with Ouachita-Appalachian orgeny
  - Tectonically inactive
- Series of uplifted and dissected plateaus
- Gently dipping Ordovician to Pennsylvanian strata





Hudson and Murray(2003)

- Integral method of channel profile analysis & chi gradients
  - Perron and Royden(2013)

$$\frac{\mathrm{d}z}{\mathrm{d}x} = \left(\frac{U}{K}\right)^{1/n} A\left(x\right)^{-m/n}$$

- Quantify channel steepness with effect of basin area removed using chi gradients

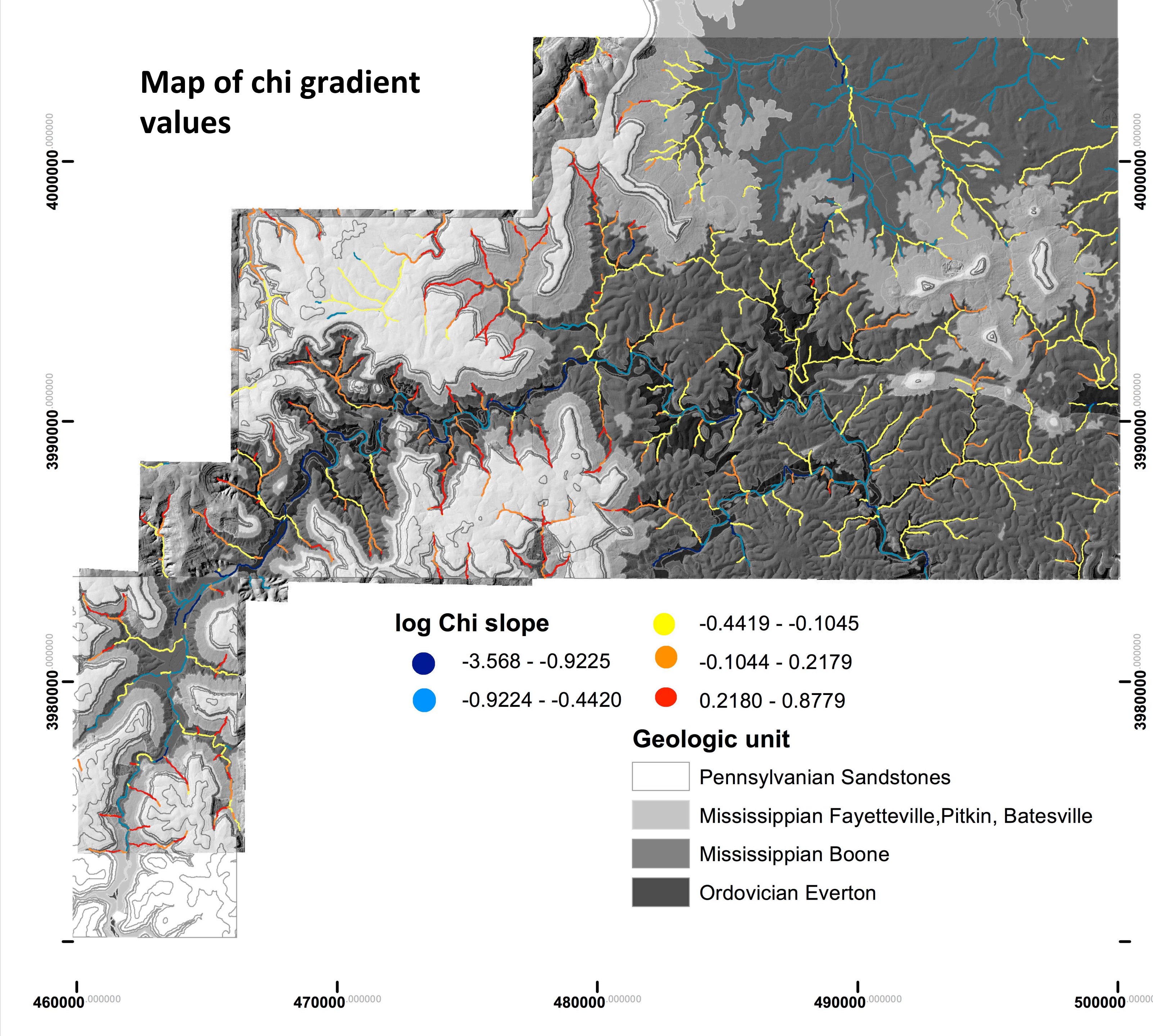
$$z\left(x\right) = z\left(x_0\right) + m_\chi \chi$$

- Analysis was done using LSDTopoToolbox
  - Calculates chi gradient and drainage area at evenly spaced nodes along channel
  - Concavity is 0.45
  - Basins below $10^{5.7}m^2$ were trimmed

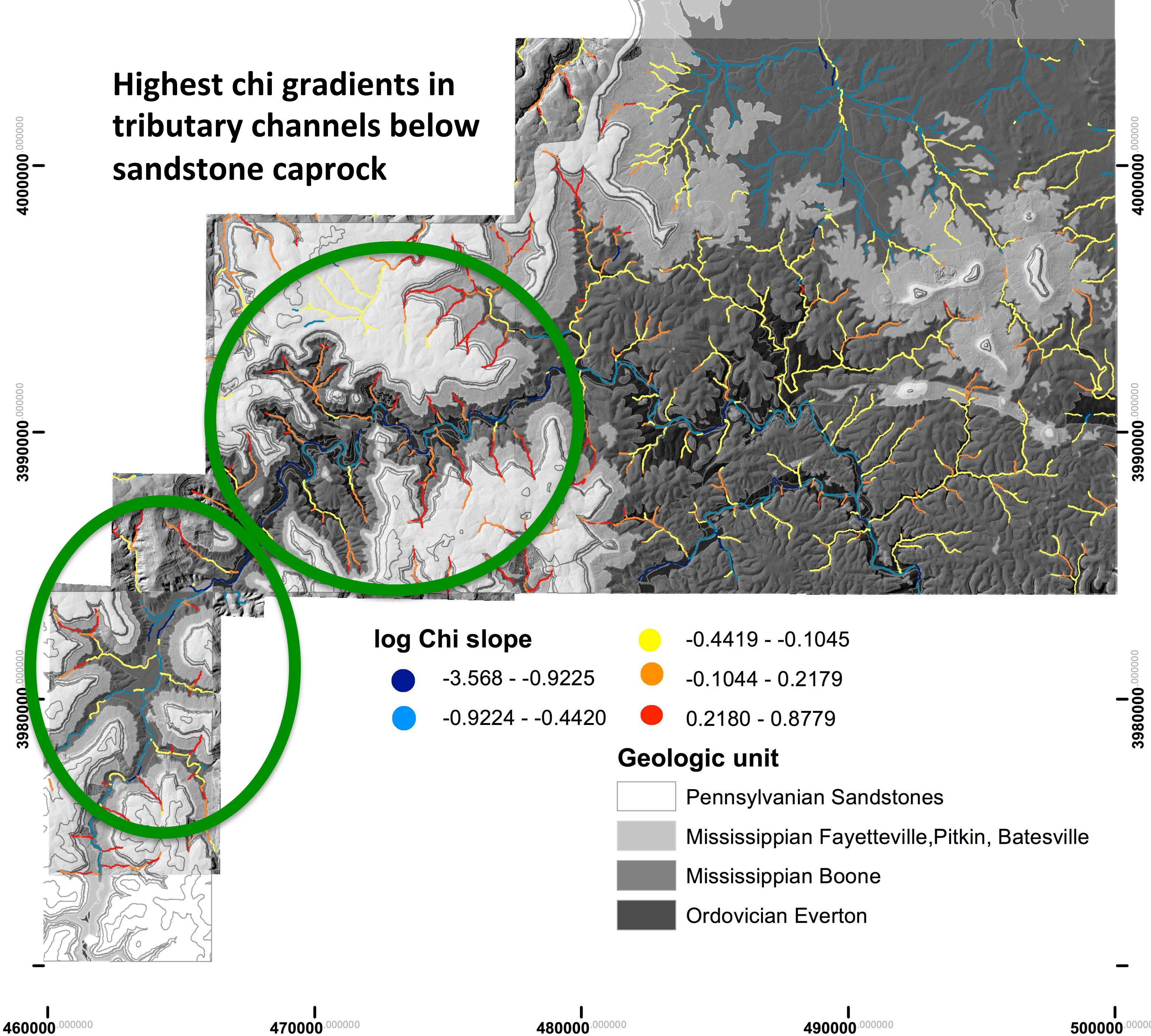
Where

$$m_\chi = \left(\frac{U}{K A_0^m}\right)^{1/n}$$

$$\chi = \int_{x_0}^{x} \left(\frac{A_0}{A(x)}\right)^{m/n} \mathrm{d}x$$



Map of chi gradient values
log Chi slope
-3.568 - -0.9225
-0.9224 - -0.4420
-0.4419 - -0.1045
-0.1044 - 0.2179
0.2180 - 0.8779
Geologic unit
Pennsylvanian Sandstones
Mississippian Fayetteville,Pitkin, Batesville
Mississippian Boone
Ordovician Everton
4000000.000000
3990000.000000
3980000.000000
460000.000000
470000.000000
480000.000000
490000.000000
500000.000000


Highest chi gradients in tributary channels below sandstone caprock
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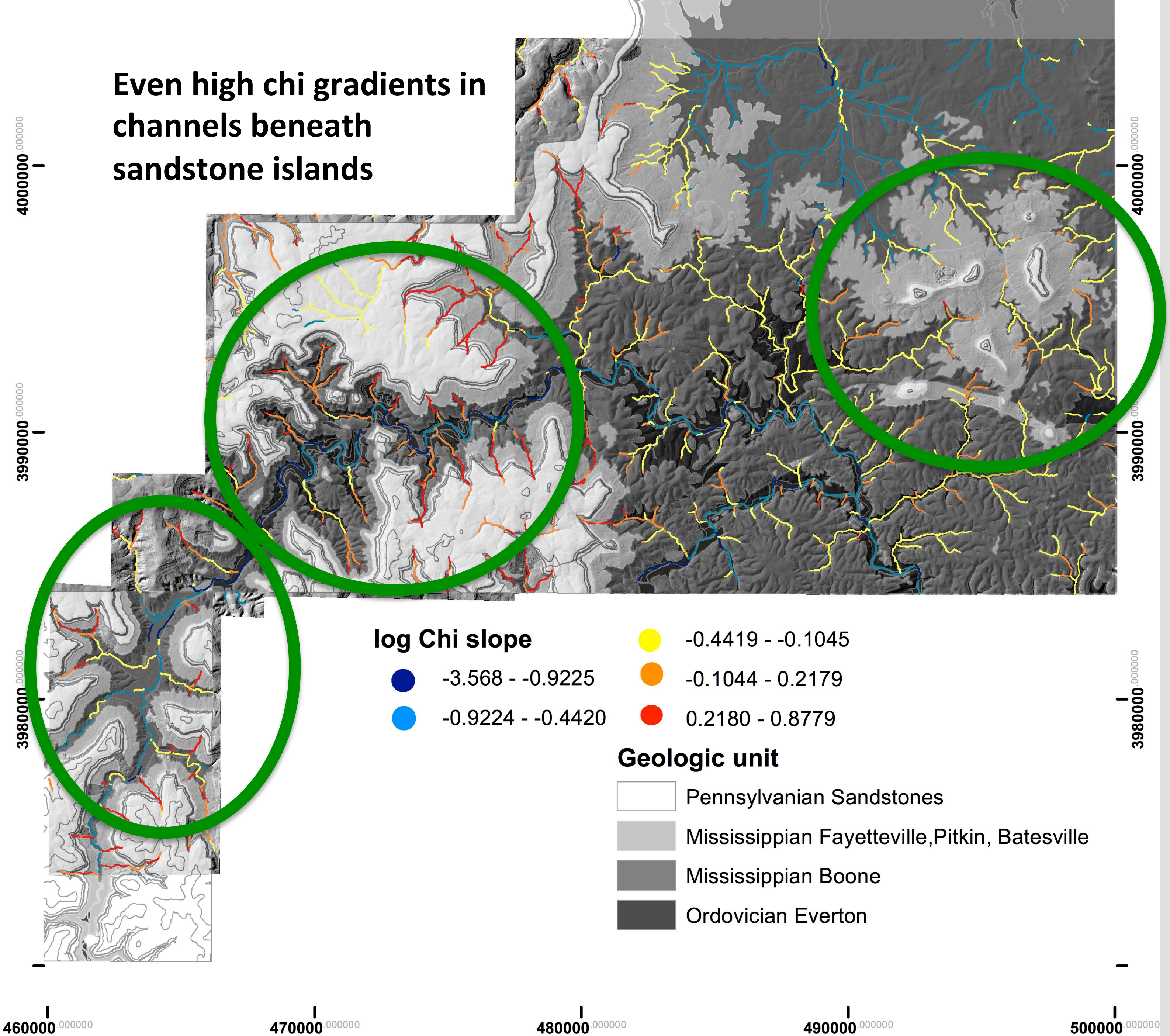
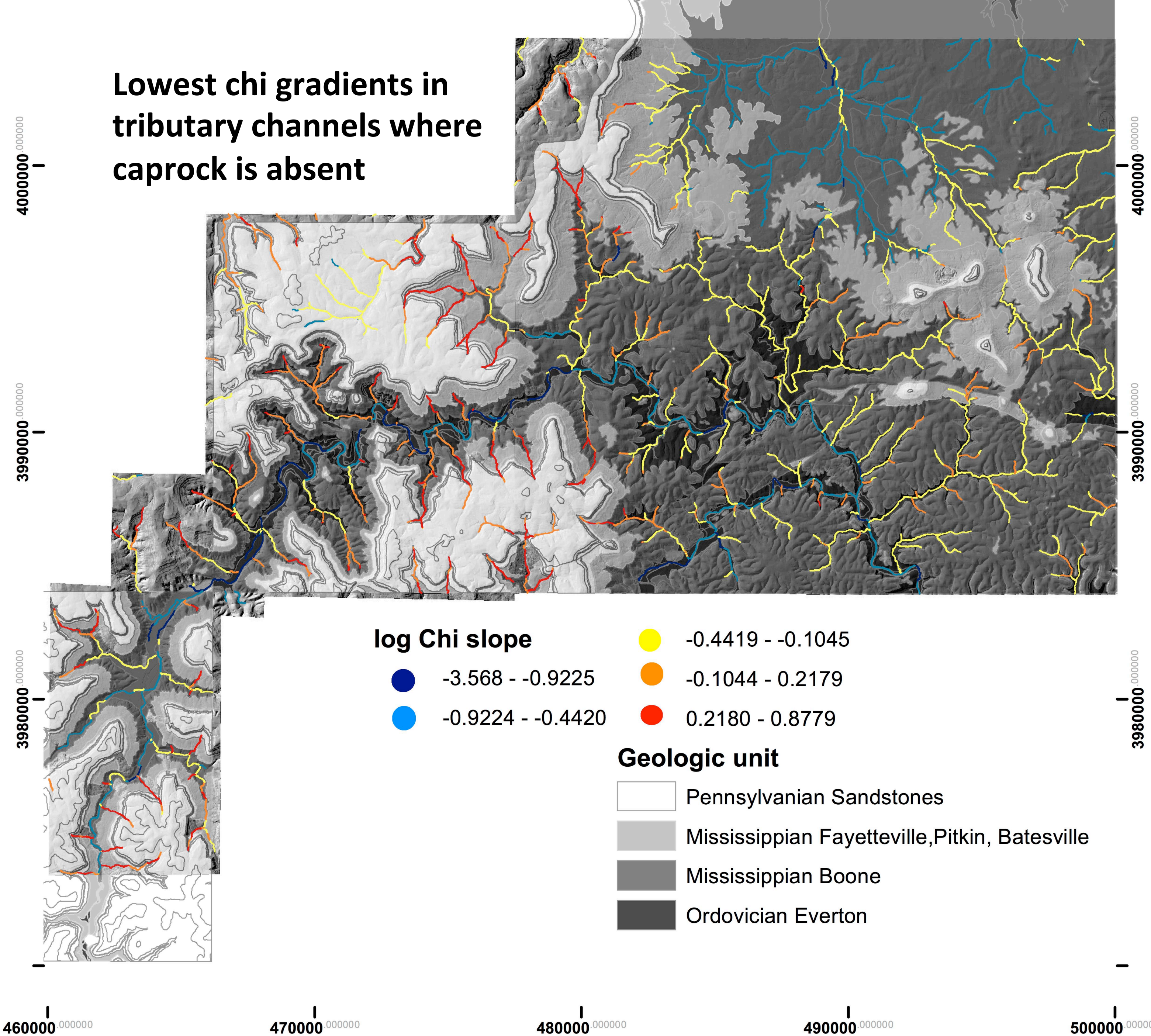
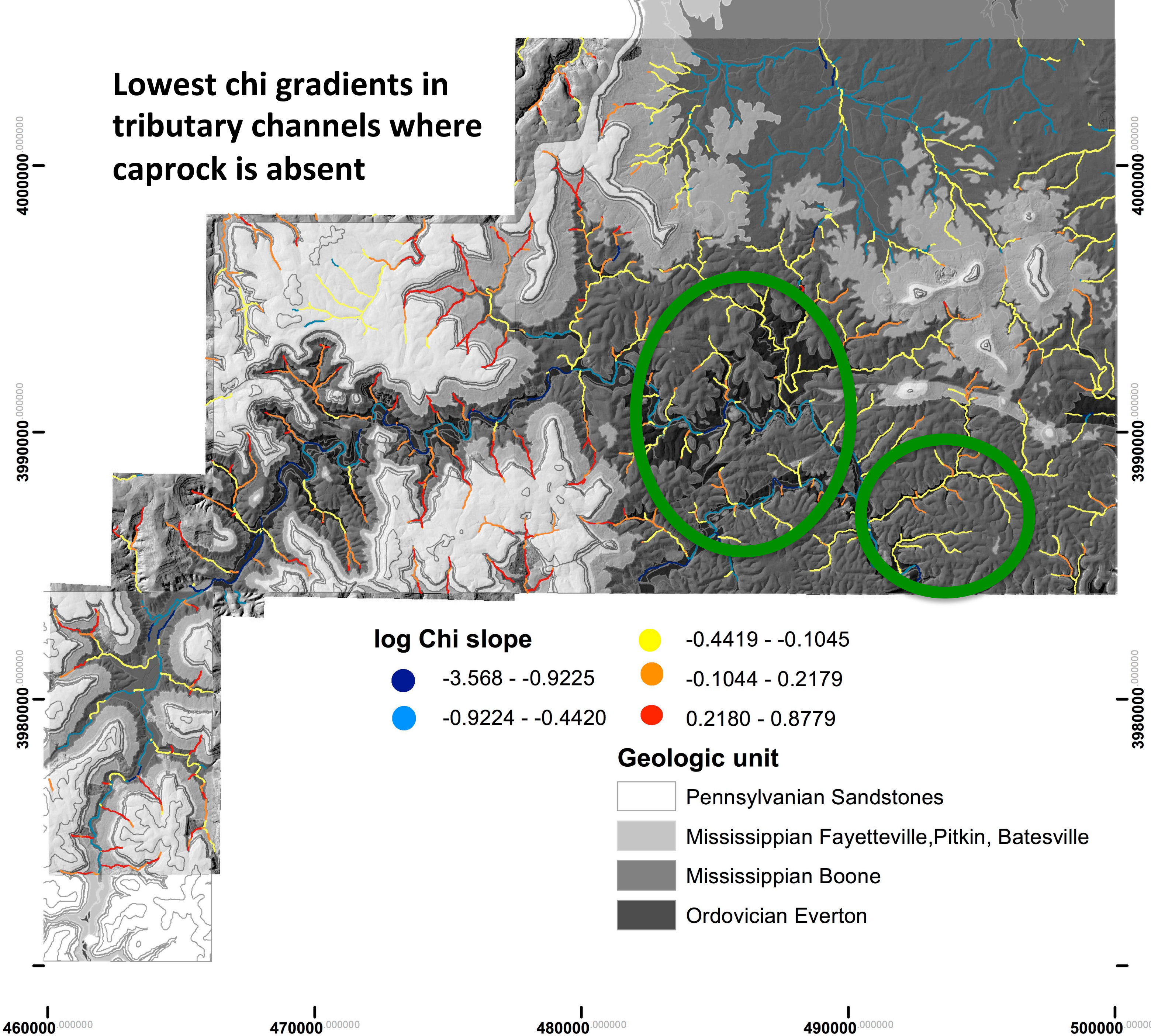
Even high chi gradients in channels beneath sandstone islands



Lowest chi gradients in tributary channels where caprock is absent





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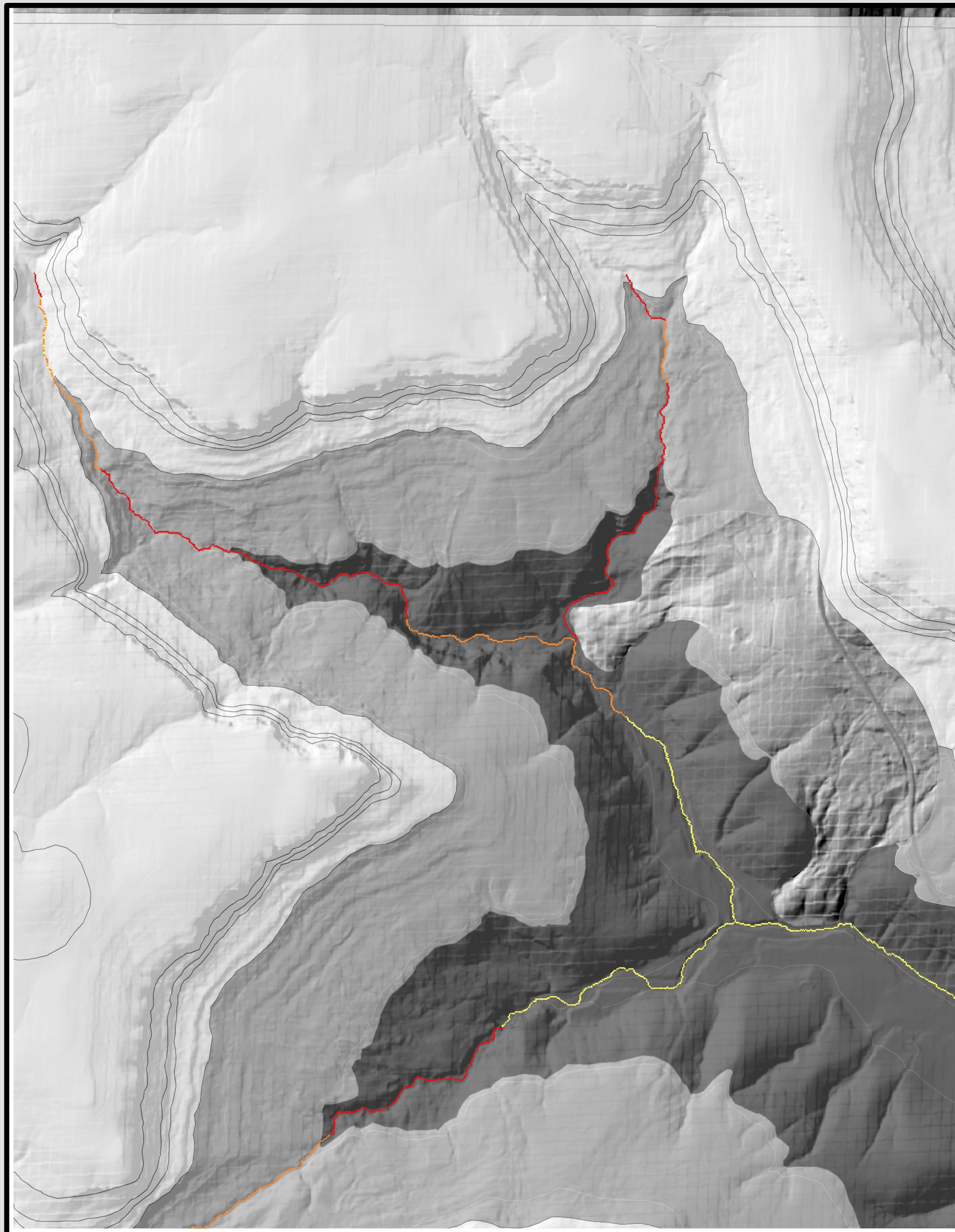
Segmentation of channels to avoid serial correlation

- Each channel is divided into reaches separates by junctions
- Further subdivided into lithologic reaches
- Node chi gradient values were averaged for each lithologic reach
  - Each reach is represented by a single chi gradient value
- Data showed no serial correlation
- Nemenyi multicomparison test was used to determine if different lithologies have systematic differences in chi gradient



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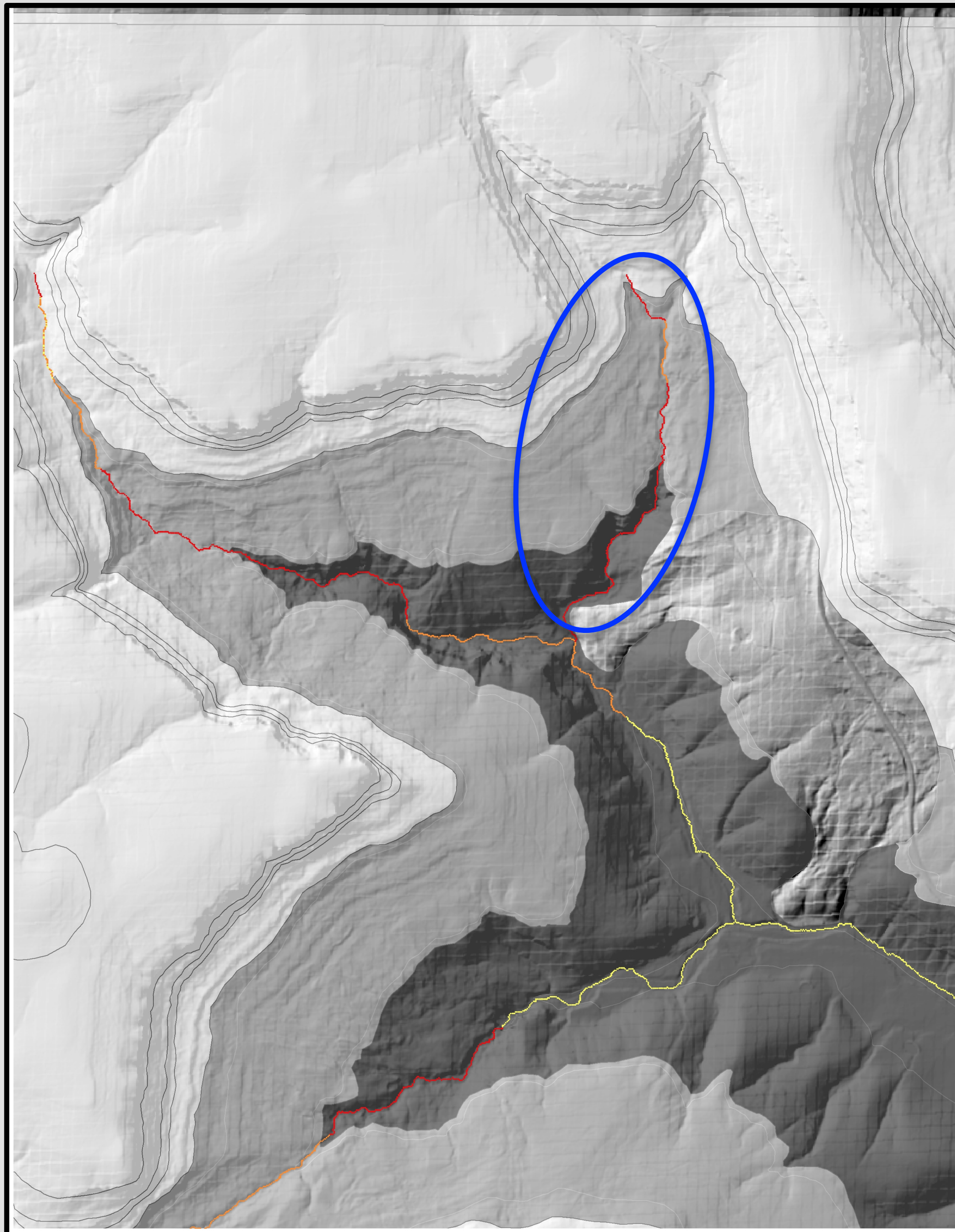

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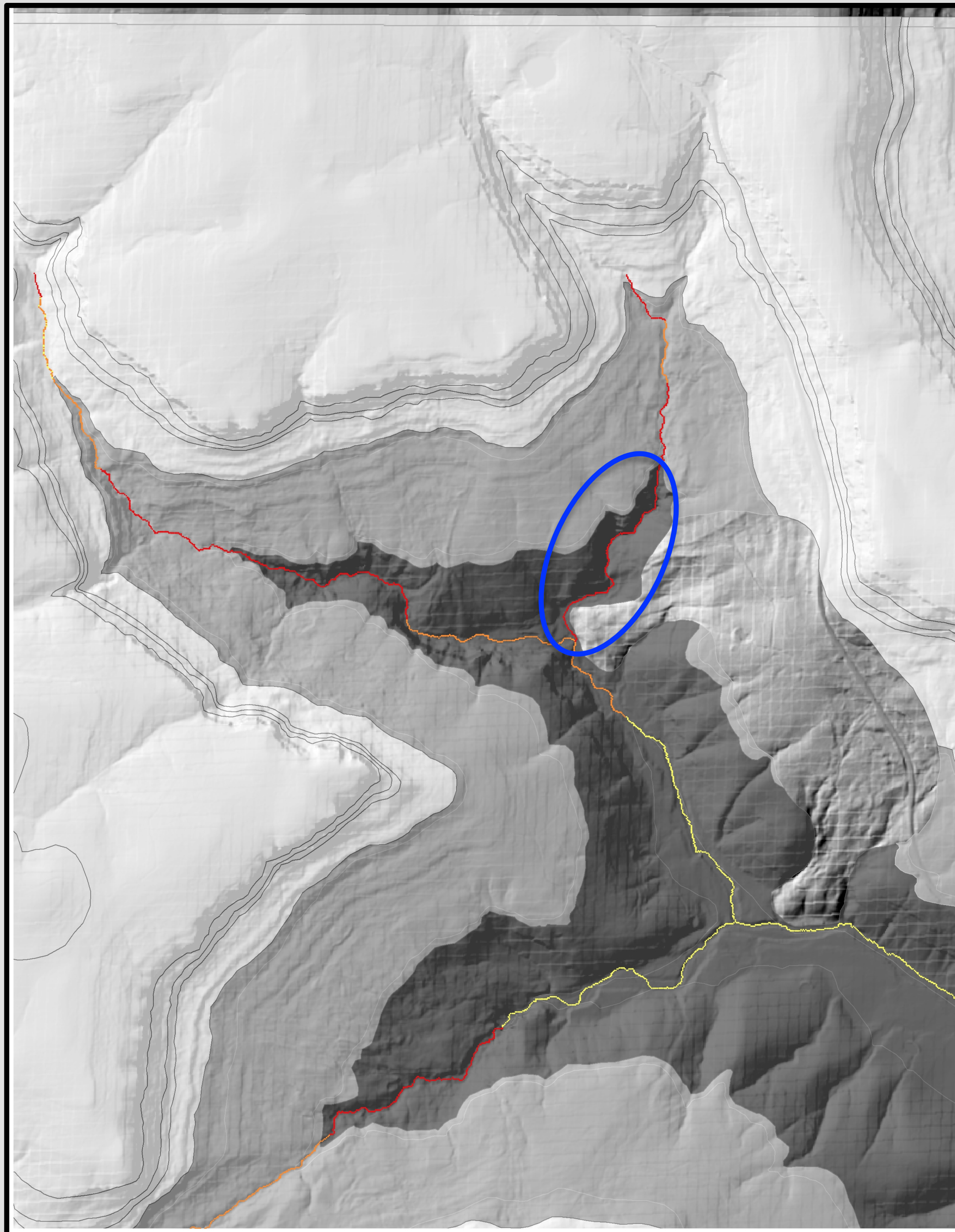
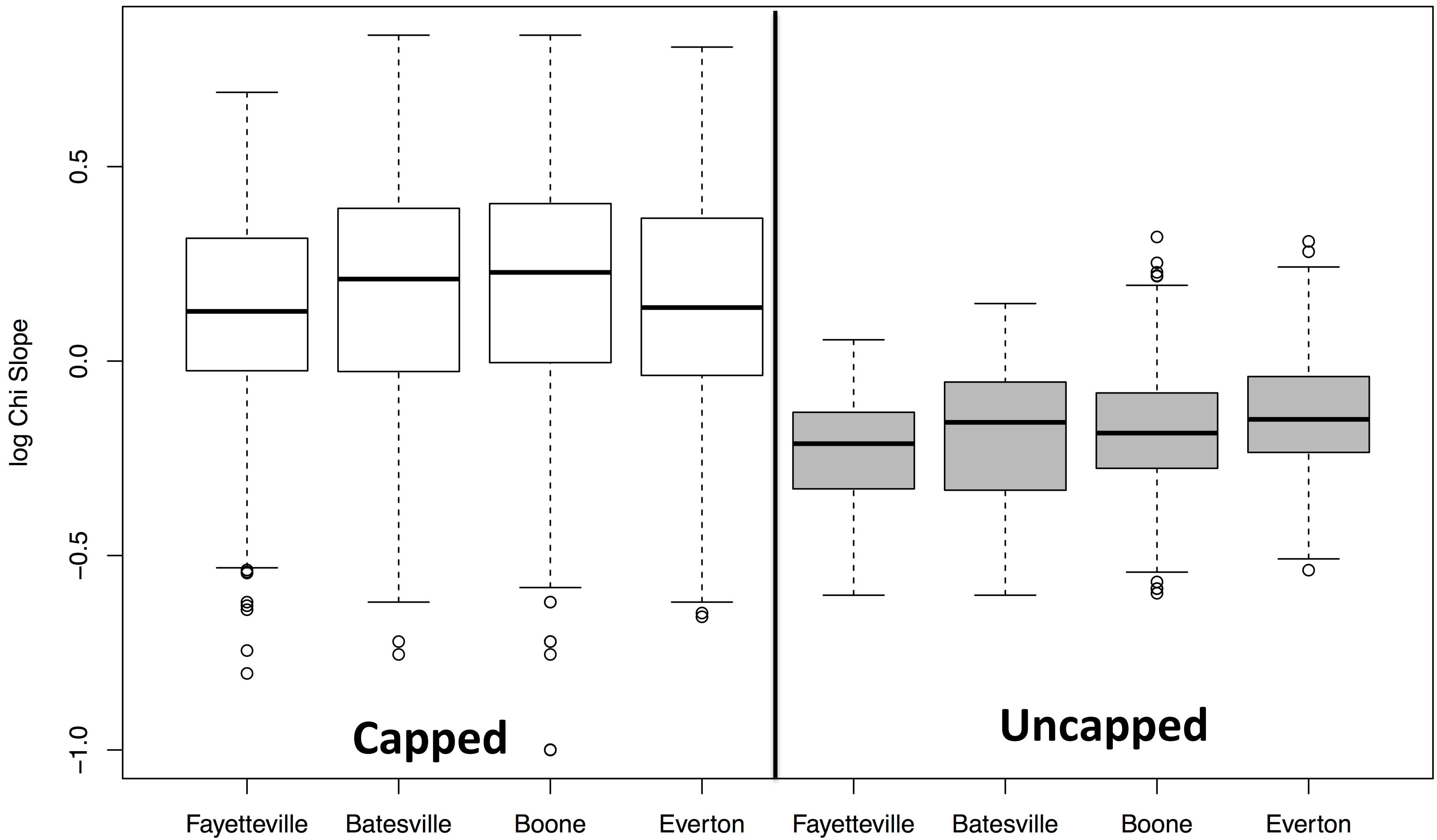


Tributary channels



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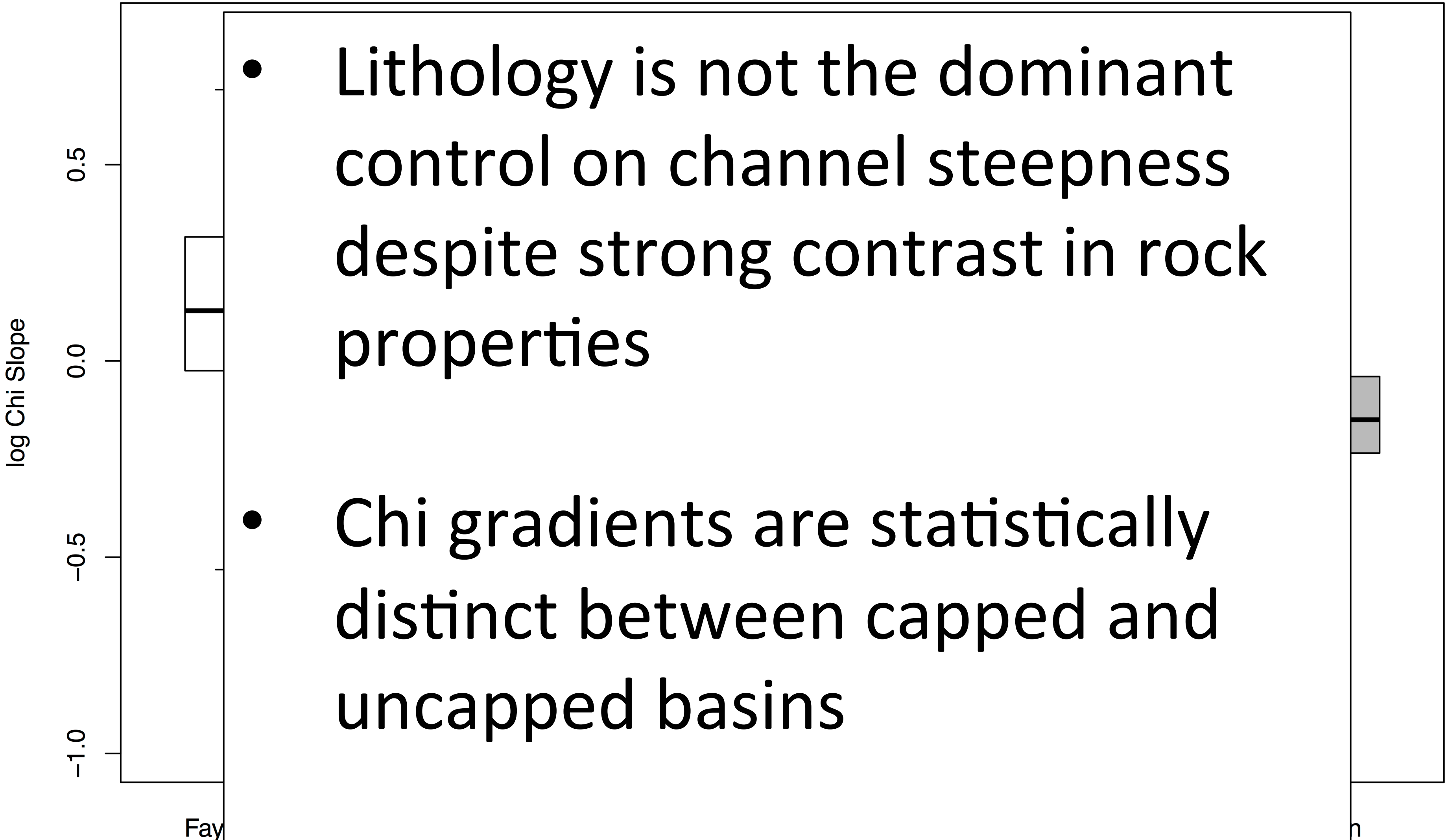
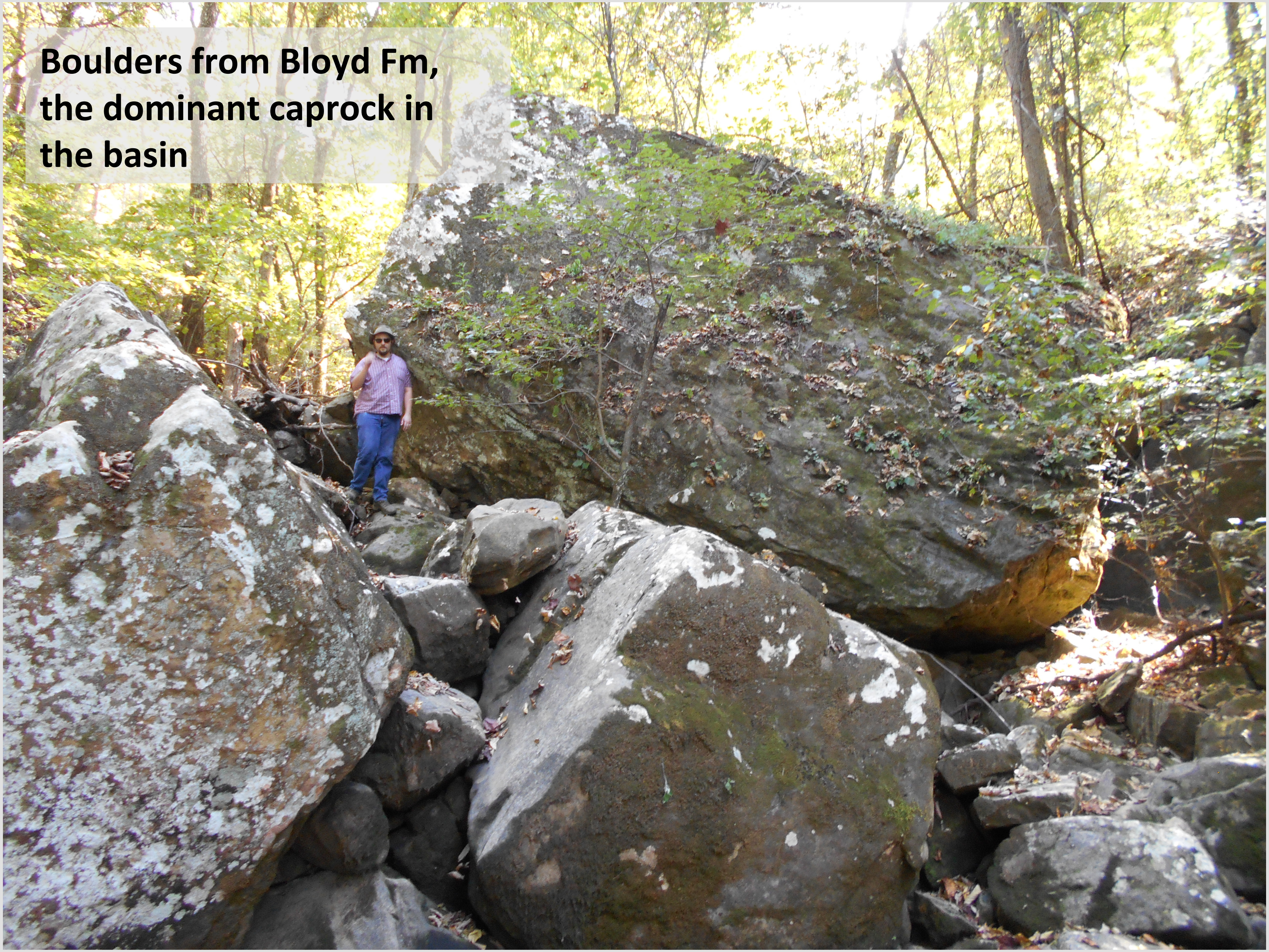
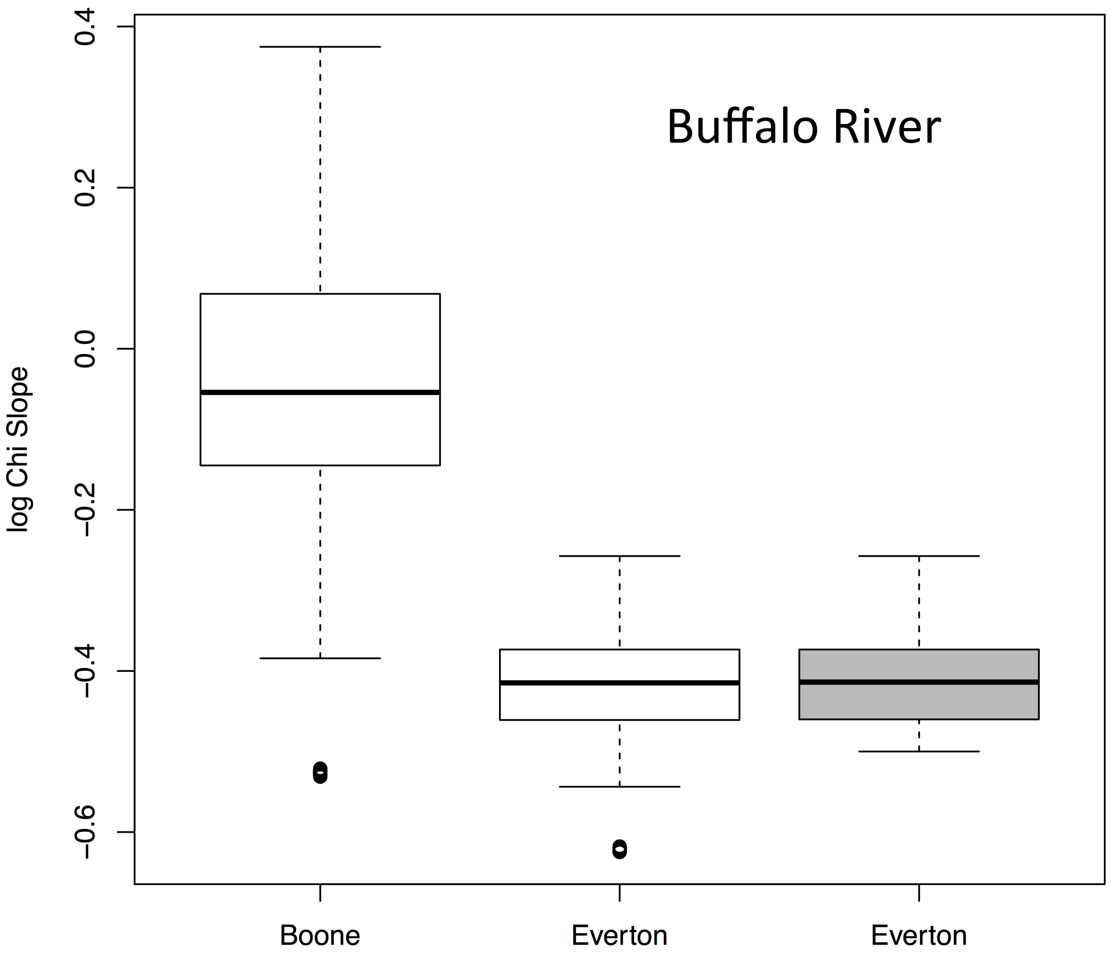


- Lithology is not the dominant control on channel steepness despite strong contrast in rock properties

- Chi gradients are statistically distinct between capped and uncapped basins


Boulders from Bloyd Fm,
the dominant caprock in
the basin



- Boone reach has multiple landslides and some large sandstone boulders in channel
- Minimal Influence of sandstone caprock on reaches in Everton Fm

$$E = -K m_\chi^n A_0^m$$

$$m_\chi = \left(\frac{U}{K A_0^m}\right)^{1/n}$$

$$\frac{E_1}{E_2} = \frac{k_1 (m_{\chi,1})^n}{k_2 (m_{\chi,2})^n}$$

In the Buffalo Basin:

- No constraints on erosion rates or erodibility values
- Can still use ratios of chi gradients to get relative erosion rates or relative erodibility under certain assumptions
  - n=1

$$\frac{E_1}{E_2} = \frac{k_1(m_{\chi,1})^n}{k_2(m_{\chi,2})^n}$$

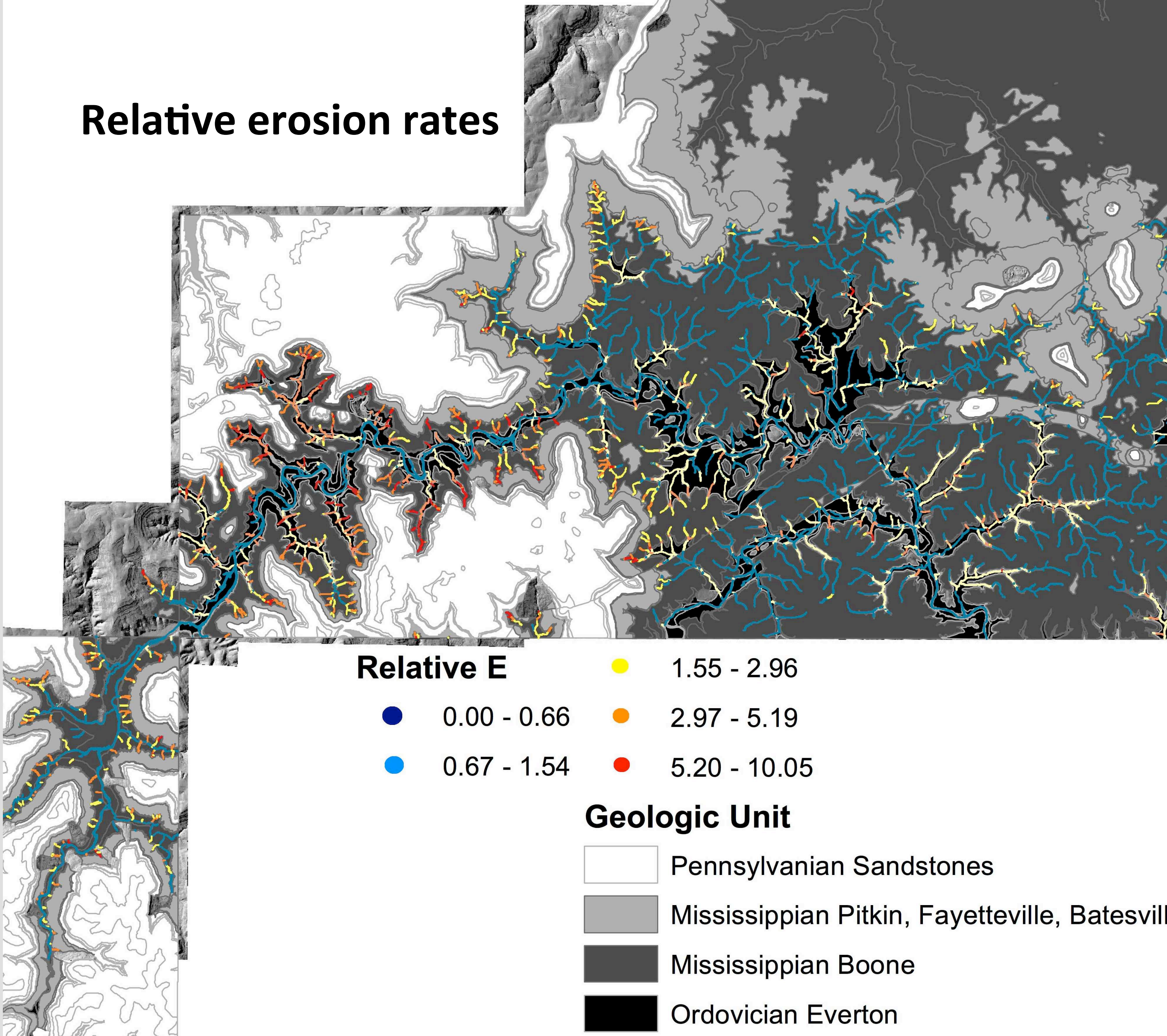
- Assume erodibility is solely a function of lithology
  - Allows maps of relative erosion rates in a given lithology

$$\frac{E_1}{E_2} = \frac{(m_{\chi,1})^n}{(m_{\chi,2})^n}$$

- Assume erosion rates of Boone and Everton are equal in the main stem

$$K_{\text{boone}}(m_{\chi,Boone})^n = K_{\text{everton}}(m_{\chi,everton})^n$$

Relative erosion rates



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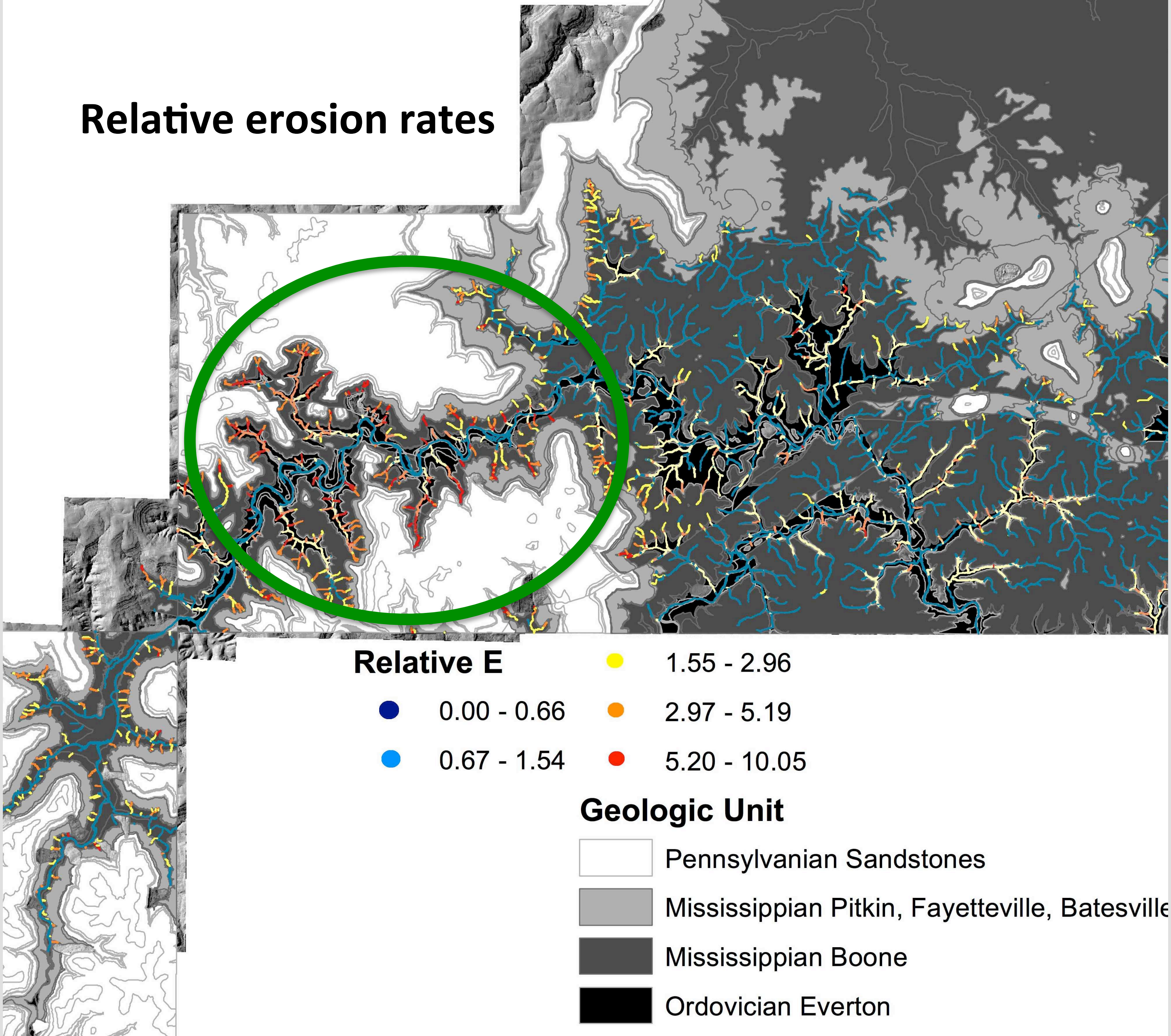


$$\frac{E_1}{E_2} = \frac{k_1(m_{\chi,1})^n}{k_2(m_{\chi,2})^n}$$

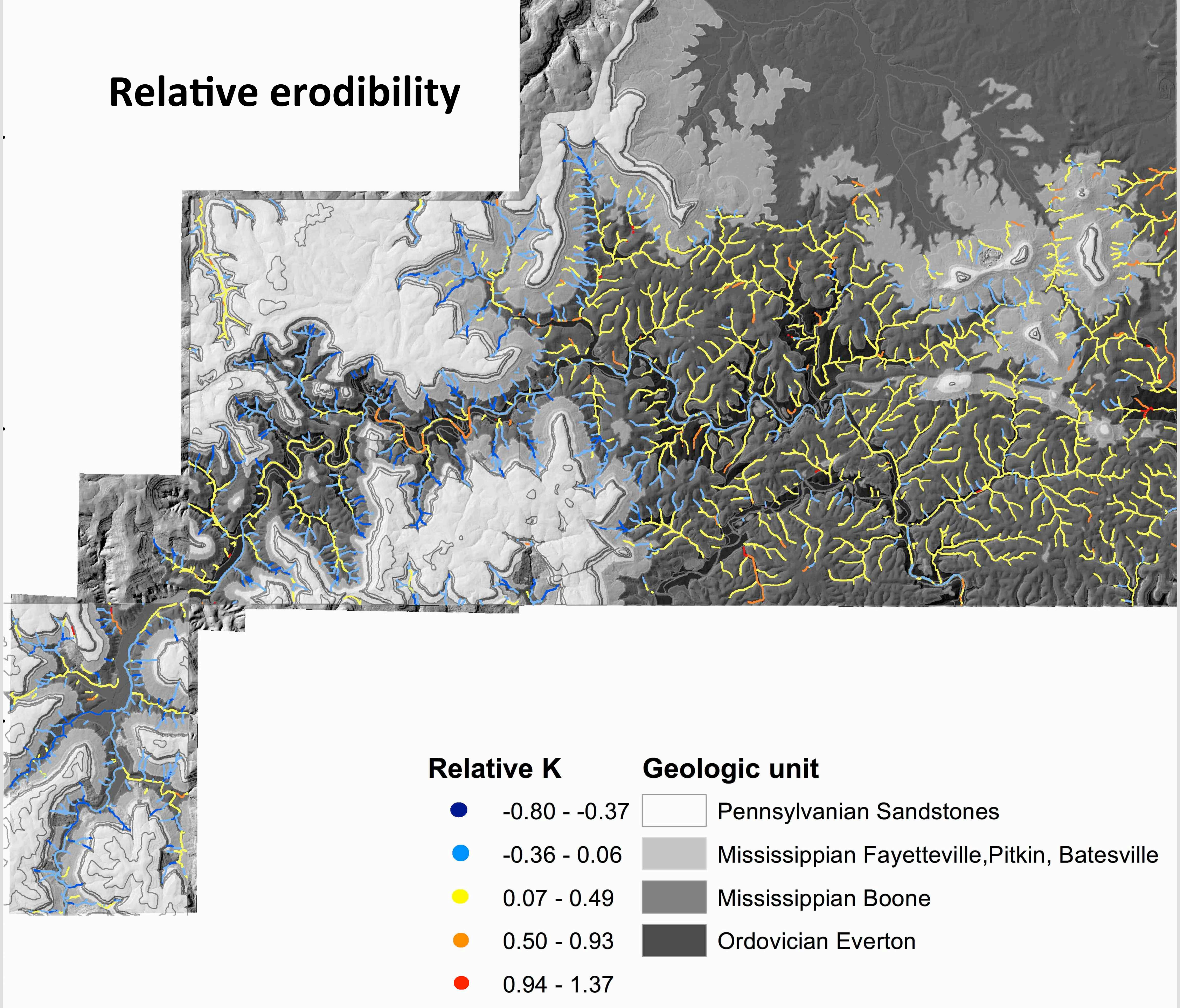
$$\frac{k_1}{k_{ref}} = \left(\frac{m_{\chi,ref}}{m_{\chi,1}}\right)^n$$

- Assume erosion rates throughout the basin are equal
- Don't assume erodibility is solely a function of lithology
    - Determine relative erodibility

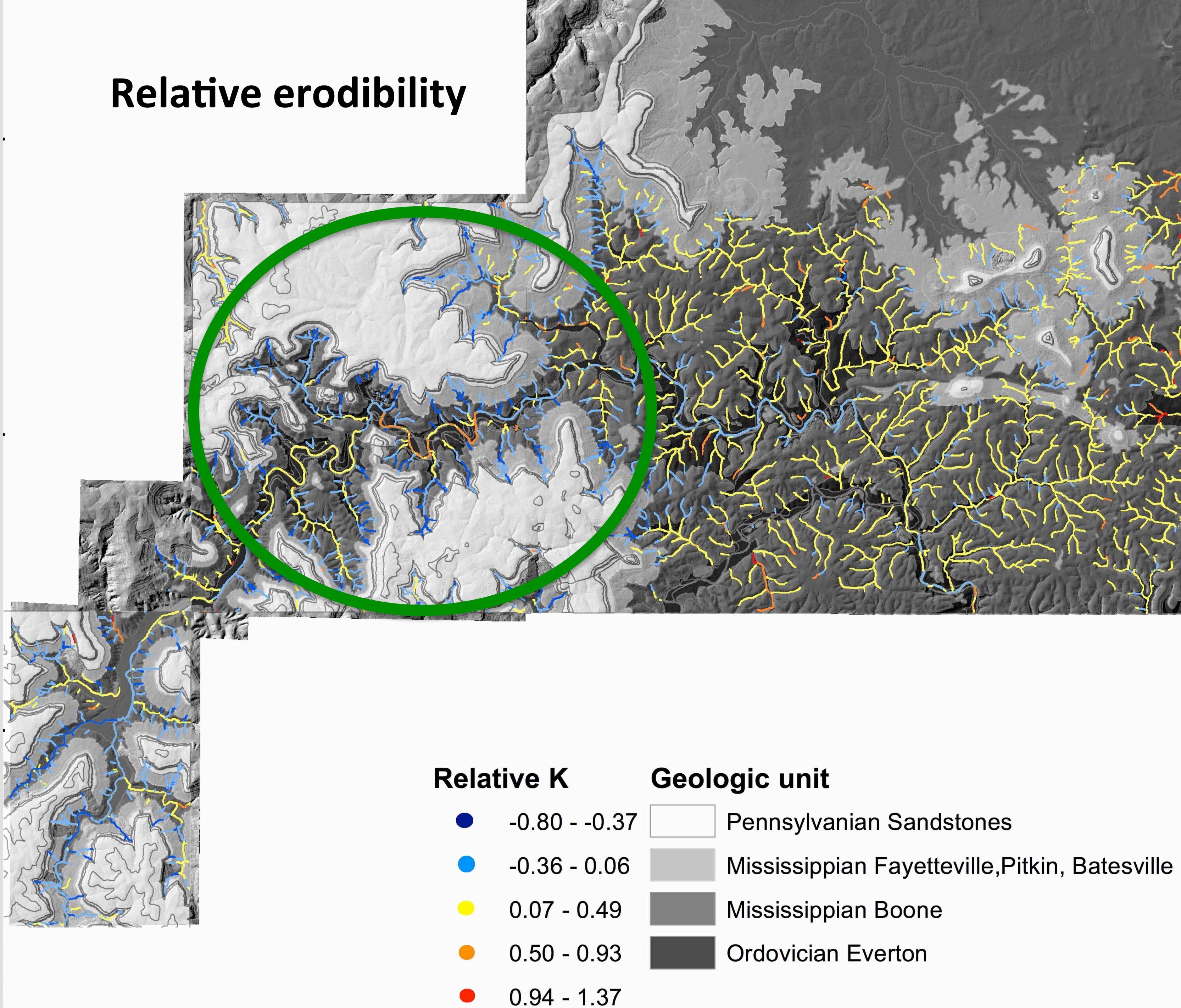
- n=1

- Reference chi gradient value is the mean of all chi gradient values in the basin

Relative erodibility



Relative erodibility



Conclusions

- Dominant control on bedrock channel steepness is not substrate lithology, but sediment supply from sandstone caprock
  - Overwhelm channel's ability to mobilize sediment
  - Removal of caprock material limits the rate of tributary channel erosion
- Ratio of chi gradients
  - Highest relative erosion rates beneath sandstone caprock
  - Lowest relative erodibility beneath sandstone caprock
    - Boulders armor channel and prevent erosion (Sklar and Dietrich, 2004)
- The main stem of the Buffalo is less affected by the sandstone caprock


Questions?

Schmidt Hammer scores of the dominant lithologies in the basin