Detecting Neogene uplift along the Jemez lineament with GIS

Motivation: Rivers in the Southeastern Rockies drain into the Rio Grande and Canadian drainage basins crossing the Northeast trending Jemez lineament. Using GIS to analyze these rivers where they cross the lineament may allow isolation of uplift caused by faulting and broad doming from the more easily identified climate and geomorphic controls. Of particular interest is the Canadian river, which was found to have anomalous incision rates compared to other rivers crossing the Jemez lineament (Wisniewski and Pazzaglia, 2002). Additionally, the Canadian river is separated from tectonic influence of the Rio Grande rift.

Background: Approximately 1.8 billion years ago, a continental collision between the Mazatzal and Yavapai provinces left a weakened suture zone that crosses present day New Mexico (*Figure 1*). A series of island arcs constitute the source material for the Mazatzal province, subsequent tectonism and magmatic activity contributed to structural weakness in the region (Magnani et al., 2004). Continental extension thinned and weakened the crust roughly 70 million years ago, leading to the region we now know as the Rio Grande rift. The suture zone reactivated during this period of extention. The Jemez lineament is the linear topographic feature created by the opening of the Yavapai-Mazatzal suture. The lineament extends from the middle Arizona-New Mexico border northeast to the eastern Colorado-New Mexico border

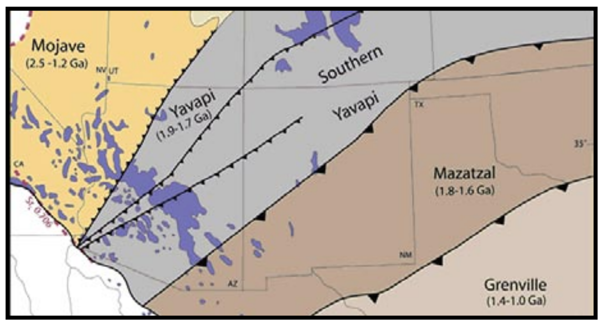

Figure 1 (Karlstrom and Humphreys 1998)

defined by volcanic activity (Figure 2). Recent volcanism along the Jemez lineament has occurred for the past several million years. Recent volcanic events occuring in the region include supervolcano sized eruptions of the Valles Caldera, 1.2 and 1.6 million years ago.

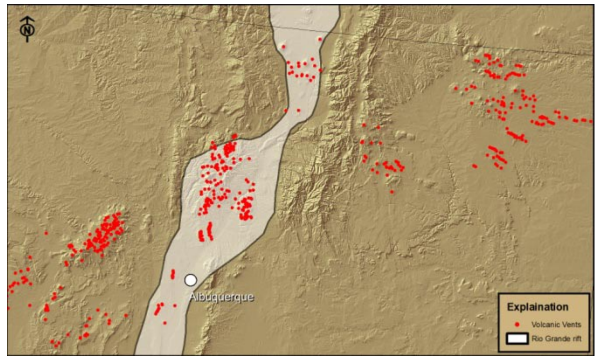

Figure 2, Rio Grande rift and Jemez lineament

Objective: Analyze longitudinal river profiles with ArcGIS and Matlab to determine whether uplift can be detected and isolated from climate and geomorphic controls.

Methods:

Data sources:

<u>DEM:</u> USGS seamless web server (http://seamless.usgs.gov). Projection: NAD83> Albers Equal Area Conic USGS. Only available as raster data. The size of the study required merging of several downloaded areas. 30m DEMs were downloaded to run the initial analysis but the resulting ascii files were too large for Matlab to process. Subsequent DEMs have been scaled to 90m when running analysis over the entire field area.

<u>Volcanic Vents:</u> Vector layer generated by graduate students of Dr. Karlstrom over the past several years. Eileen Embid is one of the students who worked to compile the data. Projection: Albers Equal Area Conic USGS

<u>Geology:</u> USGS Arc/Info coverage (http://pubs.usgs.gov/of/1997/ofr-97-0052/) Projection: Albers Equal Area Conic USGS. Vector data. Geology covered in this data set is adequate for large scale analysis.

Projection:

Albers Equal Area Conic USGS was used to properly calculate the area of the river basins. A projection without equal area would yield incorrect calculations for the basins. Since the Matlab portion of the analysis calculates basin area for each point in the river the errors would multiply rapidly with a non-equal area projection.

Software environment:

All analysis was performed using ArcInfo license level. Key extensions include Spatial Analyst Tools>Hydrology>Fill, Flow Accumulation, and Flow Direction, Conversion Tools>Raster to ASCII, Data Management Tools>Raster>Mosaic to New Raster, and Data Management Tools> Projections and Transformations>Raster>Project Raster. Model Builder was used for repetitive processing (Figure 3).

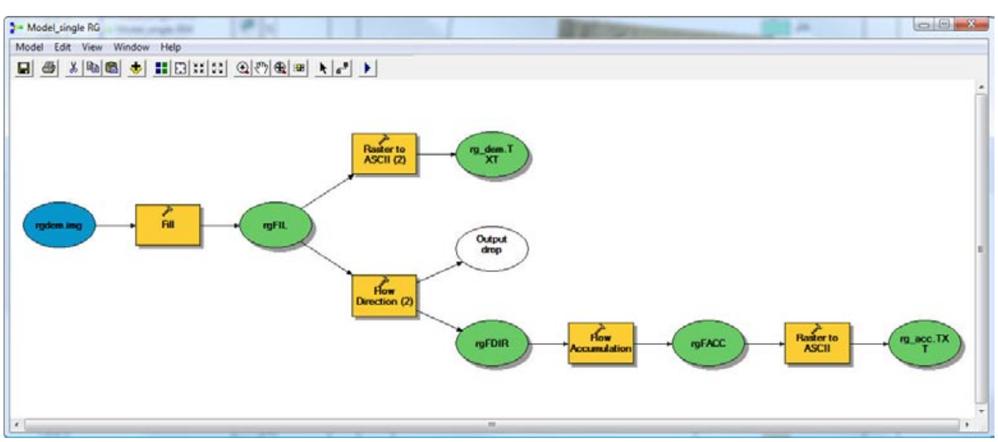

Figure 3, Model Builder

The core component of the analysis is achieved with the Stream Profiler Toolset (SPT) developed by Kelin Whipple et al. Installing SPT involved registering DLLs with the operating system and ArcMap, adding the profiler toolbar to ArcMap, and turning on the new extension. SPT consists of a set of scripts written in Python and Matlab that extract longitudinal river profiles, calculate the slope of each point on the river, and calculates basin area feeding each point. This provides a proxy for stream power, if the slope of the river is steeper than a reference slope for the area of basin feeding that point, the stream is cutting faster than average.

Analysis:

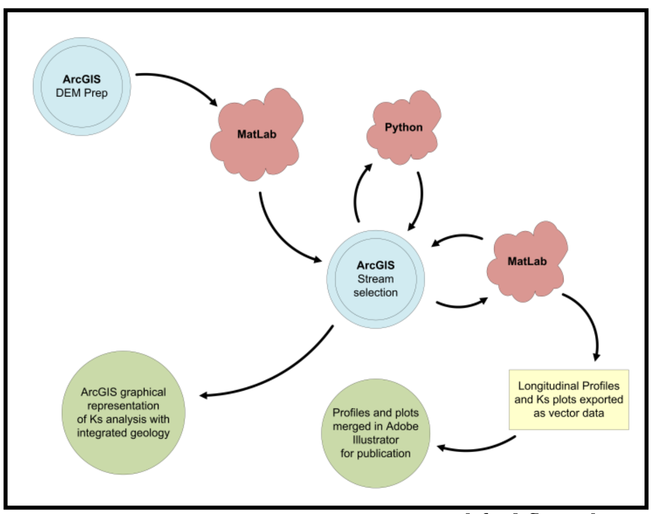

Figure 4, Simplified flow chart

To remain within the scope of this paper, I will overview the fundamentals of SPT. A simplified flow chart is likely the most direct method to illustrate the ping pong processing (Figure 4). DEMs are mosaiced, filled, flow directioned and accumulated, then exported to ASCII for Matlab to process. The first step for Matlab is converting the ACSII files to Matlab native files. Computing time required for these initial steps on the Rio Grande basin from head waters to Elephant Butte plus the Canadian/Mora basin to the Texas border is roughly three hours. Ensuring all parameters (extent, scratch, etc) are set properly the first time is critical.

ArcMap: Most of the analysis for this project is done in Matlab. ArcMap is used to select the headwaters of rivers for analysis, Matlab works from the headwaters down to the mouth. In regions where the slope/area values were anomalously high, I "selected by location" the geology of these reaches of river to determine the bedrock conditions. These initial investigations returned some promising results for more detailed future study.

Matlab: There are two Matlab components of the analysis. One creates a slope/basin area layer for import into ArcMAP. The second consists of selecting certain reaches of the rivers for slope determination. This portion of the process is still under development to, hopefully, be mastered before AGU in December. My advisor and I are currently working on a systematic way to compare rivers using the second Matlab component.

The key GIS analysis is correlation of knick points or convexities, in the longitudinal river profiles with geological bedrock. The slope/area map should match with knick points in the longitudinal profile. Certain areas are known to contain bedrock controls for the well defined convexities. The Rio Grande Gorge near Taos is one of these regions. Thick basalt, lava flows filling the river valley require the Rio Grande to get steeper in order to continue cutting its way up stream. All rivers would like to have a nice smooth concave profile (Figure 5), when a convexity forms in the profile the river works hard to remove it.

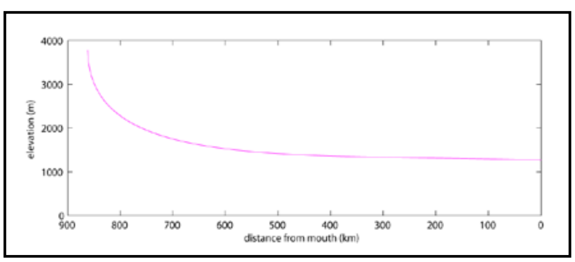

Figure 5, Concave profile

Results: Initial results look promising. The knick points in the longitudinal profiles match nicely with the bedrock controls on the Rio Grande, as expected (Figure 6). Lava flows creating the convexity in the river profile are clearly visible in orange on the map generated in ArcMap. The markers showing beginning and end of knick points line up nicely with the boundaries of the basalt.

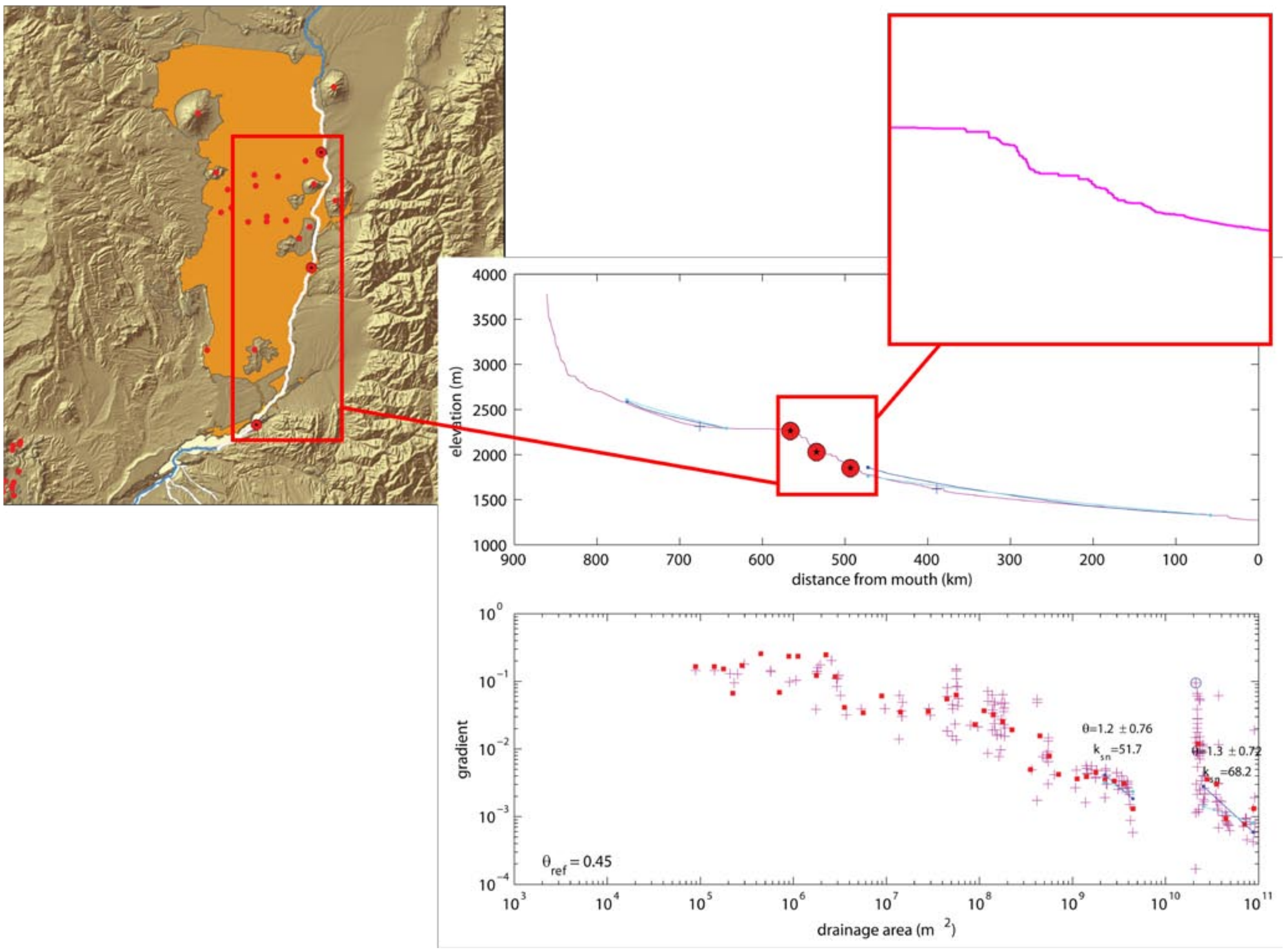

Figure 6, Rio Grande

On the Canadian river we see slight doming of the longitudinal profile (Figure 7). A much more subtle convexity but still something that needs explaining and there are no bedrock controls on this reach of the river. All surface geology is relatively soft sandstone and limestone. This is an excellent case to fit the doming hypothesis.

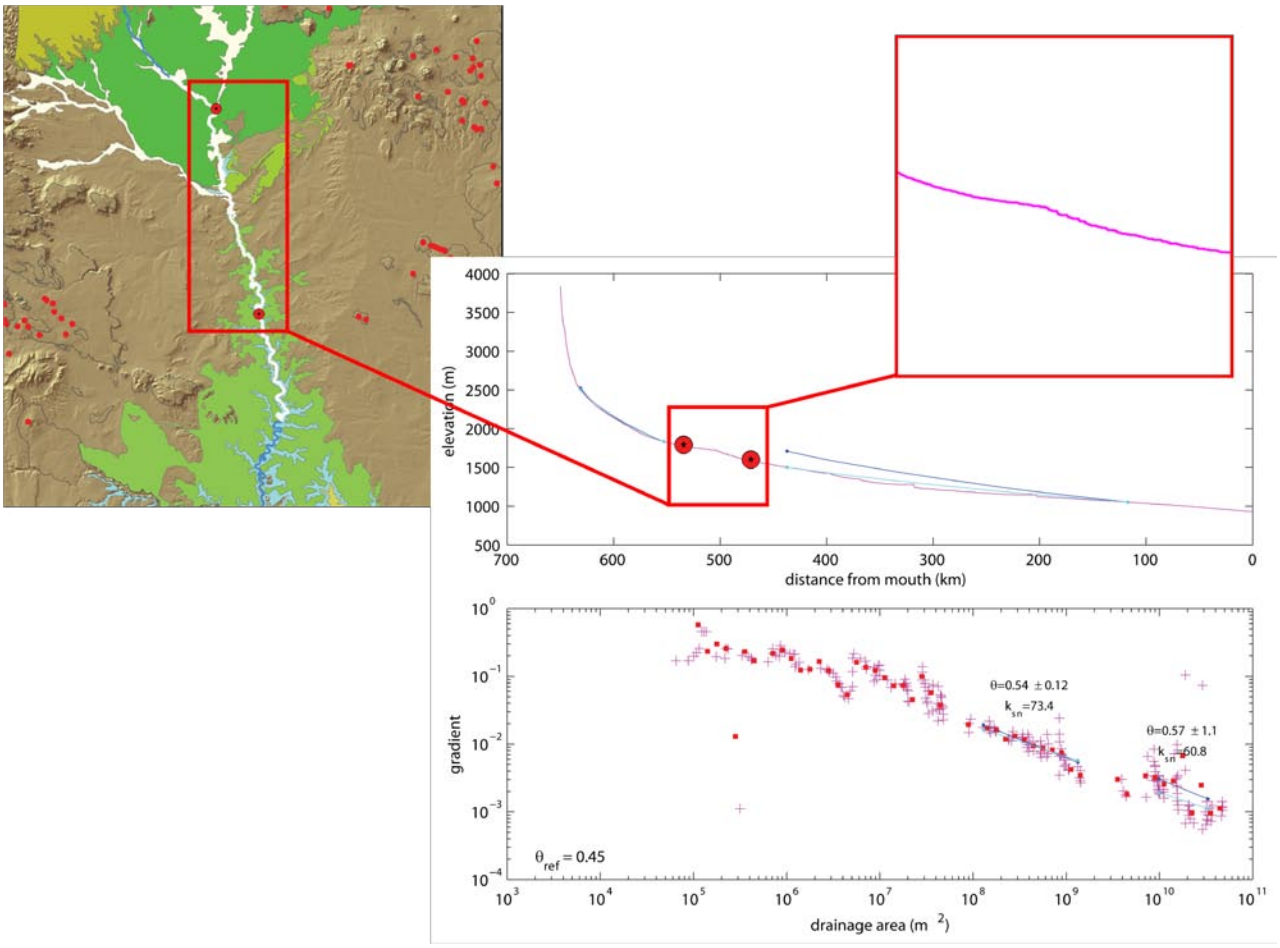

Figure 7, Canadian River

Matlab exported data of the slope/area analysis (Figure 8) picks out "hot spots" where the slope of the river is anomalous for the drainage basin serving that area. These maps match the regions of convexities or knickpoints on the longitudinal river profiles. Future locations for field work may be determined from this GIS output.

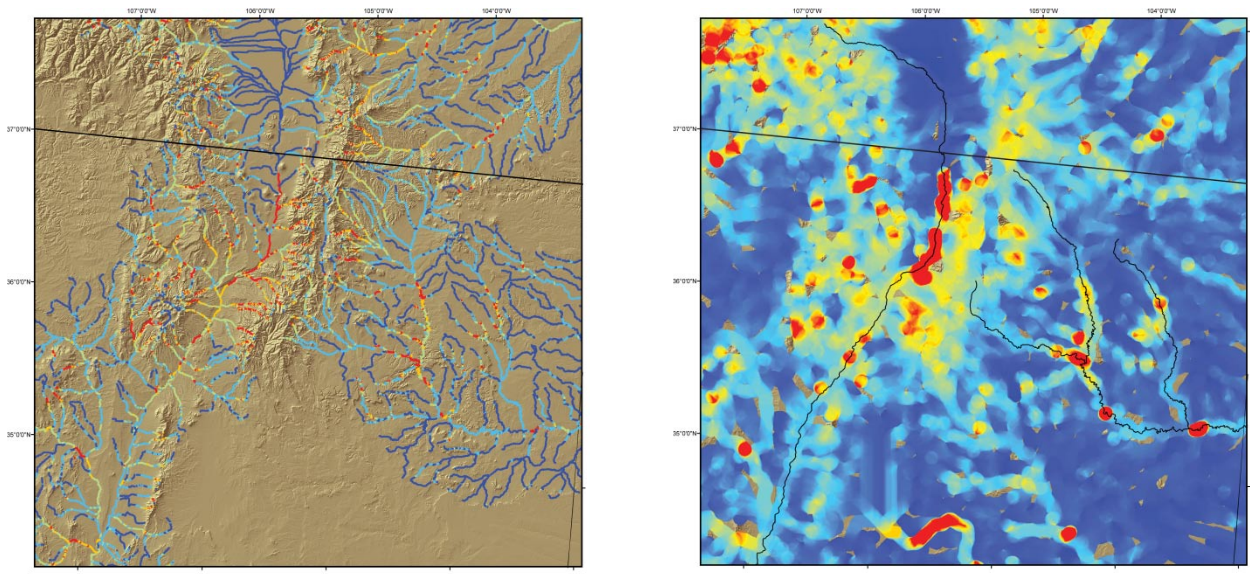

Figure 8, Slope/Area Analysis

Conclusions: Preliminary results look promising. The slope/area maps show regions where field work or high resolution DEMs may yield valid quantitative evidence of uplift clearly isolated from bedrock or climate controls. More fine tuning is necessary to extract the proper data from the Matlab analysis to yield a publishable paper.

Future work:

Run analysis with higher resolution DEMs (30m or higher) on smaller sub-basins, if possible.

Some field work and creation of custom geologic coverages from cross sections of detailed regions is required for future analysis.

Develop more accurate stream selection methods for Matlab.