Terrain Analysis and Paleoaltimetry Proxy Evaluation

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INTRODUCTION

Chingaza National Park (PNN), located east of Bogota, Colombia in the Eastern Cordillera, is the site several ongoing studies by the Organic Paleogeochemistry Research Group at the Jackson School of Geoscience. These studies include paleoclimatic reconstructions using lacustrine sediment cores, mapping of quaternary glacial deposits, constraining the environmental controls on hydrogen isotope fractionation in plants, and paleoaltimetry of the Andes mountains. A high level of spatial understanding is paramount in much of this work. For example, highly accurate topographic data combined with aerial photographs is essential for reconstructing past equilibrium line altitudes (ELA) of alpine glaciers (Osmaston, 2005). These reconstructions help us understand past glacier responses to temperature and precipitation forcings and more accurately predict future change. Additionally, spatial representations of paleoaltimetry proxies allow for the recognition of factors (other than altitude) that may influence the variability of the proxy, thus complicating interpretations of past elevations (Rowley, 2007). My term project begins to address some of these needs, conducting preliminary terrain analysis of Chingaza PNN and investigating the controls on paleoaltimetry proxies in the Eastern Cordillera.

Figure 1. Initial map for georeferencing scan

METHODS

This project consisted of several components: basemap import and georeferencing, aerial photo georeferencing, bathymetry mapping of Laguna Chingaza, moraine mapping, and spatial interpolation to investigate paleoaltimetry proxies. Due to contractual issues between our funding partner (Ecopetrol) and UT-Austin, we have not received some of our gear (ie, GPS unit with bathymetry data) and some high resolution maps. This has caused some of the goals of this study to be postponed, unfortunately. My first attempt to import a topographic map used a map scanned after use in the field (Figure 1). I quickly found this map to be too faded, in addition to it's fairly coarse resolution, 1:100,000. However, through a collaborator I was able to obtain some photomosaics and DEMs from Chingaza PNN and it's surroundings. These files were not georeferenced. To georeference the images, I manually entered ~15 control points to assure the image would accurately represent the land surface (Figure 2). To create an effective initial basemap for our purposes, I integrated the DEM with the photomosaic. I wanted to be able to see the aerial photos clearly while still having the elevation change accurately represented. I extracted contour lines from the DEM at a 50 meter contour interval and overlaid them on the photomosaic (Figure 3). I also plotted my sediment core locations on Laguna Chingaza, which will be effective when bathymetry has been added to the lake. The second main step of this project was the spatial representation and interpolation of water isotope and soil temperature data - important parameters for carbonate isotope and soil archeal bacteria-based paleoaltimetry, respectively. We have deployed HOBO temperature loggers at 10 cm soil depth over the past year, and downloaded ~1.5 years of data from the loggers in August 2011. These data (originally every 2 hours) were converted into mean annual air temperatures. During field seasons in January and August, we also collected ~100 water samples from streams across the Eastern Cordillera. The locations, δD and δ18O values of these samples were imported into ArcMap. Both datasets were subjected to several interpolation procedures (Kriging, Spline, Nearest Neighbor, etc) using the spatial analyst toolbox.

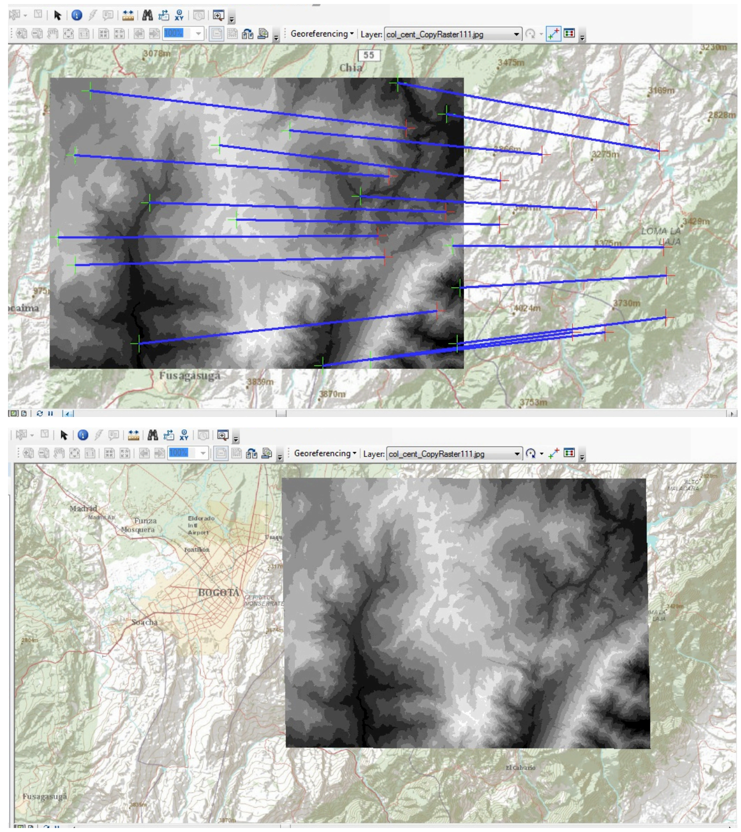

Figure 2. Georeferencing procedure used for Chingaza PNN DEM

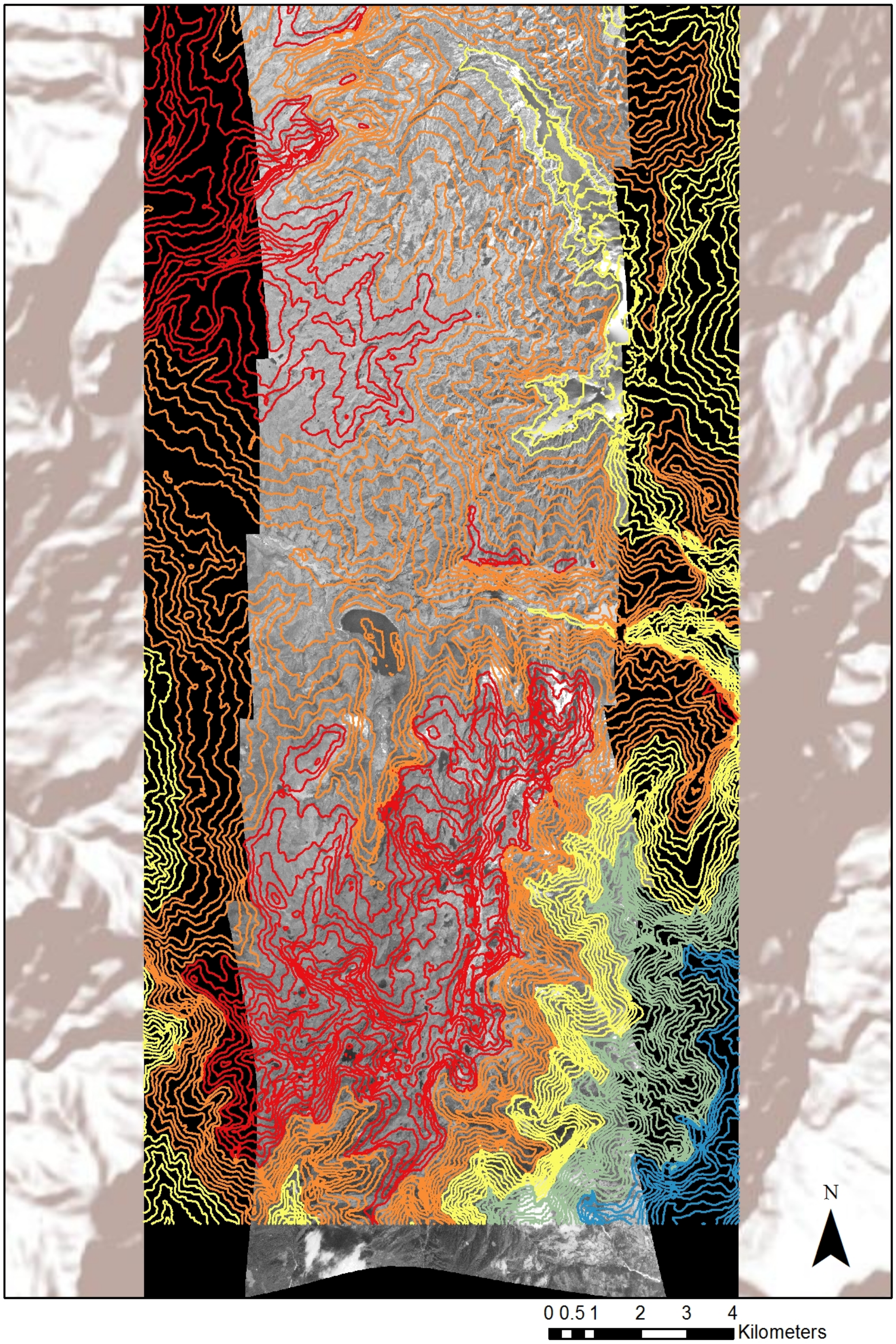

FIgure 3. Photomosaic with DEM contour lines overlain, clearly showing the glacial valley above Laguna Chingaza

RESULTS

The overlay of the DEM-derived topographic contour lines on the aerial photomosaic clearly show the glacial heritage of Chingaza PNN, a cirque and glacial valley rising in elevation are easily seen using the combination of the aerial photos and topographic contours. The photomosaic allows for the identification of major moraines in the area: one damming Laguna Chingaza, and two further up valley from the lake (Figure 4). Such a well defined glacial valley coupled with easily identified moraines will allow our group to accurately reconstruct glacial ELAs using the area altitude balance ratio method.

Due to contractual issues, I do not have the bathymetry data or geologic maps as of this point. However, once I receive that data, it can be used to improve our studies. In particular, the bathmetry data can confirm that our sediment cores were taken from a well planned location, free from geomorphic evidence of channelization or sediment reworking which could affect the chronology of our climate record.

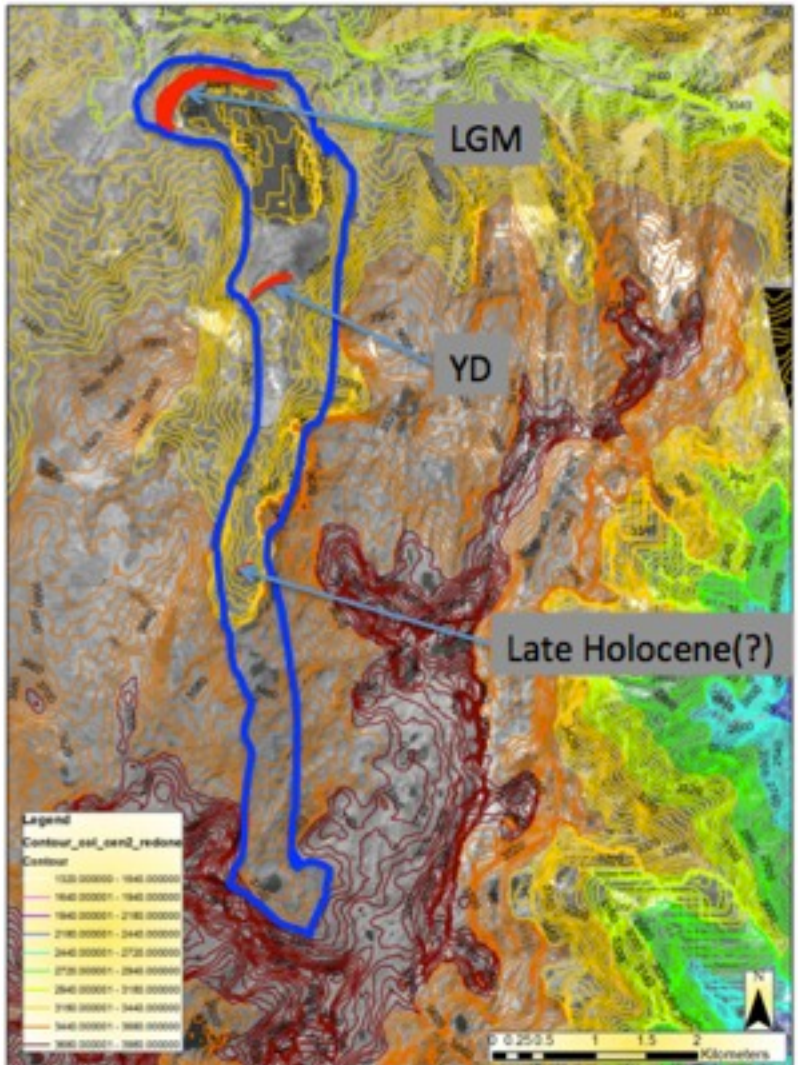

Figure 4. Chingaza PNN glacial outline with moraine deposits

Results from spatial analysis provide support for our argument regarding the most useful paleoaltimetry proxy. Stable isotopes of hydrogen and oxygen in precipitation have been shown to vary with altitude in a predictable fashion. However, in areas of high relief, water rarely remains stationary. Thus, the rain water providing the source of oxygen in carbonates may have traveled a significant distance (and elevation change) from their source (Saylor et al, 2009). Apparent in Figures 5 and 6, stable isotopes of stream water do not seem to correlate very well with elevation. This is a significant issue in paleoaltimetry, and can introduce significant uncertainty into the data from pedogenic or lacustrine carbonates. GDGTs, membrane lipids of archeal bacteria (Tierney and Russell, 2007), have the potential to address this issue. These bacteria live in soils, and their membrane lipids vary in characteristics (eg, amount of methyl groups or cyclopentane rings) based on temperature. It is clear in Figures 7 and 8 that our soil temperature monitors show a better correlation (compared to stream water isotopes)

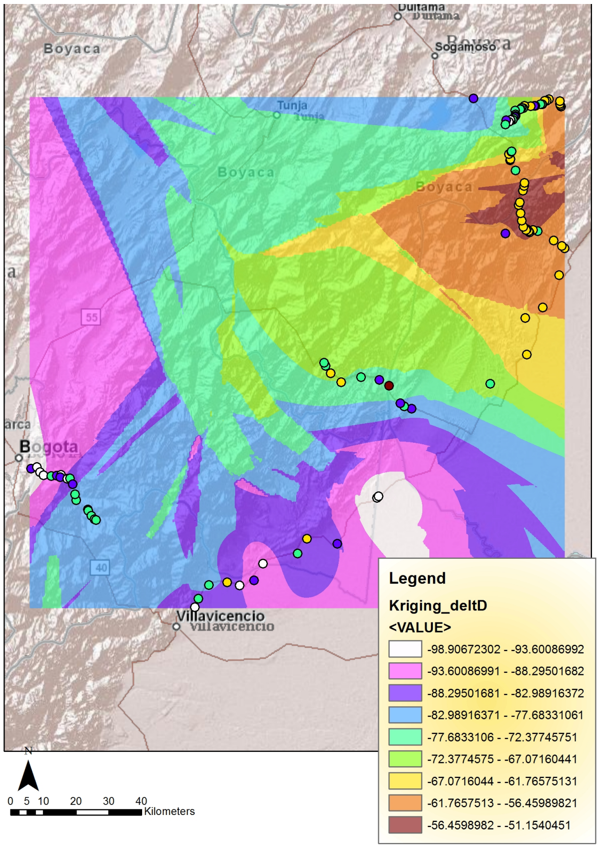

Figure 5. Kriging interpolation of stream water hydrogen isotopes

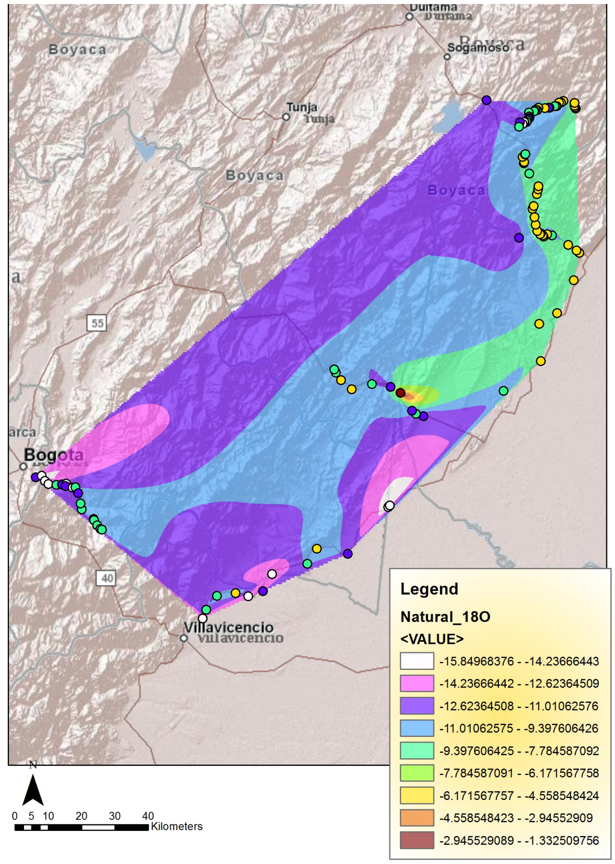

Figure 6. Nearest neighbor interpolation of stream water oxygen isotopes

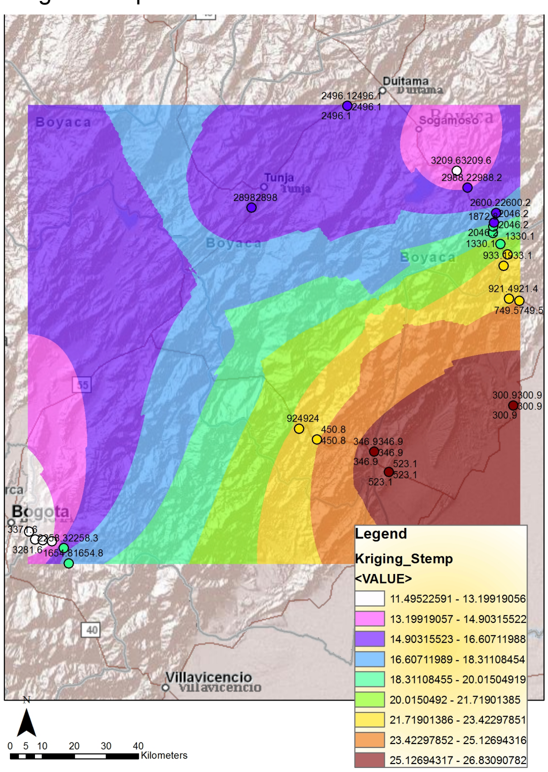

Figure 7. Kriging interpolation of soil temperature

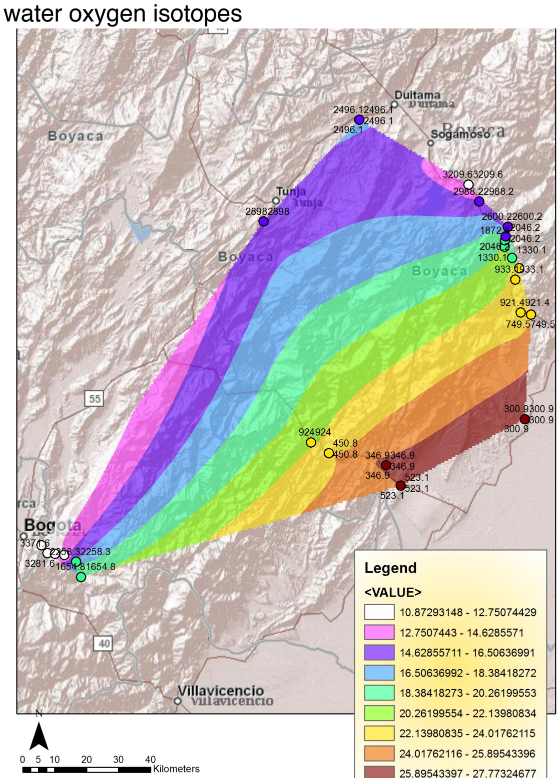

Figure 8. Nearest neighbor interpolation of soil temperatures

with elevation change in the Eastern Cordillera. This data provides a good initial argument for the use of soil GDGTs instead of oxygen isotopes from carbonates as a paleoaltimetry proxy.

CONCLUSIONS

The creation of higher resolution DEM and aerial photomosaic basemaps for Chingaza PNN in the Colombian Eastern Cordillera provides an excellent geographic context for analysis of our data collected over two field seasons. The Chingaza basemap clearly shows the extent of the glacial valley that defines the area, and will be very useful for future glacial equilibrium line altitude reconstructions using area altitude methods. Spatial interpolation of paleoaltimetry proxies in the Eastern Cordillera provides additional spatial evidence for the utility of in situ soil GDGTs over water isotopes in carbonates for documenting the rates and timing of the uplift of the Andes and justifies further work in this branch of our research program.

FUTURE WORK

After contractual issues between Ecopetrol and UT-Austin have been resolved, more data will be available to improve our GIS database for Colombian research. GPS points and depth measurements will be used to create a bathymetry map for Laguna Chingaza, validating coring site selection and guiding future coring expeditions attempting to address different questions. Additional high resolution aerial photographs in stereo pairs will be used to map smaller late Holocene glaciers in the region. Higher resolution topographic maps will be added to increase the spatial resolution of elevation data, thus increasing our accuracy of glacier ELAs from the area altitude methods.

ACKNOWLEDGEMENTS

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