QUATERNARY INCISION OF THE ARKANSAS RIVER, COLORADO

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INTRODUCTION

Rapid incision has dominated the Quaternary history of the Colorado Rockies. The young, steep-walled gorges of rivers like the Gunnison, Animas, and Arkansas serve as evidence of the dramatic downcutting of river systems in the region. In the Black Canyon of the Gunnison about 350m of incision has been recorded since the deposition of the Mesa Falls Ash 1.2 Ma (Hansen, 1987). The Animas River near Silverton, CO, has cut a canyon 1300m deep since the Pliocene (Gillam, 1986). Geomorphic features of the Arkansas River drainage suggest a young and dynamic incision history as well. These include the narrow, precipitous bedrock chasms of the lower Arkansas Canyon and Royal Gorge, and the eight different terrace levels correlated to glaciations now deeply incised by the river, north of Salida.

The upper Arkansas flows through the northernmost extension of the Rio Grande Rift Valley until it turns to the southeast near Salida (see reference map). The broad, flat valley is filled with river gravels dating back to the early Quaternary. Downstream of Salida, the river cuts through Paleozoic sandstones and carbonates before flowing into the broad, terraced Howard Valley. Flowing out of Howard, the river pitches into a steep gorge of Precambrian crystalline rocks that continues for some sixty kilometers until it enters the Great Plains near Pueblo, CO.

Two terrace levels from the Upper Arkansas Valley have been dated by the presence of Bishop, CA ash of 700,000 years ago and an ash presumed to be 600,000 year old Lava Creek B (Van Alstine, 1974). In the lower Arkansas Valley, segments of the fluvial terraces identified by Taylor, et al. (1975) are preserved and can be used to determine timing and rates of Arkansas River incision during the Quaternary. The Quaternary development of stream systems in south-central Colorado is poorly known but may help resolve the current debate over the interplay between climate change, erosion, tectonic uplift, and isostatic uplift as contributors to the landscape evolution of the region.

This study focuses on the measurement of Arkansas River terrace heights from Nathrop, CO, to Five Points Gulch, 108km downstream (Figure 1). In this study I investigated the Quaternary incision history of the Arkansas River using a differential GPS and digital topographic maps.

METHODS

In order to calculate accurate incision rates based on ancient river elevations, I took at least three data points containing northing, easting, and elevation measurements for thirty-three terrace surfaces over a 110km length of the Arkansas with a differentially corrected global positioning system. When a lengthy portion of terrace was accessible, I walked a transect perpendicular to the river with the GPS to create a profile. In cases where neither transects nor points were feasible, I took one point and used an inclinometer to determine the grade of the terrace towards the river. Transects and/or points were taken from the surfaces of thirty-three terraces between Nathrop, CO (about twenty miles north of Salida) and Five Points Gulch in the Arkansas Canyon. When road and property access allowed, I recorded a GPS point at river level adjacent to the terrace. In addition to surface mapping, I recorded characteristics of individual terraces.

In particular, I measured clast composition and imbrication when outcrops and time allowed. One hundred clasts were counted from ten terraces in order to characterize clast populations

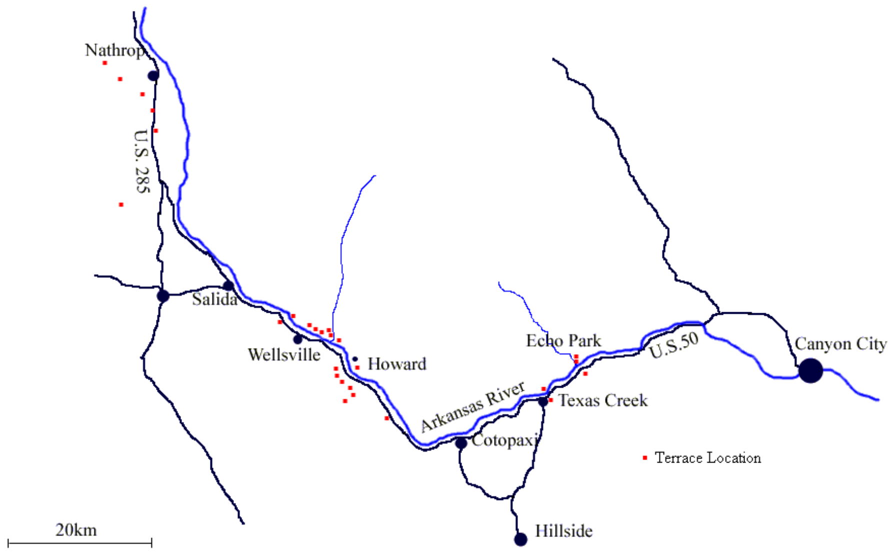

Figure 1: Locations of the 33 terraces mapped alongside a 110-km stretch of the Arkansas River (some locations contain multiple terrace levels).

Terrace Elevation Above the Current River

Determination of the paleoelevation of the Arkansas River based on terraces requires extrapolation of terrace surfaces to the current river location and calculation of the predicted terrace elevation above current river level ("terrace height"). Extrapolation of each individual surface surveyed becomes necessary, as the mapping methods used varied depending on the size, accessibility, and shape of the terrace. I used three different methods for calculating terrace height for each of these data types. Unless a GPS point was taken at river level adjacent to the terrace, I used the topographic map program Topo! to substitute river locations into terrace surface equations and determine terrace height above river level.

Points/slope combinations—I fit a linear equation to the top of the terrace with the measured gradient as slope and elevation (from the GPS data point) as the y-intercept. Distance to the river from the GPS point and river elevation were determined by constructing a transect (using Topo!) perpendicular to the river. Terrace height is determined by substituting the distance from the GPS point to the river into the terrace surface equation to determine terrace elevation above mean sea level and subtracting river elevation.

Transects perpendicular to the river—I calculated distance from the starting point of the transect to each subsequent point using a standard distance equation. I used Excel to find a best-fit function for the profile of the terrace surface, which is a second-order polynomial for most terraces. A method similar to this profile/polynomial model process was used by Cole (2001).

Three or more points—I calculated elevations by averaging the projected terrace elevations of all of the planes formed by the different three-point groups (this meant averaging four planes for terraces with four points, ten for those with five, etc.). Each plane was described in the form *Ax+By+Cz+D=0.*

I then calculated terrace height based on the average terrace height predicted by all planes. Downstream distance was calculated using the digitized topographic maps to construct a downstream profile of the Arkansas River and measure the distance to each terrace, using the Hwy 24/285 bridge in Buena Vista as a starting point.

RESULTS/DISCUSSION

Figure 2 is a graph of terrace height and downstream distance of the three most common Quaternary units in Arkansas terraces as identified by Taylor, et al. (1975). It shows a very loose distribution of terrace elevations, with substantial height variation within terraces of each unit. One terrace of Qbo—when extrapolated—indicates paleolevations lower than the current river elevation, even though it is clear that the Arkansas is currently downcutting. Although this discrepancy is reasonable in the case of several terraces not shown in this chart due to co-deposition of the Arkansas and side streams in those particular locations, Qbo is purely an Arkansas river deposit and should indicate incision. In the upper section of the Arkansas, a terrace of Qpo (the youngest unit) is shown by this method to be higher than a Qbo terrace at a similar downstream distance. I believe this to be the result of incision and weathering on the terrace surface causing large variations in the planes and profiles fit to them. The profiles of the terraces adjacent to Cherry and West Creeks (Figure 3) show how a longer profile leads to a more accurate extrapolation. Larger terraces are often more heavily incised, leading to greater variability in extrapolations from short transects or closely packed GPS points. Additionally, while polynomial models work well for terraces with long exposed surfaces perpendicular to the river, they generally work poorly for shorter profiles, as they only present a short segment of a lengthy terrace surface. Because of this systematic error and the fact that elevation profiles of the two ash-bearing terraces showed the two outcrops were each located in a horizontal terrace surface, I decided to use the actual elevation of the two ash outcrops to calculate incision rates. The Bishop Ash's elevation of 163m above current river level indicates a minimum incision rate of 0.23m per thousand years, while the location of the Lava Creek B ash 129m above

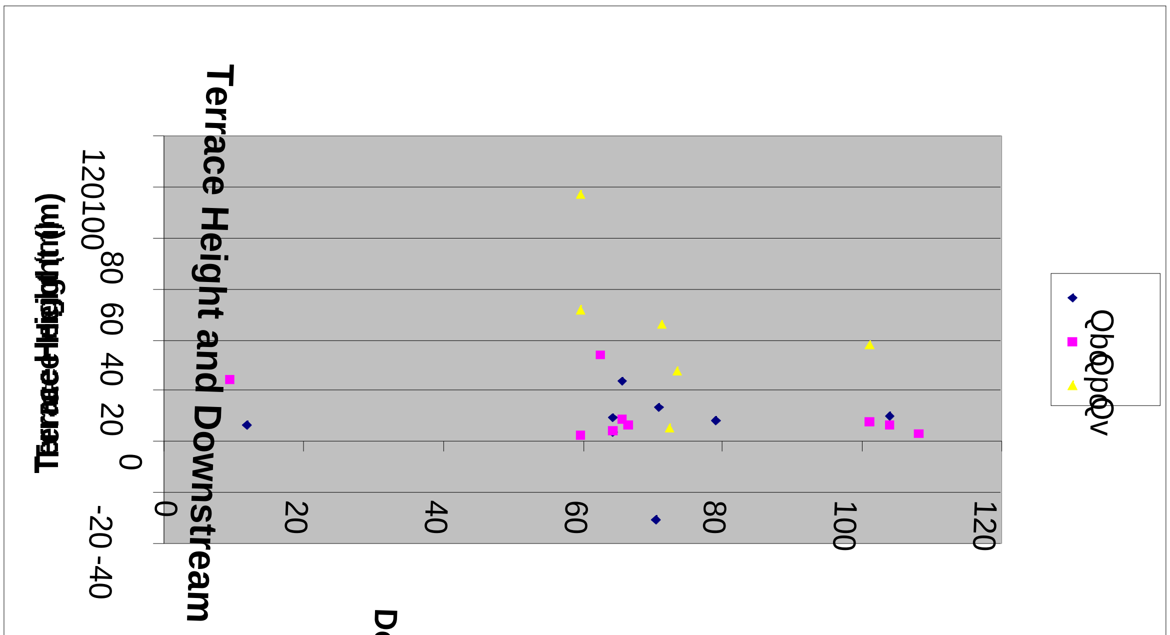

Figure 2: Graph of the terrace height-downstream distance relationship of the three most common units— Qpo (Pinedale Outwash), Qbo (Bull Lake Outwash), and Qv (Verdose Alluvium)

the Arkansas suggests an incision rate of 0.21m/thousand years.

CONCLUSIONS

Elevations of terraces containing dated ashes suggest minimum incision rates for the Arkansas between 0.21m/1000yr and 0.23m/1000yr. These values are similar to those calculated by Cole (2001), who calculated a rate of 0.17m/1000yr over the last 10my for the Colorado and Gunnison Rivers, and Hansen (1987), who found the Gunnison to be incising at about 0.29m/1000yr over the last 1.2my. These values confirm that rivers of southern Colorado have been incising rapidly in the late Tertiary and Quaternary.

It is clear that using GPS to map terraces in the Arkansas Canyon accurately is difficult due to the unevenness of most terrace surfaces and innaccesibilty. This study showed little correlation between downstream distance and terrace height above base level. However, since terraces represent river paleoelevation, they contain a wealth of information on Quaternary incision. I believe that while GPS has weaknesses in mapping larger terraces, it may be useful for investigating the recent history represented by smaller, younger terraces in the Arkansas Canyon.

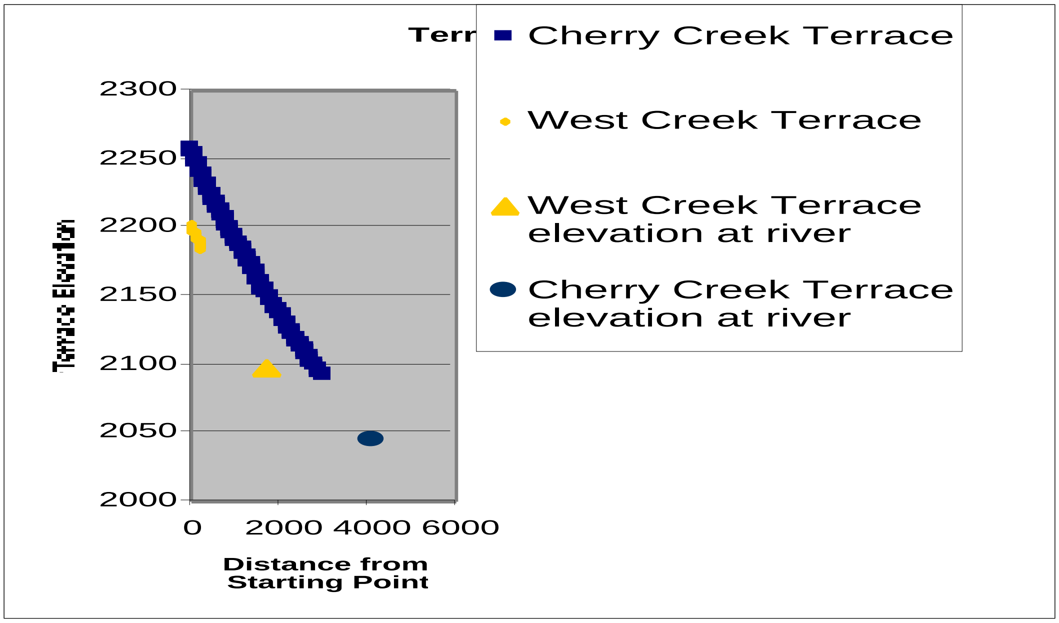

Figure 3: GPS profiles of Cherry Creek and West Creek Terraces showing the greater uncertainty of calculating terrace height from a short transect far away from the river as compared to a longer transect ending closer to the river.

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