Erosional History of the North Platte River, Casper, WY, USA

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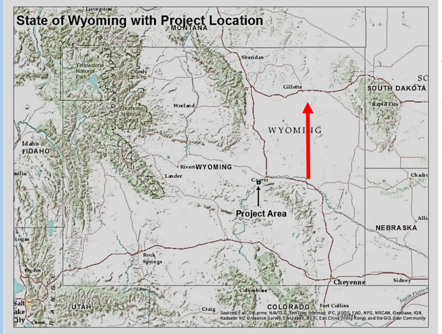
Abstract

The North Platte River is a critically important resource of central Wyoming and its erosional history is linked to past regional climate conditions. Specific questions investigated in field work near Casper, Wyo., during summer 2012 were the locations and elevations of past channels, relations between river sediment and locally derived sediment, timing of erosion and deposition by the river in the study area, and change over time in river sediments. The river appears to have been consistently downcutting in the study area for at least 4500 years, based on one carbon date, but possibly not at a steady rate as suggested by bedrock truncation. Local streams have generally followed this trend with some minor episodes of aggradation. Dating by optical stimulation luminescence on fluvial deposits ranged from 5,320 +- 180 ybp on the lowest elevation sample up to 15,700 +- 1500 ybp on the highest sample.

Old river channels are present in the study area up to 150 feet above and 1 mile to the side of the modern channel. During the recent Quaternary time represented by these deposits, the size of particles transported has decreased, the number of metamorphic clasts have decreased while igneous and sedimentary percentages have remained stable, and angularity of the clasts has increased. These trends may be due to a past decrease in flow and to changing erosional patterns upstream.

Location



The study area was located along the North Platte River, parallel to the northern face of Casper Mountain, near Casper, Wyoming.

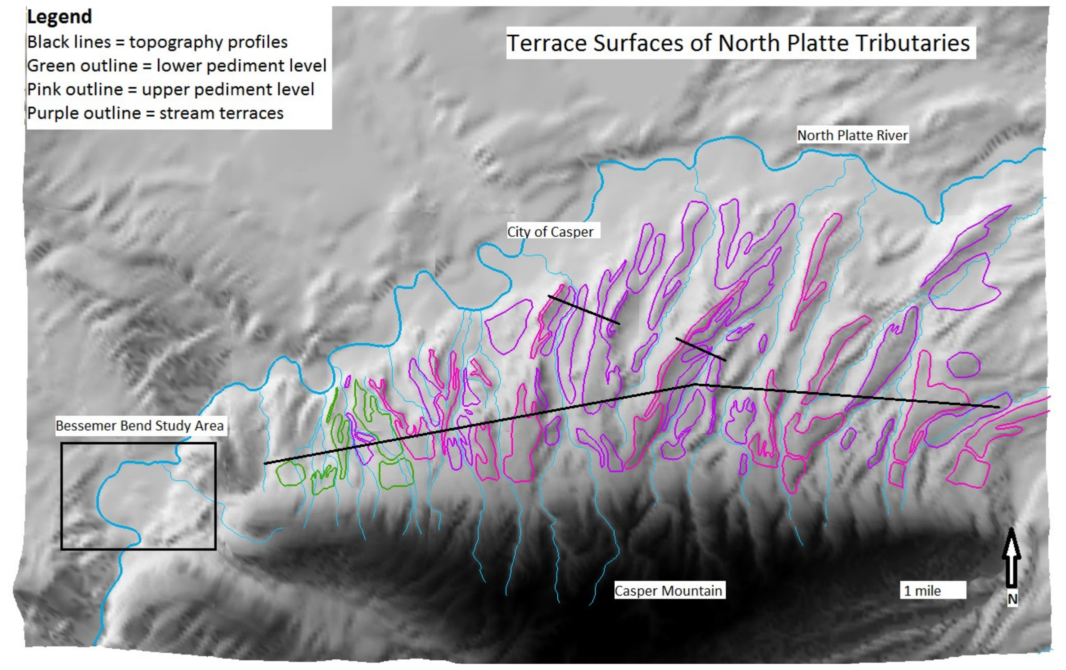
Introduction

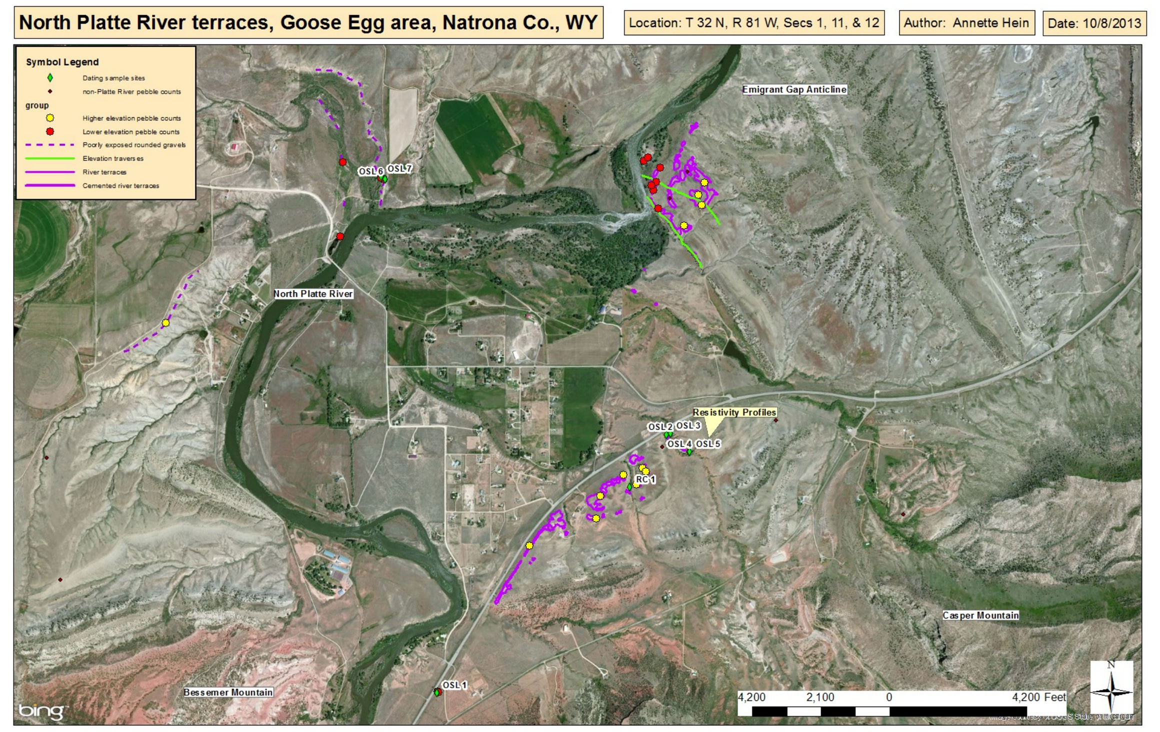
The North Platte River is a critically important resource of central Wyoming and its erosional history is linked to past regional climate conditions. In central Wyoming, the Platte flows around the north end of the Laramie Range, a resistant upland of Paleozoic sedimentary formations and crystalline Precambrian bedrock uplifted by Laramide-age faulting. The Platte is superposed across Casper Mountain (the northern tip of the Laramie Range) at the west end of the study area, then flows parallel to the mountain front across soft Cretaceous shales. A terrace sequence of the Platte has been briefly described near Casper (Albanese 1974), and this study mapped river terraces in an area just to the west. Specific questions investigated in this project were the locations and elevations of past channels, relations between past river levels and those of its tributaries, timing of erosion and deposition by the river in the study area, and change over time in river sediments. Many studies (e.g. Bridgland and Westaway 2008) have recognized climate as a major control of river terrace formation. Other studies in the area have documented possible Pleistocene glaciation on Casper Mountain (Anderson and Sundell 2008), and alternating drought and moist climate in the Casper Dune Field during the Holocene (Halfen et al 2010).

Methods

A detailed map of river deposits spanning terrace levels up to 170 feet above the river was made by GPS from field work in a small study area on private land near Bessemer Bend, WY. In a larger study area along the north face of Casper Mountain, deposits and erosional surfaces of tributaries were located on topographic maps and air photos, then visited in the field where private landowners granted access. On all gravel deposits, pebble counts of 100 randomly chosen clasts were used to characterize particle size, shape, and composition in gravel deposits. Radiocarbon dating was done on mammal bones and carbonaceous soil from river and local stream deposits associated with erosional surfaces. Optical stimulation luminescence (OSL) dating was performed by a USGS lab in Denver on sand and silt samples from river deposits and associated sediment. Two resistivity profiles were done across Quaternary alluvium to aid in mapping an underlying river gravel deposit. The data was acquired using an AGI SuperSting resistivity meter and a dipole-dipole array.

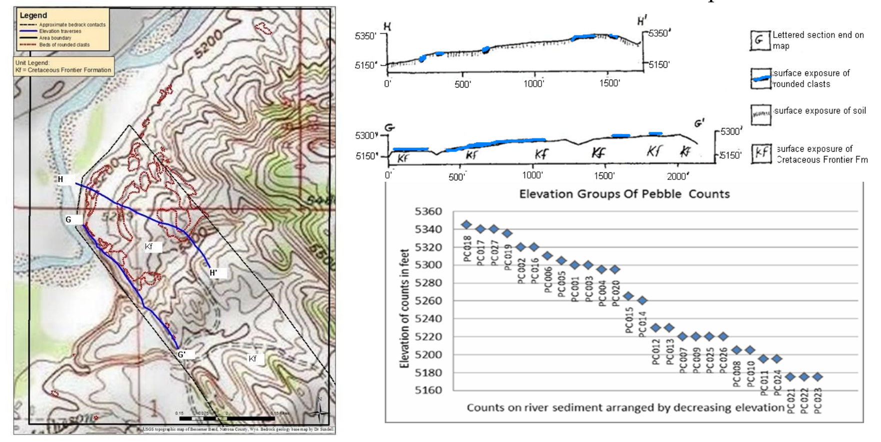
Results





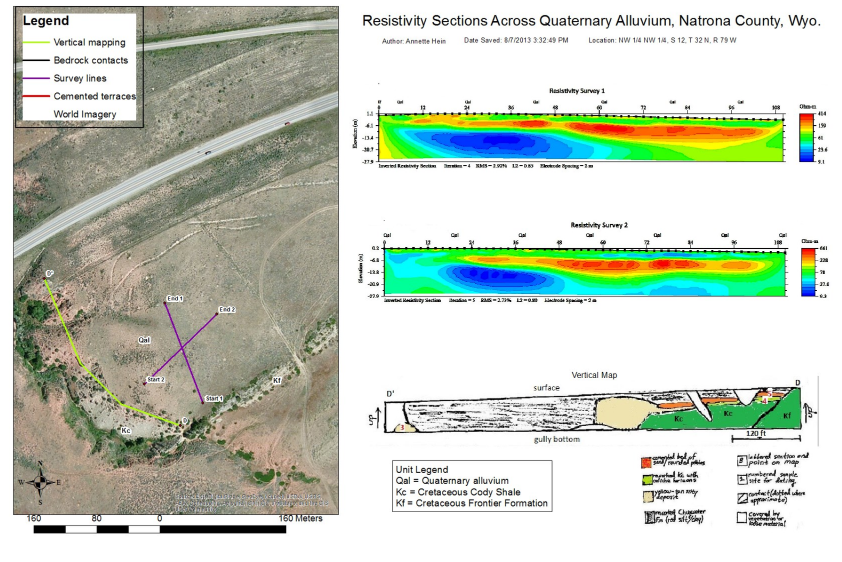
Elevation of River Terraces

Two main Platte River terrace levels were identified in the Bessemer Bend study area; one above 5250' elevation (more than ~80 feet above the river) and the other below this level. Terraces were found up to 170 feet above the river. Truncation of a resistant sandstone bed near the river showed these two terraces, and the distribution of pebble counts followed a similar elevation pattern.



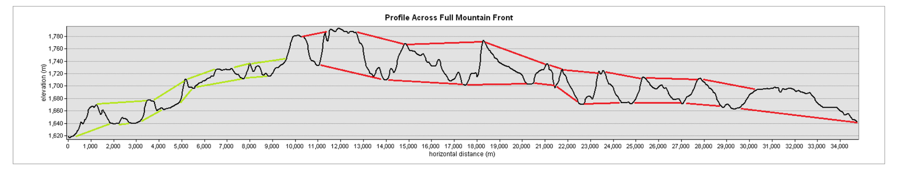
Geophysical Data

Two 112-m long resistivity surveys were performed across unconsolidated Quaternary sediment near an outcrop of cemented North Platte channels and local alluvium, using a dipole-dipole array. The inverted sections show low-resistivity Cretaceous Cody Shale, and medium- to high-resistivity alluvium. The highest resistivity alluvium is interpreted as sand and gravel North Platte deposits continuing back into the hill and thickening, while the more conductive alluvium could be a clay-rich deposit of local streams.



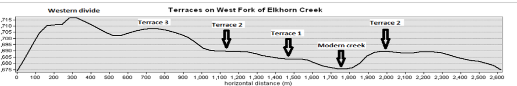
Tributary streams

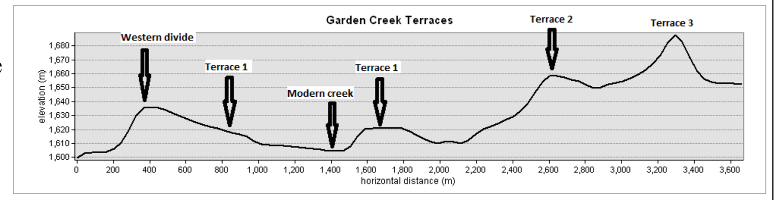
Nine North Platte tributaries in the study area flow from Casper Mountain to the river. Casper Mountain is a resistant upland formed of hard Paleozoic and Precambrian formations, and bounded on the north by a reverse fault. Across the fault is soft Cretaceous shale, into which the streams have incised. All the streams are flanked by benches cut in the shale and capped by gravel deposits of about 5 feet in thickness. These benches form the divides between stream drainages and are usually about 50 to 250 feet above modern stream levels. Near the mountain, the divides between the streams potentially correlate on the basis of height to form two surfaces, one lower elevation than the other.



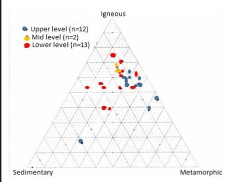
The gravel deposits capping the benches are composed of angular to subangular clasts of gneiss, granite, sandstone and limestone, all lithologically similar to rocks outcropping on Casper Mountain. No marker minerals such as banded iron formation characteristic of North Platte deposits were found in these gravels. Clasts in the deposits were frequently coated with 1/8" to 1/2" thick pedogenic calcium carbonate (caliche). The size range in most capping deposits was generally sand to 8" cobbles, although one stream's benches have boulders up to 7 feet in diameter, as was noted in a previous mapping project in this area (Anderson and Sundell 2008).

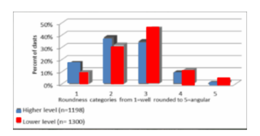
Within the stream valleys, each stream has formed a variable number of gravel-capped terrace surfaces. The streams are not consistent in number of terraces or in the terrace heights from drainage to drainage. The streams with the smallest drainage basins on the mountain tend to form no terraces within their valleys, while the largest streams (Garden Creek and Elkhorn Creek) each showed 3 terraces. Although Garden Creek and Elkhorn Creek are adjacent drainages, their terrace sequences are different. Elkhorn Creek's terraces parallel the stream's current course while Garden Creek's terraces fan out toward the east with increasing height; Garden Creek's terraces are at 30, 160, and 260 feet above the stream while Elkhorn's terraces are at 30, 50, and 100 feet above the stream.

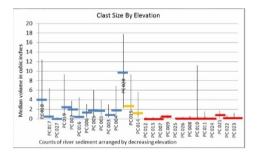




Change Over Time in River Sediment







There was a difference in composition between the higher elevation counts (n=12) and the lower elevation group (n=13). The higher elevation group showed significantly more metamorphic rocks ($p = 0.0005$) and fewer mineral clasts ($p = 0.006$) than the lower elevation group (n=13), although there was no significant difference in percentage of igneous ($p = 0.596$) or sedimentary ($p = 0.11$) clasts between the two groups. Roundness also showed a change, with the distribution dependent on elevation. All the z-scores on the residuals in the z-test for independence were higher than the 1.645 cutoff for 95% confidence, and higher elevation gravels tended to be more rounded than those at lower elevation. Size also changed between the two groups, with a significant difference in median size between the groups ($p = 0.0002$) The higher elevation group had much more variability and overall larger median size than the lower elevation group.

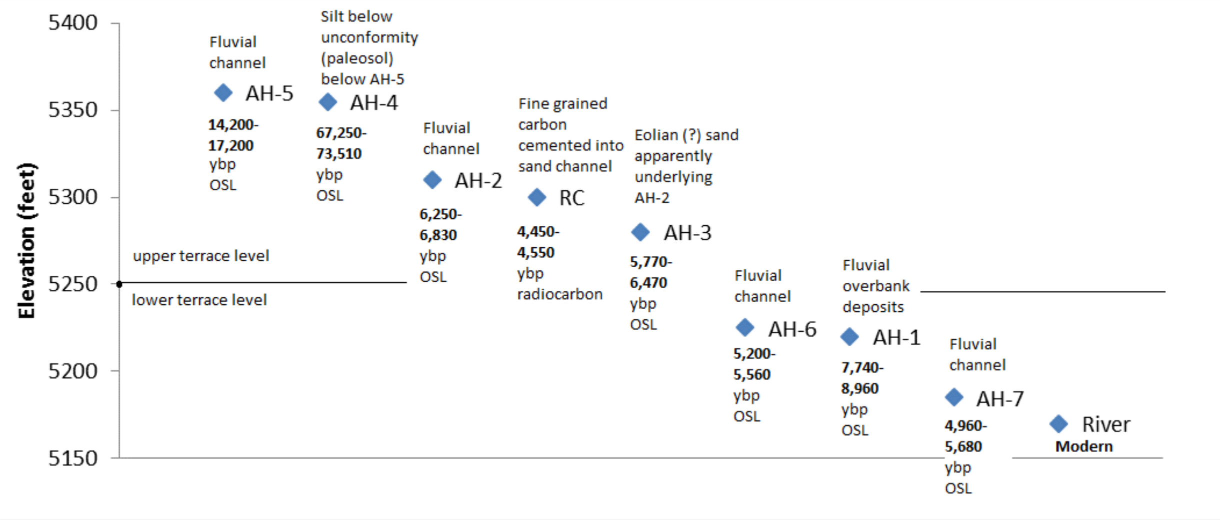
TABLE 1: Quartz OSL data and ages from terraces of the North Platte River near Casper, WY

Sample ID	% Water content[a]	K (%)[b]	U (ppm)[b]	Th (ppm)[b]	Cosmic dose (Gy/ka)[c]	Total Dose Rate (Gy/ka)	Equivalent Dose (Gy)	n[d]	Age (years)[e]
AH-1	3 (28)	1.26 ± 0.04	1.63 ± 0.27	6.45 ± 0.60	0.20 ± 0.02	2.06 ± 0.13	17.2 ± 0.67	11 (20)	8,350 ± 610
AH-2	0 (26)	3.93 ± 0.04	1.96 ± 0.13	12.16 ± 0.35	0.24 ± 0.02	4.60 ± 0.08	30.1 ± 1.26	5 (21)	6,540 ± 290
AH-3	0 (26)	1.82 ± 0.05	1.90 ± 0.31	5.82 ± 0.34	0.20 ± 0.02	2.58 ± 0.10	15.8 ± 0.63	9 (24)	6,120 ± 350
AH-4	0 (29)	0.72 ± 0.02	1.46 ± 0.10	4.77 ± 0.28	0.34 ± 0.03	1.58 ± 0.06	111.2 ± 2.58	10 (21)	70,380 ± 3,130
AH-5	0 (26)	1.46 ± 0.05	0.95 ± 0.30	2.29 ± 0.49	0.24 ± 0.02	1.86 ± 0.17	29.2 ± 0.76	3 (21)	15,700 ± 1,500 4,500 ± 50[f]
AH-6	0 (26)	0.81 ± 0.03	2.02 ± 0.13	16.92 ± 0.41	0.21 ± 0.02	2.47 ± 0.05	13.3 ± 0.35	4 (24)	5,380 ± 180
AH-7	0 (21)	2.59 ± 0.05	0.98 ± 0.32	4.76 ± 0.42	0.18 ± 0.01	3.01 ± 0.15	16.0 ± 0.74	16 (20)	5,320 ± 360

[a] Field moisture, with figures in parentheses indicating the complete sample saturation %. Ages calculated using 50% of saturation values.
[b] Analyses obtained using laboratory Gamma Spectrometry-high resolution Ge detector.
[c] Cosmic doses and attenuation with depth were calculated using the methods of Prescott and Hutton (1994). See text for details.
[d] Number of replicated equivalent dose (De) estimates used to calculate the mean. Figures in parentheses indicate total number of measurements made including failed runs with unusable data.
[e] Dose rate and age for fine-grained 250-180 or 250-90 um quartz sand. Linear + exponential fit used on age, errors to one sigma.
[f] radiocarbon on organic matter

Dating

Optical stimulation luminescence was used to date sand from fluvial channels and associated deposits in the Goose Egg area. The dates on fluvial deposits ranged from 5,320 +- 180 ybp on the lowest elevation sample up to 15,700 +- 1500 ybp on the highest sample.



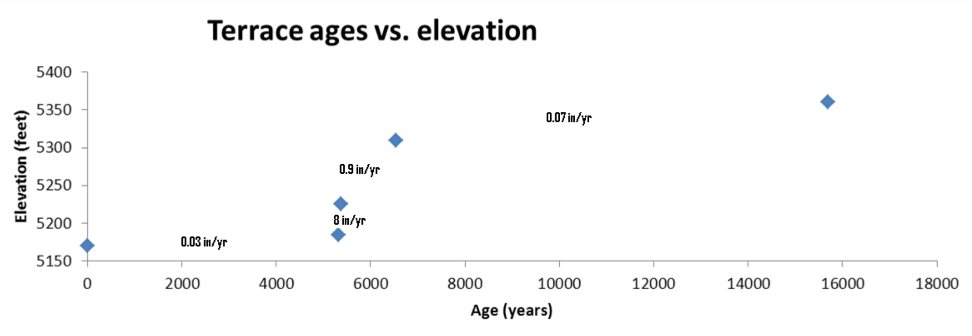
Discussion

Overall, the mapping results indicate that both the North Platte and its tributaries have been degrading their channels. Features that indicate this include the old river terraces up to 170 feet above the river, and high-elevation gravel capped benches along its tributaries. Most geomorphic studies assume that such terraces are the result of a period of stability and lateral corrasion of the stream followed by incision. However, the precise controls of the downcutting are harder to determine. One obvious control on local streams would be the incision of the North Platte River. However, the variability in local stream terraces would indicate that the Platte has not been the only control of its tributaries' downcutting, because changes in the Platte should affect all tributaries simultaneously.

In 1974, Casper geologist John Albanese identified five levels of North Platte terraces near Casper. He dated the upper three as Pleistocene on the basis of a Pleistocene camel bone found in gravels of the highest level (about 160 feet above the river), a 10,000 ybp carbon-dated archaeological site (the Casper Site) on the second level (about 140 feet above the river), and contorted sedimentary structures and sand wedges indicative of frost action in the third level (about 80 feet above the river). Terraces below this level he classed as Holocene. Although the present study area in Bessemer Bend did not show five clear terrace levels, the cutoff between the two main levels observed was at a similar height, about 80 feet above the river.

This study does, however, differ from Albanese's work as regards age of terraces. Only the date on the very highest channel sampled falls within the Pleistocene; all others are Holocene. Using the dates found in this study, the upper terrace level (170-80 feet above the river) would appear to span time from 15,700 +- 1500 ybp to 6120 +- 350 ybp. During this time, the river was transporting more metamorphic rocks than it has since then, and the clast size was larger and the shape more rounded. These are perhaps indications of a higher energy stream with more flow during that time.

The dates obtained in this study show that the river has been downcutting at a variable rate. Using OSL dates from channel sediment itself (these ages are supported by dates on associated sediment as shown earlier), the data suggest a period of stability from about 15000 to 7000 years before the present, then incision over a period of about 2000 years, followed by relative stability since about 5000 years. The earlier period of stability of the river appears to correlate by age with a Pleistocene terrace surface (showing sand wedges) on a tributary stream dated to 11,450 +- 50 to 16,860 +- 60 ybp by radiocarbon. The dated surface is located approximately 60 feet above the Platte and is downstream and considerably below the highest stream pediment surface. This date is in some disagreement with the OSL Holocene ages on river sediment of similar elevation.



Conclusions

The North Platte River has been degrading its channel over a period of at least 15,000 years in the Casper area. This erosion has been punctuated by at least two periods of stability (slow erosion rate) and one episode of swifter incision.

Tributary streams have generally followed the river in downcutting but have also shown individual chronologies that have varied between adjacent streams; therefore, local controls have had significant influence.

As the Platte has degraded its channel, it has become a lower energy stream overall, as shown by decreasing size and increasing angularity of transported clasts.

Future Work

There are many opportunities still open for further work on Quaternary geology of the Platte River system. Some possibilities in the Casper area could include further geophysical investigations for subsurface mapping of gravel and/or river terrace deposits (which could have potential for commercial exploitation), numerical modeling to explore possible past behavior and/or controls of tributary streams, and further dating of stream terraces and detailed mapping of their deposits to build a more comprehensive dataset on the timing of erosion and deposition in the stream system.

Acknowledgments

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