Arroyos: How the West was Carved
or
Recent Environmental Change in the Little Missouri Badlands

by Mark A. Gonzalez

When Theodore Roosevelt joined a burgeoning population of cattlemen in the Little Missouri Badlands in 1884, he commented (1888) that the gullies of the Little Missouri Badlands were rapidly forming and growing during his time. He and other area residents attributed this "gullying" of streams in the Badlands to overgrazing. There may be some truth to this; but in a recent study, it is apparent that the streams in the Badlands had begun to undergo a radical change even before the first large-scale stock operations began in the Badlands in the 1880s. This article is a condensation of the findings of my recent work, which recounts some of the major changes that have taken place along streams of the Badlands in the past couple centuries. Interested readers can find more information and greater technical discussion in a new NDGS publication (Gonzalez, in press).

Nature of the Problem

The Little Missouri Badlands is an environment in which the effects of running water are evident (Fig. 1). It is a highly sensitive landscape that responds rapidly to even small changes in environmental conditions. The questions posed here are 1) how do the stream systems in the Little Missouri Badlands respond to changes in the environment, and 2) did the period of severe cattle grazing in the 1880s lead to major changes in the stream system?

Settlement History of the Little Missouri Badlands

The Little Missouri Badlands was among the last places settled in the western United States, primarily because this was the last frontier in the contiguous United States reached by railroad.

Figure 1. View of the headwater region of the Paddock Creek basin illustrates the typical topography, vegetation cover, and relief in much of the Little Missouri Badlands.

Ranching activities and homesteading began in the early 1880s when the Northern Pacific Railroad extended its track westward to Medora, North Dakota (Robinson, 1966, p. 184, 188-190), a small, historic cattle town on the east bank of the Little Missouri River (Fig. 2). The cattle boom in the Little Missouri Badlands was short-lived. Drought, grasshopper infestation, and widespread fire in the summer of 1886, combined with a severe protracted winter in 1886-1887, led to the loss of an estimated 75% of the cattle in the region (Roosevelt, 1888; Robinson, 1966). By 1889 Medora was deserted (Robinson, 1966, p. 190).

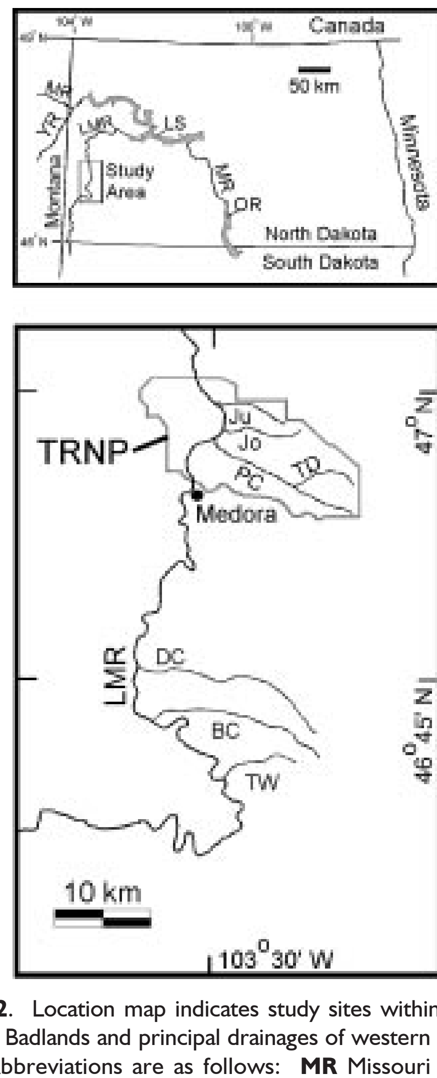

Figure 2. Location map indicates study sites within the Little Missouri Badlands and principal drainages of western North Dakota. Abbreviations are as follows: **MR** Missouri River; **YR** Yellowstone River; **LMR** Little Missouri River; **LS** Lake Sakakawea; **TRNP** South Unit of Theodore Roosevelt National Park; **Ju** Jules Creek; **Jo** Jones Creek; **PC** Paddock Creek; **TD** Talkington Draw; **DC** Dantz Creek; **BC** Bear Creek; and **TW** Toms Wash.

Study Design

The objective of my study was to determine how and when stream systems changed. That is, what environmental changes have occurred, when did these changes occur, and how did the small (i.e., ephemeral) streams respond to these changes? Previous investigators have debated what drives streams to change. One school of thought suggests that, when climate becomes wetter, there is more runoff, which leads to more erosive power, so that streams cut narrow, deep, steep-walled channels, called arroyos. Another camp counters with just the opposite, arguing that streams cut arroyos when the climate becomes drier, not wetter. Their reasoning is that when there is less vegetation on the hillslopes, perhaps from drought, fire, or severe grazing, little resistance is offered to the forces of a powerful thunderstorm. Thunderstorms attack the vulnerable landscape, water runs off in tremendous quantities because no vegetation exists to impede surface flow, and the streams cut deep arroyos. This argument also postulates that, during periods of wetter climate, the vegetation on the hillslopes grows denser and actually protects the landscape from erosion and formation of arroyos.

To evaluate these competing ideas and to determine what most likely happened in the streams of the Little Missouri Badlands in the past 200 years, I set out to study seven small streams; four in the South Unit of Theodore Roosevelt National Park (Jules Creek, Jones Creek, Paddock Creek, and Talkington Draw (informal name)), and three south of Medora (Dantz Creek, Bear Creek, and Toms Wash) (Fig. 2). To determine when changes occurred, I needed an accurate dating method. Dendrochronology, the dating of events by use of annual tree rings, in this case cottonwood trees found growing along the streams , served my objectives, because the life history of cottonwood trees is closely tied to stream events. By coring trees with an increment borer (Fig. 3), I could determine the age of a tree and the year in which it germinated without killing or injuring it. By studying the position of the tree with respect to the stream channel and its sediment, I could determine if the stream was filling up with sediment (Fig. 4A) or cutting arroyos (Fig. 4B).

Figure 3. Retired thoracic surgeon, Dr. Gilberto Gonzalez, is illustrating his method for an invasive procedure on a cottonwood tree. He extracted a 50-cm long core from the tree. The tree is purportedly doing well and has made a full recovery at the time of this writing.

Finally, I needed a means of reconstructing climate, so I could tell when there were periods of drought and periods of high precipitation. Unfortunately, the tree rings of cottonwood trees are not very sensitive to rainfall, because

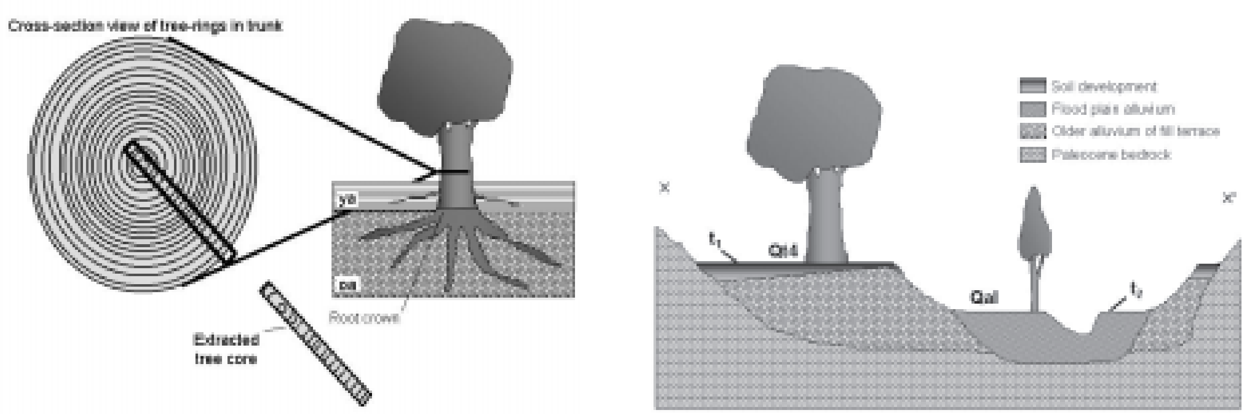

Figure 4. **(A)** Schematic view illustrates the relation between root crowns and age of alluvium. Tree ages provide minimum age constraints on older alluvium **(oa)** that lies at or beneath the root crown and maximum age constraints on younger alluvium **(ya)** that lies above and buries the root crown. In addition, an average rate of aggradation can be calculated conservatively by dividing the thickness of younger alluvium **(ya)** by the tree age. **(B)** Schematic view (*see* cross-section X-X' in Fig. 7 for relative location) of cottonwood trees on two different fluvial surfaces, **Qt4**—a low terrace, and **Qal**—the modern flood plain. When stream incision occurs, the old flood plain becomes a terrace (Qt4), and the lower inset surface (Qal) becomes the modern flood plain. The ages of trees on the two surfaces provide a constraint on when the incision occurred. The time of stream incision within a given reach is constrained by the ages of the youngest cottonwood tree on the abandoned surface (i.e., Qt4 terrace) and the oldest tree on the inset active flood plain (Qal).

cottonwood trees get much of their moisture from shallow groundwater sources. For this reason, I turned to the ponderosa pine trees in nearby Slope County to get a record of precipitation over the past few hundred years. Ponderosa pines are very sensitive to changes in moisture. During years of drought, the ponderosa pines add a very narrow growth ring around their trunk; however, when there is an abundance of precipitation, the trees drink up the moisture and add a wide growth ring (Fig. 5). Therefore, even though the historical record of rainfall in the region goes back only to the 1890s, the study of tree rings in ponderosa pines allows for the reconstruction of a precipitation record for the past several hundred years (my current data extend back to 1520 A.D.).

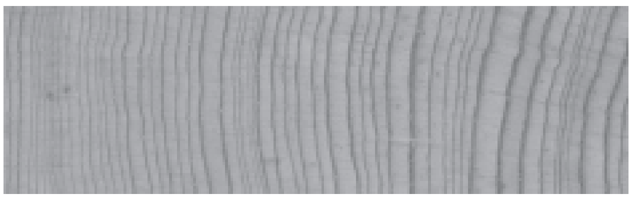

Figure 5. Close-up view of annual growth rings in a cross-section of ponderosa pine. Narrow rings correspond to dry years and wide rings to wet years. Field of view is about 3" across.

Findings: The Story of Change Unfolds

After examining approximately 300 trees in the seven study basins, a clear picture of the types and times of changes in the stream systems has begun to appear. Some of the notable finds include (1) the oldest sampled trees date back to the 1770s and are at least 225 years old; (2) nearly two-thirds (65%) of the sampled trees germinated within a 40-year period from 1861 through 1900; and half (51%) of the sampled trees germinated in only a 20-year interval from 1861 through 1880 (Fig. 6). As other investigators have pointed out, the germination of cottonwood trees is tied to disturbances and changes in the stream system. Undoubtedly, the period from 1861 through 1880 was one of tremendous change along the streams of the Little Missouri Badlands.

When the establishment dates of the trees are mapped from the mouth to the headwaters of each stream (Fig. 7), a general similarity between dates and stream changes appears in the seven study basins. The formation of arroyos follows a 4-stage cycle of evolution. In Stage I, streams are in a state of equilibrium, or balance, and the streams are neither filling with sediment nor cutting deep arroyos. Soils form on the flood plain during this period of geomorphic stability.

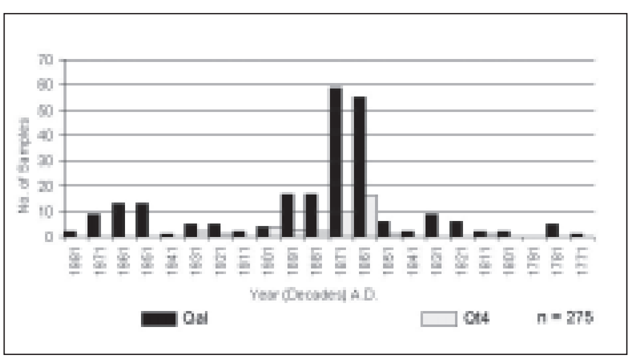

Figure 6. Histogram showing the decade of establishment of 275 sampled trees. [Decades are treated as beginning in year 1 (*e.g.*, 1841) and ending in year 10 (*e.g.*, 1850) of the decade.]

In Stage II, the channels begin to incise along the middle reaches of the streams to form arroyos (see Fig. 4B). The formation of arroyos began in the 1860s and 1870s (Fig. 7), clearly before the first Europeans settled in the Little Missouri Badlands. The cause of channel incision cannot be blamed on humans in this case, but appears to have been related to some natural change in the environment.

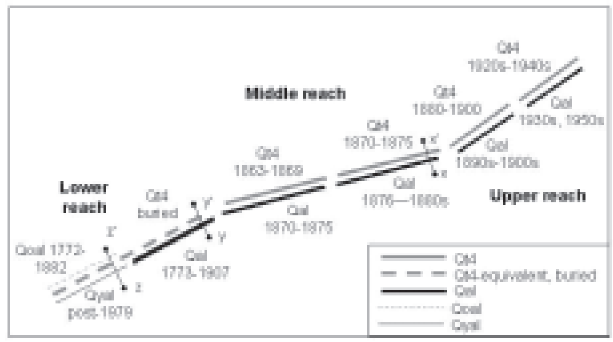

Figure 7. Schematic diagram summarizing the dates when trees are germinating on different surfaces and along various reaches of the streams. The Qt4 surface is the old, pre-incision, flood plain, which became a terrace surface following channel incision; whereas, the Qal surface is the modern flood plain. The youngest date of germination on the Qt4 surface and the oldest date on the Qal surface constrain the time of incision along each reach.

In Stage III, the incision progresses upstream (Fig. 7). The existing data indicate that the headward migration of incision occurred in the 1880s and 1890s, though some incision occurred intermittently as late as the 1930s and 1950s in some stream reaches (Fig. 7). This headward extension of the arroyos coincides with the brief period when large-scale cattle drives and huge numbers of cattle grazed the Little Missouri Badlands. The unresolved question is whether grazing is to blame for this headward extension of arroyos, or whether the headward extension was a natural process that was bound to occur once incision of the channels had been initiated in the 1860s and 1870s. The role of grazing to cause, to propagate, or to exacerbate stream incision cannot really be determined with certainty from the data collected thus far.

During Stages II and III, another interesting change occurs in the stream systems. The sediment produced by channel incision in the middle and upper stream reaches is carried downstream. However, the gradient of most streams decreases in a downstream direction; therefore, the ability to transport sediment decreases too. The small, ephemeral streams in the Little Missouri Badlands generally show that much of the sediment could not be moved through the downstream reaches. Instead the excess sediment began to fill up the stream valleys, a process known as aggradation. The evidence for aggradation comes from the cottonwood trees themselves. All the old trees along the lower reaches of the streams have been partly buried by stream sediment. For example, the root crown, which marks the original ground surface at the time a tree germinates, is invariably buried by one to 10 feet of sediment (Figs. 4A and 8A). Additional and more detailed evidence is discussed in Gonzalez (in press).

During Stage IV, the over-thickened downstream reaches that had been accumulating sediment for 100 or more years finally incise to form arroyos (Fig. 8B). Incision of the lower reaches has only begun in a couple of the study streams (Dantz Creek and Toms Wash) since 1979; it is likely to occur in the near future in the other study streams.

Conclusions

It has been fashionable to blame humans for carrying out practices that radically change the environment. Indeed, many places do bear the telltale signs of human abuse and mismanagement of the landscape. The recent formation of arroyos in the Little Missouri Badlands has been thought by many land managers and local residents to have occurred as a response to the introduction of domesticated cattle in the area. However, the evidence I have gathered by studying the cottonwood trees that grow along the small badlands streams conclusively demonstrates that the incision of stream channels to form deep arroyos began in the 1860s and 1870s, well before the area was settled and grazed by cattle.

The 1860s and 1870s was an anomalous period in the Little Missouri Badlands, as indicated by the study of the climate record preserved in the growth rings of ponderosa pines (Fig. 5). The tree-ring record indicates that the most severe, protracted drought in the past 480 years in western North Dakota occurred from 1863 through 1875. This 13-year-long drought was of sufficient duration and intensity that much of the vegetation on the hillsides would have died back. Climate, not human activities, created the conditions to trigger radical changes in the small streams of the Little Missouri Badlands. Human-related activities, such as grazing, may have exacerbated and propagated the formation of arroyos, but they cannot explain the initiation of the process.

Acknowledgements

I would like to thank Mr. Noel Poe, Superintendent of Theodore Roosevelt National Park, and Mr. Lesley W. Thompson and Mr. Norm Bishop of the Medora District of the Little Missouri National Grasslands for granting access to federal public lands. I am indebted to local ranchers, Ray Paasch and Robert, John, and Jennifer Hanson, for strong coffee, good conversation, and free access to private lands. Partial funding was provided by the Faculty Research Fund of the University of Denver. Johnathan Campbell took the digital photograph used in Figure 5. I am most indebted to my field assistant, friend, and father, Dr. Gilberto Gonzalez (Fig. 3), for his company and untiring help in the field.

References

Gonzalez, M.A., in press. Recent fluvial history and environmental change of some ephemeral streams in the Little Missouri Badlands of southwestern North Dakota: North Dakota Geological Survey Report of Investigations 101.

Robinson, E.B., 1966. History of North Dakota. University of Nebraska Press, Lincoln, 599 p.

Roosevelt, T. 1888. Ranch Life in the Far West. Originally in Century Magazine, 1888: reprinted 1981 by Outbooks, Golden, CO.

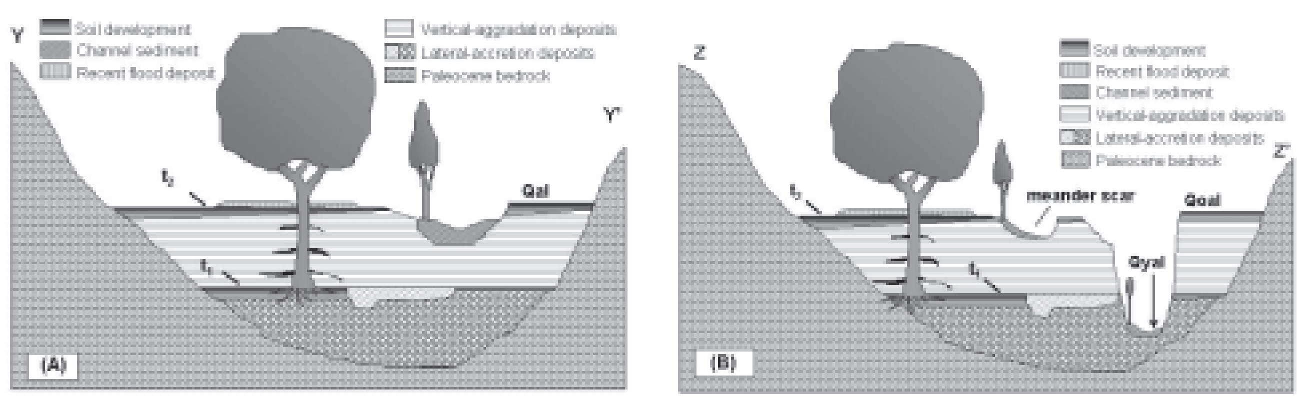

Figure 8. **(A)** Along downstream reaches the flood plains show progressive aggradation, that is accumulation of sediment, which buried old trees beneath as much as 10 feet of sediment (*see* cross-section Y-Y' in Fig. 7 for relative location). **(B)** Along the downstream reaches of Dantz Creek and Toms Wash the period of aggradation ended some time after 1979, and the stream channel has incised to form a narrow, deep, steep-banked arroyo (*see* cross-section Z-Z' in Fig. 7 for relative position).