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Stop #1 Cottonwood Campground
Day 1- Thursday April 26, 2007

At 5:10 am the geography 364 class of 11 students and professor Doug Faulkner departed for the little Missouri badlands/ Teddy Roosevelt National park in North Dakota via I-94. The drive was about 12 hours long and gave us plenty of time to observe many interesting landforms out the windows of the vehicles. One interesting thing to note is the dense vegetation cover over Minnesota, and the change in vegetation and one enters North Dakota due to the more arid climate. Also one may notice large boulders that seem out of place near the freeway. The rocks are known as erratics and were deposited from glaciers in the past. The erratics are composed of granite from Canada.

Stop #1- Teddy Roosevelt National Park Overlook

At 5:00 pm we arrived at the Teddy Roosevelt National Park Overlook with temperatures in the upper 50’s, light rain, overcast skies and winds 5-10 mph. From the overlook there are a number of interesting geomorphic features visible in the surrounding landscape. There are red topped buttes, known as clinker, which is a result of lighting strikes that have ignited lignite bands causing the resulting metamorphism of the surrounding rock layers forming porcelainite. These fires occur often and sometimes referred to as the burning hills. Lignite is low grade coal derived from peat. When looking out across the landscape one may notice that the vegetation or tree cover is only present on the north facing slopes of the badlands. This is a result of the sun baking the south facing slopes and removing the little moisture present in the soils.
Figure 1: Note the clinker, porcelainite, as reddish orange layers. The clinker is very prevalent throughout the park. Also note the location of the vegetation, typically located on the north side of all the hill slopes.

Day 2 - Friday April, 12th 2007

Stop #1- Cottonwood Campground 8:28 am

The first stop of the day started at Cottonwood Campground at 8:28 am where the temperature was in the low 50’s with sunny skies. We walked near the Little Missouri River on the east bank. Here there was visible scroll bars on the flood plain which were standing on (Figure 2). The cottonwood trees were in enechelon—rows following the depositional bars. There were small cottonwood trees growing on the sags and swales of the depositional bars. There was also evidence of vertical accretion (overbank) deposits in the form of silts on the floodplain. The river appears to be migrating west at this point in time but didn’t always follow this same pattern. There is evidence that the river once
flowed closer to the east. This evidence is in the form of cottonwood trees. Cottonwood trees require fresh bare mineral solid to germinate. This soil only results from alluvial deposits that typically occur yearly. This is the reason for the cottonwood trees to be in rows, because they are growing on the flood deposits from a specific year. By aging the cottonwood trees one can determine the age of the flood that deposited the soil the trees are growing on.

**Figure 2:** Drawing from Field notebook of the floodplain at Cottonwood Campground.

**Stop #2- Arroyo 9:20 am**

An arroyo is an incised ephemeral stream that typically has very steep embankments. This stream also has a terrace visible in Figure 3. The lateral erosion of the Little Missouri River created a nickpoint on the ephemeral stream. This nickpoint has been migrating upstream since then (Figure 4). This arroyo widens as the tributaries enter the arroyo. The Little Missouri River valley is aggrading from sediment form the bandlands.
Figure 3: Illustrates the visible terrace and arroyo formation near cottonwood campground. A terrace is evidence of a once aggrading floodplain that is now being incised.

Figure 4: Illustrates a head cut at the head of the arroyo near cottonwood campground. Mass wasting processes are visible by the collapse of the banks near where the students are standing.
Stop #3- Terrace Overlook

Here overlooking Teddy Roosevelt National Park one can view the T-4 terrace of unknown age. This terrace is believed to be of approximately Pleistocene age. We know this is a terrace and not a structural bench due to the composition of the underling sediment. There is a thin layer of sediment composed of rounded rocks, generally grinidic rocks from the black hills in Wyoming, indicating a fluvial depositional environment. This thin layer of sediment overlies bedrock indication a rock cut terrace. There is also a thin wind blown loess deposited on the top of the terrace (Figure 5). This wind blown slit is of the Oahe silt formation (Figure 6). The Oahe formation is of variable age of the late Wisconsinan glaciation into the Holocene.

![T-4 Terrace](image)

**Figure 5:** The T-4 terrace is visible in the distance. This photograph was taken overlooking 1-94 in Teddy Roosevelt National park.
Figure 6: Loess is wind blown silt of the Oahe silt formation. Note the dark color of the silt. This silt was removed from the top of the T-4 terrace.

Stop #4- Slump Formation 1:25 pm

A slump is a portion of a hillside that slides down, or slumps off of a hillside (Figure 7). A stream that is eroding the base of the hill slope can cause the hillside to become over steepened cliffs resulting in slumping during wet periods, preserving the internal stratigraphy (Figure 8). Evidence of slumping is easily viewed by looking at horizontal layering in the rocks. In a slump formation the internal layering, stratigraphy, appears no be non horizontal. This is not a result of tectonics but a result of mass wasting and slumping.
Figure 7: Slump formation in the national park. Note how the layers do not appear horizontal which a good indicator of a slump formation. The individual layers could be matched to the parent material on the hillside to further indicate slumping.

Figure 8: Illustrates the slump formation process and how the internal stratigraphy of the layers are preserved in the slump.
Stop #5- Caprock Coulee Nature Trail 1:00 pm

At the caprock coulee nature trail we hiked a few miles to observe features such as piping, pediments, and bentonite beds. Piping is subsurface erosion in bedrock jointing (Figure 9). When pipes collapse then can appear as a valley created from surface run-off, with no way to differentiate between pipe collapse and run-off created valley. Pediments are a flat area of sediment at the base of a hill slope (Figure 10). Sediment is in transport in a pediment, literally resting at the base of the hill slope. Pediments are erosional features composed of a thing veneer of sediment/ alluvium. Valleys widen from pedimentation. Bentonite is a dark grey volcanic ash weathered to clay approximately 55 million years old. There are multiple bentonite beds visible throughout the park (Figure 11). During wet periods the bentonite can become saturated and flow down hill slopes this is visible in Figure 12.

Figure 9: Illustrates piping present in much of the badland topography of the Little Missouri Badlands.
Figure 10: Pediment at base of hill slope. By digging into the soil one can find the underlying bedrock to determine the thickness of the sediment awaiting transport.

Figure 11: Bentionite beds visible on hill slopes. Note the dark grayish color of the beds.
Figure 12: Note how bentonite appears to flow down a hill slope. By looking at the horizontal layering one can see that the bentonite was deposited after the underlying layers because the layers are not deformed from the bentonite formation.

Stop #6- Cannonball Concretions 5:00 pm

Cannonball concretions are large spherical boulders that are mostly round. These concretions are formed within shale, sandstone, or clay by the deposition of mineral core (Figure 13).
Day 3- Saturday April 28, 2007

Stop #1- Little Missouri National Grassland

On a sunny morning we traveled to the Little Missouri National Grassland with Mark Gonzalez to use dendrochronology to estimate relative age of flood deposits and arroyo formation on buckhorn creek (Figure 14).

The US forest service manages about 120 million acres of land 4 million of which are grasslands. The grasslands were acquired through the reacquisition of homesteads during the 1930’s drought. In 1957 the first well was drilled in the National Grasslands located near Elkhorn Fields. Today these oil wells produce about 100,000 barrels of oil per day.
There are several variable factors in arroyo formation; natural climate, climate, road building, and semi arid climates. Semi arid climates have little precipitation but when precipitation occurs it is short duration, high intensity causing maximum overland flow. To estimate the relative age of an arroyo Mark Gonzalez finds the youngest tree on top of the arroyo (when germinated) and then the oldest on the incision. These trees are typically cottonwood trees. Cottonwoods only germinate under certain conditions discussed earlier in this paper. Mark then took several tree cores from trees near the arroyo using an increment bore. Counting the tree rings gives a good estimation of the age of the tree and therefore the age of the arroyo. There are only a few ways tree ring growth can be affected including; temperatures, precipitin, competition, and fire. When choosing trees it is important to try and choose trees that would be influenced by the same factors. From evaluating the trees rings near the arroyo Mark was able to conclude that the arroyo started incising in the 1860’s before the grazing of cattle dominated the west. Not only does Mark study floodplains with cottonwood trees he studies climate by using tree cores derived from Ponderosa Pines.
Stop #2- Fantail Creek

At Fantail Creek Mark Gonzalez taught us how to use an increment bore to date the cottonwood trees on the floodplain (Figure 15 &16). This floodplain exhibits evidence of recent aggradation. The fence posts that cross the valley have been buried, rebuild and reburied (Figure 17). A second sign of aggradation is adventitious roots grown by cottonwood trees (Figure 18). Adventitious roots are roots above the root crown to compensate for an aggrading floodplain. A third sign of aggrading was located using an auger locate a buried soil A horizon (Table 1). A reason for this recent aggradation can be attributed to a fire in 1989 that removed most of the vegetation cover.
from the surrounding hill slopes therefore increasing erosion and sediment supply to fantail creek.

When walking around fantail creek one notices mud cracking in the ephemeral stream which is evidence of suspended load during flooding. There are also natural levees present that have been created by vertical accretion deposits from flooding (Figure 18). When walking along the modern day arroyo which is about 20 feet deep, terraces are visible at varying heights. Only remnants of the T-4 terrace remain, while there is much more evidence of terraces T-1 – T-3 visible (Figure 19).

**Figure 15:** Ryan Werner takes a turn at using the increment more to take a core sample from a cottonwood tree.

<table>
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<th>Location</th>
<th>Name</th>
<th>Hue</th>
<th>Value</th>
<th>Chroma</th>
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<td>4</td>
<td>2</td>
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<tr>
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<td>2.5Y</td>
<td>4.5</td>
<td>2</td>
<td>Black</td>
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</tbody>
</table>
Table 1: Data from the auger depicting sediment classification.

Below Lens Loamy Sand 2.5Y 4 3 Olive Brown

Figure 16: Mark Gonzalez shows how to count tree rings on a cottonwood tree core extracted by Ryan Werner.

Figure 17: Fence post with field notebook for scale. This fence post was once exposed 1-2 meters above the ground before the floodplain began to aggrade.
**Figure 18**: Illustrates adventitious which above the root crown to compensate for an aggrading floodplain.

**Figure 19**: Illustrates natural levees built from over bank flow causing vertical accretion deposits to form (natural levees).
Day 4- Sunday April 29, 2007

Stop #1 Cottonwood Campground

On Sunday the entire class participated in a survey of the Little Missouri River. The research consisted of total station survey, discharge measurements using a flow probe, and global positing systems (GPS) data. The total station was used to accurately map the river channel and surrounding flood plain. This data will be used later to calculate the cross sectional area. The discharge measurements were taken to get real time flow data to be used later to interpolate results of other flooding events. The GPS data was collected to record heights of terraces and bank locations for future reference. This data was then complied upon our return to Eau Claire to calculate discharge at different bank full heights.