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Using Climatological and Geological History to Develop a Physical Model that Describes change in Stream Morphology in the Upper Dearborn River.

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I. Introduction

The valley of the Dearborn River, located in the Lewis and Clark National Forest in the Bob Marshall Wilderness Reserve in Montana, was the site of a vegetation and geological study from late June to early July of 2004. The research site was located near the boundary of the Scapegoat Wilderness and the Lewis and Clark Wilderness within the Bob Marshall Wilderness Reserve. The study site consisted of a narrow valley and flood plain, as well as the adjacent north and south facing slopes. This study examined the influence of climate on the changes in the formation of the present day valley.

II. Geologic history of the Dearborn River in northwestern Montana

The history of the formation of the Dearborn River Valley can be traced to the Cretaceous period. According to Sears (2001), this region of Montana was formed when the crustal scale Lewis-Eldorado-Hoadley (LEH) thrust slab was emplaced during the Late Cretaceous and Early Paleocene Laramie orogeny. Sears records that geologic data indicates that the entire length the slab was emplaced during the 15 my time interval from 74 to 59 Ma (2001, p 360). The map image in Figure 1 represents the geologic profile of the study area.

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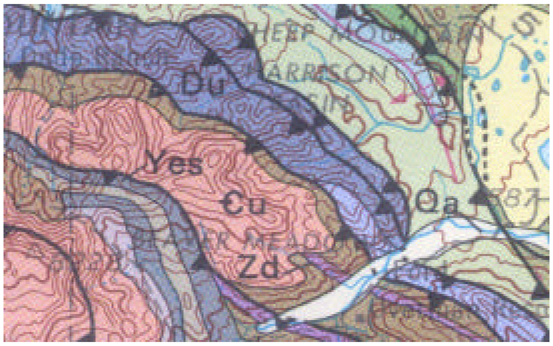

Figure 1: Geologic map of the research site

The region studied is referred to as the "Disturbed Belt." Mudge, et. al. (1980) report that periodic uplift and erosion continued through the Cretaceous and very early Tertiary periods. The amount of uplift may have reached 45,000ft during late Cretaceous to late Eocene. The Lewis fault is known to be 452 km long, extending from Central Montana up into Canada. The Hoadley fault, Lewis fault, and Continental Divide syncline probably formed simultaneously under the same stress field. The Hoadley fault originated 28 km north of the origin of the Lewis fault and runs parallel to the Lewis Thrust Fault, extending further to the south. The Lewis thrust plate consists of Precambrian rocks in Glacier National Park, but further south toward the study area, the rocks are younger, dating to the Mississippian and Paleozoic periods.

The river valley was formed by a series of thrusts and faults which created a graben as the faults uplifted nearby formations (Figure 2) The valley filled with glacial outwash between 10 and 25 thousand years ago, most likely from the Pinedale lobe of the continental glacier. Evidence of these deposits, specifically lateral moraines, were observed along the walls of the river basin. Additional glacial outwash was

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observed by the presence of stramatoliths and sundry boulders, cobbles, and gravel that are identified as belonging to formations located west and northwest of Helena, Montana.

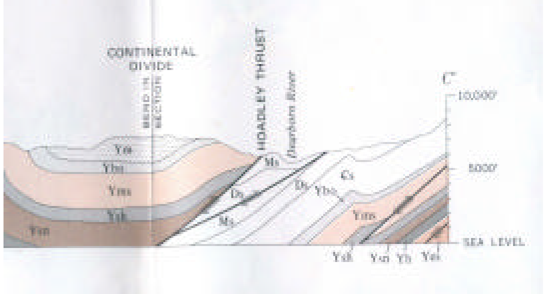

Figure 2: Cross section of the Dearborn River

Evidence of the changes in the valley was noticed by the study group and thought to be precipitated by large energy events that altered or formed a myriad of channels. The ox-bows and meanders that were observed from high elevations were probably not there 100 years ago. Fires also appeared to affect changes in the valley. As a result of these observations, the team elected to try to reconstruct and explain the physical changes that may have occurred in the area over the past hundred years.

III. Problem

While at the site, the study group engaged in a series of holistic investigations. The intent was to construct a profile concerning the influence of climatic variables on the changes that were hypothesized to have occurred in the valley.

Mapping:

To complete this objective, the group focused on mapping the area surrounding a north-south transect line created and used by the botany studies team. The mapping employed a format using 25 by 25 meter grids. Due to the time constraints imposed on the group, only a 100 meter by 175 meter grid pattern was completed. (50 meters east or west from the north-south 175 meter transect line were mapped) The mapping extended from the wall at the base of the south-facing slope to the beginning of the forest near the base of the north-facing slope. Figure 3

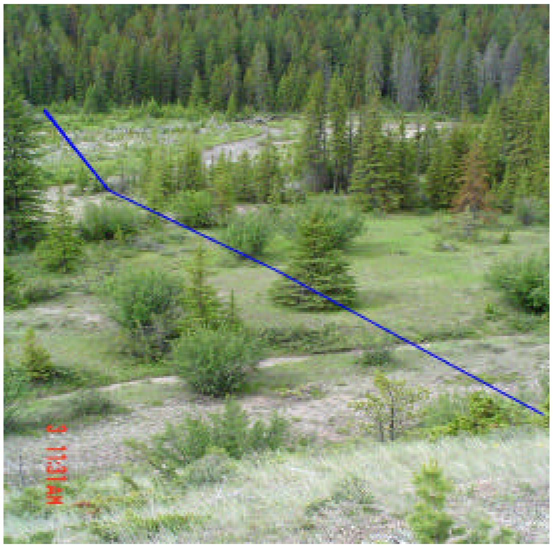

Figure 3: North-South mapping line.

Using laser range finders, the grids were outlined and the corners of each were marked with surveyors tape. GPS instruments were used to identify the latitude and longitude of the corners of each of the grids. The elevation in the study area as determined by the GPS was 1590 meters. This changed very little along the transect with the exception of a one meter drop near the stream. Although there were some slight depressions along the transect, the altitude changed less than 0.5 meters over a 100-meter interval from the north wall to the streambed. This change, although visible, may not have been within the accuracy limits of the instrument.

The first such depression appeared to be a former meander channel that was filled in by eroded colluvium from the south-facing slope. On the south side of the stream there was no significant change in elevation except a rise at the edge of the forest. The mapping of the area was intended to define the terrain around the botany transect line. It was also meant to support the historical interpretation of the morphological changes in the valley by the river channel over the past century.

The general morphology of this area appears to be a series of active and passive meander bars associated with catastrophic climatic events, most likely due to flooding events which will be discussed later in this paper (Figure 4).

Figure 4: Meander bar

Vegetation: To support and test the hypothesis about the flooding events, a comprehensive investigation of changes in vegetation was initiated. The vegetation of the area was examined from the north facing slope to the south facing slope along a 160 meter transect line. A north south line was drawn across the valley. Markers were placed every five meters and the study of the vegetation was conducted in one meter quadrants, on alternating east and west sides of the transect line. Figure 1 shows a sample grid. The species of vegetation present were identified using both human and textual resources. The regions of study were photographed and recorded for further plant identification and reference following the Daubenmire Method. Figure 5 illustrates the photo requirements of the Daubenmire process (http://fire.fws.gov/ifcc/monitor/RefGuide/daubenmire_method.htm). Percent cover was estimated with the aid of the point intercept method using knitting needle pins on a meter stick frame (Elzinga, 1998).

Figure 5: A sample quadrant demonstrating the procedures employed to conform with the Daubenmire process.

Soil: At each grid site, various aspects of the soil were investigated. The soil was analyzed for moisture content, infiltration rate, and the pH was measured. Some soil samples were taken from key areas along the transect line for further analysis. At the location of each extracted sample, a soil column was dug and the site was photographed. Figure 6 demonstrates the type of column dug and examined.

Figure 6 : Sample soil column

Data Collection:

` For each grid studied, various tests were conducted to allow for the determination of plant succession in the river valley. The tests completed were: pH, percent moisture, percent ground cover, average soil temperature, average surface temperature. Other key identification points were: plant identification in the grid and surrounding area, slope angle of the grid, and light intensity.

Discussion of Plant Studies:

The investigation of plant life in the Dearborn River Valley shows several trends in plant succession. Moving north to south along the transect line, a significant distribution of vegetative species were observed. Toward the Dearborn River on the north side, the plant density thinned into dearth and the soil column deepened. The plants that grow on the rocky flood plain adjacent to the stream are "pioneer species," or species native to the central Montana environment. Figure 7 contrasts the consistency of a pioneer species (shrubby cincafoil) along the transect line to that of an alien species (grass). At the research site, pioneer species included vetch, yellow mountain aven, willows, and spruce trees. The fact that only the pioneer species thrived on the flood plain shows that the rockiness of the soil there provides a particularly harsh environment.

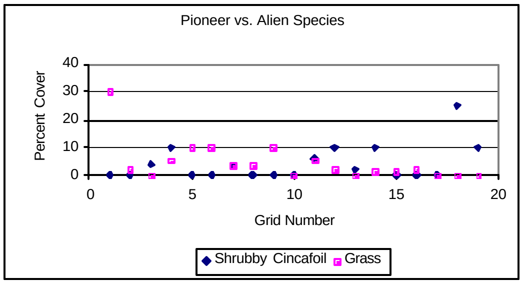

Figure 7: Plotting the Botany Data

The density and diversity of plant life within the research site was limited. Possible causes of this blight in addition to the many floods endured by the region, can be attributed to fires. Around the turn of the 20th century, a fire wiped out much of the flora on the north-facing slope of the site. As a result of the fire, the climax trees (Engleman spruce, Sub-Alpine fir) ringing the slope were killed, and lodgepole pines and cottonwoods, both alien species, came to dominate. In addition, the fire enabled massive slope erosion, covering the south side of the research site with colluvium soil. This soil covered former gravel beds, filled a truncated oxbow, and enabled different species to flourish on that side of the river. This was evidenced by an abundance of willows, particularly wolf willow, and other small shrubs. In fact, although that the southern side of the transect was more recently vegetated, it exhibited a greater dominance of woody plants than were observed in the older sections north of the river channel.

As mentioned earlier in the paper, the north-most point on the transect, adjacent to the vertical wall that marked the beginning of the mapping line, probably marked the original streambed. Present on this side of the river is a juvenile stand of 50 to 60 year old spruce trees. This stand is thought to have originated after the flood experienced by the region in 1953. The young trees are sidled up to a thick forest of bigger spruce, up to 160 years old. These older trees, most likely the northern extension of the forest edge community, provided the seeds for the younger forest after the streambed had changed position.

Interpreting the influence of Climate

As previously stated in the geological history of the valley, the Dearborn River itself has been the subject of several shifts and changes over the past century. These changes in streambed and direction were mostly the result of three major floods that pervaded the area over the last 100 years. To the north, early maps (circa 1900) support a river channel along the south-facing slope with gravel deposits toward the south. (Figure 8).

Figure 8: 1900 topographic map showing the north bending meander at the arrow.

Later mapping in 1969 (Figure 9) indicates that the former channel migrated to the south wall undercutting the tree line. This was most likely associated with the flooding of 1953, when up to 26 inches of rain fell on the Great Falls area.

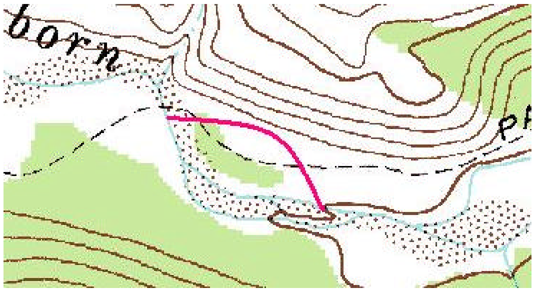

Figure 9: Dearborn River (1969) showing the new meander channel toward the south. The red indicates 1900 channel.

The storm had a drastic effect on the Dearborn River at our research site, which is evidenced through the change in the river's position. Further support of this theory includes the dense population of spruce trees on the north side of the river, all approximately 50 to 60 years old. These trees would have begun to grow around the mid-1950's, and were probably enabled to do so by the great flood which washed the stream away from their growth site. The 1969 map also illustrates significant channel development toward the middle of the valley. This change probably followed the flood in 1964. During the storm that caused this inundation, between 8 and 14 inches of rain fell in a single day. The current channel cuts off the meander of 1953 and follows the new channel of 1964. The energy for these changes are most likely associated with the flooding that occurred in 1973, when another storm hit the Dearborn Valley.

Flooding affected the valley in more ways than simply the position of the Dearborn River. Massive erosion was caused by the great amounts of rainwater experienced within the area. On the north side of the river, there is relatively little soil between the small trees and shrubs and the steep limestone wall. This area of thin soil traverses a rocky area as well as the original stream bed from before the 1953 flood, all the way up to the south-facing slope. The soil covering this area is less than 50 years old. However, closer to the Dearborn River and up onto the rocky flood plain, the soil becomes older and much deeper. There are two explanations for this phenomenon: either the sediments were washed by the stream onto the flood plain, or old, residual soil eroded down from the hillside. During our field presence, after several significant rainfalls were experienced. Because the Dearborn was always devoid of suspended sediments after rain, the first explanation is highly unlikely. Therefore, the old, rich soil was probably washed down from the south-facing slope, eroding until it came to rest on the now rocky flood plain. The south-facing slope is dry and relatively barren of vegetation, thus supporting of this hypothesis.

Concluding Discussion

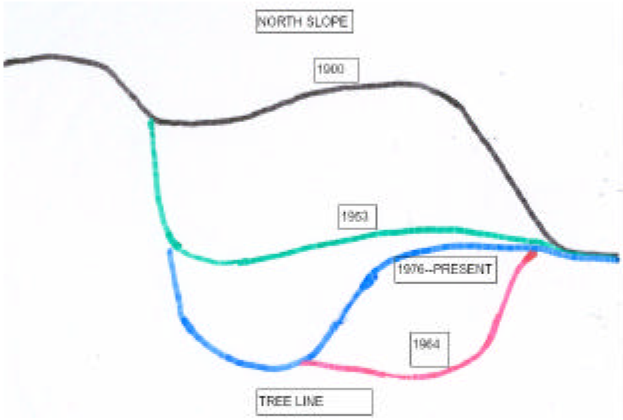

Figure 10 Hypothesized changes in the Dearborn River channel

The section of the Dearborn River studied indicates that numerous changes have occurred over time. It is hypothesized that the river has experienced at least four changes in the past 100 years. The assumed path of the river from 1900 until 1953 is located along the north cliff (Coopers Lake Map). Various cobbles and gravel at the foot of the cliff and a visible old streambed support the suggestion of the river's initial path. Observations from higher altitudes also recognize filled meander channels. In 1953, a flood, classified as a 200 year event, washed away the old river channel, truncating the existing meander and created a new channel parallel to the cliff and 100 meters away as seen in green in Figure 10. This channel remained until it was shifted by another flood initiated by torrential rains in 1964. This storm and subsequent flooding was classified as a 500 year event. The flood caused the river's path to be diverted 50 meters further south of the 1953 channel as seen in red (Figure 10). In 1975, another storm (identified as a 100 year event) morphed the valley to change the river's path, turning its course 100 meters closer to the cliff as indicated by the blue line in Figure 10. The deduction concerning the alteration of stream morphology and interpretations of events was enabled after a collection of significant relevant data. Information such as the relative ages and concentrations of certain plant species was used to support the amount of time the river flowed in each channel. Geologic research was necessary to describe the channel characteristics and permit estimations of the required energy to alter channel development. For example stromatolith cobbles in the 1953 river channel provided evidence of the amount and direction of the energy sources required to alter the channel morphology. Historical records concerning the climatology events influencing the valley were provided by Warren Harding, Forest Service Meteorologist during most of the significant changes and Dave Bernhardt, current Science and Operations Officer (SOO) NWS Great Falls, Montana.

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