The Development of a Model of Archaeological Sensitivity for Landforms in the Red Wing Locality, Pierce County, Wisconsin

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# Table of Contents

**Table of Contents** .................................................................................................................................................. 2

**List of Figures** ....................................................................................................................................................... 3

**Introduction and Purpose of Investigation** ............................................................................................................. 4

**Location of the Study Location** .................................................................................................................................. 5

**General Geomorphic History** ..................................................................................................................................... 6

- Late Wisconsin Glacial History .................................................................................................................................. 6
- Holocene Vegetational History ............................................................................................................................... 9

**Methods** .................................................................................................................................................................... 11

- Lab Methods .............................................................................................................................................................. 11
  - Base Map and Units ............................................................................................................................................... 11
  - Core Interpretation ............................................................................................................................................... 13
  - Terrace Correlation and Tributary Profiles ......................................................................................................... 13
- Field Methods ............................................................................................................................................................ 13
  - Sampling ............................................................................................................................................................... 13
  - Coring ................................................................................................................................................................. 14
- Sediment Analysis and Composition ............................................................................................................................. 14
- Radiocarbon Dating .................................................................................................................................................. 15

**Results** ..................................................................................................................................................................... 15

- Terrace Correlation .................................................................................................................................................. 15
- Descriptions of Tributaries ........................................................................................................................................ 16
  - Cannon, Trimbelle and Rush rivers (>25km) ...................................................................................................... 16
  - Big and Wind Rivers and Isabelle Creek (10-25km) ............................................................................................ 17
  - Dry Run, Hope and Morgan Coulees (<10km) ...................................................................................................... 18
- Core Interpretation ..................................................................................................................................................... 18
- Radiocarbon Dating .................................................................................................................................................. 19
- Grain Size Analysis Results ..................................................................................................................................... 19

**Discussion** ................................................................................................................................................................. 19

- Late Glacial Environments ...................................................................................................................................... 19
- Tributary Response to Wisconsin Stage Glaciation .................................................................................................. 20
- Holocene Environment and Landscape Response of the Red Wing Locality ........................................................................... 21
- Landscape Evolution and Archaeological Significance .............................................................................................. 24

**Conclusions** ............................................................................................................................................................. 26

**References** ............................................................................................................................................................... 29
## List of Figures

<table>
<thead>
<tr>
<th>Title</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Wing Locality</td>
<td>1</td>
</tr>
<tr>
<td>Study Area Location</td>
<td>2</td>
</tr>
<tr>
<td>St. Croix Phase</td>
<td>3</td>
</tr>
<tr>
<td>Pine City Phase</td>
<td>4</td>
</tr>
<tr>
<td>Cross-Section Location Map</td>
<td>5</td>
</tr>
<tr>
<td>Terrace Location Map</td>
<td>6</td>
</tr>
<tr>
<td>Topographic Cross-Sections</td>
<td>7</td>
</tr>
<tr>
<td>Terrace Correlation Diagram</td>
<td>8</td>
</tr>
<tr>
<td>Tributary Profiles</td>
<td>9</td>
</tr>
<tr>
<td>Geomorphic Map of the lower Trimbelle River</td>
<td>10</td>
</tr>
<tr>
<td>Geomorphic Map of the Big River</td>
<td>11</td>
</tr>
<tr>
<td>Geomorphic Map of the Hope Coulee</td>
<td>12</td>
</tr>
<tr>
<td>Stratigraphic Cross-Section of the Mississippi River</td>
<td>13</td>
</tr>
<tr>
<td>Transverse Cross-Section of the Mississippi River at</td>
<td>14</td>
</tr>
<tr>
<td>L&amp;D #3</td>
<td></td>
</tr>
<tr>
<td>Numerical Models of Sedimentation</td>
<td>15</td>
</tr>
<tr>
<td>Climate Change and Fluvial Response of the Upper</td>
<td>16</td>
</tr>
<tr>
<td>Mississippi Valley</td>
<td></td>
</tr>
<tr>
<td>Late Glacial Landscape Diagram</td>
<td>17</td>
</tr>
<tr>
<td>Early Holocene Landscape Diagram</td>
<td>18</td>
</tr>
<tr>
<td>Middle Holocene Landscape Diagram</td>
<td>19</td>
</tr>
<tr>
<td>Late Holocene Landscape Diagram</td>
<td>20</td>
</tr>
</tbody>
</table>
Introduction and Purpose of Investigation

The Red Wing Locality (Dobbs, 1985; Dobbs and Breakey, 1987) is an exceptionally dense concentration of earthworks and habitation sites clustered in a 150.3 square kilometer (58 square miles) area at the confluence of both the Cannon and Trimble Rivers with the Mississippi River (Fig. 1.). These sites were principally occupied between about AD 1050 and 1300 and are associated with the Mississippian culture, the first Native American farmers in Minnesota and Wisconsin. Although there are a variety of other sites from many time periods in the vicinity, the Red Wing Locality is particularly significant since it represents one of the largest concentrations of the Mississippian culture archaeological sites along the Mississippi River north of Illinois.

The Red Wing Locality has undergone a complex history of landscape evolution since late glacial time around 12,000 years BP. These complex changes coincide with the time of human immigration and settlement of the Upper Midwest. Dobbs and Mooers (1991), as well as others, have suggested that the Upper Mississippi River system and its tributaries, with Lake Pepin as the hub, provided a natural transportation system that linked areas of diverse natural resources. The Cannon River provided ready access into southern Minnesota and to the prairie region with its diverse resources. The lower 2 to 4 kilometers (1.2-2.5 miles) of the course of the Trimble River may have provided access to settlements during the Mississippian occupation of the region, and the upper portion of the course of the Trimble River may have served as a transportation corridor into western Wisconsin. Farther to the north the St. Croix River provided access to the hunting and trapping areas of eastern Minnesota and western Wisconsin, the Mississippi itself was a route to the wild rice country of central Minnesota. At the southern end of Lake Pepin, the Chippewa River provided access to central Wisconsin.

The Mississippi Valley and the valleys of tributary streams contain geomorphic features that record the geomorphological evolution during Late Glacial and Holocene time. The Mississippi River was the major course for glacial meltwater, and the valley repeatedly filled with glacial outwash and then incised, correlating with the glacial advance and retreat respectively. Tributary valleys alternately filled and downcut in response to the changes in the Mississippi River. Deposits of many of these events can be identified and used to interpret the complicated glacial history. Holocene changes in the landscape were equally dramatic. Following glaciation the Mississippi River floodplain was at least 30 meters below its present elevation, and the valley has infilled to its present configuration in about 9000 years (Wright, 1972; Zumbeerge, 1952) The changing landscape influenced the human settlement and migration patterns, and the record of human occupation is recorded in the sediments. Paleoindian sites, associated
with the late-glacial/early Holocene period have been found in a variety of settings along the Upper Mississippi River including tributary valleys and uplands. Sites of the Mississippian Tradition are typically located along glacial outwash terraces within the Mississippi River Valley and its tributaries. This is, however, a rather biased record of human occupation. For instance, one might ask why there are no Paleoindian sites along the Mississippi River or the lower portion of its tributaries? The answer is simple; during Paleoindian time the Mississippi and the lower portion of the tributaries were 20-30 meters below their present elevation. Cultural artifacts dating to this period are deeply buried and have likely been redeposited many times. Where then are the best places to look for old cultural materials, or for later artifacts for that matter? Prediction of the location of occupation sites and associated cultural resources must consider the changing configuration of the Mississippi Valley and the tributaries.

This investigation focuses on the establishment of a time-dependent model of the late-glacial and Holocene evolution of the Upper Mississippi River Valley and tributaries. Emphasis is placed on glacial outwash terraces and on the valleys of tributary streams in Pierce County, Wisconsin, for the purpose of identifying the age and origin of habitable land surfaces. The glacial outwash terraces record multiple events of glacial advance and retreat in Minnesota and Wisconsin, and they have provided stable surfaces suitable for human occupation since their formation 12,000 to 14,000 years before present (BP). Identifying and tracing terrace surfaces provides a method of correlation with the established sequence of glaciation. During glacial advances outwash filled the Mississippi River valley. During subsequent retreat of glacial ice, meltwater streams became incised leaving remnants of the higher river levels as terraces along the edge of the Mississippi River valley and in tributary valleys. Each time the level of the Mississippi River, the master stream, changed, tributaries were forced to adjust to the changes in base level. Since each tributary has a different discharge, sediment load, and slope each responds differently to the changes in the Mississippi base-level. To evaluate the response of tributaries and the potential for each tributary valley to contain a record of human occupation, the tributaries were broken into three size classifications.

The Cannon River in Minnesota and the Trimble and Rush Rivers in Wisconsin represent larger tributaries, the Big and Wind River as well as Isabelle Creek represent tributaries of intermediate discharge, and the Hope, Morgan and Dry Run Coulees represent the small intermittent tributaries. Three of these, the Trimbee River, the Big River, and Hope Coulee were selected for detailed investigation.

Location of the Study Location

The area adjacent to the Mississippi River in Pierce county, Wisconsin, is the focus of
this investigation. However, to establish regional relationships, the general study area was expanded to include the area along the Mississippi River southeastward from St. Paul, Minnesota, to the position of the Chippewa River delta near Pepin, Wisconsin, a distance of approximately 120 kilometers (Fig. 2.). The larger area includes portions of Pierce and Pepin Counties, Wisconsin, and Dakota and Goodhue Counties, Minnesota.

General Geomorphic History

**Late Wisconsin Glacial History**

During the Late Wisconsinan glacion, numerous ice lobes invaded east-central Minnesota and west-central Wisconsin. However, deposits of the Itasca-St. Croix-Chippewa Phase of the Wadena, Rainy, Superior, and Chippewa Lobes and the Bemis, Altamont, Algona, and Big Stone Phases of the Des Moines Lobe account for nearly all of the sediments and landforms pertinent to this study. The Wadena, Rainy, and Superior Lobes advanced forming a contemporaneous moraine system that marks the terminus of the respective ice margins (Wright, 1972).

In Wisconsin, the Chippewa Lobe advanced to its maximum, forming the Chippewa Moraine, which is considered contemporaneous with the St. Croix Moraine (Knox, 1985). The Chippewa River carried Chippewa Lobe outwash to the Mississippi River during this period. According to Andrews (1965), the Chippewa River filled with glacial outwash that graded presumably to the ice margin. After the demise of the Chippewa Lobe, downcutting of the Chippewa River produced the Wissota terrace that has an elevation of 290 meters at the headwaters and 235 meters at the confluence of the Mississippi and Chippewa Rivers.

Meltwater carried sediment from the active ice margins into the Mississippi River drainage system. Meltwater relationships of the Wadena and Rainy Lobes are difficult to reconstruct because the courses of these channels are buried by younger glacial drift. Meltwater relationships of the Superior Lobe are generally clear. Beneath the Superior Lobe tunnel valleys carried meltwater and sediment to the ice margin, through the St. Croix Moraine (Wright, 1973). Approximately twelve major tunnel valleys have been identified in Minnesota. The outwash is expressed within the Mississippi River Valley as a high terrace of approximately 275 meters above sea level, and is traceable from the former ice margin several kilometers downstream. As the Superior Lobe retreated from its maximum, proglacial lakes formed and drained to the south across the St. Croix Moraine and ultimately to the glacial Mississippi River. Wright (1972) places the date of maximum Superior Lobe ice advance during this phase, based on radiocarbon dates to approximately 20,500 BP. Clayton and Moran, (1982) and Mooers *et al.* (unpublished data) suggest a date of about 15,500 BP on this phase (Figure 3).
The Itasca-St. Croix Phase was followed by the Automba Phase of the Superior Lobe. The Automba Phase has been interpreted by Wright et al., (1973) as representing a time of stability in glacial regime after a period of wastage. The Rainy Lobe was much thinner than its counterpart, and likely receded northeast into Canada. The Superior Lobe retreated to the Lake Superior Basin. During the Automba, the Rainy Lobe readvanced to the Vermillion Moraine, which makes an interlobe junction with the Highland Moraine of the Superior Lobe near Isabella, Minnesota. The Superior readvanced in a southwesterly direction until it reached the edge of the Lake Superior basin, where it then proceeded to the west. Here, it formed the Automba drumlin field and the Wright and Cromwell Moraines along its northwest flank. Proglacial lakes Upham I and Aitkin I formed from glacial meltwater draining from the ice lobes to the north. The Superior Lobe during the Automba phase terminated at the Mille Lacs Moraine. Wright (1972) was unable to date this phase with any certitude. However, subsequent investigations by Clayton and Moran (1982) and Mooers et al. (unpublished), have suggested a date of around 13,500 BP for this phase.

The Superior Lobe during the Split Rock phase readvanced as far as the southwest portion of the Lake Superior basin, as recorded by the deposition of a characteristic red clayey till (Wright, 1972). Meltwater derived from the Superior Lobe drained to the south along the Kettle River and into the St. Croix River drainage and ultimately to the Mississippi River.

Based on the relationship of meltwater drainage, the Split Rock Phase of the Superior Lobe is correlated with the maximum extent of the Grantsburg Sublobe of the Des Moines Lobe (Fig. 4) in the Pine City Phase. The Grantsburg Sublobe of the Des Moines Lobe overrode the St. Croix moraine and terminated near Grantsburg, Wisconsin, at the Pine City moraine. From radiocarbon dating techniques, Wright (1973) dates the Grantsburg Sublobe between 16,000-14,000 BP. Clayton and Moran place the event at 12,500 BP which seems too young in relation to proceeding events. Mooers et al. (unpublished), suggests a date of 13,500 BP. The most convincing evidence that correlates the two lobes spatially and temporally is Glacial Lake Grantsburg, which formed north of the Grantsburg Sublobe by damming of the Mississippi River and other drainages by the advancing ice. The lacustrine sediments are gray in color, characteristic of the material associated with the Des Moines Lobe, and are typically less than a few meter thick. In the Wisconsin portion, however, the sediments are generally thicker and often red in color. Based on the counting of sections of varved lake sediment, the eastern part of the lake lasted about 2000 years, while the western area existed for a much shorter period (Wright, 1973). Cooper (1935) postulated that the outlet of Glacial Lake
Grantsburg was at the margin of the Grantsburg ice near its terminus. Wright (1973), suggests that there are several candidates for drainage in Wisconsin including the Apple River.

During wastage of the Grantsburg Sublobe, meltwater from the Grantsburg and contributions from the diverted Mississippi drained to the northeast into the Snake River; which drained into the St. Croix River and ultimately, the Mississippi River. The Anoka sandplain was formed in the process (Cooper, 1935). The diverted Mississippi River intercepted a low spot in the St. Croix moraine near St. Paul. According to Wright (1972), the river extended its valley train down stream, which is expressed by the 245 meter terrace remnants in the Upper Mississippi Valley. He further asserts that outwash sedimentation was so great in the Mississippi River Valley that streams tributary to it were back flooded, potentially forming small lakes in their lower reaches.

Continued retreat by the Des Moines Lobe to the north of the continental divide in western Minnesota resulted in the formation of Glacial Lake Agassiz. Lake Agassiz drained to the Mississippi river along Glacial River Warren, now the course of the modern Minnesota River. Meltwater flowing along Glacial River Warren was relatively free of sediment and was therefore highly erosive (Matsch and Wright, 1967). The valley quickly became inciesd well below modern levels. During the downcutting of the Mississippi River Valley by Glacial River Warren a series of strath terraces formed at various elevations. These are easily identified above the modern Mississippi Floodplain, and presumably similar terraces were formed below the modern floodplain level and have since been obscured because of Holocene infilling. The downcutting event removed approximately 30–40 meters of glacial drift exposing the Paleozoic bedrock near St. Paul, Minnesota.

During the Nickerson-Alborn Phase of the Superior and St. Louis Lobes meltwater flowed to the south through the Kettle and St. Croix River drainages into the Upper Mississippi River. As the Superior Lobe retreated Glacial Lake Duluth was formed in the western end of the Lake Superior Basin. The St. Croix River carried Lake Duluth water into the Mississippi River during this period as well. Wright (1973) places the minimal date of the St. Louis Sublobe to be about 12,000 BP based on radiocarbon dates. Clayton and Moran (1982) and Mooers et al. (unpublished) date this event at ca. 11,700 BP.

The final drainage of Glacial Lakes Agassiz and Duluth left the Mississippi River grossly underfit. Tributaries that were also filled with glacial outwash during the late glacial period were now actively incising into the sand and gravel terraces transporting their sediment load into the Mississippi Valley. The underfit Mississippi River was unable to transport the additional sediment resulting in the formation of alluvial dams.
The sediment load supplied by larger tributaries, such as the Chippewa River, aggraded rapidly and lakes were ponded upstream of the sediment dams. Zumberge (1952) classifies these lakes as master streams dammed by tributaries. It has been suggested that Lake Pepin, dammed by the Chippewa River, extended as far upstream as St. Paul, Minnesota and has subsequently been infilled to its present position (Zumberge, 1952). This scenario has never been confirmed with a continuous stratigraphic cross section and core information and other large tributaries, such as the Cannon and Trimble Rivers may have also played an important role in the Holocene geomorphic evolution of the Mississippi River valley.

**Holocene Vegetational History**

Based on stratigraphy, radiocarbon dating, and pollen analysis, a general trend of climatic and vegetational shift in the midwest has been established. Beyond the Wisconsinan ice margin these relations are difficult to interpret because the source of this data, lakes and bogs, are virtually absent (Chumbley, et al., 1990). The major post glacial landform changes in the Upper Mississippi River valley were weathering and erosion, influenced by climate (Mc Dowell, 1983). Vegetation directly after ice retreat was likely a tundra, based on pollen assemblages dated to about 13,300 BP (Wright, 1976). As the ice retreated and stagnant ice melted, the climate began to gradually warm, with a decrease in precipitation. Vegetation began to reestablish the region, likely through large valleys, which served as migration corridors during glacial-interglacial periods (Baker, et al., 1993). A general warming and drying trend occurred in the early Holocene (8000-5500 BP), with a maximum xeric condition at about 7800 BP to 5700 BP, followed by a marked increase in precipitation from 5500 BP to 5000 BP. Several investigators have interpreted this climatic evolution, but also noted local variations (Mc Dowell, 1983).

In the study area, a vegetational history based on pollen assemblage has been determined that chronicles the vegetational changes in the Holocene. From about 13,270 BP, a spruce (Picea) parkland existed, that closed into a forest by about 12,050 BP. Within this forest, ash (Fraxinus), tamarack (Larix) and other thermophilous were also present.

From 12,050 BP to 10,230 BP, ash (Fraxinus) and ragweed (Ambrosia) began to decline as sage (Artemisia) and birch (Betula) increased. As climatic conditions changed to warmer conditions, the thermophilous plants declined, giving way to a spruce (Picea) forest (Watts and Winter, 1966).

By approximately 10,230 BP, considered the beginning of the postglacial period, rapid vegetation changes occurred (Wright et al., 1963) Spruce (Picea) forest was replaced by Betula (Birch) and alder (Alnus), followed by pine (Pinus), ash (Fraxinus)
and fir (Abies) forest. Elm (Ulmus), Oak (Quercus), and other hardwoods became more dominant toward the end of this trend around 9300 BP (Watts and Winter, 1966).

According to Wright et al. (1963), a time of drying occurred between 9300 BP and 7100 BP which is marked by a change in forest variety. The mixed forest was replaced by a deciduous counterpart. New dominant species were the elm (Ulmus) and oak (Quercus) with other species such as ironwood (Ostrya), hornbeam (Carpinus), basswood (Tilia americana) and maple (Acer). Herbaceous plant populations were also increasing (Wright et al., 1963).

With the change to a warmer, dryer climate, vegetation responded accordingly. The boundary of the Prairie Peninsula began to shift to the northeast about 120 kilometers in western Minnesota (Wright, 1969). The mid-Holocene drying period lasted approximately 4000 years from ca. 8000-4000 years ago, reaching a maximum around 7000 BP (Wright, 1971; Webb and Bryson, 1972). The Prairie Peninsula reached its maximum eastern migration during this phase (Bernabo, 1977).

From 7100 to 5100 BP the Prairie Peninsula migrated into the study area. Oak (Quercus) forests were being replaced by prairie and oak (Quercus) savanna (Watts and Winter, 1966). Sage (Artemisia), ragweed (Ambrosia), chenopods (Chenopodiaceae/Amaranthaceae), and grasses (Gramineae) were some of the members of the advancing prairie landscape (Wright et al., 1963). Several droughts are believed to have occurred based on fluctuations of chenopods (Chenopodiaceae/Amaranthaceae), and ragweed (Ambrosia) populations during this period (Watts and Winter, 1966).

A mesic oak (Quercus) forest returned to the area around 5100 BP marking the change to a cooler, wetter climate (Watts and Winter, 1966; Wright et al., 1963). Other species to appear during this time were elm (Ulmus), ironwood (Ostrya), hornbeam (Carpinus), ash (Fraxinus), basswood (Tilia americana), Hickory (Carya), and Walnut (Juglans). Though forests were advancing during this period, isolated patches of prairie were still present in Dakota County (Heinselman, 1974).

The vegetation of the study area remained relatively stable since the establishment of the oak (Quercus) forest, until about 200 years ago. Land clearance by European settlers has altered the vegetation patterns throughout North America. Forest/prairie coverage was largely replaced by agriculture and other anthropogenic changes within the drainage basins tributary to the Mississippi River Valley. This has resulted in an increase in flood frequency and magnitude, and sedimentation which has altered channel depth and width (Knox, 1977). Soil conservation projects, beginning in the late 1920's, have resulted in a decrease of sediment contributions to the Mississippi River. The Lock and Dam projects by the Army Corp of Engineers has been a major control on the style and rate of
sedimentation to the upper Mississippi River.

While the vegetation was undergoing adaptation to the post glacial climate, physical changes were also occurring on the landscape. At about 9300 BP, Glacial River Warren was diverted to the northeast, effectively ending the contributions of meltwater from Glacial Lake Agassiz. Eyster-Smith (1977), reports a date of 9500 BP as the change in drainage of Glacial River Warren based on radiocarbon dating and pollen assemblages. The Mississippi River was left grossly underfit and was unable to accommodate the sediment load of the major tributaries degrading sediment into the valley. The major tributary furnishing sediment to the valley was the Chippewa River, near Pepin, Wisconsin, which produced an alluvial fan that dammed water up to about St. Paul, Minnesota, creating Lake Pepin. The original lake was approximately 120 kilometers long (Zumberge, 1952).

The Mississippi formed a delta at the head of the lake which has advanced downstream filling in the lake to its present position near Bay City, Wisconsin. As the delta progressed down stream it dammed the mouth of the St. Croix River creating Lake St. Croix, which is filling in from its headwaters in a similar fashion to that of Lake Pepin. Investigations by Mrachek (1994) have indicated that the Cannon and Trimble Rivers, near Redwing, Minnesota, may have created ponds or lakes behind their deltas in the Mississippi River approximately 6500 BP.

Methods

The process-response geomorphic model of the area was produced from topographic map interpretation, core compilation, development of valley and tributary lithologic cross-sectional profiles, grain size analysis, radiocarbon dating, sedimentation modeling, and terrace elevation projections. A series of diagrams reflecting the evolution of the late glacial and Holocene morphology of the Red Wing locality were then compiled. From the data gathered, potential archaeological sites can then be designated using the geomorphic information compiled.

Lab Methods

*Base Map and Units*

Using 1:24,000 and 1:72,000 scale aerial photographs (USDA 1991, 1968) of the area with a 4 X stereoscope, landform features and terraces were identified in the Mississippi valley and tributaries. Within the Mississippi River Valley proper, infilling features, backwaters, beaches, and deltas were also delineated. These data were transferred to mylar overlays of 1: 24,000 topographic maps (USGS, 1972), and then digitized using AutoCAD™ software. Areas for subsurface stratigraphic analysis were selected based on geomorphic features identified on these maps.
According to Dobbs and Mooers, (1991), geomorphic units that have been subject to vertical accretion during the time of human occupation will provide the best opportunity for recording human activities. Therefore, units that have been continually reworked over the period of human occupation are less likely to contain artifacts \textit{in situ}. Geomorphic units were chosen that would reflect the relationship between landform evolution and human occupation. Specific units include:

\textbf{Upland Areas-U}

The upland areas are those above and separating the steep-sided tributary valleys, and surrounding Mississippi Valley. The upland areas are generally the same elevation and are characterized by relatively flat terrain. Much of the surficial geology is pre-Wisconsinan till. Several exposures of limestone and sandstone bedrock have been recorded throughout the area. Agriculture is the primary landuse.

\textbf{Slope-S}

Areas of extreme, steep elevational changes in the tributary and Mississippi River Valley are recorded as slope. The average relief of the valley floor to the upland is approximately 60 meters. The valley walls are composed of limestone and sandstone. Colluvium derived from the bedrock valley walls and sediment carried from the upland areas are deposited along the valley floor.

\textbf{Floodplain-Flp}

The tributary floodplains vary in length and width, but are similar in the variety of landforms they contain. Landforms within the floodplain include intermittent streams, inactive channels, alluvial fans from tributaries and the main channel. Much of the active main channel bed is gravel armoured.

\textbf{Alluvial Fan/Delta}

The formation of an alluvial fan or delta is due to the reduction of river velocity as the flow enters a body of standing water (Ritter, 1986). Several deltas have formed at the mouths of tributaries to the Mississippi River, reflecting the inability of the Mississippi to accommodate the sediment contribution. Many of these deltas, primarily the Cannon and Trimble, control the direction of flow of the Mississippi. Larger deltas, such as the Cannon and Trimble, contain backwaters, ponds and meander scrolls.

\textbf{Terrace}

Terraces are landforms that mark former base levels of a river or stream. The terraces of the Upper Mississippi are a product of sediment-rich glacial meltwater, and composed of glacial outwash. They are likely graded to the former glacial icemargins. Several terraces are present in the study area at various elevations.
Core Interpretation

A compilation of existing core information was undertaken. Several sources of subsurface stratigraphy were used including the United States Army Corps of Engineers, the Minnesota and Wisconsin Departments of Transportation, and a M.S. thesis (Eyster-Smith, 1977). The core data collected from the various sources were compiled into two geological cross sections based on the three lithological generalizations. Because of the variety of original purposes for which these cores were obtained they were often difficult to interpret geologically. A method of stratigraphic correlation was needed, and 2 additional cores were taken and are discussed below in the section on field methods.

Terrace Correlation and Tributary Profiles

From the 1:24,000 U.S.G.S. topographic maps, a total of five cross-sections were drawn across the Mississippi River from Inver Grove to Red Wing, Minnesota, a distance of approximately 45 kilometers (Fig. 5). The cross-sections were used to determine and elucidate the number of terraces and their respective elevations above sea level as well as identify and correlate phases of infilling and downcutting to glacial advance and retreat.

Using the 1:100,000 scale surficial geologic maps of Dakota and Washington Counties, Minnesota, (Hobbs, et al., 1990; Meyer, et al., 1990) and information gathered in the field and literature, two distinctive outwash plains were identified. Using the 1:100,000 scale geomorphic base map (Fig. 6), an approximate thalweg line was drawn down the Mississippi Valley from St. Paul to Red Wing, Minnesota. From the thalweg base line, a terrace correlation diagram was constructed, indicating location, elevation and continuity from each valley side. The terrace correlation diagram provides data that identifies base-level changes that would have been influential to the gradients of the tributaries. Because tributary response differs with length and grade, tributaries were assigned to specific size categories based on length. The criteria is presented as follows:

- Small- <10km
- Medium- 10 to 25km
- Large- >25km

Outwash identified with the Superior Lobe is plotted in red, while Grantsburg Sublobe outwash is plotted in blue. The approximate slope for the Superior Lobe outwash plain was calculated using a simple rise-run relationship, and extrapolated downstream. The slope of the Grantsburg Sublobe outwash has been documented to the south of the study area (Flock, 1982), and a base-level was correlated accordingly.

Field Methods

Sampling

Approximately 40 sites were selected from the base map to be investigated in the
general study area. These sites consisted of road cuts, gravel pits, and construction sites. At each site measurements of bed thickness and sedimentary structure were recorded. Samples were collected and categorized by grain size, color, sorting, and organic content if necessary.

Coring

Two sediment cores were taken to use as stratigraphic standardization. Drill sites were located to provide a transverse stratigraphic sequence of valley alluvium at the Trimbelle/Cannon River delta. A 13.7 m core obtained with a Gidding’s truck-mounted soil auger. An auger 10 cm in diameter and 1.22 meter long auger was used. The core was described, and samples were collected from each stratigraphic unit. Samples were stored in plastic bags for further analysis.

A 32m core was obtained with a Rotosonic drill rig. The continuous core was described qualitatively in the field and described in detail in the lab. The 32m core provided the most accurate stratigraphic control.

Qualitative descriptions included color and percent of organic matter when appropriate. Sediment type was determined through interpretation of sedimentary assemblages and categorized into three lithologic units: alluvium (Cannon, Trimbelle, and Mississippi Rivers), lacustrine (Lake Pepin), and glacial gravels. Alluvium consisted of silt and fine to coarse sand; lacustrine sediments were defined as silty clay, clay, and gyttja with an abundance of organic matter; and glacial gravels consisted of coarse sands to gravels with abundant glacial erratics. Core data obtained from the U.S Army Corps of Engineers, the Minnesota and Wisconsin Departments of Transportation, and other studies were assigned a lithologic unit based on available sediment descriptions and personal interpretation. The environment of deposition was indicated based on sediment type and organic content.

Sediment Analysis and Composition

The lithologies of the sand and gravel that comprise the glacial outwash were determined by point counting under a petrographic microscope and by simple hand-specimen identification. Two methods were chosen because of the various outwash sources. Superior Lobe outwash contains high percentages of quartz sand. Since there is little lithologic diversity in this size fraction few inferences can be made on sediment origin. Therefore lithologic identification of pebbles after separating the quartz smaller than -1ø (2mm) through sieving provides greater lithologic diversity and serves as a tool for the determination of provenance.

Samples were prepared for point counting using the following procedure:

1) Samples were placed in 200ml Erlenmeyer flasks and left to dry on a hot plate
for approximately 4-6 hours.

2) A mixture of Buehler® epoxide was prepared per instructions and each sample mixed individually at a 1:1 ratio in a paper cup. The sample was then poured into a well-marked container with separate compartments (an ice cube tray works well for this). Left at room temperature, these grain mounts will cure in about 6 hours.

3) After removal from the containers, the grain mounts can be cut and prepared as thin sections, mounted with any standard epoxy. However, for better results, it is best not to use thermally activated epoxies as they tend to soften the sample, creating air bubbles in the process.

Each slide was described in detail, including lithology, grain-size, and alteration. Using a standard scope-mounted Zeiss® point counter, 300 counts were made per slide. Lithologic categories were selected that represent bedrock regions overrun during glacial advance. Grain size analysis involved the standard sieving procedure to separate sediment according to size. Grain size frequency plots were made of the data using the Cricket Grapher III® statistics program.

The orientation of sedimentary structures were also measured in the field. Rose diagrams were then constructed to provide a method of comparison of flow directions.

*Radiocarbon Dating*

Wood collected at a depth of 13.7m in the short core and at depths of 11.12 m and 19 m in the Rotosonic core were dated by the radiocarbon dating method. Because of the small mass of the samples the Accelerator Mass Spectrometry method of dating was used. Information from previous studies which have dated the age of the glacial gravel-alluvium boundary in the region was also collected.

The radiocarbon date from the short core, along with an age at the modern surface, were used to develop three sedimentation models in an effort to estimate the rate of valley infilling; a linear model, a power law model, and a third order polynomial model. In order to develop the third order polynomial fit a fourth point was required. A fictitious dat at a depth of 45.72m was assumed to be 10,000 years old. This depth and age was chosen by projecting the curve beyond the known data points. This assumption is valid because slight variations in the location of the fourth point will not significantly influence the curve through the known data points.

**Results**

*Terrace Correlation*

A series of five cross sections from USGS 1:24,000 topographic maps (St. Paul Park, Hastings, Diamond Bluff West and Redwing Quads) were drawn to identify terraces in
the study area from Inver Grove to Red Wing, Minnesota (Fig.7). The Upper Mississippi River Valley is characterized by steep valley walls, approximately 100 meters from the valley floor to the uplands. From the cross sections, terraces at the 285, 280, 260, 245, 240 and 220 meter elevations above sea level were recorded along the Mississippi River Valley. Elevations of terrace segments were plotted on a longitudinal profile of the Mississippi River system. Terrace segments that could be correlated with one another were then connected to determine the slope of the former glacial outwash systems (Fig 8).

**Descriptions of Tributaries**

After identifying and correlating the terraces within the Mississippi River Valley, longitudinal profiles of the tributaries were produced. Construction of longitudinal profiles aids in the identification of nick points that may represent adjustments of the tributaries to base level changes (Figure9). In addition, remnants of glacial terraces occupying portions of the tributary valleys were identified.

<table>
<thead>
<tr>
<th>Tributary</th>
<th>Length (km)</th>
<th>Gradient (m/km)</th>
<th>Terrace elevations (m)</th>
<th>Nick points from profile (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rush River</td>
<td>53.0 km</td>
<td>2.7 m/km</td>
<td>275, 270, 263, 255, 245, 240</td>
<td></td>
</tr>
<tr>
<td>Cannon River</td>
<td>40.0 km</td>
<td>1.1 m/km</td>
<td>250, 245, 238, 224, 220</td>
<td></td>
</tr>
<tr>
<td>Trimble River</td>
<td>30.0 km</td>
<td>5.8 m/km</td>
<td>255, 250, 245</td>
<td></td>
</tr>
<tr>
<td>Isabelle Creek</td>
<td>20.0 km</td>
<td>7.3 m/km</td>
<td>250, 245, 238</td>
<td></td>
</tr>
<tr>
<td>Big River</td>
<td>15.0 km</td>
<td>7.3 m/km</td>
<td>238</td>
<td></td>
</tr>
<tr>
<td>Wind River</td>
<td>12.0 km</td>
<td>10.0 m/km</td>
<td>245, 238</td>
<td></td>
</tr>
<tr>
<td>Hope Coulee</td>
<td>7.0 km</td>
<td>14.3 m/km</td>
<td>245, 238, 224</td>
<td></td>
</tr>
<tr>
<td>Dry Run Coulee</td>
<td>5.0 km</td>
<td>15.8 m/km</td>
<td>238</td>
<td></td>
</tr>
<tr>
<td>Morgan Coulee</td>
<td>4.0 km</td>
<td>24.0 m/km</td>
<td>222</td>
<td></td>
</tr>
</tbody>
</table>

Cannon, Trimble River and Rush rivers (>25km);

The Cannon, Trimble (Fig. 10) and Rush rivers are drainages that have a linear distance greater than 25km. The Trimble and Rush rivers, Pierce County, Wisconsin, have a north-south orientation, while the Cannon river runs generally east to west. Each drainage is highly integrated. The bedrock valley walls are steep with an average relief of 145 meters. Depth to bedrock from the floodplain of the tributaries is greater than 30 meters in some areas. Watershed areas are between 50,000 and 100,000 acres. Soil and water retaining dikes have been constructed along streams tributary to these rivers in an
effort to retard soil loss and keep sediment contributions to the Mississippi at a minimum. Each river has constructed a distinct and sizeable lobate delta into the Mississippi River (Ritter, 1986).

The Cannon river grade has been altered by the construction of a dam at Cannon Falls, Minnesota, creating Lake Byllsbey. Within the Cannon river, several sediment samples and structural measurements were taken from exposures along terraces. Compositionally, the sediment is gray and highly calcareous, reflecting its source from the Des Moines Lobe and Grantsburg Sublobe. Much of the outwash is course-grained and well rounded through most of the channel. At approximately the 238 meter elevation near the mouth of the Cannon and its tributaries, a dark gray thinly laminated (approx. 1cm) sequence of silt and clay were observed. Overlying this assemblage is a veneer of course grained outwash less than 1 meter in thickness. Structural evidence indicates that flow direction of the course grained outwash was to the east. Much of the structure consisted of cross bedding with intricate cut and fill structures. The silt/clay layers are horizontal.

The confluence of the Trimbelle and Mississippi was altered by the Army Corp of Engineers in an effort to minimize sedimentation behind Lock and Dam #3. The original drainage was controlled by terrace remnants at the 220 meter elevation. The Trimbelle and Rush rivers have terrace exposures at various elevations in their reaches. The sediment at both locations is similar in composition and grain size. Grain size is primarily fine to very fine grained sand. Structural data indicates a southerly flow direction throughout the terrace exposures to an elevation of approximately 244 meters. Here again, much of the structure consisted of cross bedding with intricate cut and fill structures. The terraces near the mouths of the Trimbelle and Rush are composed of outwash derived from the Superior Lobe at an elevation of approximately 245 meters and lower.

The floodplain of the Trimbelle River contains several alluvial fans deposited by intermittent streams tributary to the Trimbelle. Inactive channels and meanders exist throughout the floodplain, particularly at the confluence of these tributaries to the main river. Soil boring in the floodplain revealed approximately 1 meter of locally derived sediment atop glacial outwash. The main channel is armoured by gravel and cobbles, and is characterised by bars, riffles and meanders. Based on oral communication with landowners, a potential archaeological site was recorded near the mouth of the Trimbelle River

Big and Wind Rivers and Isabelle Creek (10-25km)

The Big (Fig.11) and Wind River as well as Isabelle Creek are drainages that have a
linear distance between 10 and 25km, representing the medium sized tributaries. These tributaries are located in Pierce County, Wisconsin and have relief similar to those of the larger tributaries previously mentioned. Watersheds average around 12,000 acres for these particularly well integrated drainages. Several terrace remnants are recorded, however, no exposures were located and access to the terraces was difficult due to lack of roads and dense vegetation.

The floodplain of the Big River (Figure 11) contains several alluvial fans deposited by intermittent streams tributary to the Big River. Much of the floodplain was forested, covering much of the landform features. The channel was armoured with gravel and cobbles and contained bars and riffles. According to topographic data, much of the flow of the Big River is ephemeral.

Dry Run, Hope and Morgan Coulees (<10km)

The Dry Run, Hope (Figure 12) and Morgan Coulees are drainages with a linear distance of less than 10km, representing the smaller tributaries. These coulees are located in Pierce County, Wisconsin, and have an orientation similar to the other drainages in the county. Average relief is similar to those of the other tributaries in the area. Watersheds average approximately 2000 acres. Similar soil conservation measures have been taken along the uplands of the tributaries to the coulees. Though terraces are recorded, exposures were not located and lack of accessibility denied any truck-mounted soil boring attempts.

The Hope Coulee floodplain is characterized by dense forest, obscuring much of the landscape. From air photos, alluvial fans are the dominant landform present on the floodplain. The coulee is ephemeral, and drains into the Mississippi River through the former Trimble channel.

Core Interpretation

Locations of the U.S. Corps of Engineers cores and the 13.7m and 32m cores are indicated (Figure 13). The two lithologic cross sections were used to interpret the activity in the Mississippi River valley. Consistent with Zumberge (1952), the longitudinal cross section reveals lake sediment extending from the Chippewa River delta to St. Paul, MN directly overlaying glacial gravels (Figure 14). Alluvium overlies the lacustrine sediment from St. Paul, MN to the present head of Lake Pepin as a result of the subsequent progradation of the Mississippi River delta and the infilling of the river throughout the Holocene. At the Cannon River confluence there is a wedge of alluvium interbedded with the lake sediments. The transverse cross section located near the Cannon River delta (Fig. 13) also shows the wedge of alluvium interbedded with the lake sediments. This cross section included the 13.7m core (short core), core #93-24M from the Corps of
Engineers, and the 32m Rotosonic core, which provided the best control. The stratigraphy of the 32m core is broken into five lithological units. Glacial gravels, containing very coarse sand and gravel (clasts up to 10cm in diameter) are overlain by lacustrine sediments interpreted to be deposited in the initial lake that existed immediately after the final drainage of Glacial Lakes Agassiz and Duluth (Figs. 14, 15). A sequence of 7.5m of stream alluvium overlays the lacustrine sediments. It has been interpreted that the source of these sediments is the Cannon River. Lacustrine sediments overlay the alluvium for a depth of 3.3m until Mississippi River alluvium from the infilling of the river is identified at the top of the core. The Corps of Engineers core also contains two lacustrine sequences separated by alluvium. The lacustrine and alluvial sequences are thinner than those found in the 32m core and it is believed that these two lacustrine sequences are the result of the same events. This sequence of events are not found in the 13.7m core; the core may not have penetrated deeply enough to intersect these lacustrine sediments.

**Radiocarbon Dating**

The results of the AMS radiocarbon date from the wood collected at 13.4m gave a date of 6680 +/- 60 BP. The two AMS radiocarbon dates from the 32m are still pending. Previous work has radiocarbon dated the final retreat of Glacial Lakes Agassiz and Duluth at 9400 BP.

The radiocarbon dates and a modern date at the surface were used to develop three sedimentation models (Fig. 16). The linear model corresponds to a constant rate of infilling throughout the Holocene. The power law model and the third order polynomial model indicate rapid infilling initially and a decrease in the rate of infilling throughout the Holocene. We consider either the power law or the third order polynomial model to be most accurate because they best honor the data control points.

**Grain Size Analysis Results**

The 13.7m core was analyzed for grain size based on Folk (1974). These results are utilized to interpret the environment of deposition in the Cannon River delta. The results are found in Appendix I.

**Discussion**

**Late Glacial Environments**

Periglacial environments have been heavily investigated for almost a century (Lozinski, 1912). Therefore a fairly accurate model of such environments exist for comparison. Since approximately 16,000 BP, much of the study area has been unglaciated, but was heavily influenced by the arctic climate imposed upon it by the Wisconsinan Stage ice sheets (Fig. 17). Overall average temperature, available moisture,
and sea levels were far lower than modern measurements. Precipitation and fluvial
discharge would have been concordant with seasonal warming trends. Eolian processes,
permafrost, and frost-related activities dominated much of the periglacial landscape.
Vegetation was likely sparse and similar to the present Arctic tundra.

*Tributary Response to Wisconsinan Stage Glaciation*

Rivers and streams continually adjust to changes in slope, discharge, and sediment
supply (Mackin, 1948). Glacial advance and retreat as well as the accompanying climatic
changes in the study area provided causal mechanisms that streams and rivers
accommodated, chronicled by a sedimentary record of the events.

During the Itasca/St. Croix/Chippewa phase (Figure 3), the Mississippi River Valley
was host to outwash derived from the Superior Lobe in the study area and the Chippewa
Lobe just south of it. The main valley was aggraded to approximately the 274 meter
elevation, and likely had a braided stream architecture with disparate seasonal discharges.
The braided nature of the channel would have produced topographic high and low spots
that could have intermittently dammed tributaries.

As the valley filled with glacial gravels from the combined Itasca/St. Croix/Chippewa
phase, tributaries were backfilled by Superior Lobe outwash. However, the degree of
transport of sediment up the tributaries varied with tributary size. Larger tributaries filled
their valleys with sediment derived from their own water sheds, and glacial gravels were
likely confined to the extreme lower portions of the tributaries. Medium-sized rivers that
carried less sediment would have allowed glacial outwash to infill farther upstream, and
many of these may have had lakes temporarily dammed in their lower reaches. Small
tributaries and coulees would have been filled almost entirely. Sediment loads of the
tributaries may have been considerably greater during the late glacial because of
increased land instability associated with periglacial processes.

After the retreat of the Superior/Rainy and Chippewa Lobes, meltwater derived from
retreating and stagnant ice downcut the existing valley train of the Mississippi River
Valley. The large, and possibly medium-sized tributaries, accommodated the changing
base-level by incising at various rates. Small tributaries and coulees were generally
unable to downcut. At this point remnants of the early glacial outwash terraces were left
stranded within the tributary valleys. Some of these remnants are present today and
represent roughly 12,000 years old surfaces. In many cases, relatively little
sedimentation has occurred on them.

The Grantsburg Sublobe of the Des Moines Lobe (Figure 4) advanced into the Twin
Cities area and the outwash within the Mississippi Valley aggraded to an elevation of
about 250 meters, 25 meters lower than during the previous glacial phase. Aside from the
Mississippi River Valley, the Cannon and Vermillion Rivers were also principle conduits of the Grantsburg Sublobe outwash.

In Pierce county, the larger and medium sized tributaries were able to again accommodate the change in Mississippi base-level based on structural data from exposures along the terraces. As the valley once again filled with glacial gravels from the Grantsburg Sublobe, tributaries were backfilled by outwash. Larger tributaries once again likely filled their valleys with sediment derived from their own water sheds, and glacial gravels were likely confined to the extreme lower portions of the tributaries. Medium-sized rivers that carried less sediment would have allowed glacial outwash to infill farther upstream and form new terrace remnants were formed at slightly lower elevations than during the previous glacial advance. Small tributaries and coulees may not have been affected by the lower stage of terrace formation because they were still full of sediment from the previous events and there may have been no place to deposit younger sediment.

As the Grantsburg Sublobe retreated, downcutting of the Mississippi Valley occurred from discharge of Glacial Lake Grantsburg and meltwater of the retreating ice. This is likely the origin of terraces excavated just below the 250 meter elevation in the Mississippi and of the larger tributaries.

As the Des Moines ice retreated further, an eastern outlet to Glacial Lake Agassiz opened, with its confluence near Fort Snelling, Minnesota. Because of the nature of the excessive catastrophic discharge, extreme excavation of the Mississippi Valley took place within the study area, erasing most of the Grantsburg Outwash terraces except around the mouths of tributaries.

_Holocene Environment and Landscape Response of the Red Wing Locality_

A detailed Holocene geomorphic evolution of the Red Wing Locality can be described based on previous work, sedimentological cross sections, sedimentation models, and terrace correlation. Correlation's to the 13.7 m and the 32 m drill cores are noted for the discussion of each stage of geomorphic evolution.

Figure 18 illustrates a late Wisconsin glacial period when the Mississippi River channel was filled with glacial outwash. Numerous sand and gravel bars existed in the braided stream system. The remnants of these sand and gravel bars are the glacial outwash terraces found along the Mississippi River valley banks today. The highest of these terraces 243 meters is seen at the Cannon and Mississippi River confluence (Dobbs and Mooers, 1991). This terrace was most likely active during the Pine City Phase of the Late Wisconsin glaciation. The advance of the Des Moines Lobe downcut the pre-existing outwash terraces and activated terrace development at a lower level (Dobbs and
Mooers, 1991). Tributaries were graded to the level of the Mississippi River channel. According to Sardeson, (1933), outwash may have dammed some of the tributaries resulting in ponded stream channels.

Figure 19 represents a post glacial period after Glacial River Warren had dissected the valley with discharge from Glacial Lakes Agassiz and Duluth. After the final drainage of the glacial lakes the Mississippi River was grossly underfit. The Chippewa River adjusted its steep slope in response to the new low elevation of the Mississippi River channel by erosion of the valley fill and deposition of the sediment into the Mississippi River channel. The Chippewa River delta probably aggraded rapidly, as predicted by the sedimentation models, resulting in the formation of an alluvial dam that ponded a lake as far upstream as the present location of St. Paul, Minnesota. This event correlates with the first and lowest lacustrine sequence found directly above the glacial gravels in the 32m core and in the cross sections and supports Zumbelege's theory of Lake Pepin development immediately after the final drainage of the glacial lakes.

The progradation of the Cannon River delta into the valley is depicted in Figure 20. At this time the rate at which the Cannon River delta aggraded was consistent with or more rapid than the aggradation of the Chippewa River delta which had been slowing through time as indicated in the sedimentation model. The reduced rate of sedimentation of the Chippewa River delta enabled the Cannon River delta to build its own alluvial dam which resulted in the pinching off of the already present lake or the ponding of another lake entirely. This assemblage correlates to the wedge of alluvium found in the 32 m core and core #93-24M from the U.S Army Corps of Engineers and in the cross section at the mouth of the Cannon River. The Mississippi River was infilling the upper part of the river.

It is possible that fluctuations in lake levels in the Red Wing Locality are the direct response to climatic changes. Several studies have confined a climatic change to the Middle Holocene based on pollen studies in streams of southwest Wisconsin and east central Iowa. The level of Lake Pepin at this time is unknown as it was controlled by the aggradation of the Chippewa River delta (Dobbs and Mooers, 1991).

The effect of the Middle Holocene warm and dry period is indicated by vegetation changes determined from the pollen record. A period of relative increase in temperature has been recorded during the Middle Holocene in works by Knox (1983) and others through use of pollen analysis. The boundary of the Prairie Peninsula began to shift to the northeast about 120 kilometers in western Minnesota (Wright, 1968). The mid-Holocene drying period lasted approximately 4000 years, from ca. 8000-4000 years ago, reaching a maximum around 7000 BP (Webb and Bryson, 1972; Wright, 1971). The
Prairie Peninsula reached its maximum eastern migration during this phase (Bernabo and Webb, 1977).

From 7100 to 5100 BP the Prairie Peninsula migrated into the study area. Oak (Quercus) forests were being replaced by prairie and oak (Quercus) savanna (Watts and Winter, 1966). Sage (Artemisia), ragweed (Ambrosia),chenopods (Chenopodiaceae/Amaranthaceae), and grasses (Graminaceae) were some of the members of the advancing prairie landscape (Wright et al., 1963). Several droughts are believed to have occurred based on fluctuations of chenopods (Chenopodiaceae/Amaranthaceae), and ragweed (Ambrosia) populations during this period (Watts and Winter, 1966). A mesic oak (Quercus) forest returned to the area around 5100 BP marking the change to a cooler, wetter climate (Watts and Winter, 1966; Wright et al., 1963). Other species to appear during this time were elm (Ulmus), ironwood (Ostrya), hornbeam (Carpinus), ash (Fraxinus), basswood (Tilia americana), Hickory (Carya), and Walnut (Juglans). During times of forest cover (cooler climates) there was net erosion in the valley. The increased temperature in the Middle Holocene resulted in a dominant prairie vegetation which corresponds to net aggradation in the valley (Van Nest and Bettis, 1988). The radiocarbon date of 6780 +/- 60 BP at a depth of 13.4 m in the Cannon River delta correlates with this period of net sedimentation in the Buchanan Drainage basin. Therefore, the rapid aggradation of the Cannon River delta may be attributed to the warmer climate during the hypsithermal period of the Middle Holocene.

During the Middle Holocene some time after 6780 +/- 60 BP the Chippewa River delta once again aggraded more rapidly than the Cannon River delta enabling it to flood the Cannon River delta. The lacustrine sediments that were deposited during this lake stage correlates with the second and highest lake sediment sequence shown in the cross sections at the mouth of the Cannon River.

The increased aggradation rate of the Chippewa River delta may also be in response to regional climatic changes. Van Nest and Bettis (1988) discuss increased aggradation in Buchanan River valley in east central Iowa as a result of decrease in regional temperatures. Knox (1972) suggests that the reduction in rainfall during 7000-6000 BP was slightly less in southwestern Wisconsin than in southeastern Minnesota due to the variable influence of tropical air. Knox (1972) states that a reduction in annual rainfall of 15% in a region dominated by prairie vegetation will enhance the magnitude of large floods. He observed basal coarse gravel dated at 6000 BP overlain by silty clay overlain by recent alluvium. He attributes the gravel to a channel system that was active near the end of the Middle Holocene drought. The silty clay has been interpreted to represent a climatic change from an arid to a more humid climate during the Late Holocene (Knox,
The progradation and flooding of the Cannon River delta may have also been directly influenced by the annual temperature and the type of vegetation present similar to the geoclimatic changes suggested by Van Nest and Bettis and Knox.

Finally, Figure 21 illustrates the landscape during a period approximately 1000 BP at the height of the Mississippian Tradition. The Mississippi River had infilled about 75km from St. Paul, Minnesota to the mouth of the Cannon River (Dobbs and Mooers, 1991). The Cannon River delta had again aggraded rapidly into the valley as it drained much of southeastern Minnesota and its influence on the course of the Mississippi River is still evident today. Sediment transported along the Cannon River was deposited within the Mississippi River valley at this time and forced the course of the Mississippi River to be confined to the Wisconsin side of the floodplain. The Trimbelle River drains a somewhat smaller area of west-central Wisconsin and has a considerably smaller discharge than the Cannon River. The influence of the Trimbelle River on the course of the Mississippi is somewhat less than that of the Cannon River. The influence of the Trimbelle River is not trivial, however, as the course of the Mississippi River has been diverted away from the Wisconsin side of the valley by the deposition of sediment in the floodplain.

The various geomorphic features of the study area have been altered, obliterated and created through various environmental and anthropogenic means. Therefore, the potential for discovery of in situ artifacts is largely dependent on the level of disturbance imposed on the particular geomorphic unit. Geomorphic features produced by continuing dynamic processes such as deltas and alluvial fans may potentially contain artifacts collected and concentrated by the river or stream that created the feature. Each geomorphic unit in this investigation has a specific archaeological potential, described below.

Upland Areas-U

The upland areas have been essential stable since the retreat of glacial ice. Until approximately 300 years ago, major landscape alterations were changes in vegetation and animal migration patterns. European settlers cleared and cultivated much of the land, increasing sediment load to the drainage system and disturbing archaeological sites. In relation to other landscape features, the upland areas experience relatively gradual erosion and slow rates of slope/creep. Recent land use management practices have decreased the amount of upland derived sediment contributions to the drainage system. According to Dobbs and Mooers, (1991), Native American artifacts have been recorded in the upland vicinity of Red Wing, Minnesota. The potential for cultural materials does exist in the uplands. Older material may exist in the sloped areas, transported by slope/creep and
erosion. However, bioturbation through agricultural practices may have obliterated several sites.

Slope-S
The sloped areas have in the past, and continue today to undergo geomorphic change. In relation to other landforms, they are unstable as the rates of slope/creep and erosion are far greater than other locations. Despite the relative instability of this landform, archeological properties exist such as; quarrying for chert nodules from bedrock, caves and rockshelters, petroglyph sites. Older cultural materials may have been carried from upland areas (Dobbs and Mooers, 1991).

Floodplain-Flp
The floodplain of the Mississippi River and its tributaries is constantly being reworked. Changes in the channel morphology such as logs, trees, dams etc. redirect the flow into new channels. Periodic floodwaters further rework the floodplain sediments, and redirecting channel patterns. The potential for cultural materials in situ in the floodplain is likely quite low with the exception of features such as levees and other topographically higher features isolated from the extensive reworking effects of the river.

Alluvial Fan/Delta
The deltas and alluvial fans of the study area have been in existence since approximately the cessation of Glacial River Warren. The development of deltas and fans is in part a function of the change in watershed stability due to climate and land use, and the base level of the body of water in which it is formed. Therefore, the deltas and fans of the Upper Mississippi Valley have undergone excessive morphologic alteration since the initial formation. The channel migration of the Mississippi and its tributaries has reworked the deltas throughout the period of human occupation, possibly disturbing and transporting cultural materials.

The alluvial fans within the tributaries may stabilize the portions of the floodplain they cover, increasing the likelihood of preservation of cultural materials in the underlying floodplain. Deltas contain diverse ecosystems and resources, as well as access to the open waters of the Mississippi and Lake Pepin. Deltas of particular note are the Mississippi River Delta at the head of Lake Pepin, Trimbelle, Cannon, Rush and Big rivers.

This geomorphic assemblage of 1000 BP helps to define the location of human settlement. The head of Lake Pepin was located near the mouths of the Cannon and Trimbelle Rivers. Both sides of the Mississippi River Valley have broad glacial outwash terraces, areas ideally suited for the establishment of villages. The Cannon River delta, the Mississippi River floodplain, and the head of Lake Pepin would have provided
abundant and diverse resources. The Mississippi River has subsequently infilled 8km to
the present head of Lake Pepin.

Terrace

The terraces of the Upper Mississippi River Valley have remained largely unchanged
since their formation, approximately 10,000 years ago. Alluvial fans from ephemeral
coulees and streams, along with colluvium from the upland areas blanket much of the
terrace surface, possibly preserving sites of archeological importance. According to
Dobbs and Mooers, (1991), several prehistoric sites have been recorded along the terrace
surfaces. Terraces provide excellent habitation sites as they are dry protected areas that
give access to the upland areas and the river below as well as security. Areas where
agriculture dominates the terraces, especially for the last 150 years, has disturbed the
upper meter or so of sediment, possibly scattering cultural materials.

Conclusions

During the Late Wisconsinan Stage, the Upper Mississippi River Valley carried
meltwater and outwash of the advancing and retreating glacial ice. The tributaries
responded to the changing base level according to their specific length, discharge, and
sediment flux. During the St. Croix Phase of the Rainy/Superior Lobe (16,000 BP), the
Upper Mississippi River Valley was graded approximately to the 275 meter elevation
near St. Paul Minnesota. The slope of this outwash surface was steeper than surfaces
associated with the younger Grantsburg sublobe advance. In fact this older terrace
apparently dips beneath the younger surfaces well to the north of the Red Wing Locality.
It is very likely that all tributaries were backfilled to some extent, with only the larger
tributaries able to adjust to the higher base level.

During the Pine City Phase of the Grantsburg Sublobe the Upper Mississippi Valley
became graded to approximately the 256 meter level near St. Paul, Minnesota, and the
245 meter elevation in the Red Wing Locality. The drainage mechanics were
significantly different than the previous ice advance in that outwash was delivered to the
Upper Mississippi Valley via several conduits from different directions. The Cannon and
Vermillion Rivers carried large amounts of outwash to the Upper Mississippi Valley.
The smaller tributaries in Pierce County, Wisconsin backfilled with Grantsburg outwash,
however, medium to larger tributaries were probably able to aggrade rapidly enough that
glacial outwash did not dam and subsequently fill the tributary valleys.

The slope of this outwash surface is apparently considerably less than the earlier
phase of Late Wisconsinan glaciation.

Since the retreat of the Late Wisconsinan Stage glaciers and the final drainage of
Glacial Lakes Agassiz and Duluth, the Mississippi River valley has undergone
continuous net accumulation of sediment. The rate of sediment infilling of the Mississippi River valley was rapid initially and has slowed throughout the Holocene. The infilling rate of the Cannon River delta was consistent with the infilling rate of the Chippewa River delta throughout most of the Holocene. One exception to this occurred in the Middle Holocene when the Chippewa River delta aggraded relatively more rapidly than the Cannon River resulting in the flooding of the Cannon River delta.

The geomorphology in the Mississippi River valley in southeastern Minnesota and western Wisconsin has undergone extensive evolution throughout the Holocene. Detailed stratigraphic cross sections and sedimentation models reveal the complex history of the Red Wing Locality.

Several fluvial systems influenced the changing geomorphic assemblage at the Red Wing Locality. It has long been known that the Chippewa River has played an important role in the Holocene evolution of Lake Pepin but the Cannon River has also been greatly influential in the Holocene evolution of the Mississippi River at the Red Wing Locality and the Trimbelle River was important to human settlement in the Mero site on the Wisconsin side of the valley. The position of the head of Lake Pepin is determined by the extent of infilling of the Mississippi River. Fluvial systems responded to glacial activity and climatic changes. Tributaries responded to the fluctuating accumulations and erosional periods of the main Mississippi River channel.

A detailed longitudinal cross section from St. Paul, Minnesota to the Chippewa River delta confirms Zumberge's theory stating that the Chippewa River built an alluvial dam in the Mississippi River channel which allowed for the ponding of Lake Pepin. This cross section indicates a wedge of alluvium completely contained within lacustrine sediments near the Cannon River and Mississippi River junction. The detailed transverse cross section of the Mississippi River valley near the Cannon River confluence reveals a complex series of fluvial and lacustrine events. The wedge of alluvium is the result of the Cannon River delta prograding into the Mississippi River valley after an initial period of lacustrine sedimentation. Another sequence of overlaying lacustrine sediments indicates the existence of another lake. Alluvial processes again resulted in the Cannon River delta prograding into the main valley. The Holocene evolution of the Mississippi River and Lake Pepin in southeastern Minnesota and western Wisconsin must be revised to include the influence of the Cannon River.

Complex glacial and Holocene geomorphic processes in the Red Wing Locality eventually establish the terrain much as it appears today. Beginning about 1000 BP, members of the Mississippian Tradition began to inhabit the region. The geomorphic assemblage at this time consisted of the Mississippi River delta defining the head of Lake
Pepin near the mouth of the Cannon and Trimbelle Rivers. The Cannon River had prograded far into the Mississippi River valley pinching off the river and controlling the flow of the Mississippi River similar to its present configuration. The communities of Bryan, Silvernale, and Energy Park sites could flourish along the Cannon River floodplain and take advantage of the various resources readily available to them. In Pierce County, Wisconsin, a similar scenario existed in and around the Trimbelle River and Hope Coulee. Furthermore, a prominent glaciofluvial terrace that is currently occupied by Hager City and Bay City, Wisconsin was very likely heavily occupied by Mississippian Tradition denizens.

The Trimbelle River delta is located immediately beneath the Mero bluff, which was the site of a large Mississippian presence between 1050 and 1300 AD. The delta is slightly higher and considerably drier than adjacent areas of the Mississippi River floodplain. This area was probably used extensively for cultivation by Native American peoples (Dobbs 1985; Dobbs and Breakey 1987). Farther toward the active Mississippi River channel the area would have been expected to become wetter and, with a higher content of silt deposited by Mississippi River floods, more poorly drained. It is likely therefore that activities would be concentrated near the Mero bluff and usage would have decreased toward the Mississippi River.

Because of the proximity to the Cannon and Trimbelle Rivers, the Mississippi River, and Lake Pepin, the Red Wing Locality was ideal for human habitation 1000 years B.P. The Mississippi River has subsequently infilled Lake Pepin another 8km to the present head of Lake Pepin.
References


Wright, H. E., Jr., Matsch, C. L. and Cushing, E. J. (1973). The Superior and Des


Figure 2
Figure 3. Rainy, Superior, and Chippewa Lobes advance, St. Croix Phase. (Mooers et. al. 1994)
13,500 B.P.

Figure 4. Pine City Phase and Grantsburg Sublobe advance. (Mooers et. al., 1994).
Figure 7. Topographic cross sections on the Upper Mississippi River Valley.
Figure 9
Profiles of Mississippi River Tributaries.
Geomorphic Map of the Lower Trimble River
Pierce County
Wisconsin

Scale 1:100000

Magnetic Declination=6°

0 2000 Meters

Map Explanation

- Modern Floodplain
U Upland Area
----

- Streams with active channel changes (e.g., braids), terraces, and
  terraces

- City, Town or Village

Terraces are shown in bold.

University of Minnesota
James Johnson
June, 1994

Figure 10
Figure 11.

Geomorphic Map of the Big River
Pierce County
Wisconsin

Scale 1:100,000

Map Explanation

Flp Modern Floodplain
U Upland Area
S Terrain with extreme elevation changes (Shaped)
O Well

Terrace elevations are recorded in feet

University of Minnesota
James Sullivan June, 1994
Geomorphic Map of the Hope Coulee
Pierce County, Wisconsin

Scale 1:100000
Magnetic Declination = 6°

Map Explanation

Fp Modern Floodplain
U Upland Area
S Terrain with extreme elevation changes (Slope)
O Well
City, Town, or Village

Terrace elevations are recorded in feet

University of Minnesota
James Sullivan June, 1994

Figure 12
Figure 13

Longitudinal Cross Section of the Mississippi River Channel
From St. Paul, MN to the Chippewa River Delta
Figure 15

Linear model of age vs. depth in Cannon River Delta

\[ y = 74.468x + 1339.074 \]

Powerlaw model of age vs. depth in Cannon River Delta

\[ y = 1833.809x^{0.344} \]

3rd order polynomial model of age vs. depth in the Cannon River Delta

\[ y = 0.005x^3 - 1.828x^2 + 223.281x - 0.000 \]
<table>
<thead>
<tr>
<th>Approximate Age (ka)</th>
<th>Red River and Des Moines Lobes</th>
<th>Alluvial Activity</th>
<th>Discharge</th>
<th>River Base Level</th>
<th>Sea Level (Meters)</th>
<th>Climate</th>
<th>Superior Lobe</th>
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<td></td>
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<td></td>
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<td>5</td>
<td>Lake Agassiz</td>
<td>Chippewa River Delta forms the upper Mississippi River.</td>
<td>present</td>
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<td>-100</td>
<td>+</td>
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<td>Glacial River Warren</td>
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(Mooers and Kemmis, 1990; Chappell and Shackleton, 1986)

Figure 16 Summary Diagram relating global climatic changes and fluvial response of the Upper Mississippi River
FIGURE 17

LATE GLACIAL

Big R.

Trimble R.

Water level 740 feet

Braided Glacial Outwash system

Sand/Gravel Bars (to be Prairie Island)

Cannon R.

elevation 750'

Spring Cr.

Hay Cr.

0 1 2 3 miles

N
LATE HOLOCENE

Figure 20