Late Quaternary Eolian Dunes and Fluvial Terraces of the Lower Chippewa River Valley

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Introduction

The Lower Chippewa River Valley (LCRV) extends south-southwest ~100 km from Eau Claire, Wisconsin to its confluence with the Mississippi River near Wabasha, Minnesota (Figure 1). The Lower Chippewa River is the second largest tributary to the Mississippi River in Wisconsin and drains a watershed area of 24,600 km2. A sequence of seven paired alluvial terraces were previously mapped throughout the LCRV (Speer et al, 2007). Speer et al (2007) also noted the existence of eolian sand dunes present in close proximity to the Wissota and T-6 Terrace scarps. However, their distribution within the LCRV was unknown.

The Wissota Terrace is the highest and most extensive terrace within the LCRV (Andrews, 1965). The Wissota Terrace tread is thought to represent the braided channel floodplain of an aggrading Chippewa River which served as a meltwater stream during Late-Wisconsinan time (Syverson, 2007). At some point the Chippewa River began to incise into the underlying coarse glacio-fluvial sediment forming a sequence of six lower terraces. T6 through T1 are inset below the Wissota Terrace and suggests a sequence of episodic incision and subsequent peroids of floodplain formation (Speer et al, 2007).

The primary objective of this research was to ground truth the original terrace map created by Speer et al. (2007) and map the spatial distribution of the eolian sand dunes observed throughout the LCRV. The secondary objective was to field test ground penetrating radar (GPR) to determine its effectiveness in describing sedimentary structures in LCRV sediments. The third objective was to assess the utility of optically stimulated luminescence (OSL) in establishing an absolute chronology of terrace formation in the LCRV.

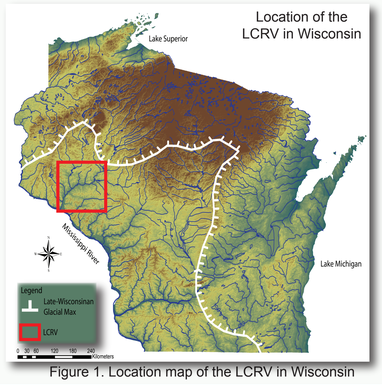


Figure 1. Location map of the LCRV in Wisconsin

Methods

Terrace Mapping

A sequence of seven paired alluvial terraces, previously mapped by Speer et al (2007), were ground truthed and a new terrace map was created using the following methods:

- 30,000+ spatial and elevation data points collected in the field using Trimble Pro XR and XT differentially corrected global positioning systems.
- Interpretation of aerial photographs
- Detailed field observations

The final compilation of terrace data sets was organized in a GIS database. Based on previously established criterion, ArcGIS software was used to digitize and correct the terrace shapefiles (Speer et al. 2007).

Eolian Dune Mapping

Soil Survey Geographic data (SSURGO) was used as an initial method to indentify eolian dunes within the Lower Chippewa River Valley. SSURGO data was downloaded from the Natural Resources Conservation Center website throughSoil Data Mart. SSURGO data was then organized into personal geodatabases in ArcGIS (Figure 2). Using SSURGO data tables the following criteria were used for formatting multiattribute database queries to isolate eolian dunes. Attributes selected are:

Slope: between 2-6%
Soil texture: fine sand, sand
Drainage class: excessively drained, well drained
Soil Taxonomy: psamments, udipsamments

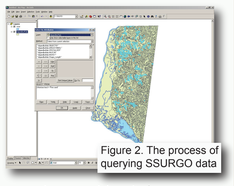


Figure 2. The process of querying SSURGO data

Overall, the most successful database queries combined slope (average four percent), followed by selecting only those polygons with sandy and fine sandy soil texture. In Pepin County data, the Chelsea Soils Series is already mapped as eolian dunes.

Ground Penetrating Radar

PulseEkko 100 and 1000 GPR systems were used at two locations within the LCRV. To verify GPR applicability in LCRV sediments, two field sites were chosen to represent similar forms throughout the LCRV. An eolian dune, the Roy Street Dune Site (Larson et al., this conference), and an alluvial terrace, the DCD gravel pit in Pepin county, were surveyed using both GPR systems.

A single 42 m line was surveyed at the DCD site using 50, 100, 200, 225, 450, and 900 mHz frequency antennae (Figure 3). The ranges of frequencies were used to determine depth of penetration, resolution, and overall quality of the subsurface imagery for LCRV terrace sediments. GPR profiles were topographically corrected using a Topcon RL-HA laser level.

A common midpoint survey was conducted at 50 and 100 mHz frequencies to determine the EM velocity through the sediments. The resulting velocity was calculated at 0.14 m/ns.

Figure 3. Conducting GPR survey at DCD site

Results: LCRV Terraces and Eolian Dunes

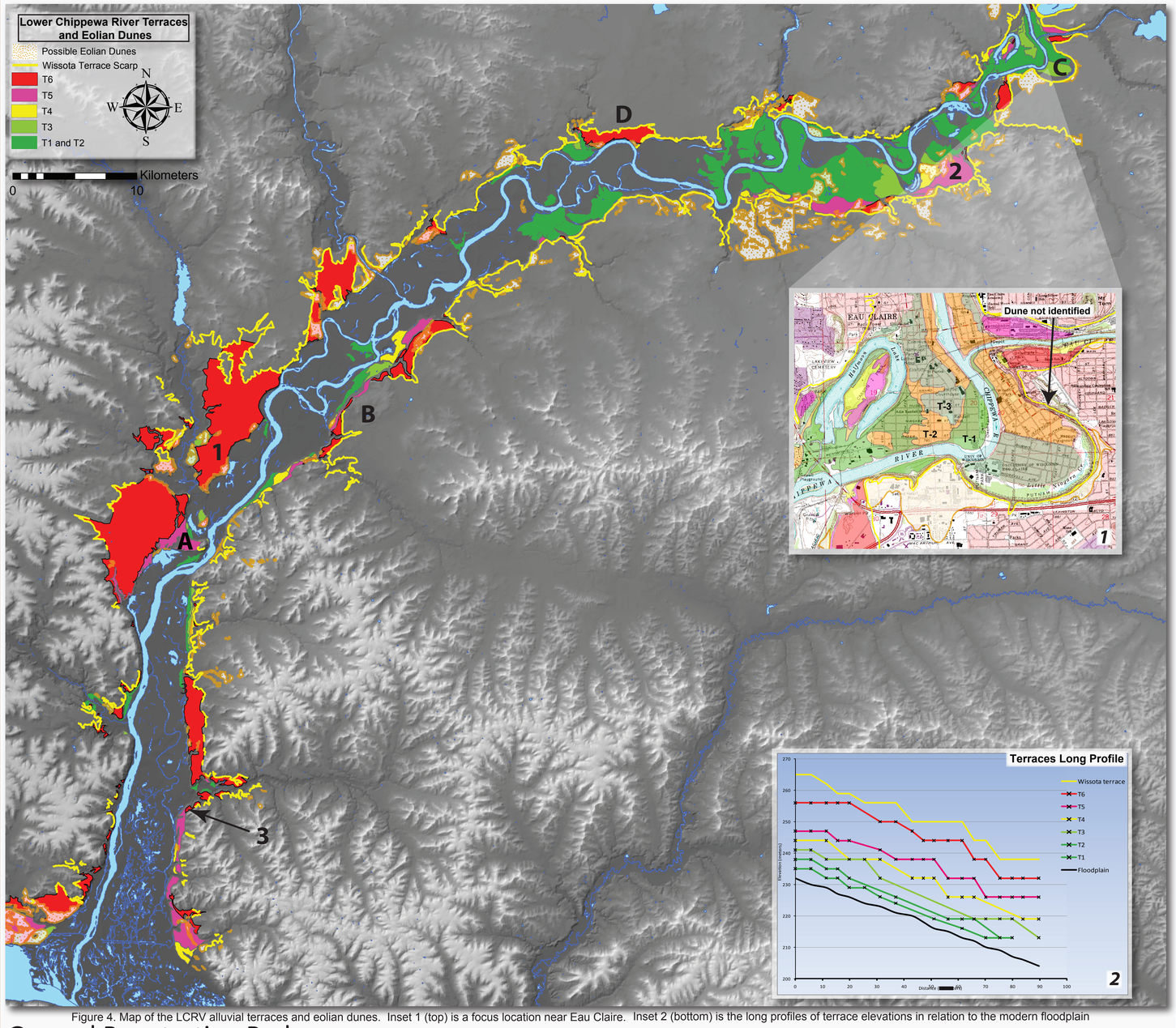
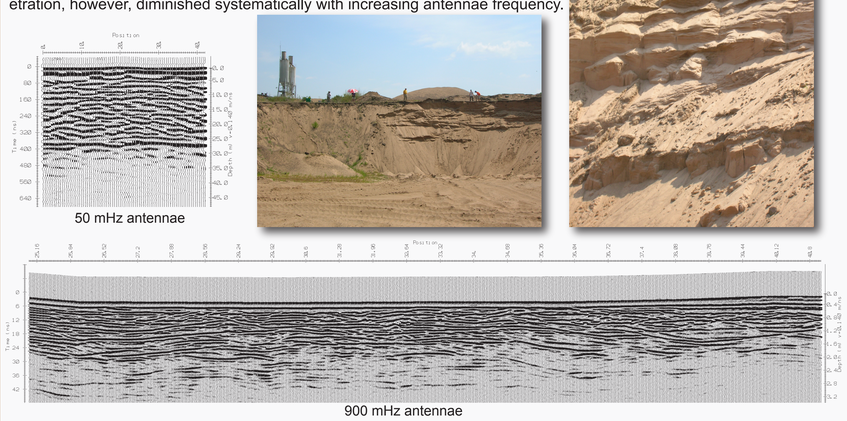


Figure 4. Map of the LCRV alluvial terraces and eolian dunes. Inset 1 (top) is a focus location near Eau Claire. Inset 2 (bottom) is the long profiles of terrace elevations in relation to the modern floodplain

Ground Penetrating Radar

The GPR investigation at the DCD site was conducted in order to test the applicability of GPR in describing terrace fill sedimentary structures throughout the LCRV (Figure 5). Low frequency antennae (50 and 100 mHz) yields the greatest depth of penetration in subsurface imagery. 50 mHz antennae penetrated ~30 m. 100 mHz penetrated ~20 m. Subsurface imagery collected using higher frequency antennae (200 – 900 mHz) reveal highly detailed images. Depth of penetration, however, diminished systematically with increasing antennae frequency.



50 mHz antennae

900 mHz antennae

Figure 5. DCD GPR field site with 50 and 900 mHz frequency GPR images

Preliminary Optical Stimulated Luminescence Dates

Three OSL dates have been collected to date. Processing of the samples was conducted by Henry Loope, University of Wisconsin-Madison, at the University of Nebraska-Lincoln OSL laboratory. The OSL samples were obtained at locations 1, 2, and 3 shown on the map at left (Figure 4).

	Burial Depth (m)	H2O (%)*	K2O (%)	U (ppm)	Th (ppm)	Cosmic (Gy/ka)	Dose Rate (Gy/ka)	De (Gy)	# of Aliquots	Age (ka)
UNL-1716 Hwy D-DC1 (T6,1)	8.3	3.78	1.30	0.7	2.7	0.06	1.43±0.06	30.11±0.68	26	21.00±1.16
UNL-1727 MitchellRd1 (T5,2)	0.15	2.83	1.40	1.0	3.6	0.21	1.81±0.07	21.13±0.54	29	11.70±0.65
UNL-1729 Hwy KK2 (T6,3)	0.7	2.98	1.33	0.8	3.2	0.19	1.65±0.07	21.22±0.43	10	12.86±0.69

* In-situ Moisture Content
Error on De is 1 standard error
Error on age includes random and systematic errors calculated in quadrature

Terrace ground truthing and interpretation of aerial photographs confirm most of the terrace locations mapped by Speer et al, (2007). However, ground truthing revealed some inaccuracies in their map. Our modifications focused on the T3 through Wissota terrace levels (tread elevations a.s.l.); the results are shown on the map above (Figure 4). Spatial distribution of the terrace remnants are similar to Speer et al. (2007), although modifications were made to the extent and correlation of several terraces.

Wissota terrace remnants, averaging ~30 m above the modern floodplain (amf) are the most aerially extensive and prominent terrace remnants throughout the study reach (Figure 6). Wissota Terrace remnants are, however, less aerially extensive downstream from Round Hill (A, Figure 4). T6-T3 terrace levels are ~25-10 m amf. T2 and T1 terraces levels (6 to 3 m amf) are mapped as a single unit because of the absence of a continuous distinguishable scarp seperating them.

Terrace remnants below the Wissota terrace have an apparent spatial distribution. The spatial distribution is most evident in the prevalence of the T6 terrace downstream of Round Hill (A, Figure 4) and the T2-T1 terrace level upstream of Durand (B, Figure 4). All seven terrace levels have been preserved in the Eau Claire area (C, Figure 4, and map inset ***1***).

Queries performed on tabular data provided in the SSURGO data identified locations of possible eolian dunes within LCRV (Figure 4). ArcMap queries proved successful in the majority of ground truthed locations. Many possible eolian dune locations, where dunes are present near a terrace scarp, are consistent with the cliff-top dune formation model proposed by Larson et al. (this conference). Some known eolian dunes were not identified using this method and in some cases non-dune landforms were included in the map.

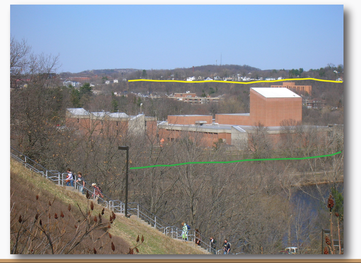


Figure 6. Eau Claire, WI Wissota and T2 terraces

Discussion

Interpretation of aerial photographs frequently reveals a distinct braided channel pattern on the Wissota terrace and T6 terrace treads (Figure 7). The braided channel pattern on the Wissota terrace formed as the meltwater-laden Chippewa River aggraded to its maximum level during the Late-Wisconsinan. Wissota terrace remnants can be traced throughout the LCRV and can be found upstream in tributaries near the confluence of the Chippewa and Mississippi Rivers. A similar terrace level, the Savanna terrace, is located within the upper Mississippi River Valley (UMV). Based on the elevation amf and spatial distribution patterns, it appears the Wissota terrace correlates to the Savanna terrace. Limited radiocarbon dates from the UMV near Onalaska, Wisconsin, suggest aggradation ended and incision to the approximate level of the modern floodplain occurred ~17-16000 yr B.P. (Knox, 2005). It seems likely that incision occurred in response to the catastrophic draining of any one of a number of proglacial lakes in the region (e.g. Glacial Lake Duluth, Glacial Lake Agassiz). It also seems likely that incisoin of the LCRV would have occured around the same time of the incision of the UMV. However, our preliminary OSL date from Hwy KK2 conflicts with dates collected by Knox (2005) and suggests that incision below the T6 level occurred after ~12800 yr B.P. More extensive dating of terrace fills in both the UMV and LCRV is needed to determine which (if either) incision chronology is correct. The terraces below T6 represent additional episodes of downcutting and subsequent floodplain formation. These terraces could have been a result of incision in the UMV. However, it is possible that terrace incision was also influenced by wastage of the Late-Wisconsinan Chippewa Lobe, which would have removed a significant sediment source from the LCRV drainage (Syverson, 2008)

Figure 7. Braided channel pattern observed on T6 terrace tread (D. Figure 4).

The eolian dunes mapped throughout the LCRV have, based on preliminary ground truthing, shown a high degree of accuracy. A few mapped dune locations have been verified as eolian dunes however a small number of locations have proven to be inaccurate and known eolian dunes were missed in some locations (Figure 4, Inset 1). Possible eolian dune locations on the high terraces, near the terrace scarps, appear consistent with the cliff-top dune formation model proposed by Larson et al, (this conference). Other dune locations will require future research to determine their age, origin, and paleoenvironmental significance.

GPR and OSL methods have proven to be effective tools for describing and dating sedimentary structures in the LCRV sediments. The depth of penetration and quality of high resolution subsurface imagery will allow for further investigations of sedimentary structures in both terrace and eolian dune deposits.

Summary

Seven paired alluvial terraces within the LCRV have been identified and ground truthed using aerial photographs and dGPS. The highest and most prominent, the Wissota Terrace, represents the maximum aggradational floodplain level of the meltwater-laden Chippewa River during the Late-Wisconsinan. The lower six terraces are inset into the Wissota Terrace and represent a sequence of episodic incision and subsequent floodplain formation. Locations of eolian dunes have been mapped based on SSURGO data throughout the study reach. Dune mapping has narrowed down the possible locations of these landforms. Many mapped dunes show close proximity to the Wissota and T6 terrace scarps which supports the model of dune formation currently proposed (Larson et al, this conference). Further ground truthing will be needed to verify and refine the dune map. OSL and GPR methods were used successfully in the LCRV. Future investigations using these techniques will focus on determining the ages and geomorphic evolution of alluvial terraces and eolian dunes within the LCRV.

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