Sediment provenance of Twin Ports baymouth bars

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Introduction

Minnesota and Wisconsin Points (MWP) are perhaps the most iconic landmarks in Western Lake Superior. Despite this, relatively little is known about how the baymouth bars comprising MWP or the neighboring Connor's and Rice's Points formed. Existing models (Kemp et al., 1978; Barlaz, 1983) call on a combination of longshore drift from the Wisconsin side of Lake Superior and sediment supply from the Nemadji and St. Louis Rivers (Figure 1), but none of these models can describe all observed features of the bars. Ongoing research by Mr. Swenson has led to a new conceptual model of bar formation. A fundamental component of this model involves determining the source, or provenance, of the sand that comprises these bars. A provenance study was conducted utilizing point-counting to further investigate the formation of MWP.

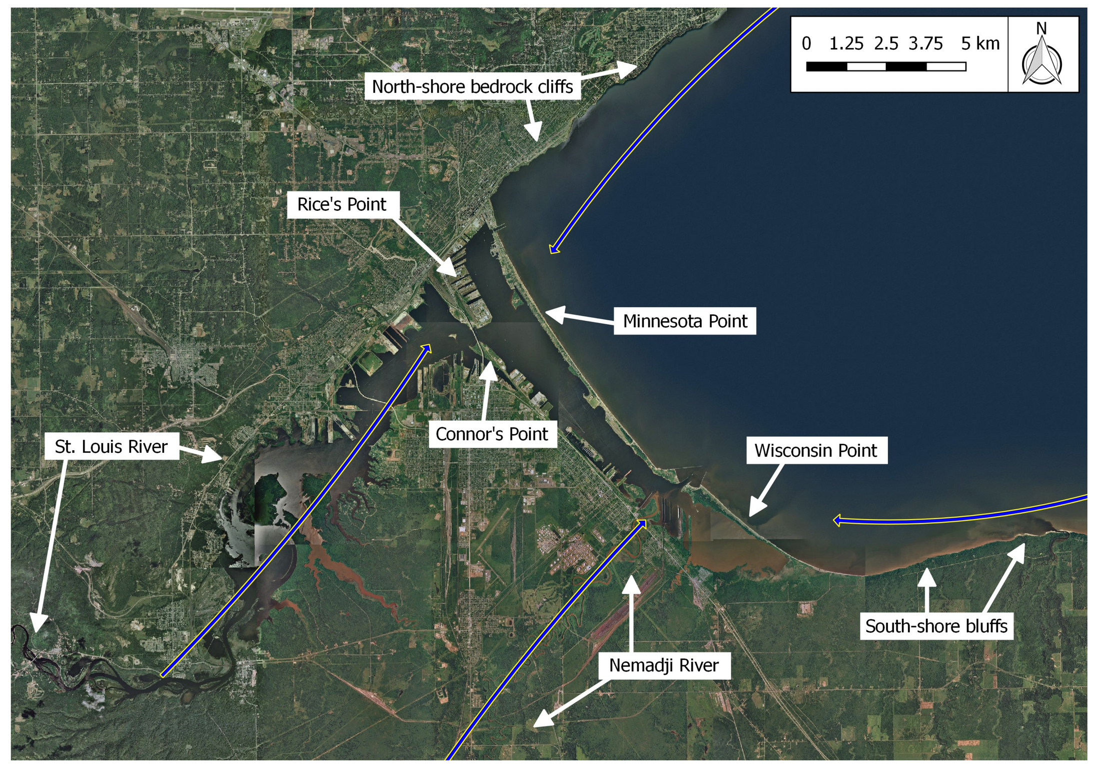

Figure 1: The study area considered. Blue arrows indicate sediment sources and white arrows indicate relevant land features. In addition to the original three sediment sources, a fourth, north-shore bedrock cliffs, was considered for this study.

Methods

Sampling

2-4 bags of sediment around 2.0 kg each were collected from Mission Creek (a tributary to the St. Louis River), the Amnicon, Nemadji, and St. Louis rivers, and MWP (Fig. 2). The samples then dried in an oven and sieved to extract the 1-2 mm fraction. For each sampling location, the samples were combined by splitting the samples equally such that the contributions from each sample bag summed to two grams. For example, if there were three samples for MPCP, 0.67 g was taken from each sample and combined to form an "average" of that location.

Analysis

The technique utilized in this study was adapted from an earlier method developed by Howard C. Hobbs (1998) for tracing past glacier movement. In Hobbs' method, for a given till sample, the 1-2 millimeter fraction was extracted, cleaned, and sorted under a binocular scope based on age, color, and rock type (shale, carbonate, basalt, etc.) (Fig. 3). The technique used here keeps the spirit of Hobbs' technique but adjusts it for use in northeastern Minnesota and northwestern Wisconsin. The bedrock in the study area is all around the same age (Paleo to Mesoproterozoic), so differentiating based on age is not useful. Color is retained as an indicator, as this will be universally applicable, but instead of rock type, the "coarseness" (an arbitrary term taking into account weathering, size of crystals, how well crystal faces were formed, and roundedness) of the sand grain was used in lieu of sorting grains based on specific rock type. The decision to remove rock type as an indicator was made due to time constraints, lack of rock type variety, and difficulty distinguishing rock types. However, certain rock types were tracked as "indicator lithologies", or rock types that could definitively indicate the influence of a certain river, such as Fond du Lac Formation sandstone, Thomson Formation shale, or banded iron formation.

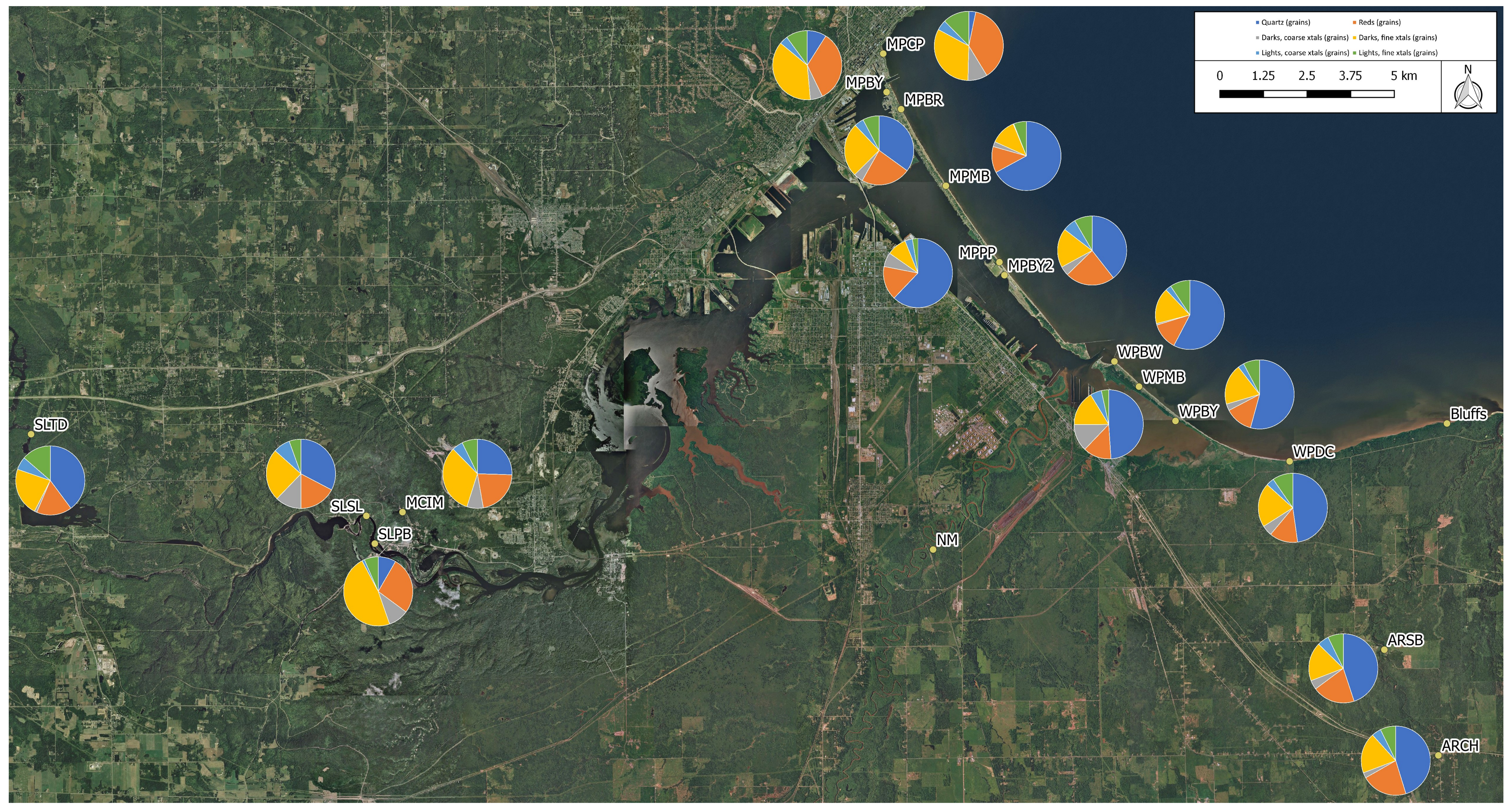

Figure 2: Sampling locations (yellow dots) and grain counts (pie charts) across the Twin Ports area. The Bluffs and NM samples did not yield usable sediment and lack pie charts as a result.

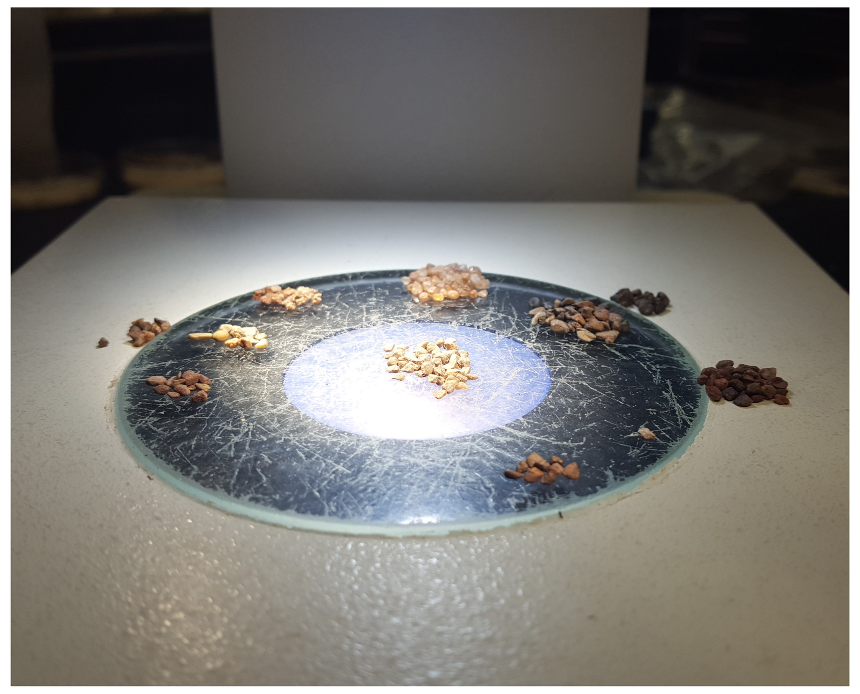

Figure 3: A sample nearing the end of analysis. Next, the grains are counted and tested for magnetism.

Sample ID	Quartz	Reds	Darks, coarse	Darks, fine	Lights, coarse	Lights, fine	Total
MPCP	12	142	34	121	18	46	373
MPBY	25	94	16	104	11	28	278
MPBR	127	84	16	92	16	28	363
MPMB	257	47	9	46	1	23	383
MPPP	215	55	23	32	12	9	346
MPBY2	127	75	14	59	20	27	322
WPBW	252	55	3	74	12	41	437
WPMB	185	50	48	62	20	13	378
WPBY	191	46	11	67	10	27	352
WPDC	194	54	20	84	15	39	406
MCIM	70	60	21	90	14	20	275
SLTD	137	57	4	78	21	47	344
SLSL	83	44	31	62	20	14	254
SLPB	14	45	16	80	2	11	168
ARCH	143	68	8	60	14	23	316
ARSB	124	55	12	50	15	20	276
Total	2156	1031	286	1161	221	416	5271

Table 1: Grain counts for each sample.

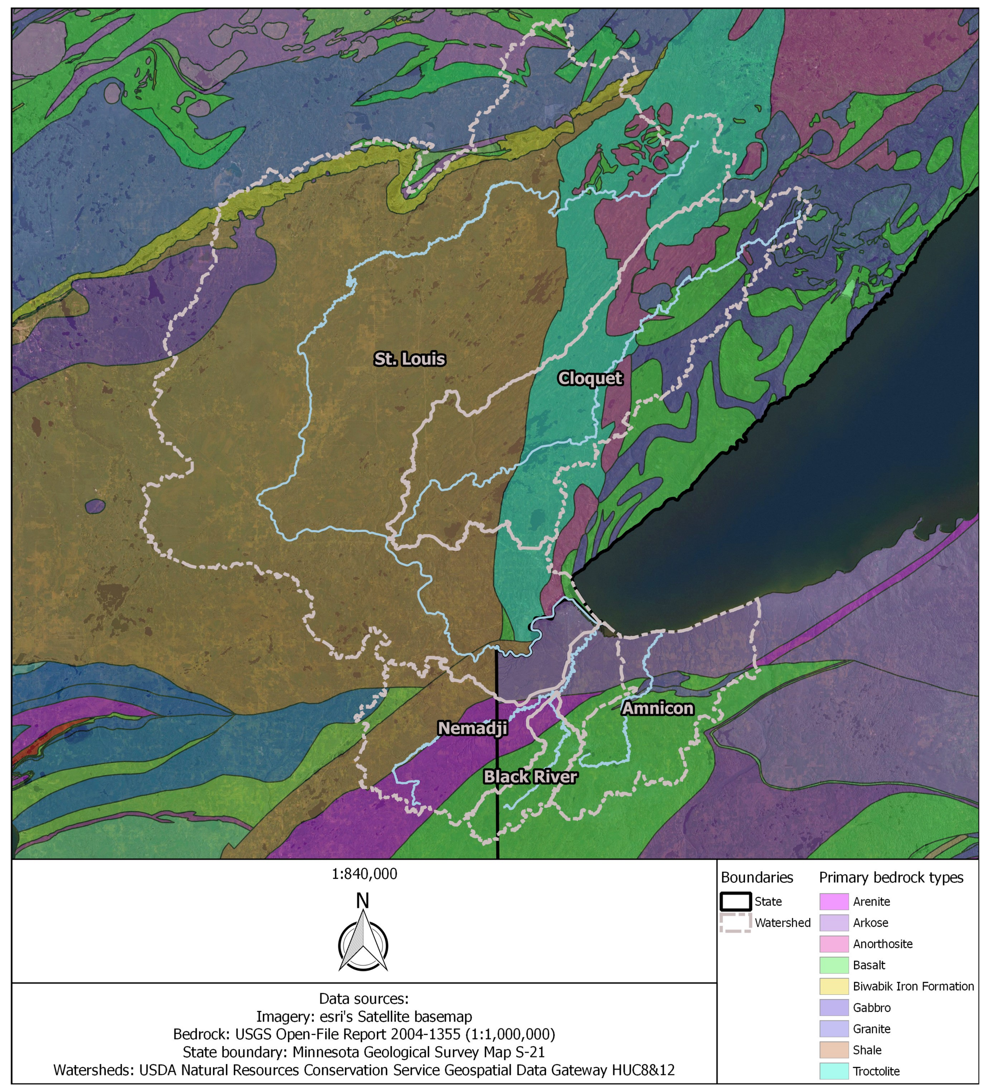

Figure 4: Local bedrock types and watershed boundaries for the rivers feeding MWP. Because the bedrock data used is at the 1:1,000,000 scale, it is subject to overgeneralization, particularly with regard to the area covered by the Animikie Basin. This data was used for the sake of readability.

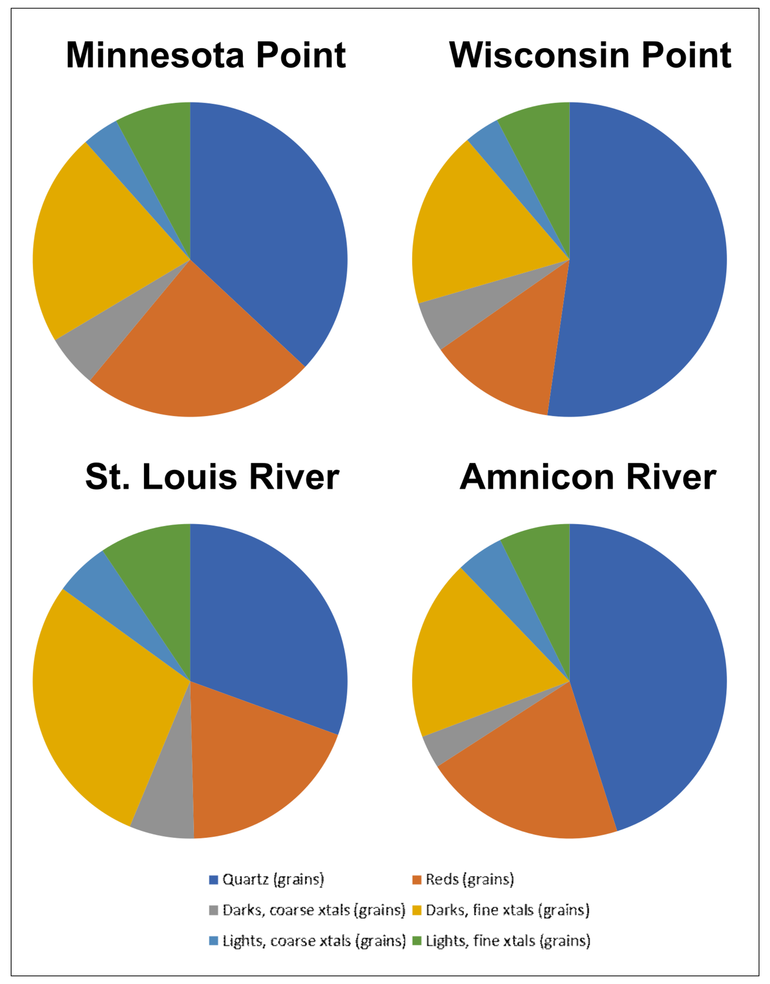

Figure 5: Equation 1 results for the Minnesota Point, Wisconsin Point, St. Louis River, and Amnicon River locales.

Results & Discussion

The grain counts are recorded in Table 1 and visualized in Figure 2. Indicator lithologies, such as Fond du Lac Formation sandstone and Thomson Formation shale, were tracked throughout the duration of this study, but were merged with the primary grain categories for display here. The samples of the Nemadji River and Bluffs did not yield usable sediment and thus were not accounted for in this study.

Sample analysis revealed a major complication: Indicator lithologies expected to be found only in certain rivers were identified in every river. The most significant example is Fond du Lac Formation sandstone, expected to be found only in the Mission Creek and St. Louis River samples, but also found in the Amnicon River locations, making a conclusive decision regarding MWP's formation much more difficult. This is unexpected—the Amnicon River watershed does not intersect the Fond du Lac Formation (Fig. 4), but the presence of these grains may be attributed to the movement of glaciers. As seen in Figure 2, there is no obvious trend between the river samples and the MWP samples. To resolve this dilemma, various ratios were developed to try and identify trends. After several unsuccessful attempts, Equation 1 revealed an actionable trend, visualized in Figure 5.

$$\frac{Qtz_{WPBW}+Qtz_{WPMB}+Qtz_{WPBY}+Qtz_{WPDC}}{Total_{WPBW}+Total_{WPMB}+Total_{WPBY}+Total_{WPDC}}$$

Equation 1: Calculation for deducing the primary grain ratios for each locale. This example is for quartz at the Wisconsin Point locale.

Conclusion

Based on the similarity of pie charts developed using Equation 1, the Amnicon River and south-shore longshore drift are the most likely source of the sediment comprising Minnesota and Wisconsin Points.

- The north-shore bedrock cliffs can safely be eliminated as a significant source of sediment due to low weathering and transport rates (Lambert and Swenson, 2016)
- The St. Louis River's contribution is likely severely inhibited due to sediment being trapped behind the Thomson and Fond du Lac dams, as well as the flooding of the St. Louis estuary due to isostatic rebound (Clark et al., 1994)
- The Nemadji is contributing sediment to MWP, but it is too fine to be usable and its contribution is negligible for the purposes of this study

Future studies will find success with two improvements to this study: trace-element geochemical analysis and high resolution point-counting. Geochemical analysis would be the optimal technique; it would likely identify subtle differences between the different bedrock varieties in the Twin Ports area and all sediment could be used, not just a certain fraction. High-resolution point-counting is an alternative for those short on money: Every type of grain (grey conglomerate, red conglomerate, potassium feldspar, basalt, etc.) would tracked instead of tracking only color and coarseness.

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