The Edinburg Moraine

Part 1: Affirming a long-standing problem

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Introduction

The early history of glacial Lake Agassiz was punctuated by episodes of glaciation when the generally receding Laurentide Ice Sheet readvanced into the southern Red River Valley (Arndt, 1977; Clayton and Moran, 1982). Lithostratigraphy and a series of ice margins suggest that ice was active in and around the valley on at least four occasions between about 14,000 and 11,000 years BP (figs. 1 and 2). Where they cross the Agassiz lake plain, wave action and burial by lake sediment have virtually erased the ice-marginal landforms associated with all but the most recent of these events (Harris, 1987a, 1995; Harris and Luther, 1991).

The Edinburg moraine

The maximum extent of the last major readvance of Late Wisconsinan ice into the Red River Valley is marked by the Edinburg moraine (fig. 1c + key) and the areal extent of the Forest River Formation (Harris, 1995, 1998; Harris and others, 1974; Johnson and others, 2016). In North Dakota the moraine extends southwestwards from the Canadian border as far as central Traill County where it crosses the Red River into Minnesota a few miles east of Hillsboro (fig. 3). As with the older glaciations, the Edinburg moraine's southern margin has been smoothed and is traceable only on air photos and by a subtle change in the surface sediments from lake clay to till. Near Inkster in Grand Forks County, however, its western boundary begins to emerge as a distinct topographic feature in the form of a string of increasingly broad and more prominent till-cored ridges. At its widest point, just south of the town in Walsh County after which it is named, the moraine measures approximately 2.5 miles from east to west and reaches its highest elevation of just over 1,300 feet – more than 100 feet above the surrounding lowlands (fig. 4). When the ice that deposited the Edinburg moraine began to recede, Lake Agassiz expanded northwards, inundating the lower slopes of the moraine and making islands out of the higher elevations. A sizeable part of the morainal surface is consequently wave-eroded to some degree but above about 1,225 feet the glacial sediments are essentially undisturbed and the hummocky collapsed topography that typifies the ice margins of the region is preserved.

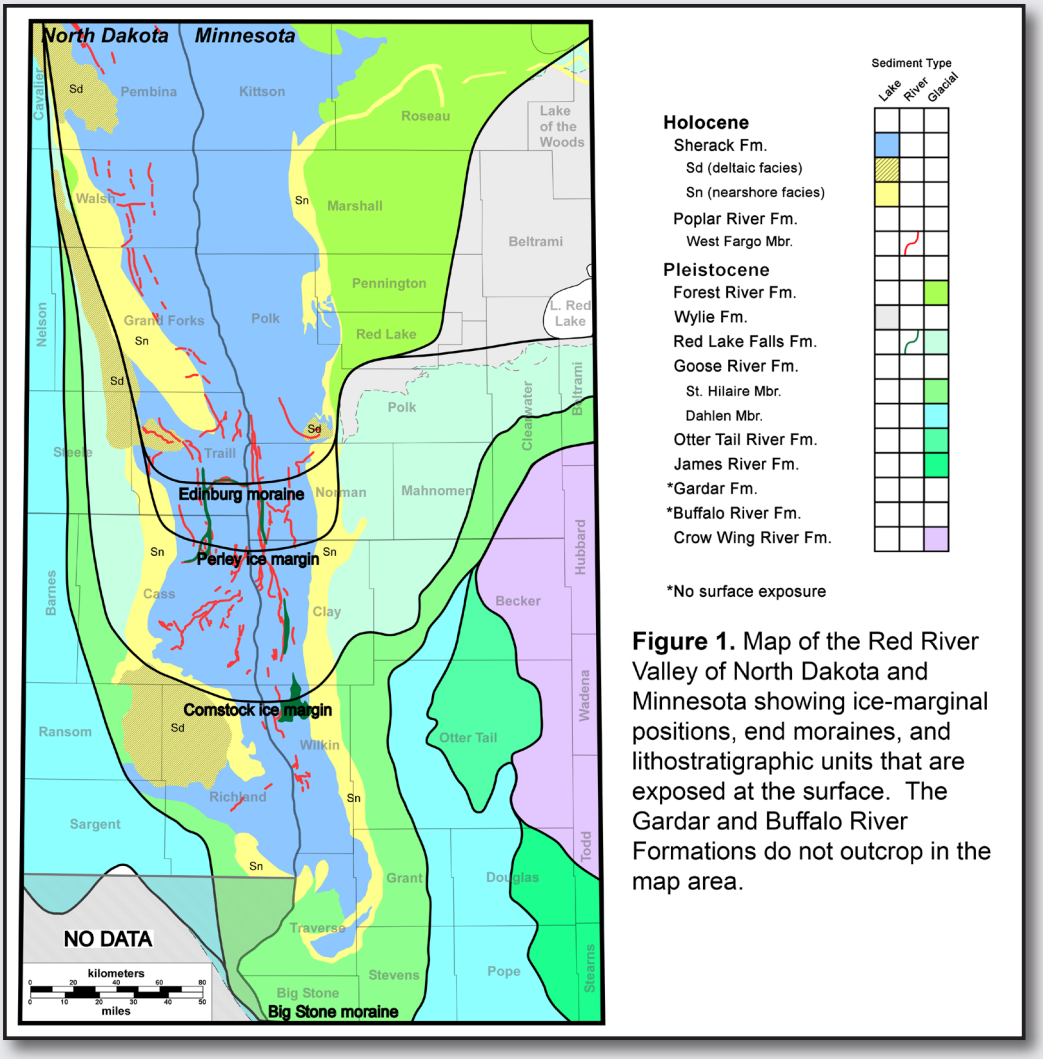

Figure 1. Map of the Red River Valley of North Dakota and Minnesota showing ice-marginal positions, end moraines, and lithostratigraphic units that are exposed at the surface. The Gardar and Buffalo River Formations do not outcrop in the map area.

The Forest River Formation consists of two laterally equivalent members (K.L. Harris, written

commun., 2014; Johnson and others, 2016). The Falconer Member is a silty, clayey loam till that occurs throughout much of the northern Red River Valley. It grades down ice towards the glacier margin into the more clayey, less pebbly Huot Member (fig. 3). Although their textures differ, the tills are very similar lithologically, suggesting a common source area. The textural changes are the result of the entrainment of clayey lake sediment by the advancing glacier as it moved southwards into the Agassiz basin.

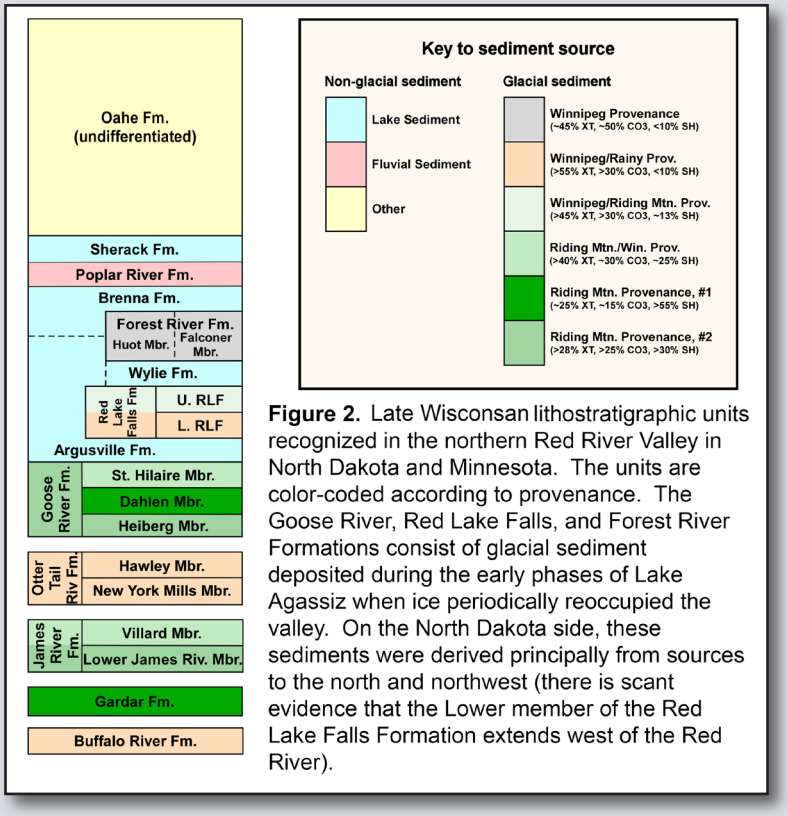

Figure 2. Late Wisconsan lithostratigraphic units recognized in the northern Red River Valley in North Dakota and Minnesota. The units are color-coded according to provenance. The Goose River, Red Lake Falls, and Forest River Formations consist of glacial sediment deposited during the early phases of Lake Agassiz when ice periodically reoccupied the valley. On the North Dakota side, these sediments were derived principally from sources to the north and northwest (there is scant evidence that the Lower member of the Red Lake Falls Formation extends west of the Red River).

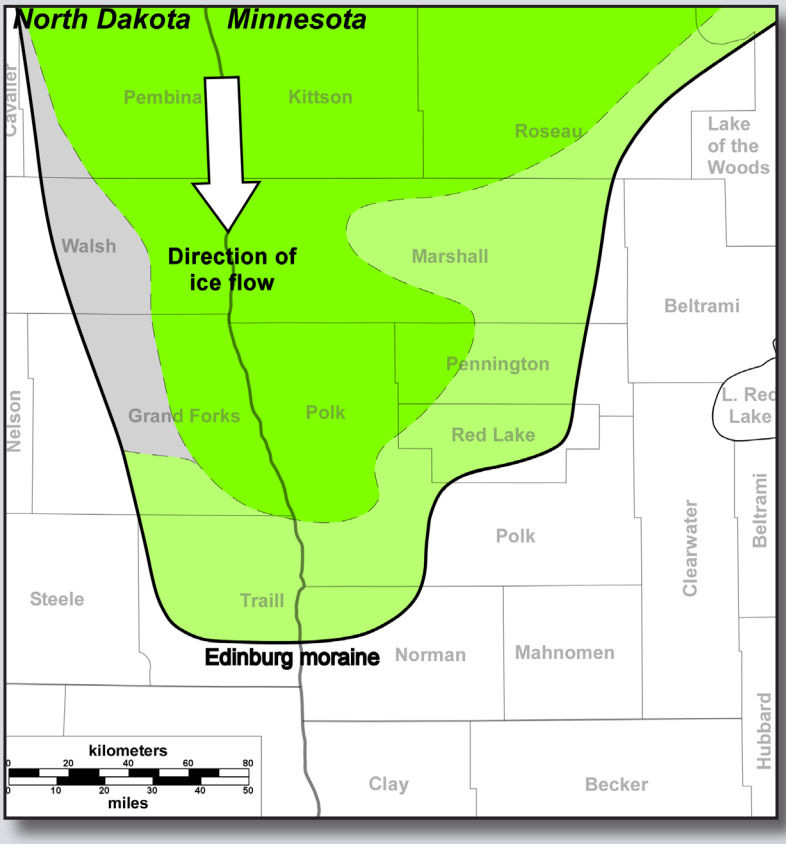

Figure 3. Areal map of the Forest River Formation in the Red River Valley of North Dakota and Minnesota. These sediments were deposited by ice that readvanced from the north into glacial Lake Agassiz about 11,500 years ago and formed the Edinburg moraine. The Falconer Member (dark green) grades down ice into the laterally equivalent Huot Member (light green) – a textural fining brought about by the incorporation of increasing amounts of clayey offshore sediment as the glacier moved into the lake. The gray-shaded area approximates to the section of the Edinburg moraine and the eastern part of the adjoining landscape that is the subject of this article.

Till composition vs source area (provenance)

Till lithology is a reflection of provenance. Glaciers entrain any loose material in their path and may transport it for hundreds of miles before setting it down again. The mineralogy and physical characteristics of those deposits are indicative of the route the glacier traveled. A generalized bedrock geologic map of North Dakota and the surrounding region (fig. 5) shows that the bedrock east and northeast of the Red River Valley consists primarily of Precambrian igneous and metamorphic (crystalline) rocks of the Canadian Shield. By contrast, the Paleozoic and Mesozoic rocks to the north, and the Cretaceous and Paleogene rocks to the northwest and west are all dominated by sedimentary lithologies. The tills derived from each of these source areas are lithologically distinct. Those deposited by glaciers entering the Red River Valley from the northeast (Rainy provenance) are generally crystalline-rich. Profuse carbonate rock fragments characterize tills deposited by ice advancing from the north that overrode Paleozoic limestones and dolostones around Lake Winnipeg. Tills originating from source areas to the west and northwest (Riding Mountain provenance) contain appreciably more Cretaceous shale than those from other sources as well as, in places, bits of local sandstone and other sedimentary bedrock. All these provenances are represented in the Late Wisconsinan tills deposited in the Red River Valley.

The problem

Geologists familiar with the Quaternary stratigraphy of northeastern North Dakota have been aware of an anomaly in the sediments of the Edinburg moraine for many years. There is no question that it was constructed by the same glacier that deposited the tills of the Forest River Formation but there is a lithologic mismatch. High carbonate concentrations in the Forest River Formation clearly point to a northern (Winnipeg) source area. Yet tills in the same stratigraphic position, sampled on and adjacent to the western arm of the Edinburg moraine, do

Figure 4. View from the Edinburg moraine westward across the Elk Valley to the Pembina Escarpment. The elevation change from the summit of the moraine to the valley floor in this area, which is a few miles south of the town of Edinburg, is about 80 feet.

not fit the description of either the Falconer or the Huot Member. Resemblances to older tills derived from more northwesterly provenances were noted by Harris and others (1974) and also by Reid (1996) but defied satisfactory explanation owing to a lack of quantitative data. This shortage also precluded attempts to reliably correlate the observed irregularities or determine their overall extent.

QBASE and Computer-Assisted Lithostratigraphy

N-File is a digital compilation of raw, nearsurface stratigraphic data for North Dakota generated and maintained by the North Dakota Geological Survey (North Dakota Geological Survey, 1995). It is also a component of the Minnesota Geological Survey's QBASE, a database containing information on glacial sediments including geologic setting, textural, and compositional data, collected from approximately 4,000 sites throughout eastern North Dakota and western Minnesota. Among its many benefits, QBASE is an excellent source of good statistical data that enables geologists to identify, interpret and correlate glacial lithostratigraphic units on a regional scale.

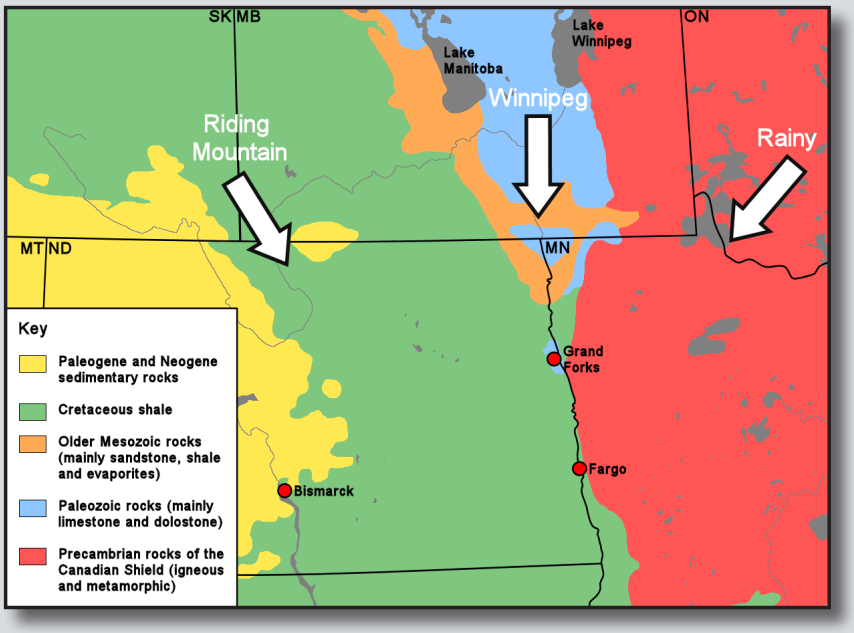

Figure 5. Simplified bedrock map of North Dakota and the surrounding region showing the general direction of ice flow (white arrows) and the source (provenance) of glacial sediments deposited in the Red River Valley.

Within QBASE is a large dataset for the Red River Valley. A recent analysis of this data, performed as part of an ongoing mapping project to investigate sand and gravel resources in eastern North Dakota, has provided compelling evidence that a roughly 30-mile-long upland section of the Edinburg moraine between Inkster and the Walsh-Pembina County line (fig. 3) is not made of Forest River tills (K.L. Harris, unpub. data, 2014).

Natural textural and lithologic modal tendencies (clusters) in the data were identified, delimited, and their member samples tagged with the aid of software developed by Harris (1987b, 1998). Textural analysis provides the percentage composition of sand, silt, and clay. Grain-count analysis of the lithology of the coarse-sand fraction (1-2 mm) provides the percentage composition of crystalline and metamorphic rock fragments (XT), limestone and

Table 1. Summary of cluster analysis results and general character of the Late Wisconsinan tills shown on the cross plot in figure 6.

Till unit	N*	Texture				Coarse sand lithology			Provenance
		mean %			Matrix	mean %			
		Sand	Silt	Clay		Xtal	CO_3	Shale	
Forest River Fm									
Huot Mbr	100	10	28	62	Clay-silty clay	46	48	6	Winnipeg
Falconer Mbr	54	28	47	25	Loam-clay loam	44	50	6	Winnipeg
Red Lake Falls Fm									
URLF Mbr	134	35	39	26	Loam-clay loam	53	34	13	Winnipeg/Riding Mt
Goose River Fm									
St Hilaire Mbr	272	28	42	30	Loam-clay loam	41	35	24	Riding Mt/Winnipeg
Dahlen Mbr	713	33	39	28	Loam-clay loam	26	18	56	Riding Mt
Heiberg Mbr	641	32	41	27	Loam-clay loam	32	26	42	Riding Mt
James River Fm									
L James River Mbr	268	40	37	23	Loam-clay loam	43	27	30	Riding Mt
Gardar Fm	338	31	41	28	Loam-clay loam	15	11	74	Riding Mt
Edinburg moraine	82	33	43	24	Loam-clay loam	36	25	39	Riding Mt

* Number of samples

dolostone rock fragments (CO_3), and shale fragments. The final dataset is arranged sequentially by site location and sample collection depth in order to facilitate mapping and stratigraphic interpretation.

Findings

Figure 6 is a cross-plot of the cluster analysis results that shows the relationship between till composition and source area for Late Wisconsinan tills deposited in the Red River Valley. Each circle represents the mean detrital (coarse-sand) grain composition (% shale vs % carbonate [CO_3]/crystalline) of between 50 and 700 samples of each till unit and is color-coded according to provenance (table 1). All but one (denoted by the green star) correlate with known lithostratigraphic units. Similar in composition to the Heiberg Member of the Goose River Formation, this till plots in a position consistent with a northwestern (Riding Mountain) provenance, virtually undiluted by material from other source areas. Excluding three outliers in Minnesota, the till was identified in 79 samples from 34 separate locations, mostly in the vicinity of the Edinburg moraine in western Grand Forks and central Walsh Counties, but also in places on the lake plain and along the western margin of the Agassiz basin, and on the till-covered uplands to the west (fig. 7). It is the surface or uppermost till unit at 30 of the 34 sites, where it typically overlies the Goose River Formation, and present as a lower till unit at the remaining four. Because it was presumed by tradition to be the same age as the Forest River Formation, albeit very different to the other members lithologically, the till was associated with the formation as member number three and informally designated the Inkster* after the town of that name in Grand Forks County. As such, it is the only member of the Forest River Formation found in stratigraphic sections throughout this part of the moraine and most of the surrounding area.

The composition and geographic origin of the Inkster member firmly supports the possibility of a relationship between it and the tills of the Goose River Formation, especially the Heiberg Member.

But the question of the apparent age discrepancy remains, and the answer to that is another story . . .

To be continued.

**Referred to as Falconer 2 in some datasets. This term is now obsolete.*

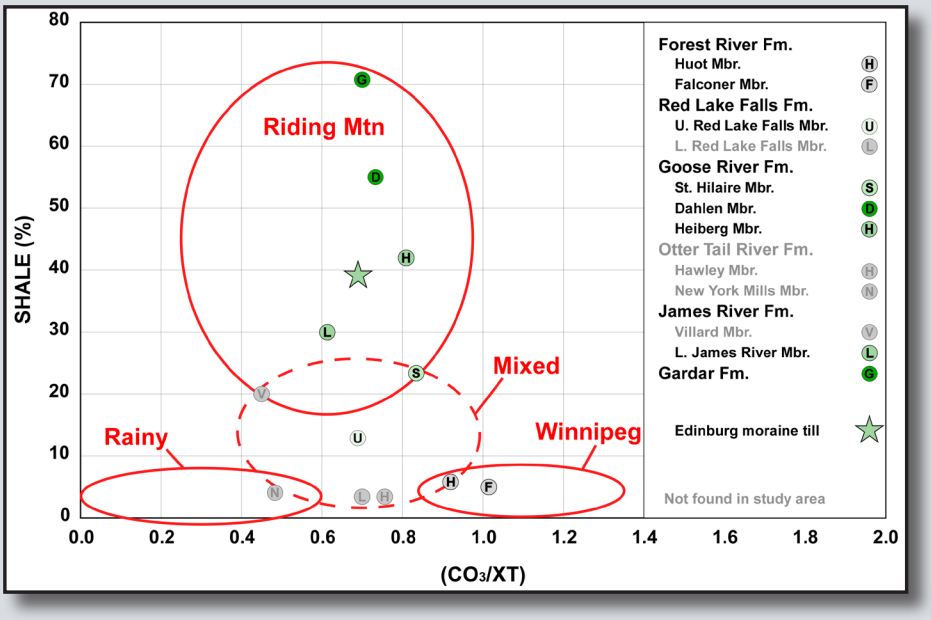

Figure 6. Cross plot of shale versus carbonate fragments/crystalline (CO_3/XT) in the coarse sand fraction of Late Wisconsinan tills deposited in the northern Red River Valley in North Dakota showing the relationship between lithology and provenance. Each circle represents the mean composition of between about 50 and 700 samples of each unit. Till samples collected on and around the Edinburg moraine plot as a discrete cluster (green star) that clearly implies a northwestern (Riding Mountain) provenance.

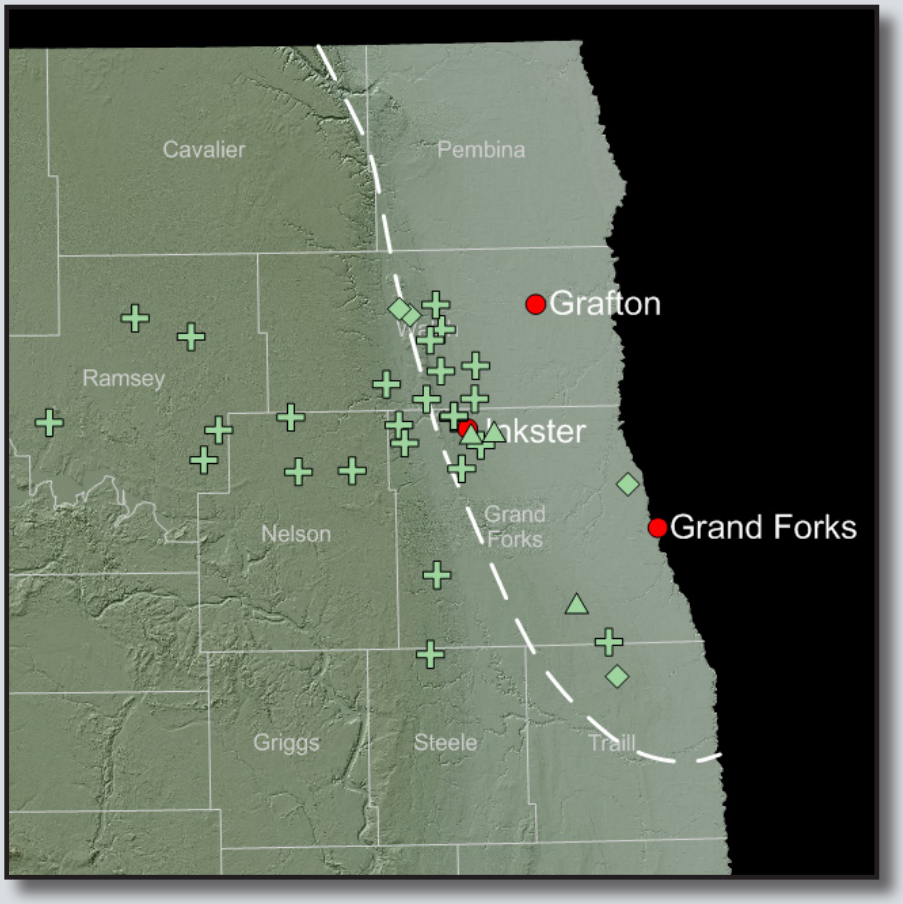

Figure 7. Shaded relief map of northeastern North Dakota showing the approximate location of the Edinburg moraine (dashed line) and sample sites at which the Edinburg moraine (Inkster) till was identified as either the surface unit (green crosses), the uppermost till unit (triangles) or, rather more tentatively, as a lower till unit (diamonds) overlain by the Falconer or Goose River tills.

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