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# Using Postglacial Eolian Dune Depositional Ages from Northeast Alberta, Canada to Assess the Likelihood of Northwestward Routing of Lake Agassiz Overflow at the Onset of the Younger Dryas Cold Event

Ken Munyikwa[1,*], [1]*Centre for Science, Athabasca University, Athabasca, Alberta, Canada*

*Email: kenm@athabascau.ca*

## Objectives

The release of freshwater into the North Atlantic by glacial Lake Agassiz towards the end of the last glacial period is hypothesized to have triggered the Younger Dryas cold event of 12.9 -11.7 ka ago. It is thought that the influx of freshwater weakened meridional overturning circulation, impeding heat transport to the northern latitudes. However, there is debate as to whether the freshwater from Lake Agassiz was introduced to the ocean eastwards along the St Lawrence River to the North Atlantic, or northwestwards along the Mackenzie River to reach the Arctic Ocean (e.g., Tarasov and Peltier, 2005; Teller et al., 2005; Murton et al., 2010; Crondon and Windsor, 2012; Leydet et., 2018). As a contribution to the debate, this investigation focuses on the northwestward route. Improved age constraints for the retreat of the Laurentide Ice Sheet from northeast Alberta, Canada (Figure 1), a region that lies along the northwestward flow path, may make it possible to ascertain if overflow along the Mackenzie River triggered the Younger Dryas event. Thus, this study collects postglacial eolian dune samples from northeast Alberta and analyzes them using luminescence methods to determine their burial ages. The chronologies obtained are then used to assign constraints on the appearance of an ice-free landscape following the retreat of the Laurentide Ice Sheet from the region. The results are compared with chronologies for deglaciation reported (Leydet et al., 2018) for the opening up of the eastward flow path.

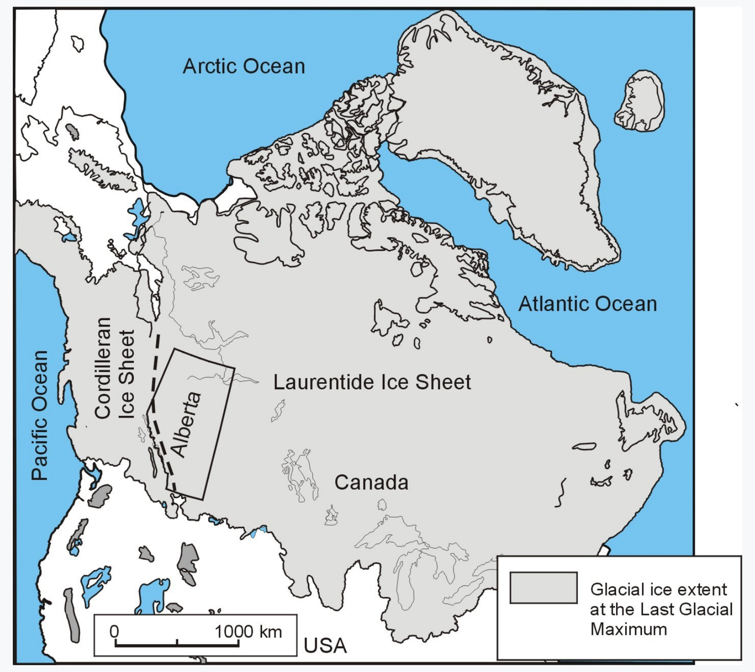


**Figure 1** North America at the Last Glacial Maximum

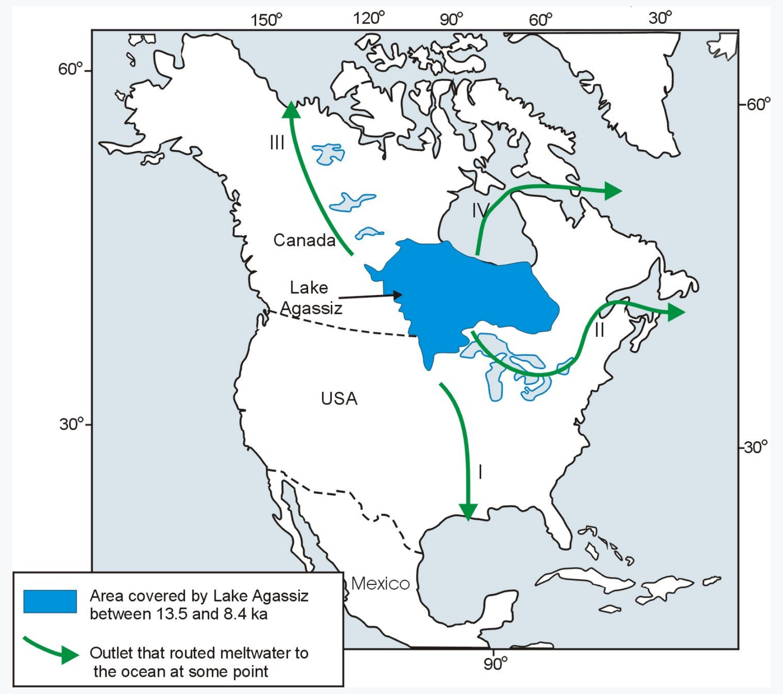


**Figure 2** Areas covered by glacial Lake Agassiz between ca. 13.5 and 8.5 ka ago (after Leverington and Teller, 2004)

## 1.0 Introduction

Lake Agassiz was a large glacial lake that existed in central North America sometime between 13.5 and 8.5 ka (Figure 2) as a result of freshwater that was dammed by the southern margin of the retreating Laurentide Ice Sheet (e.g. Leverington et al., 2002; Teller, 2013). Prior to ca. 13 ka, overflow from Lake Agassiz was routed to the Gulf of Mexico along the ancestral Mississippi River system (Fig 2). Around 12.9 ka cal. BP, the level of the lake began to fall significantly (e.g. Teller, 2013). Around this time, it is also thought that drainage southwards to the Gulf of Mexico stopped (e.g. Leydet et al., 2018). However, what remains a subject of debate is how the freshwater released by the lake was routed to the oceans. There are two main hypotheses (e.g. Teller and Boyd, 2006; Murton et al., 2010; Leydet et al., 2018); one is that the overflow drained eastwards to the North Atlantic along the St Lawrence River System (e.g. Broecker et al., 1989; Leydet et al., 2018) while the other suggests it was routed northwestwards to the Arctic Ocean along the Mackenzie River (e.g. Peltier and Tarasov, 2005; Teller et al., 2005; Murton et al., 2010; Crondon and Winsor, 2012).

Murton et al. (2010) identified a flow path along the Mackenzie River system in northwestern Canada comprising erosional and depositional landforms on the Canadian Arctic Coastal Plain. Using luminescence dating, Murton et al. (2010) concluded that a high -energy fluvial event occurred in the area sometime between 13.0 ka and 11.7 ka ago. The chronologies appeared congruent with the timing of the Younger Dryas event. However, in contrast, Leydet et al. (2018) reported surface exposure ages from eastern Canada that suggest that the eastward route that led to the St Lawrence River became ice-free around 13.0 - 12.7 ka, a time period that also brackets the onset of the Younger Dryas event. Leydet et al. (2018) have argued this chronology indicates that overflow of Lake Agassiz eastwards triggered the Younger Dryas event but also suggest that eastward flow terminated around 12.2 ka due to isostatic rebound after which northwestward flow along the Mackenzie system began. Hence, there is a suggestion that Agassiz overflow routing associated with the Younger Dryas event began with eastward flow between 13.0 ka and 12.2 ka after which northwestward flow was initiated from 12.2 ka and ended ca. 11.9 ka (Leydet et al., 2018). This study aims to improve on the sampling reported by Murton et al. (2010) by obtaining additional luminescence ages further south along the flow path of the northwestward route in order to determine a more precise timeline of when overflow along the Mackenzie River system became possible.

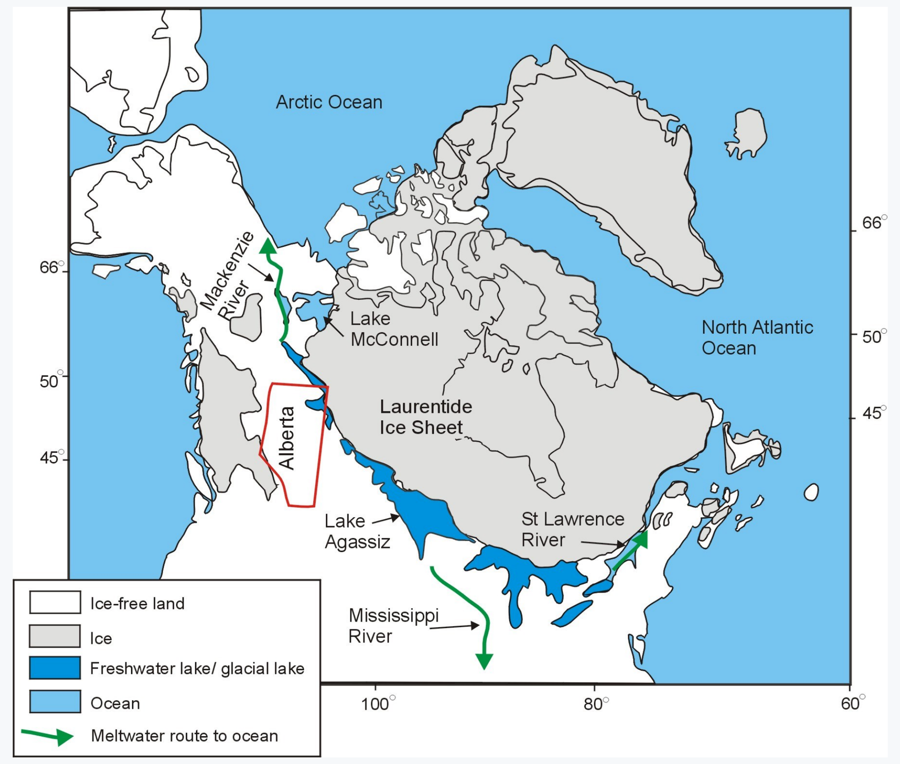


**Figure 3** Alternate glacial Lake Agassiz overflow pathways showing the eastern route (via the St Lawrence River) and northwestward route (via the Mackenzie River). Prior to ca. 13 ka, the drainage was southward towards the Mississippi River system (after Murton et al., 2010).

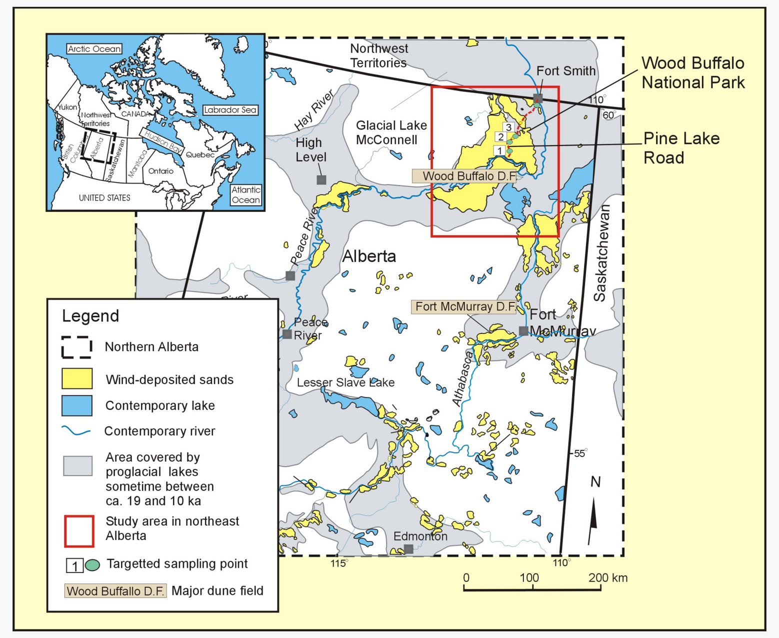


**Figure 4** Study area in northeast Alberta, Canada. Sampling was conducted at three sites in the Wood Buffalo National Park along Pine Lake Road.

## 2.0 Study Area

In order to determine a timeline for the deglaciation of the northwestward route, we collected postglacial eolian dune sands from the Wood Buffalo Sand hills in northeast Alberta Canada, an area through which water from Lake Agassiz would have had to pass in order to reach the Arctic Ocean. The dune sands were sourced by wind from sediments left behind following the drainage of glacial Lake McConnell which had also been dammed in the region by the Laurentide Ice Sheet (Figure 4). For the northwestward route to become available, Lake McConnell would have had to drain northwestward first, also along the Mackenzie River. Three sampling sites were identified from Google Earth imagery by selecting well formed parabolic dunes in areas accessible via Pine Lake Road, the only service road in the area.

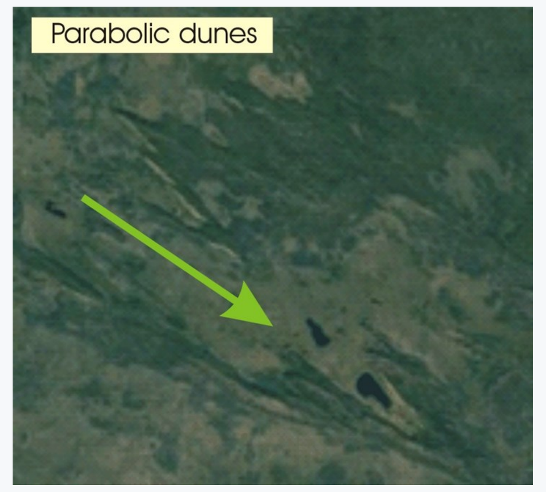


**Figure 5a** Google Earth image of parabolic dunes selected for sampling.

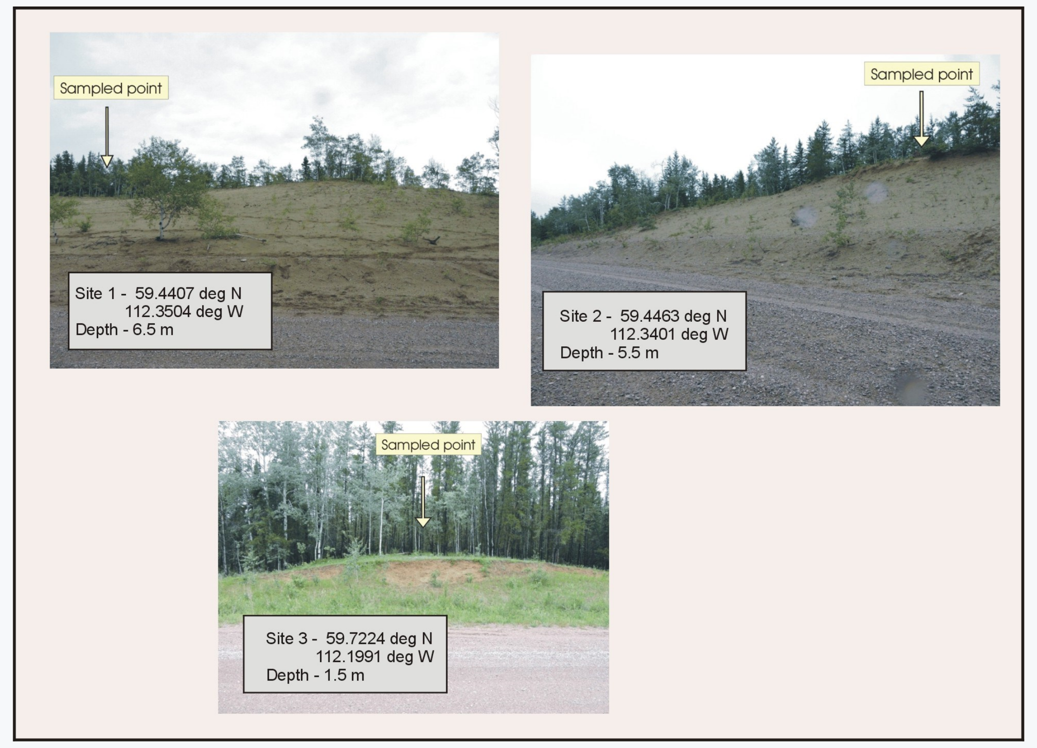


**Figure 5b** Parabolic dune sites sampled at Sites 1, 2 and 3.

## 3.0 Methods

Samples were recovered from the three sites (Figure 4) by drilling vertically using an auger (Figure 6). At each site, once the desired depth was reached, an opaque sampling module was hammered into the sediment using a slide hammer (Figure 6). Samples for dating were then packaged to shield them from sunlight. Additional samples were also collected for sedimentological analysis. At the lab, one set of dating samples was analyzed using a portable OSL reader and a standardized growth curve (Figure 7) (e.g. Munyikwa et al., 2014) to determine the approximate equivalent dose. Another set of samples was submitted to the Utah State University Luminescence Lab for more detailed analysis using regular luminescence dating protocols. We still await the results from the full-fledged luminescence dating but preliminary results are presented below.


**Figure 6** Luminescence dating sample extraction using auger. Desired depth is reached by extracting successive tailings retained in drill bit (A-B). Opaque sampling module is then attached to end of drill stem (C) and hammered downwards using a slide hammer (D). Extracted sample is packaged to shield from sunlight (E).

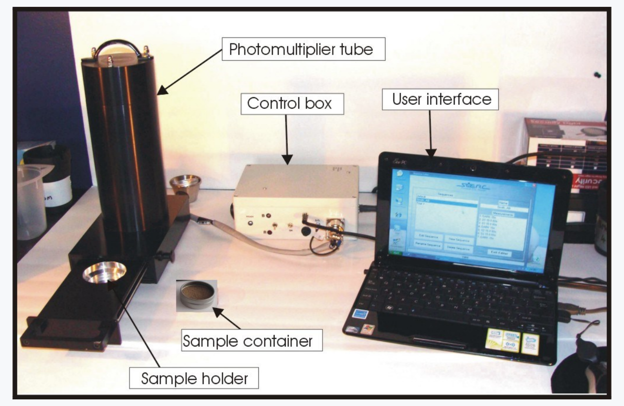


**Figure 7a** Portable OSL Reader used to estimate burial age of eolian sands.

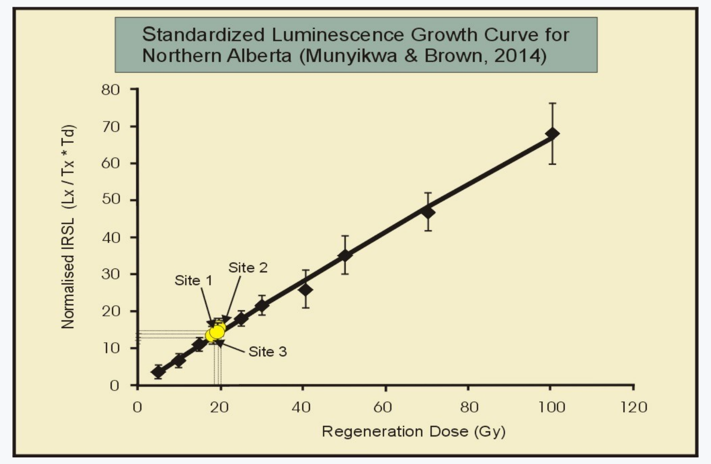


**Figure 7b** Standardized growth curve used to estimate paleodoses of dune sands.

## 4.0 Preliminary Results

Preliminary luminescence ages (Table 1) suggest that northeast Alberta had become free of both ice and glacial lakes by 13.5-12.5 ka ago. This indicates that freshwater flow from Lake Agassiz to the Arctic via the Mackenzie River cannot be excluded as a trigger for the Y.D. since the northwestward drainage path appears to have also been available at the start of the event.

**Table 1** Luminescence chronology approximated using a portable OSL reader and a standardized growth curve for northern Alberta (after Munyikwa and Brown, 2014)

| Sample Site | Coordinates | Depth | Equivalent Dose | Dose Rate (approx.) | Age Range |
|---|---|---|---|---|---|
| Site 1 | 59° 26.442' N 112° 21.023' W | 6.5 m | 19.20 ± 3.0 | 1.4 ± 0.5 | 13.2 ± 2 ka |
| Site 2 | 59° 26.778 'N 112° 20.405' W | 5.5 m | 20.05 ± 3.5 | 1.5 ± 0.5 | 13.5 ± 2 ka |
| Site 3 | 59° 43.345' N 112° 08.344' W | 1.5 m | 18.63 ± 2.8 | 1.5 ± 0.5 | 12.5 ± 2 ka |

## 5.0 Conclusions

Though full-fledged luminescence dating results are still to be received, preliminary data suggest the following:

- The northwestward route that leads to the Arctic Ocean via the Mackenzie River appears to have become available for overflow from Lake Agassiz by 13.5 -12.5 ka ago.
- Both the eastward route (via the St Lawrence River system) and northwestward route (via the Mackenzie River) were available for overflow from Lake Agassiz at the start of the Younger Dryas cold event around 12.9 ka ago.
- The preliminary chronology does not exclude the possibility that the Younger Dryas cold event of 12.9-11.7 ka was triggered by freshwater delivered to the Arctic via the Mackenzie River.

Notably, the initiation of the Younger Dryas by flow along the northwestward route has been affirmed by some modeling studies that suggest that meridional overturning in the North Atlantic would have been weakened more significantly if freshwater was introduced via the Arctic as opposed to off the Canadian east coast (Crondon and Winsor, 2012). Nonetheless, additional work needs to be conducted to determine along which route the overflow occurred first.

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