Abstract:

The Laurentide Ice Sheet (LIS) was the largest ephemeral ice sheet in the Northern Hemisphere, reaching its all-time maximum during the last glacial cycle (~115 ka to ~11.7 ka) as it coalesced with the Cordilleran and Innuitian ice sheets over northern North America and the Canadian Arctic Archipelago. At its maximum extent it was comparable in size to the modern-day Antarctic Ice Sheet and may provide a useful analogue for understanding the long-term dynamics of ice sheets. There are considerable regional variations in our understanding of the deglaciation of the LIS. In particular, the northwestern LIS remains one of the most poorly understood sectors, as the latest reconstruction of this sector dates to the early 1990s and empirical constraints on the timing of deglaciation are sparse.

In this thesis, I reconstruct the deglaciation of the northwestern LIS from its local Last Glacial Maximum (LGM) position using numerical dating methods and glacial geomorphological mapping. I use a combination of high-resolution digital elevation models (DEMs) and satellite imagery to map the glacial geomorphology of much of the Northwest Territories, Canada, and reconstruct the ice margin retreat patterns, ice flow dynamics, and interaction of the northwestern LIS with other ice masses. This new information is published in four papers, of which I am leading three and co-authoring one. The glacial geomorphological map of the Mackenzie Mountains (paper I) maps the landforms produced by the LIS, the Cordilleran Ice Sheet, and the local montane ice masses into six categories: glacial lineations, lateral meltwater channels, undifferentiated meltwater channels, lateral meltwater spillways, eskers, and moraines. These landforms constrain the maximum extent and interactions between these ice masses in the Mackenzie Mountains. In paper II, the glacial geomorphological map focuses solely on the imprint of the northwestern LIS across the Northern Interior Plains and the Canadian Shield and records the changing ice flow and margin retreat patterns. There are twelve landform categories on this map: glacial lineations, subglacial ribs, crevasse fill ridges, major and minor moraine, hummocky terrain and ridges, marginal meltwater channels, major and minor meltwater channels, shear margin moraines, eskers ridges, glaciofluvial complexes, perched deltas, raised shorelines and aeolian dunes.

Using new terrestrial cosmogenic nuclide exposure ages from the central Mackenzie Valley, we reconstruct the timing of northwestern LIS deglaciation (paper III). Samples for cosmogenic nuclide dating were taken from erratics at six sites spanning a range of latitudes, longitudes and elevations to gain an insight into the pattern of ice margin retreat and to constrain the rate of ice sheet retreat and thinning. We combine these new constraints in a Bayesian framework with the pre-existing dates and find that deglaciation occurred ~1,000 years earlier than in previous reconstructions. Between ~14.9 and 13.6 ka, we identify a period of rapid ice sheet thinning associated with warming during the Bølling-Allerød. The large uncertainties in terrestrial cosmogenic nuclide exposure dating mean that we are unable to quantify a precise rate of ice sheet thinning. Our constraints necessitate a revision of the ice margin retreat pattern, with ice retreat from the central Mackenzie Valley (~63 - 65°N) occurring in an easterly direction, rather than the previously suggested southerly retreat pattern. Using numerical modelling simulations, we calculate a contribution of ~13.4 m to global mean sea level rise from the ice saddle region, with 11.2 m occurring between 16 ka and 13 ka. Finally, our constraints indicate that the Mackenzie Valley became ice-free after 13.6 ka (14.1 – 13.2 ka) with implications for the migration of flora and fauna between Beringia and North America and glacial lake drainage routes.

The dynamics of the ice drainage network during deglaciation have not previously been reconstructed. We use the flowset mapping approach to reconstruct the changes in ice flow dynamics using the glacial geomorphological map from paper II. Our reconstruction provides evidence of the changing ice source areas related to rapid thinning of the ice saddle during the Bølling–Allerød and the increasing dominance of the Keewatin Ice Dome. The ice stream network underwent rapid changes during deglaciation that are associated with climate-driven changes in the ice sheet surface slope and facilitated by the subglacial bed conditions and the presence/absence of a calving margin. The glacial landform record indicates that dynamic ice margin retreat dominated during deglaciation, with a clear zonation that reflects the changing thermal regime.

Keywords: Laurentide Ice Sheet, glacial geomorphology, flowset reconstruction, cosmogenic nuclide exposure dating, Quaternary, sea level rise, ice streams