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Single-grain OSL dating of glaciofluvial quartz constrains Reid glaciation in NW Canada to MIS 6

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ABSTRACT

Improved chronological control on the penultimate advance of the Cordilleran Ice Sheet in northwest Canada (the Reid glaciation) is required for a better understanding of late Quaternary palaeoclimatic and palaeo-environmental change in eastern Beringia. However, reliable dating of glaciation events beyond the last glacial maximum is commonly hindered by a lack of directly dateable material. In this study we (i) provide the first combined minimum and maximum age constraint on the Reid glaciation at Ash Bend, its reference locale in the Stewart River valley, northwestern Canadian Cordillera, using single-grain optically stimulated luminescence dating of quartz; and (ii) compare the timing of the Reid glaciation with other penultimate ice sheet advances in the region with the aim of establishing improved glacial reconstructions in eastern Beringia. We obtain ages of 158 ± 18 ka and 132 ± 18 ka for glaciofluvial sands overlying and underlying the Reid till, respectively. These ages indicate that the Reid advance, at its reference locale, occurred during MIS 6. This precludes an earlier MIS 8 age, and suggests that the Reid advance may have been synchronous with the Delta glaciation of central Alaska, and is likely correlative with the Mirror Creek glaciation in southern Yukon.

Introduction: the 'Penultimate glaciation' problem in eastern Beringia

The extensive non-glaciated portions of the northern Cordillera of Yukon and Alaska, collectively termed eastern Beringia, are fringed by deposits associated with successive advances of the Cordilleran Ice Sheet and local mountain glaciers. The area provides one of the most complete continental glacial records spanning the Late Pliocene through the late Pleistocene, represented by multiple till sheets, glaciofluvial deposits and glaciolacustrine sediments (Hughes et al., 1969; Péwé, 1975; Froese et al., 2000; Kaufman and Manley, 2004; Duk-Rodkin and Barendregt, 2011). For much of this glaciated fringe, the most recent advance associated with marine isotope stage (MIS) 2 (ca. 25–10 ka) (termed the McConnell glaciation in Yukon; Fig. 1) is within the limits of earlier advances (Froese et al., 2000; Kaufman and Manley, 2004; Duk-Rodkin and Barendregt, 2011).

Relatively few of these earlier advances, however, have robust chronologies. This 'penultimate glaciation' problem is common to many areas due to the challenges of establishing reliable age constraints on sedimentary deposits that lie close to, or beyond, the limit of the radiocarbon method (e.g., Pigati et al., 2007). Opportunistic dating strategies have been used at localities that contain suitable deposits for cosmogenic techniques, such as large boulders (e.g., Goehring et al., 2008; Ward et al., 2008; Stroeven et al., 2010), or those that contain overlying, known-age tephras capable of providing minimum age constraints (e.g., Westgate et al., 2001; Ward et al., 2008). However, both these approaches require conditions that are not readily met at many field sites. A case in point is the challenge of defining reliable chronologies for Reid glaciation deposits in Yukon Territory of northwestern Canada.

The multiple, repeated advances of the Cordilleran Ice Sheet that have affected the northern Cordillera of Canada during the Quaternary period were strongly controlled by local topography and consisted of a series of coalescent lobes originating from distinct source areas (Fig. 1). Prominent lobes, including the Selwyn, Cassiar and St. Elias lobes, merged to form a near-continuous carapace of ice during these glacial advances. Although these individual lobes are likely to have had their own ice flow history, the Cordilleran Ice Sheet has been considered as a largely synchronous glacial record with distinct glacial limits assumed to represent consistent advances of the various lobes as a single ice sheet (Hughes et al., 1987; Duk-Rodkin and Barendregt, 2011). In general, the past record of the northern Cordilleran Ice Sheet is one in which the most recent late Pleistocene advances (McConnell glaciation, MIS 2) is fringed by older, more extensive advances. The penultimate glacial limit, the Reid glaciation, is represented by a more extensive moraine and drift complex in

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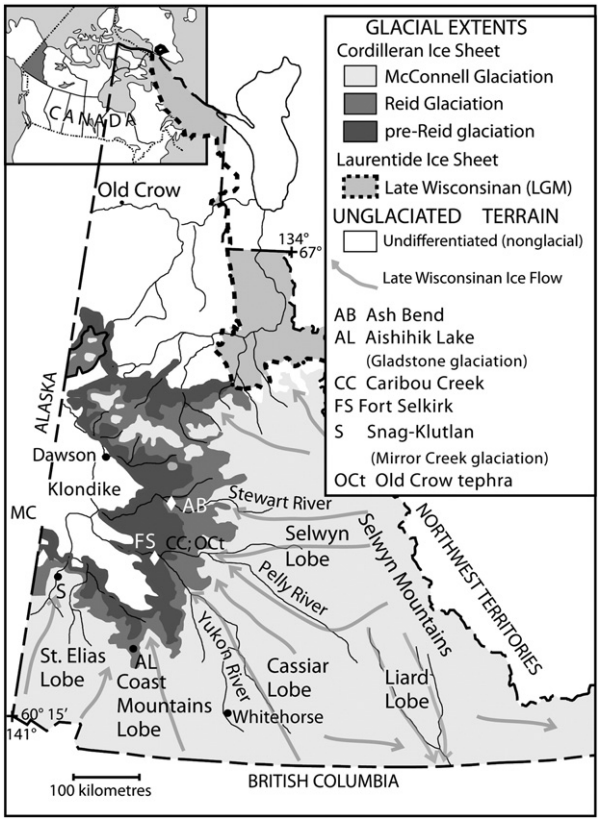

Figure 1. Extent of the McConnell, Reid and pre-Reid glaciations of the Cordilleran Ice Sheet in the Yukon Territory. Also shown are the locations of the Ash Bend site (inset) and the other sites mentioned in the text.

Stewart River valley and has been correlated to other penultimate limits in central and southwestern Yukon (Duk-Rodkin, 1999; Lacelle et al., 2007; Duk-Rodkin and Barendregt, 2011) and Alaska (Begét and Keskinen, 2003). However, at some locations it has been shown that this penultimate glacial limit is likely MIS 4 in age (Ward et al., 2007). Glacial advances that were more extensive than the Reid limits have been termed pre-Reid glaciations, and represent multiple glacial advances of the Cordilleran Ice Sheet as well as local alpine glaciations from the Late Pliocene through the early–middle Pleistocene (Froese et al., 2000; Duk-Rodkin et al., 2010). In this paper we focus on defining a chronology for the Reid glaciation in central Yukon in order to better understand the late Quaternary regional glacial record, particularly the diachronous versus synchronous nature of penultimate glacial advances across eastern Beringia.

A maximum age for the Reid glaciation of 311 ± 32 ka is provided by $^{40}Ar/^{39}Ar$ dating of basalt underlying outwash at Fort Selkirk (Fig. 1), near the confluence of Black Creek and the Yukon River, central Yukon Territory (Huscroft et al., 2004). Minimum age constraints for the Reid glaciation in Yukon Territory are more ambiguous and suggest that Reid deposits likely represent a regionally diachronous record (Ward et al., 2007, 2008). Cosmogenic dating on four boulders from deposits that have been mapped as Reid drift in the Aishihik Lake area, southwest Yukon Territory (Fig. 1), yielded ages of 54 to 51 ka (Ward et al., 2007). That study provided the first chronological evidence for a MIS 4 glacial expansion of the Cordilleran Ice Sheet. This particular glacial expansion, which represents an advance of the St. Elias and Cassiar lobes in southwest Yukon Territory, was subsequently renamed the Gladstone glaciation at the Aishihik Lake locale (Ward et al., 2007). In contrast, Reid deposits found along the Pelly and Stewart rivers, including the Ash Bend site (Fig. 1), in central Yukon Territory, belong to an expansion of the Selwyn Mountain lobe. Evidence for a MIS 6 minimum age for Reid deposits of the Selwyn lobe have been provided along the Pelly River (Caribou Creek; Fig. 1), where silts containing the Old Crow tephra (originally dated to 140 ± 10 ka) are present overlying deglacial Reid gravels (Ward et al., 2008), and from Ash Bend where the ~80 ka Sheep Creek–Klondike tephra (SCt-K) is found overlying Reid till (Westgate et al., 2008). The chronology of the Old Crow tephra has been recently revised to 124 ± 10 ka by Preece et al. (2011) from a new fission track age and improved fission-track dosimetry standard, but it still indicates a late MIS 6 age for the eruption (Reyes et al., 2010). An additional line of evidence suggesting a MIS 6 minimum age for the Reid advance in central Yukon comes from the presence of a distinctive MIS 5e surface soil, the Diversion Creek palaeosol (Smith et al., 1986; Westgate et al., 2001), which commonly overlies glacial outwash deposits in the Stewart River valley. Elsewhere, cosmogenic ages presented by Stroeven et al. (2010) within the Reid limit, but beyond the MIS 2 moraine, indicate a MIS 5 or MIS 6 minimum age for Reid deposits associated with the Selwyn lobe. Taken together, the findings indicate that the Reid drift, which has been frequently mapped as a regionally coherent advance of the Cordilleran Ice Sheet (Duk-Rodkin, 1999), may be a diachronous record in need of detailed re-examination and establishment of improved chronologies (Ward et al., 2007, 2008).

Despite the ambiguities of existing chronologies for the penultimate and earlier advances of the northern Cordillera, broad stratigraphic correlations have been proposed (Duk-Rodkin and Barendregt, 2011) with implications for regional reconstructions of palaeoclimate across northwestern Canada and eastern Alaska. However, the absence of reliable minimum and maximum age constraints directly on such glacial deposits precludes a fuller understanding of their regional climatic significance, and whether they truly represent coherent, synchronous episodes. The aim of this study is, therefore, twofold: (i) to study the OSL characteristics of individual silt-size quartz grains from glacial deposits in this region and to establish reliable chronologies for glacial advances using the latest developments in OSL dating; and (ii) to obtain new and direct chronologies for Reid deposits in central Yukon that can be integrated within the broader, regional glacial record to provide new insights into the spatio-temporal dynamics of the ice sheet advances prior to MIS 2 in eastern Beringia.

Site description

The Ash Bend site, on Stewart River (63°30′N, 137°15′W; 460 m a.s.l.), west-central Yukon Territory (Fig. 1) is located close to the type area for the Reid glaciation (Reid Lakes) as originally defined by Bostock (1966), and is recognised as one of the main reference sections for dating this glacial episode (e.g., Westgate et al., 2001). Ash Bend contains a 10-m-thick recessive sequence of Reid till and glaciofluvial gravels (Figs. 2a–b) overlain by loess deposits containing organic-rich material, bones and tephra layers (Hughes et al., 1987; Westgate et al., 2001, 2008). The till and outwash deposits were described in detail by Hughes et al. (1987), while further work by Westgate et al. (2001, 2008) has refined the lithostratigraphy of the loessal sequence overlying the Reid deposits at a channel cut exposure located towards the downstream end of the section. This overlying loess sequence contains several tephra beds and spans the glacial–interglacial cycle that succeeded the deposition of Reid drift (Schweger, 2003; Westgate et al., 2008).

Two OSL samples were collected from two glaciofluvial beds bracketing the Reid till at Ash Bend (Figs. 2c–d), described herein as Units 1 and 3 (Fig. 2a). Sample 57A was collected from the unit overlying the till (Unit 3), ~6 m below the surface. This unit is a planar–tabular cross-bedded sand deposit formed in a braided river environment. The entire deposit can be characterised as proximal-braided given the low-relief of bar forms (thin planar–tabular cross-beds) observed in the gravel section. Sample 58A was collected about 30 m below the surface from the unit immediately underlying