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Latest Pleistocene advance and collapse of the Matanuska – Knik glacier system, Anchorage Lowland, southern Alaska☆

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ABSTRACT

At the end of the last ice age, glacier systems worldwide underwent dramatic retreat. Here, we document the advance and retreat of a glacier system with adjacent marine- and land-based components during the latter part of the Termination. We utilize three lines of evidence: lithologic provenance, geomorphic mapping, and radiocarbon ages derived from lake cores to reconstruct glacier extent and timing of advance and retreat within our study area centered at N 61.50°, W 149.50°, just north of Anchorage, Alaska. Two glaciers, sourced in the Talkeetna and Chugach Mountains, flowed down the Matanuska and Knik Valleys forming a coalesced lobe that advanced onto the Anchorage Lowlands and terminated at Elmendorf Moraine. We use the presence of lithologies unique to the Matanuska catchment in glacial drift to delineate the paleoflow lines and to estimate the suture line of the two glacier systems. The eastern side of the lobe, attributed to ice flow from the Knik Valley, was in contact with elevated marine waters within the Knik Arm fjord, and thus retreat was likely dominated by calving. Geomorphic evidence suggests the western side of the lobe, attributed to ice flow from Matanuska Valley, retreated due to stagnation. We constrain retreat of the combined Matanuska and Knik lobe with thirteen new radiocarbon ages, in addition to previously published radiocarbon ages, and with geomorphic evidence suggesting the retreat occurred in two phases. Retreat from the Elmendorf Moraine began between 16.8 and 16.4 ka BP. A second, faster retreat phase occurred later and was completed by 13.7 ka BP. With the 140 km of total retreat occurring over ~3000 years or less. This pattern of glacial advance and retreats agrees well with the deglacial histories from the southern sectors of the Cordilleran Ice Sheet, as well as many other alpine glacier systems in the western U.S. and northern Alaska. This consistent behavior of glacier systems may indicate that climate oscillated over western North America early in deglaciation before it was recorded in other proxies such as ice cores. Furthermore, the period in which we note mountain glacier collapse in northwestern North America is synchronous with the worldwide glacial termination raising questions about intrahemispheric linkages.

1. Introduction

The structure and cause of the last glacial termination have long been an area of interest, as it provides a view into the most recent transition from glacial to interglacial climate. Recently, much attention has focused on the final stages of the Termination (Putnam et al., 2013; Svendsen et al., 2015; Pendleton et al., 2015). However, the structure of climate change between the peak of full-glacial conditions and the subsequent highly variable, oscillating, late glacial (18–11.6 cal ka BP) climatic conditions is less clear. Denton et al. (2006) called the period between 17.5 and 14.5 cal ka BP the "Mystery Interval" because several enigmatic changes

☆ **Summary**: Here we document evidence for a major ice advance in Alaska and perhaps across the mid-latitudes of the Northern Hemisphere, which falls between the LGM and major late glacial climate oscillations.

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occurred in the climate system, including the H-1 iceberg discharge (Bond et al., 1992; Hemming, 2004), the possibility of hyper-cold winters in Greenland (Denton et al., 2005), the expansion of closed lakes in the Great Basin (Benson, 1993; Garcia and Stokes, 2002), and the major recession of mountain glaciers in both the Southern (Denton et al., 1999; Schaefer et al., 2006; Strelin et al., 2011; Putnam et al., 2013) and Northern Hemispheres (Schlüchter, 1988; Young et al., 2011; Stroeven et al., 2014). Broecker and Putnam (2012) have divided the Mystery Interval into an older "Big Dry" (17.5–16.1 cal ka BP) and a younger "Big Wet" (16.1–14.5 cal ka BP) periods reflecting global hydrology changes. Here we refine the pattern of glacier advance and retreat during the "Mystery Interval" in southern Alaska and compare this recession to other areas in western North America. To place the existing chronology into context, we delineated the past flow lines of two confluent glacial lobes using drift clast lithology, assessed the distribution of glacial and deglacial landforms, and expanded the existing chronology with radiocarbon ages from terrestrial organics retrieved from basal-lake sediments.

1.1. Regional glacial history

In Alaska, one record of climate change is the signature of mountain glacier fluctuations. At present, the best dated records are from the Brooks Range in northern Alaska (Briner et al., 2005; Badding et al., 2013; Pendleton et al., 2015), Alaska Range in central Alaska (Porter et al., 1983; Briner et al., 2005; Dortch et al., 2010), and the Ahklun Mountains in southwestern Alaska (Kaufman et al., 2003, 2012; Briner and Kaufman, 2008). Advances associated with the Last Glacial Maximum (LGM; 22-18 cal ka BP) are constrained to ~ 21 cal ka BP across the state (Briner et al., 2005; Dortch, 2006; Pendleton et al., 2015; Kaufman et al., 2003). Moraines indicating glacial advances, or stabilizations, inboard of the LGM extent are rarer in the glacial record. Pendleton et al. (2015) collected samples from moraine boulders within the LGM extent in the Brooks Range that place a local advance at ~17.2 ± 10 cal ka BP, and Dortch collected samples from boulders on deposits assigned to the Carlo Stage in the Alaska Range, which yielded exposure ages of ~19-17 cal ka BP. Further abroad, the nearby northern sector of the Cordilleran Ice Sheet achieved a maximum position in the Mackenzie Mountains during the LGM (McConnell Glaciation) at ~18 cal ka BP, while nearby alpine glaciers reached a maximum between 22 and 17 ka (Stroeven et al., 2010, 2014).

1.2. Anchorage Lowlands glacial history

Situated in south-central Alaska, the Anchorage lowland lies on the northern margin of the Cook Inlet (Fig. 1). Continental climate dominates the interior areas, while a maritime climate characterizes southern coastal Alaska (Stafford et al., 2000). The Anchorage lowlands are bounded to the south by the Chugach Mountains and to the north by the Talkeetna Mountains. Modern glaciers found in the Matanuska and Knik valleys in the northern part of the Anchorage lowlands are fed by accumulation areas in the Chugach Mountains, which receive moisture from Prince William Sound and the Gulf of Alaska to the south (Fig. 1).

During the Naptowne Glaciation (Reger et al., 1995), a glacier system, hereafter referred to as the Matanuska-Knik Glacier, sourced in the Chugach and Talkeetna Mountains, advanced across the Anchorage Lowlands forming the Elmendorf Moraine (Fig. 1). The Matanuska Lobe flowed 170 km from the southern Talkeetna Mountains and the northern Chugach Mountains, while the Knik Lobe flowed 120 km from the southern Chugach Mountains. The confluent Matanuska-Knik Glacier flowed across the Anchorage Lowlands to a common ~100 km long terminus marked by the Elmendorf Moraine. Stratigraphically below the Elmendorf Moraine and associated drift lies the Bootlegger Cove Formation (BCF), containing a fossiliferous horizon, as well as marine clay, silt, and sand layers.

The assemblage of macrofossils from the BCF includes gastropods (*Buccinum cf., Buccunum physematum, Cryptonatica clausa, Cryptonatica* sp.), pelecypods (*Clinocardium ciliation, Clinocardium* sp., *Hiatella arctica, Macoma cf., Macoma calcarea, Mya truncata*), and barnacles (*Balanus* sp.). While late glacial estimates of past relative sea level (RSL) are scarce from the Gulf of Alaska, a few control points exist in the Cook Inlet area. Minimum constraints during the start of local deglaciation place RSL at least 10 m higher than present from 19.1 to 18.7 cal ka BP (Mann and Hamilton, 1995; Reger and Pinney, 1995; Shugar et al., 2014). Reger et al. (1995) estimate a minimum of 86 m of isostatic depression in this area at ~17 cal ka BP, with relative sea level being 36 m higher than present prior to 16.3 cal ka BP. Finally, a radiocarbon-dated peat found at 24 m above present sea level places RSL below that level between 16.8 and 14.6 cal ka BP (Rubin and Alexander, 1958).

Radiocarbon ages derived from BCF shells in front of and below the Elmendorf Moraine range from 17.6 to 15.7 cal ka BP, providing a maximum limit on the timing of moraine emplacement, and thus a constraint on the timing of the advance (Schmoll et al., 1972; Reger et al., 1995, Table 1; Fig. 2). Although nine ages provide constraints on the BCF, only one shell was collected directly beneath the Elmendorf drift, and it yielded an age of 17.5–14.3 cal ka BP (W-2389; Schmoll et al., 1972). Technically, this radiocarbon age should be the closest maximum bracket on the deposition of the Elmendorf Moraine, though this age is slightly younger, yet overlapping with the range of ages from the entire assemblage of nine samples (Schmoll et al., 1972; Reger et al., 1995). The implications of using either the single age or the range of ages, as a maximum constraint will be discussed further in the context of our new chronology in the discussion section.

The existing deglacial chronology tracks retreat of the Matanuska-Knik Glacier over 140 km during the late glacial (Table 1; Fig. 2). Organic matter from a kettle, Lorraine Lake, on the Elmendorf Moraine yields an age of 15.4–15.0 cal ka BP (Kathan et al., 2004), constraining the deposition of the Elmendorf Moraine to within the "Mystery Interval" (Denton et al., 2006). Up valley from the Elmendorf Moraine, at the Hay Flats site, organic-rich silt recovered from a borehole yielded an age of 15.3–11.3 cal BP (GX-15241; Combellick, 1990). Further up valley, at Hundred-Mile Lake, ~5 km north of the current Matanuska Glacier terminus, Yu et al. (2008) dated a terrestrial shell 25 cm above the base of a lake core that yielded an AMS age of 13.3–13.0 cal ka BP (ETH-29990). By employing an age model utilizing terrestrial macrofossil and shell pairs at higher stratigraphic levels, Yu et al. (2008) estimated an age of 14.5 cal ka BP for deglaciation at Hundred-Mile Lake. The furthest up valley constraint on ice margin recession comes from the Matanuska Glacier Bog, located 3 km from present-day Matanuska Glacier. Exposed sediment sections in a lateral moraine contain organic sediments underlying till. Williams (1986) collected peat samples that yielded ages of 15.9–15.4 cal ka BP (BETA-11174) and 14.7–13.7 cal ka BP (USGS-2175). Tom Ager of the USGS re-dated this section using accelerator mass spectrometry analysis and found ages of 13.7–13.5 cal ka BP (WW-3623) and 13.4–13.3 cal BP (WW-3618). We note that Ager dated sedge seeds from the lowest peat exposed at the time of sampling, while Williams' (1986) ages are derived from peat samples, which may contain contamination from coal deposits in the Matanuska Glacier catchment. Due to ongoing active erosion at the site, it is uncertain whether Williams and Ager sampled the same horizon. Thus, the offset in ages may be due to the fact that samples were collected from different horizons. The Hundred-Mile Lake and Matanuska