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Late Holocene activity of Sherman and Sheridan glaciers, Prince William Sound, Alaska

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ABSTRACT

Two adjacent glaciers in the Chugach Mountains of south-central Alaska have markedly different histories on decadal to perhaps centennial timescales. Sheridan Glacier has advanced and retreated hundreds of metres during the latest Holocene. Its recent fluctuations have markedly altered local base level of Sherman River, which drains Sherman Glacier and flows into Sheridan Lake. Sheridan Glacier advanced to its greatest extent during the Little Ice Age, raising base level of Sherman River and inducing aggradation there of up to 17 m of sediment. Retreat of Sheridan Glacier formed a series of lakes that have coalesced. As lower lake outlets have become available, base level of Sherman River has dropped, resulting in the evacuation of substantial volumes of sediment from Sherman River valley. In about 2000, the terminus of Sheridan Glacier began to disintegrate; retreat accelerated dramatically in 2010. By 2016, the glacier had retreated an average of 600 m from its 2010 terminus, although some areas retreated up to 1.9 km and others did not retreat at all. Meanwhile, Sherman Glacier continued a slow advance initiated by a rock avalanche that blanketed much of its ablation area in the 1964 Alaska earthquake.

1. Introduction

Glaciers are sensitive to changes in climate, but even adjacent glaciers can respond differently to climatic forcing. Depending on their size, alpine glaciers advance or retreat in response to a prolonged change in temperature or precipitation on timescales of a few years to several decades (Dyurgerov and Meier, 2000; Roe et al., 2017), but they can also be affected by other factors, for example whether they terminate on land or in the sea, or whether wind-blown snow is significant in their accumulation zones.

Nearly all alpine glaciers worldwide retreated in the twentieth century from their maximum Holocene extents achieved during the Little Ice Age (Grove, 2008). Exceptions include some tidewater glaciers in Alaska, whose regimen appears to be strongly affected by non-climatic factors (e.g. Mayo, 1989; Motyka and Echelmeyer, 2003), and some glaciers in the Karakoram that are gaining mass (Gardelle et al., 2012) following substantial mass loss since the Little Ice Age (Owen and Dortch, 2014). The amount of retreat and related glacier thinning is, in many cases, remarkable (e.g. Key et al., 2002; Moore et al., 2009; Bolch et al., 2010; Shugar et al., 2010; Bolch et al., 2012; Clarke et al., 2012) with ice volume losses in excess of 50% since the beginning of the twentieth century. Many small glaciers in marginally glacierized areas have disappeared entirely, for example in Glacier National Park in Montana. In some locations, the geomorphic response to glacier retreat has been swift, with at least one large river having been diverted (Shugar et al., 2017).

Barclay et al. (2013) describe fluctuations of four valley glaciers in coastal south-central Alaska over the past two millennia based on tree-ring and radiocarbon ages on glacially overridden stumps and logs. One of their records, for Sheridan Glacier, spans nearly 2000 years and, as those authors point out, is currently the most complete and best-constrained record of late Holocene glacier activity in Alaska. They identify four distinct phases of glacier advance

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at Sheridan Glacier: ca. 530 to 640, 1240 to 1280, 1510 to 1700, and 1810 to 1860 CE, which are broadly consistent with the main late Holocene intervals of glacier advance in Alaska described by other authors (Wiles et al., 2008; Solomina et al., 2015, 2016). Farther south in the British Columbia Coast Mountains, Hoffman and Smith (2013) describe three periods of advance at Bromley Glacier over the past 2000 years, at about cal. 30–330, 430–660, and 1040–1280 CE, while St-Hilaire and Smith (2017) describe advances at nearby Frank Mackie Glacier around cal. 250–660, 1450–1860, and 1700–1850 CE.

Here we add to this body of work with geomorphic mapping, stratigraphic analysis, and additional radiocarbon ages from the forefields of Sheridan and Sherman glaciers. We also provide a historical analysis of changes in the termini of the two glaciers using airphotos and satellite imagery dating from 1950 to 2016. We argue that Sheridan Glacier blocked Sherman valley several times during the past 1500 years, impounding a lake on each occasion. We show that a remarkably large volume of sediment was deposited in lower Sherman valley during the late Holocene and that much of this sediment has been removed since the Little Ice Age.

2. Regional setting

Sherman and Sheridan glaciers are adjacent, non-surging alpine glaciers in the Chugach Mountains near Cordova, Alaska (Fig. 1). Sherman Glacier is 13 km long, averages 2 km wide, and has a mean downvalley slope of ~2°. Its source area is about 650–1400 m above sea level (asl), and its terminus is at 150 m asl 11 km northwest of Copper River. Sheridan Glacier is 24 km long, has an average width of 2 km, and a mean downvalley slope of ~3°. Its source area is 750–1600 m asl; the glacier terminates in a proglacial lake at 90 m asl 14 km northwest of Copper River. Satellite imagery of the snowline position indicates the accumulation area ratios of Sherman and Sheridan glaciers were about 0.7, until recently. In the past decade, however, they have lowered to about 0.6.

Barclay et al. (2013) conclude that Sheridan Glacier dammed Sherman valley during an advance in the 1650s and 1660s, forming a shallow lake. Zander et al. (2013) inferred the activity of Sheridan Glacier based on cores collected from nearby Cabin Lake. They argue that the glacier briefly advanced from 11.2 to 11.0 cal Ka, and from cal. 1110 to 1180, 1260 to 1540, and 1610 to 1780 CE. There is, at best, imperfect overlap between these records and those of Barclay et al. (2013). The differences between these chronologies may result from the different approaches taken – glacially overridden and outwash-buried trees in the case of Barclay et al. (2013) and lake cores in the case of Zander et al. (2013). Further, Zander et al. (2013) point out that some advances of Sheridan Glacier may not have left a lacustrine sedimentary signature in Cabin Lake because the glacier's meltwater did not always enter the lake.

Sheridan Glacier was named during Abercrombie's (1900) expedition to the Copper River delta in 1884 and was first sketched by Seton-Karr and Bremner (1887, see Fig. 1). Early maps (Grant and Higgins, 1909; Hobbs, 1911) show Sheridan and Sherman glaciers as two tributaries feeding a single terminus, although Tarr and Martin (1914) later stated that Sherman Glacier was independent of its larger neighbour and that previous maps that showed the two as confluent were in error (see also Barclay et al., 2013). Wentworth and Ray (1936) confirmed that the two glaciers were separated by about 460 m in 1931, and they established a photo station near the terminus of Sheridan Glacier. We were unable to locate their photographs; the oldest photographs we found date to the 1950s.

Tarr and Martin (1914, p. 390) mention a mature coniferous forest just outside the terminus of Sheridan Glacier and suggest the glacier advanced prior to 1886 and had not retreated significantly by 1910. They make no mention of a proglacial lake at the Sheridan Glacier terminus or a glacier-dammed lake in nearby Sherman River valley. They do comment, however, that at the time of their survey Sheridan Glacier completely blocked the mouth of the valley draining Sherman Glacier, although it did not override a prominent rock knob on the east side of the Sheridan valley. They also suggest that Sherman Glacier had not advanced significantly in the nineteenth century, unlike Sheridan Glacier.

Based on field observations in 1926, Lutz (1930) describes recently abandoned moraine ridges about 150 m and 300 m from the Sheridan Glacier terminus. He observed 1.2-cm-tall mountain

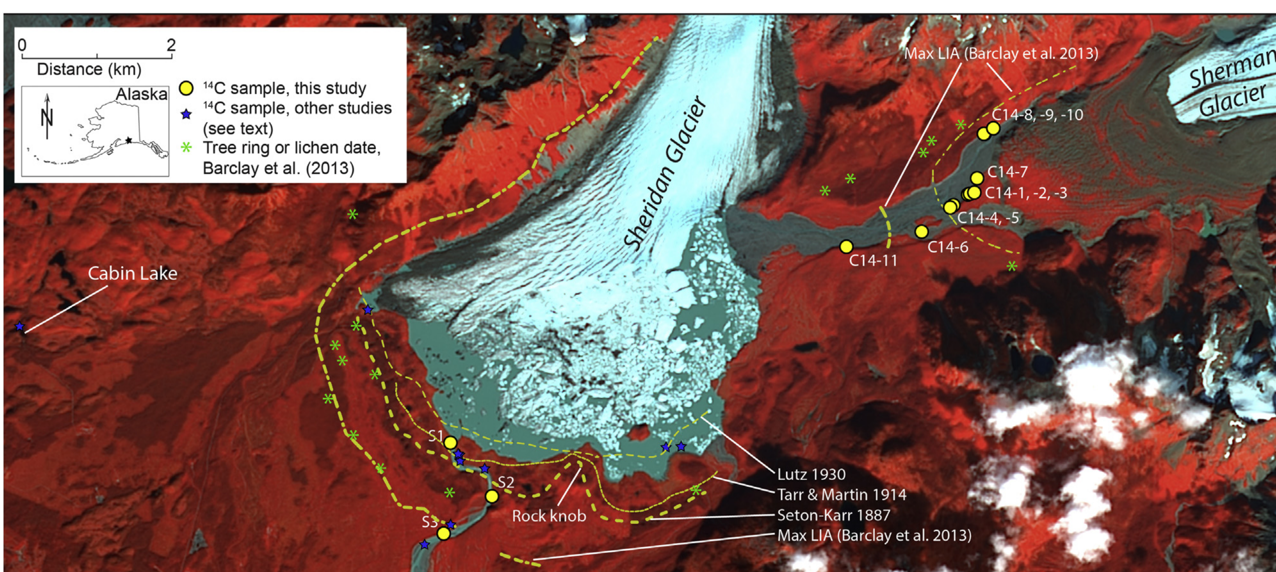

Fig. 1. Map showing the study area, radiocarbon and tree-ring locations, and Sheridan and Sherman glacier terminus positions from previous studies. Background is a Landsat 8 image (NIR-G-B) from September 7, 2015. Blue stars include radiocarbon-dated samples from Tuthill et al. (1968), Barclay et al. (2013), and Zander et al. (2013). Yellow circles represent locations of radiocarbon-dated samples of the current study. Yellow lines are approximate locations of glacier termini described by Seton-Karr and Bremner (1887), Tarr and Martin (1914), Lutz (1930), and Barclay et al. (2013). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)