A Comparison of Glacier Fluctuations on Mount Rainier to Regional Glacial Histories

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Mount Rainier is a large stratovolcano located in Mount Rainier National Park in south-central Washington, USA. Mount Rainier is the highest peak in the Cascade Range, reaching a height of 4,395 meters (14,410 feet). The volcano is flanked by a greater volume of ice than any other mountain in the conterminous United States and has 26 named glaciers on its flanks. As a result, Mount Rainier provides an exceptional opportunity to study glacier fluctuations.

Alpine glaciers are sensitive indicators of environmental change and respond to variations in climate by adjusting their width, length and thickness. A record of glacier fluctuations can be used to infer climate variability at timescales of decades to millennia. Glacial deposits, such as tills that form moraines, provide evidence of fluctuating glaciers since the retreat of the Cordilleran ice sheet in the latest Pleistocene after ca. 16 ka before present (Fulton, 1971) in the Central North American Cordillera (CNAC), which includes the Rocky, Columbia, Coast and Cascade mountain ranges.

Alpine glaciers in the CNAC underwent fluctuations of different magnitudes on a variety of timescales during the late Quaternary period. A comparison of glacier chronologies from the CNAC reveals the following general pattern: in the latest Pleistocene (ca. 16 – 11 ka before present (BP)) recession of the Cordilleran ice sheet was interrupted by episodes of frontal resurgence of the ice sheet and alpine/valley glacier advance. Alpine glaciers were within present glacial limits by the start of the Holocene (ca. 11 ka BP). The early- to mid-Holocene (ca. 11 – 7.5 ka BP) was a period of restricted glacier activity. The start of the Neoglacial interval (ca. 7.5 ka BP) marks a period of glacier re-growth that was characterized by multiple intervals of glacier advance that eventually culminated in periods of relatively extensive glacier cover during the "Little Ice Age" (LIA) in the 17th to 19th centuries (Menounos et al., 2009).

It has been argued that the magnitude and timing of latest Pleistocene and early Holocene glacier fluctuations on northern Cascade volcanoes differ from the general pattern of glacier fluctuations recorded elsewhere in the CNAC. Some researchers have suggested that alpine glaciers reached their maximum Holocene extents in the early Holocene rather than during the LIA on Mount Baker, Glacier Peak, and Mount Rainier, and that the Younger Dryas (YD) climatic reversal at the end of the Pleistocene did not occur on Mount Rainier (Begét, 1981; Heine, 1998; Thomas et al., 2000).

Specifically on Mount Rainier, Heine (1998) identifies two sets of moraines downvalley from LIA terminal moraines. Heine (1998) proposes that the older set of moraines, referred to as McNeeley 1 moraines, originated from an advance that began before 11,300 radiocarbon years before present (^{14}C yr BP) and retreated prior to the YD climatic reversal. To date, there has been no evidence found of a YD advance on Mount Rainier. Heine (1998) interprets the younger set of moraines, referred to as McNeeley 2 moraines, as evidence of an early Holocene advance that began after 9800 ^{14}C yr BP and retreated around 9000 ^{14}C yr BP. The timing of both advances is based on interpretation of lake sediments that contain dated organic matter and tephra, located adjacent to McNeeley moraines.

The apparently incongruous findings on Mt. Rainier and other Cascade volcanoes would suggest that glaciers on large isolated volcanoes responded differently to regional and local climatic shifts compared to glaciers in other topographic settings and/or that climate varied significantly over geographically small areas in the past. However, recent work that revisited proxy evidence on Mount Baker and Glacier Peak suggests that glaciers on these volcanoes were at their *minimum* Holocene extents during the early Holocene and that glacier fluctuations on these volcanoes did not vary significantly from fluctuations elsewhere in the CNAC (Ryane et al., 2008). Incongruous findings may have resulted from incomplete mapping and/or inadequate dating control (Davis and Osborn, 1987; Ryane et al., 2008).

A study in progress that involves a re-examination of proxy evidence associated primarily with lateral moraines may provide new insight into supposed anomalous glacier fluctuations that occurred on Mount Rainier. Lateral moraines are built by accretion of debris from glaciers on their distal or proximal flanks and are in many cases composite features consisting of debris related to multiple advances (Fig. 1). Radiocarbon dating of organics (e.g. branches and stumps) within or separating till sequences allows for the ages of glacier advances to be constrained (Osborn et al., 2007). Although the study of lateral moraine stratigraphy has become more common in North America over the last few decades, this is the first study examining lateral moraine stratigraphy on Mount Rainier.

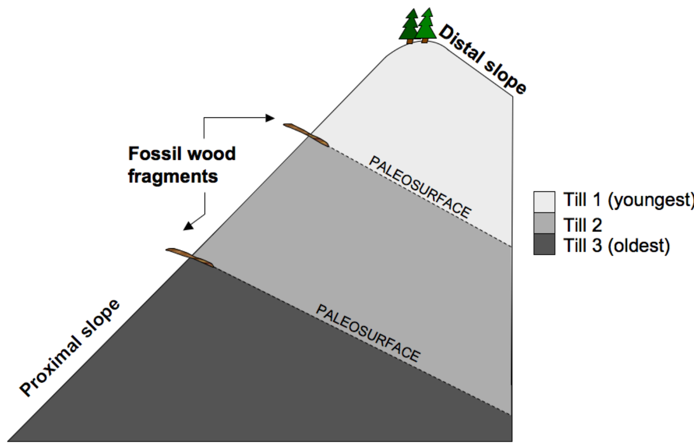

Fig. 1 A lateral moraine composed of multiple tills

Preliminary results from an ongoing study at Mount Rainier that began in 2009 reveal that lateral moraines associated with Nisqually, Emmons and Carbon glaciers, that were previously thought to be composed only of latest Holocene LIA tills, are in fact constructed of tills from multiple advances. Current results are based on six radiocarbon (^{14}C) dates from fossil wood fragments within the Nisqually Glacier lateral moraines, three ^{14}C dates from fossil wood fragments from the left lateral moraine of Emmons Glacier, and two ^{14}C dates from fossil wood in the left lateral moraine of Carbon Glacier (Fig. 2). All eleven ^{14}C dates constrain the timing of glacier fluctuations on Mount Rainier during the past two millennia.

Fig. 2 An example of a fossil wood protruding from the right lateral moraine of Emmons Glacier on Mount Rainier

Two fragments of fossil wood found eight and four meters below the right lateral moraine crest of Nisqually glacier have ages of 480 ± 70 ^{14}C yr BP [1300 – 1630 AD] and 595 ± 15 ^{14}C yr BP [1306 – 1404 AD], respectively. These ages suggest that LIA glacier expansion occurred in the second half of the last millennium after 480 ± 70 ^{14}C yr BP, and that the upper several meters of moraine date from the LIA. A second age yielded by fossil wood in the left lateral moraine, recovered close to the maximum LIA downvalley extent of the Nisqually Glacier, suggests that the LIA advance continued until at least 370±15 ^{14}C yr BP [1450- 1620 AD]. In the left lateral moraine, a sand layer and several wood fragments mark a discontinuity between tills that runs approximately parallel to the proximal moraine flank. Ages of 1670 ± 50 ^{14}C yr BP [250-530 AD], 1700±15 ^{14}C yr BP [260-400 AD], and 1715±15 ^{14}C yr BP [260-390 AD] from three fossil wood fragments along the discontinuity indicate that the glacier advanced after 1670 ± 50 ^{14}C yr BP. This advance corresponds to a period of glacier growth documented elsewhere in the CNAC, which culminated ca. 1500 ^{14}C yr BP and is referred to as the “First Millennium Advance.”

A dated fossil wood fragment in the left lateral moraine of Emmons Glacier suggests that the glacier overtopped the pre-existing moraine after 995±15 ^{14}C yr BP [990 –1120 AD] at the beginning of the LIA. In addition two fossil wood fragments retrieved from the same moraine but further downvalley have ages of 345 ±15 ^{14}C yr BP [1472 – 1633 AD] and 270 ± 50 ^{14}C yr BP [1440 – 1660 AD], suggesting renewed or continued growth of the Emmons Glacier during the middle of the last millennium. Two fossil wood fragments retrieved from the left lateral moraine of Carbon Glacier from a location above the toe of the present glacier date to 1780±40 ^{14}C yr BP [130 – 350 AD] and 1755±15 ^{14}C yr BP [238 – 336 AD]. These dates provide evidence for the expansion of the Carbon Glacier during the First Millennium Advance. Figure 3 presents an interpretation of the timing of glacier fluctuations on Nisqually, Emmons and Carbon glaciers based on the radiocarbon ages of fossil wood discussed above.

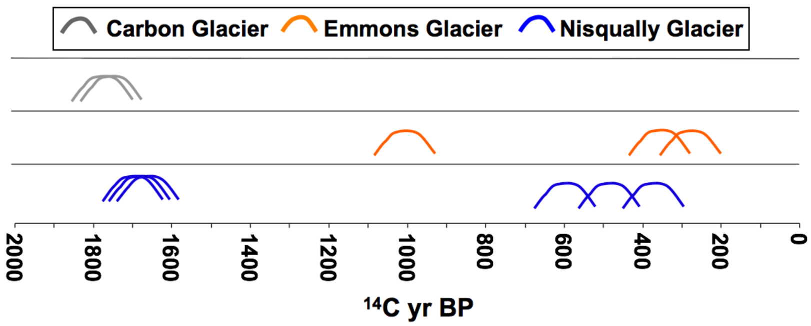

Fig 3. Maximum ages of glacier expansion on Mount Rainier

Efforts to collect lake sediments from proglacial lakes on Mount Rainier will be undertaken in spring 2010, providing an additional form of proxy evidence that can be used to construct glacial histories. Lake sediments may provide a continuous record of glacier fluctuations from the latest Pleistocene to present that may clarify the glacial history at Mount Rainier during the Pleistocene-Holocene transition.

The emerging record of late Holocene glacier fluctuations at Mount Rainier matches the record recently interpreted at Mount Baker and corresponds with records of glacier fluctuations interpreted elsewhere in the CNAC. These findings suggest that the magnitude and timing of climate change events were regional in extent during the late Holocene and resulted in episodes of synchronous glacier fluctuations across the CNAC. We expect that Mount Rainier's glacier history in earlier parts of the Holocene will also be shown to be consistent with regional records.

References

Begét, J.E., 1981. Early Holocene glacier advance in the North Cascade Range, Washington. Geology 9, 409 – 413.

Davis, P.T., Osborn, G., 1987. Age of pre-Altithermal cirque moraines in the central North American Cordillera. Géographie Physique at Quaternaire 41, 365 – 375.

Heine, J.T., 1998. Extent, timing, and climatic implications of glacier advances Mount Rainier, Washington, U.S.A., at the Pleistocene/Holocene transition. Quaternary Science Reviews 17, 1139 – 1148.

Fulton, R.J., 1971. Radiocarbon geochronology of southern British Columbia. Geological Survey of Canada Paper 71-37, 28 p.

Menounos, B., Osborn, G., Clague, J.J., Luckman, B.H., 2009. Latest Pleistocene and Holocene glacier fluctuations in western Canada. Quaternary Science Reviews 28, 2049 – 2074.

Osborn, G., Menounos, B., Koch, J., Clague, J.J., Vallis, V., 2007. Multi-proxy record of Holocene glacial history of the Spearhead and Fitzsimmons ranges, southern British Columbia. Quaternary Science Reviews 26, 479 – 493.

Ryane, C., Menounos, B., Osborn, G., Clague, J., Davis, P.T., Riedel, J., Scott, K.M., Tucker, D.S. and Clark, D., 2008. Holocene Glacier fluctuations on Mt. Baker, Washington USA. Canadian Geophysical Union Annual Meeting.

Thomas, P.A., Easterbrook, D.J., Clark, P.U., 2000. Early Holocene glaciation on Mount Baker, Washington State, USA. Quaternary Science Reviews 19, 1043 – 1046.