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A Probable Sixth Leavenworth Glacial Substage in the Icicle-Chiwaukum Creeks Area, North Cascade Range, Washington

Abstract

In the valleys of the Icicle-Chiwaukum creeks area on the eastern slope of the North Cascade Range, moraines with pronounced constructional topography are representative of the last glaciation, the Leavenworth glaciation. Recession from the Leavenworth maximum was followed by several lesser stillstands or readvances. The Larch Lake moraine at the head of Chiwaukum Creek reaches 1737 m altitude and lies between the Leavenworth V moraine and moraines of Neoglacial age. On and behind the Larch Lake moraine the ca. 11,250-year-old Glacier Peak tephra is found beneath the 6900-year-old Mazama ash. Moraines with preservation, form, and relative position nearly identical to that of the Larch Lake moraine occur in the Icicle Creek drainage beyond the fallout limit of the Glacier Peak tephra. Because the Larch Lake moraine was built prior to late-glacial eruptions of Glacier Peak but after the Leavenworth V substage, it apparently represents a previously unrecognized substage termed Leavenworth VI.

Introduction

Icicle and Chiwaukum Creeks are in the southern Wenatchee River drainage, Chelan County (Figure 1). Along Icicle Creek multiple-end moraines with pronounced constructional topography and associated outwash bodies permit subdivision of the latest glaciation (Leavenworth) into four substages (Long and Porter 1968, Porter 1969). Waitt (1977) found a fourth Leavenworth-age moraine a mile behind the Leavenworth III in lower Icicle Creek valley. Recession from the Leavenworth maximum was followed by several lesser readvances. Glaciers during the Leavenworth I, II, III, and IV substages were long valley glaciers (longest glacier 48 km). During the Leavenworth V substage they were short valley glaciers (longest glacier 12 km in Eightmile Creek).

As described by Porter (1969), the type Leavenworth V deposit is an arcuate moraine complex built by the Rat Creek glacier at the junction of Icicle Creek and Rat Creek. The inner of two moraines forms a continuous loop, crossed by Rat Creek at its lowest point at 549 m altitude, and is the lowest Leavenworth V moraine in Icicle Creek drainage. Distribution of Leavenworth V moraines in Icicle Creek is shown on the location map of Icicle and Chiwaukum Creek drainages (Figure 1).

While mapping Leavenworth V deposits along Icicle Creek, I recognized moraines behind the Leavenworth V moraines but below those in the highest cirques. The highest moraines are very fresh, as are the bedrock surfaces within their confines, suggesting that they are Neoglacial in age. The Leavenworth V and intermediate moraines have a thin soil which supports old-growth conifers, but the Neoglacial moraines have only incipient soil profiles and sparse vegetation. The intermediate moraines could represent either a previously unrecognized sixth Leavenworth substage or a post-Leavenworth advance. A reasonable solution to the problem was found in 1987 in neighboring Chiwaukum Creek valley.

Observations

The maximum length of the Icicle Creek glacier of Leavenworth V age, as measured from Josephine Lake at the source of Icicle Creek, was 10.5 km, compared to 48 km for the Leavenworth I. A moraine thought to be the terminal moraine of the Leavenworth V glacier in Icicle Creek lies at the junction of Icicle Creek and Doughgod Creek at 945 m altitude (Figure 1).

Page (1939) described a moraine-like mass just below the mouth of Glacier Creek that consists of angular schist blocks piled up in transverse fashion across the valley. This mass was thought by Page to be a recessional moraine, or one marking the termination of the glacier occupying upper Chiwaukum Canyon. Leavenworth V ice along upper Chiwaukum Creek apparently terminated here at 1158 m, about 1 km below the mouth of Glacier Creek.

The moraine forms a continuous loop which is incised by Chiwaukum Creek to a depth of about 8 m (visible on USDA serial photographs

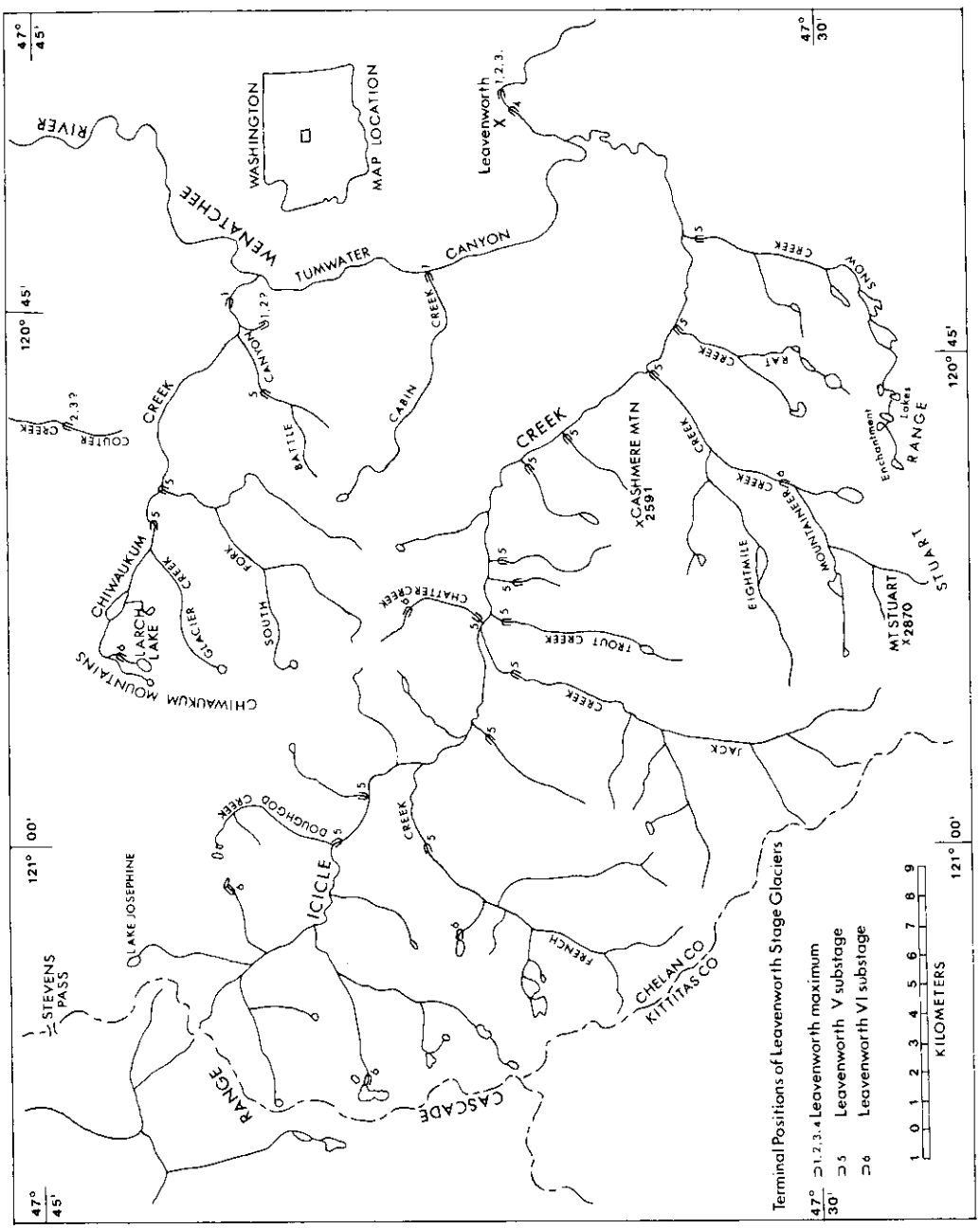

Figure 1. Location of Icicle and Chiwaukum Creek drainages and terminal position of glaciers.

1986 flight). A large swampy area behind the moraine may have been a lake. A well-defined segment of moraine remains against the south valley wall and rises 45 m above the swamp. Evidently the central part of the moraine has been eroded, thereby exposing its broad base, which rises as much as 10m above the swamp and consists of fresh rubble and angular blocks up to 8 m in diameter.

A sharp-crested, well-developed lateral moraine (altitude 1675 m) lies 90 m above the west end of Chiwaukum Lake. This moraine, recognized by Merrill (1966), is here interpreted as the right-lateral moraine of the Leavenworth V glacier. From its (1830 m) altitude, north aspect, and large size of the Jason Lakes cirque, it is clear that ice from Jason Lakes joined the Chiwaukum Creek glacier over Honour Lake at a point only 2 km above the mouth of Glacier Creek (Figure 2). The Glacier Creek glacier joined the Chiwaukum Creek glacier farther downvalley and was the most important tributary.

Larch Lake Moraine

Larch Lake is a tarn at an altitude of 1852 m (6048 ft) behind a multiple terminal moraine in the Chiwaukum Creek valley-head cirque (Figure 2). The Larch Lake moraine reaches an altitude of 1737 m and lies 8 km upvalley from the Leavenworth V moraine. At Larch Lake a yellowish-brown pumiceous tephra layer underlies a thick pale-brown fine ash in a surface locality just behind the innermost moraine. A stratigraphic section was obtained in a wet meadow inside the Larch Lake moraine at the tephra sample site (Figure 2).

As shown in Figure 3, the base of the section is in dark gray, layered lacustrine silt, the deposit of a small lake formerly dammed by the moraine. The silt is overlain by 30 cm of tephra consisting of yellowish-brown and strong brown (when wet) pumice lapilli up to 8 mm in diameter. The tephra is covered by 43 cm of dark gray sand and gravel and 30 cm of black sandy organic sediment. Above is 70 cm of strong orange to yellowish-brown (when wet) fine ash capped by about 30 cm of fine loamy sand with many roots. The unusual thickness of the volcanic ash layers is most likely due to fluvial reworking and concentration of the ashes.

Cup Lake Moraine

As described by Merrill (1966, p. 8), a moraine damming Cup Lake at an altitude of 1964 m (6443 ft), which he provisionally assigned a Neoglacial age, lies in the highest cirque of the Chiwaukum Creek drainage (Figure 4). The Larch Lake moraine separates the Larch Lake cirque from the stream draining Cup Lake. The Cup Lake moraine is very bouldery, exceedingly fresh, and shows little or no soil development. Lichen cover on moraine boulders is discontinuous and other vegetation is absent. The Cup Lake cirque has only small talus cones, in contrast to much larger talus cones just downstream on the east-facing valley wall. Because the Mazama ash apparently is absent on or behind the moraine but is present on the steep slope immediately beyond it, and because there is no hint of a stream notch, the Cup Lake moraine is considered to be late Neoglacial (late Little Ice Age) in age.

Discussion

The tephra layers were identified in the field as Glacier Peak lapilli pumice and Mazama silty ash on the basis of grain size, color, distribution and stratigraphic position. Three principal layers of pumiceous tephras, resulting from multiple eruptions of the Glacier Peak volcano in late-glacial time, cover much of the landscape in the eastern North Cascade Range (Porter 1978). In this area the Glacier Peak tephra, as shown by Porter (1978), consists largely of lapilli pumice; the grain size decreases away from the volcano, with fine ash being predominant only along the distal margins of the deposit and east of the Columbia River. Available ^{14}C dates indicate that the Glacier Peak tephras were deposited about 11,250 year B.P. (Porter *et al.* 1983). The lapilli pumice at Larch Lake could only have come from Glacier Peak, because lapilli pumice layers from any other source have not been recognized in this part of the North Cascades.

At the Larch Lake locality, the 6900-year-old Mazama tephra is a fine volcanic ash, light-yellowish-brown or tan in color when dry, and apparently reworked and concentrated to a thickness of 70 cm. The only volcanic ash megascopically similar to the Mazama that could be mistaken for it is the 3400-year-old Mount St. Helens Yn ash, which generally is found only as a thin silt layer above the Mazama in this part of

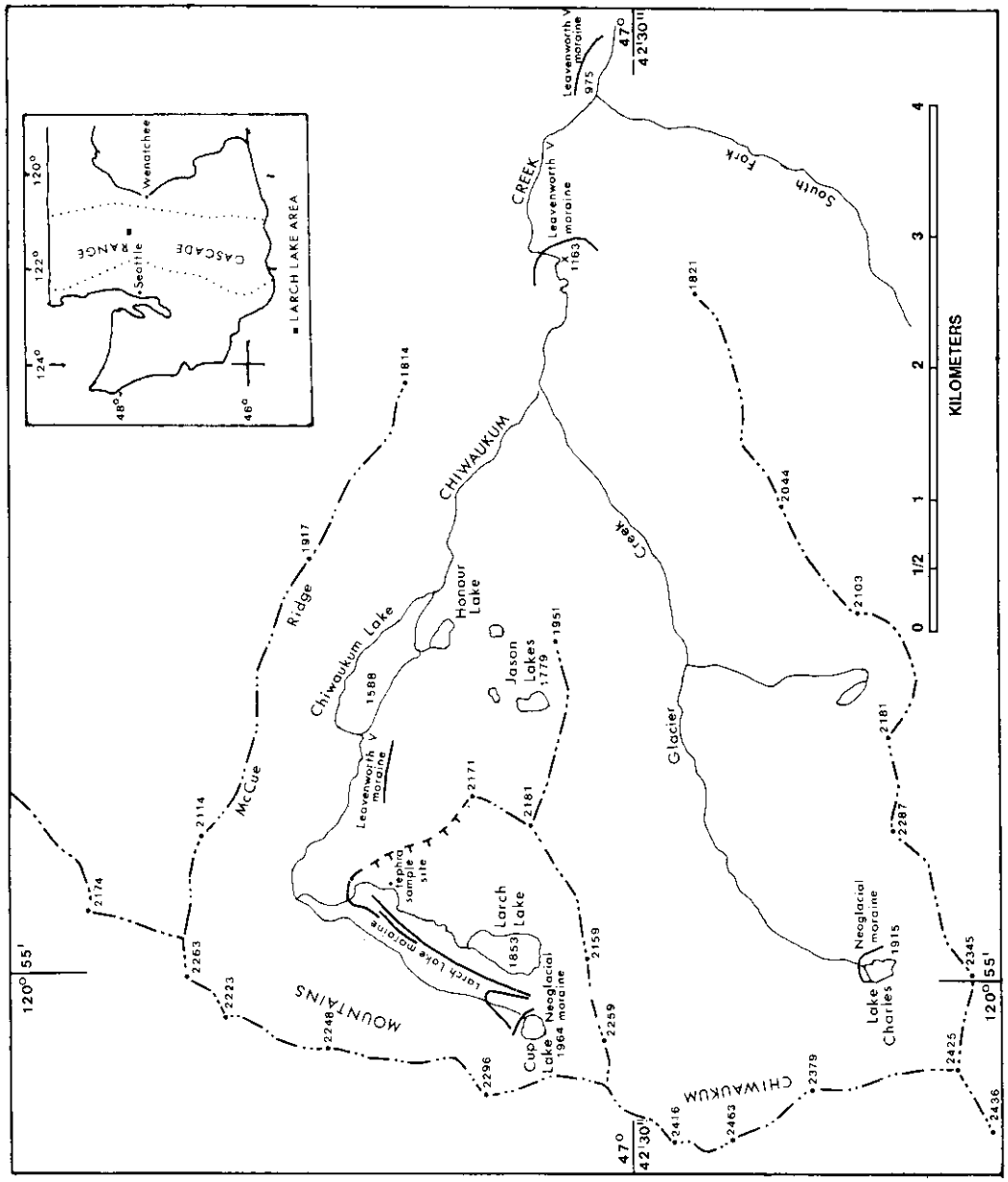

Figure 2. Map showing position of moraines at Larch Lake and vicinity.

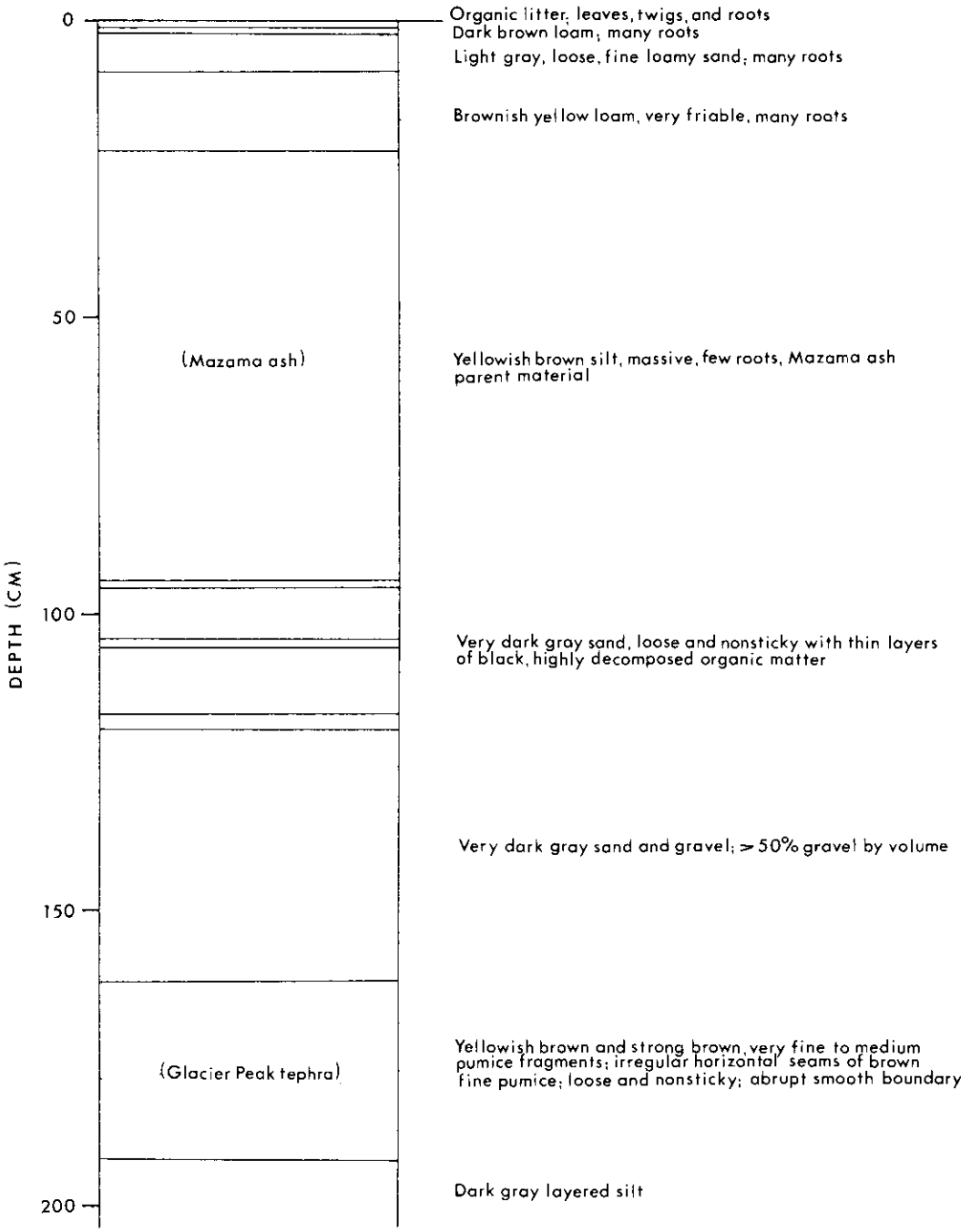

Figure 3. Stratigraphic succession at a wet meadow inside Larch Lake moraine at head of Chiwaukum Creek (See Figure 2 for location).

Figure 4. Looking south to the head of Chiwaukum Creek, with Cup Lake cirque at view center and Larch Lake in cirque at middle left foreground. Tree-covered crest of Larch Lake moraine extends diagonally downward and separates the Larch Lake cirque from the stream draining Cup Lake.

the Cascades. Because the lowermost tephra layer at a depth of 170 cm is an airfall lapilli pumice easily identifiable as from Glacier Peak, the Larch Lake moraine must be older than about 11,250 years B.P.

Waite *et al.* (1982) described two moraine sets in the upper Enchantment Lakes Basin of the Stuart Range, which drains into Snow Creek tributary to lower Icicle Creek (Figure 1). Each moraine records an episode of glacier advance after the end of the Leavenworth glaciation. The outer moraine set, the Brisingamen, lies at 2310 m, about 8 km behind and 1760 m above the type Leavenworth V moraine at the mouth of Rat Creek. Apparently there are no moraines between the Brisingamen moraine and the Rat Creek moraine. The inner moraine set, the Brynhild, lies immediately beyond Snow Creek Glacier. It is only slightly weathered, lacks a soil, and is almost devoid of lichens. The Brynhild moraines evidently postdate Mount St. Helens tephra Wn (500 years old; 1480 AD), which lies only beyond the inner moraine set, and therefore are Neoglacial in age. The Brisingamen moraine is weathered, and on and behind it the 6900-years-old Mazama ash is present beneath the Mount St. Helens Yn (3400 years old) and Wn tephra layers. Tephra from Glacier Peak eruptions was not found in the Enchantment Lakes Basin, which apparently lies south of the recognized limits of Glacier Peak tephra. Waitt *et al.* (1982) noted that despite more than seven millennia of weathering, the rock surface behind the Brisingamen moraine is measurably less weathered than the surface beyond, which was last glaciated during the Leavenworth V (Rat Creek) advance about 13,000 years ago. These data led them to assign a probable age of early Holocene to the Brisingamen moraine.

As the Larch Lake moraine lies between the Chiwaukum Creek moraine of probable Leavenworth V age and the Cup Lake moraine of Neoglacial age, it occupies a relative position similar to that of the Brisingamen moraine. The Brisingamen moraine predates the 6900-year-old Mazama ashfall, whereas the Larch Lake moraine predates the ca. 11,250-year-old Glacier Peak tephra. Thus, while the Larch Lake moraine can be assigned to latest Leavenworth time, the Brisingamen moraine could represent either an early Holocene glacier advance, as suggested by Waitt *et al.* (1982) or, if correlative with the Larch Lake moraine, it could represent a late Leavenworth event.

Conclusions

Whether the Larch Lake moraine represents a stillstand or readvance of Leavenworth ice is not clear, but the moraine's nearly complete closure and position on the northwest-facing threshold of a large valley-head cirque delimits the ice that built it. Because the Larch Lake moraine lies behind the Leavenworth V moraine in Chiwaukum Creek and has Glacier Peak tephra on and behind it, the moraine was built some time before late-glacial eruptions of Glacier Peak volcano about 11,250 years ago, but after the Leavenworth V substage. The Larch Lake moraine therefore probably represents a previously undescribed sixth Leavenworth substage.

Acknowledgments

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Literature Cited

Long, W. A., and S. C. Porter. 1968. Revision of the alpine glacial sequence in the Leavenworth area, Washington (abst), *In* Abstracts for 1967: Geol. Soc. Amer. Sp. Paper 115, p. 338.

Merrill, D. E. 1966. Glacial geology of the Chiwaukum Creek drainage basin and vicinity. University of Washington, Seattle. M.S. Thesis.

Page, B. M. 1939. Multiple alpine glaciation in the Leavenworth area, Washington. J. Geol. 47:785-815.

Porter, S. C. 1969. Pleistocene geology of the east-central Cascade Range, Washington: Guidebook for Third Pacific Coast Friends of the Pleistocene field conference. University of Washington, Seattle.

_____. 1978. Glacier Peak tephra in the North Cascade Range, Washington: Stratigraphy, distribution, and relationship to late-glacial events. Quat. Res. 10:30-41.

Porter, S. C., K. L. Pierce, and T. D. Hamilton. 1983. Late Wisconsin mountain glaciation in the western United States, *In* Porter, S. C. (ed.). Late Quaternary Environments of the United States. Volume 1, The Late Pleistocene. University of Minnesota Press, Minneapolis. Pp. 71-111.

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Waitt, R. B., Jr. 1977. Guidebook to Quaternary geology of the Columbia, Wenatchee, Peshastin, and upper Yakima valleys, west-central Washington. U.S. Geological Survey Open-File Report 77-753, 25 p.

Waitt, R. B., Jr., J. C. Yount, and P. T. Davis. 1982. Regional significance of an early Holocene moraine in Enchantment Lakes Basin, North Cascade Range, Washington. Quat. Res. 17:191-210.