Reports

Sequence of Pumiceous Tephra Layers and the Late Quaternary Environmental Record Near Mount St. Helens

Abstract. *Tephra in lake beds within 40 kilometers of Mount St. Helens was deposited an average of once every 2,700 years over the past 35,000 years, for a total of 13 layers. Times of deposition span the period of the Fraser Glaciation and intervals before and after it, and include the series of climates prevailing when vegetation west of the Cascade Range shifted between a park-tundra type and the modern western hemlock forest.*

Layers of pumiceous tephra from Cascade Range volcanoes are a common stratigraphic feature of lacustrine deposits in Washington (*1*). Their number, age, and thickness reflect the frequency of eruptions as well as the amount and geographic extent of eruptive particulates settling from the atmosphere (*2*). Tephra layers in sediments of lakes and bogs occasionally correspond to, and in some cases supplement, layers observed in upland soils. Times of deposition during the late Quaternary are often determinable by radiocarbon dating of the preserving lake mud or peat. This is less often possible for tephra layers preserved in nonlacustrine soils, where weathering processes are active.

Dating and distribution studies have concentrated on layers of tephra from four Cascade Range volcanoes: Glacier Peak, Mount Rainier, Mount St. Helens, and Mount Mazama. The late glacial and Holocene time spans have been emphasized (*3–6*). Our study provides data for an earlier sequence of late Pleistocene tephra layers in the bed of Fargher Lake, located equidistantly between Mount St. Helens and the Portland-Vancouver population center (Fig. 1). Data presented here and elsewhere provide a basis for establishing the frequency of regional eruptions. This is of significance for the future in view of the effect of the 1980 activity of Mount St. Helens on metropolitan areas in the Pacific Northwest.

Fargher Lake, at an elevation of 200 m, is 12 km north of Battleground (sections 23 to 26, township 5 north, range 2 east) and about 40 km southwest of Mount St. Helens (Fig. 1). The lake bed, exposed by ditching early in this century for the purpose of cultivating crops, covers 170 ha. Surrounding country of low hills reaching elevations of 250 m is part of the western hemlock (*Tsuga heterophylla*) forest zone (*7*), but much of it is now farmed. From the weathered state of glacial drift surrounding the lake bed, it seems that Fargher Lake formed after the wastage of a glacier of pre-Wisconsin age originating in the Cascade Range (*8*).

Seven layers of tephra were found in a 9.3-m core from the south-central part of the lake bed (*9*). The coring site is the general location where Rigg (*1*) found the deepest sedimentary record of seven soundings made along a north-south transect. He intercepted four tephra layers and indicated that no other peat deposit of 327 studied in Washington contained this many. The three additional layers we discovered further substantiate the Fargher Lake deposit as valuable for interpreting the vulcanicity of the Cascade Range.

Five of the layers are less than 1 cm thick (Table 1), which is comparable to the depth of ash that settled in southwestern Washington and northwestern Oregon after the third eruption of Mount St. Helens on 12 June 1980 (*8, 10*). The other two layers are approximately 45 and 12 cm thick and apparently were produced by eruptions of greater magnitude during times of strong northeasterly wind. Lapilli in the 45-cm layer, measuring as much as 12 mm across, are the largest pieces of pyroclastic material in all seven layers.

The tephra layers occur between 1.6 and 6.7 m in the core (Table 1). Preliminary measurements indicate that the associated organic sediments (*11*) range in age from 17,100 ± 650 (RL-1243) to $32{,}250^{+5{,}550}_{-3{,}250}$ (RL-1247) radiocarbon years. This places the times of fallout during and before the Fraser Glaciation (*12*). The lower part of the core does not show a uniform increase in age with depth, and it is suspected that contamination or sources of "old" carbon cause this irregularity. The sequence of adjusted ages for the tephra layers is derived by pollen-stratigraphic correlation with horizons from other regional deposits radiocarbon-dated with greater precision (*13*).

Pollen stratigraphy of key taxa in the core (Fig. 2) relates the layers of tephra to three distinctive assemblage zones and reconstructed environmental settings (*14*). Only one layer was deposited at the time of the early pine (*Pinus*) zone (FL-4); the remainder are associated with two successively younger zones: that of western hemlock and fir (*Abies*) (FL-3) and that of spruce (*Picea*), mountain hemlock (*Tsuga mertensiana*), grass (Gramineae), and composite (Compositae) (FL-2). Both lodgepole (*Pinus contorta*) and western white pine (*P. monticola*) are represented by the profile in Fig. 2—the former the most abundant overall, and exclusively the type in the lower half of zone FL-4. There is some suggestion, from macrofossil evidence in

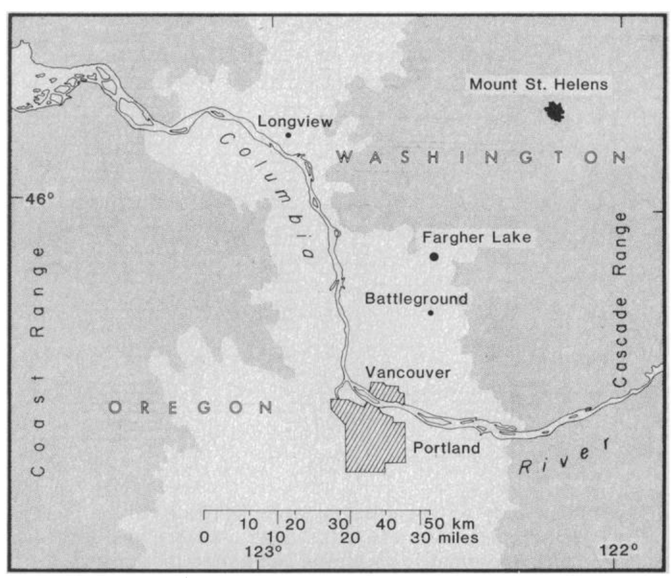

Fig. 1. Location of Fargher Lake in relation to Mount St. Helens and the Portland-Vancouver area. Shaded portions represent upland in excess of 300 m in elevation.

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Table 1. Stratigraphic and environmental data and chronology of tephra layers at Fargher Lake.

Tephra layer	Depth (m)	Thick-ness (cm)	Particle content*	Radiocarbon age (years)	Ad-justed age (*13*)	Pollen zone	Average July temper-ature (°C)	Average annual precip-itation (mm)
TA-1	1.6	< 1	Fine ash, ash (1 mm)	17,100 ± 650 (RL-1243)	17,000	FL-2	12.0	1740
TA-2	2.3	< 1	Fine ash, lapilli (5 mm)	$20,500^{+1,450}_{-1,250}$ (RL-1244)	21,000	FL-2	11.4	1960
TA-3	3.7	< 1	Fine ash, ash (1 mm)	$25,850^{+2,850}_{-2,100}$ (RL-1245)	26,000	FL-2	12.5	2010
TA-4 (top)	4.2	45†	Fine ash, lapilli (5 mm)	$22,450^{+1,300}_{-1,100}$ (RL-1246)	28,000	FL-3	13.6	2070
TA-4 (base)	4.65		Fine ash, lapilli (12 mm)	$32,250^{+5,550}_{-3,250}$ (RL-1247)	28,000	FL-3	12.2	2040
TA-5	5.3	< 1	Fine ash, lapilli (6 mm)	$30,650^{+4,250}_{-2,750}$ (RL-1248)	30,000	FL-3	14.1	2120
TA-6	5.6	12	Fine ash, lapilli (7 mm)	$27,200^{+4,250}_{-2,750}$ (RL-1249)	31,000	FL-3	15.0	1910
TA-7	6.7	< 1	Fine ash, ash (2 mm)	$25,650^{+2,250}_{-1,750}$ (RL-1250)	34,000	FL-4	13.2	1850

*Numbers in parentheses are maximum sizes. †This thickness is approximate.

a 26,000-year core taken at Davis Lake 75 km to the northeast (*15*), that the spruce in zone FL-2 is Engelmann spruce (*Picea engelmanni*). Unless indicated, species for remaining profiles were not determinable. Modern surface pollen analogs (*16*) imply that at the time of FL-4 subalpine fir (*Abies lasiocarpa*) dominated nearby forest, during FL-3 Pacific silver fir (*A. amabilis*) was dominant, and during FL-2 the vegetation consisted of park-tundra.

Average July temperatures and annual precipitation (indicating the environmental conditions during tephra deposition) were reconstructed by using transfer functions (Fig. 2). These were derived by stepwise regression relating leading factors of the modern pollen rain on the northwest coast to averages of meteorological data between 1968 and 1977 (*17*). The highest values for temperature and precipitation at Fargher Lake, 15.0°C and 2120 mm, correspond with zone FL-

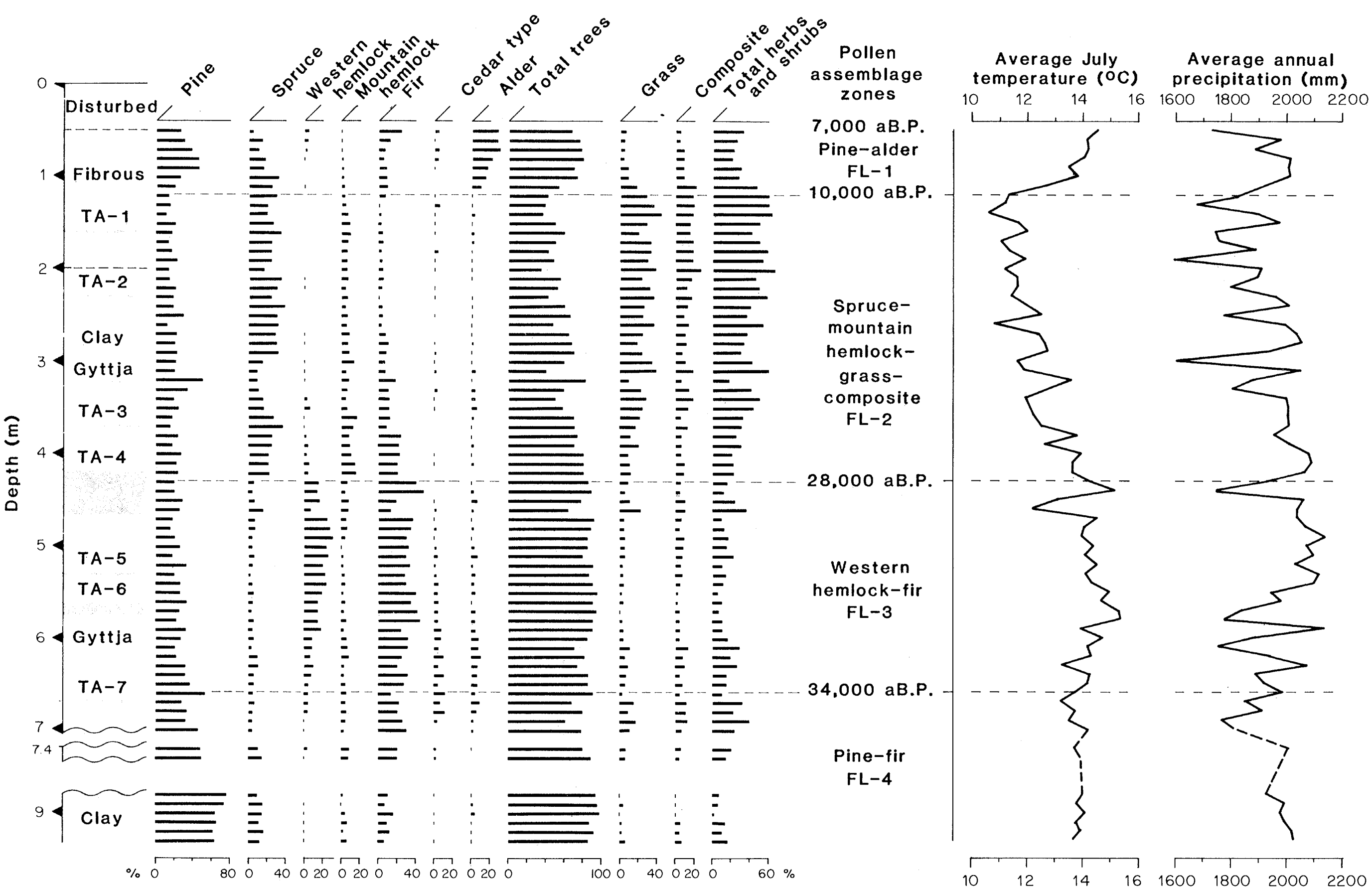

Fig. 2. Sedimentary setting of tephra layers as related to age, pollen stratigraphy, and reconstructed temperatures and precipitation at Fargher Lake. Pollen profiles were selected from 45 taxa identified and counted during analysis. Percentages of total trees and total herbs and shrubs include other representative species in addition to those listed.

3, and the lowest values, 11.4°C and 1740 mm, with zone FL-2. For comparison, present-day averages over the 10-year interval at nearby Battleground are 17.4°C and 1436 mm (*18*). This sequence covers the interval before the Fraser Glaciation (FL-3) and the succeeding Evans Creek and Vashon stades of the Fraser Glaciation (FL-2), when glaciers advanced into the lowland at different times (*19*).

The frequency of pumiceous fallout from Mount St. Helens and other Cascade Range volcanoes along a 100-km stretch to the west of the mountain front can be approximated from available lake records for the past 35,000 years. Between 35,000 and 17,000 years ago at Fargher Lake (Table 1), fallout occurred at intervals of 1000 years (TA-5 and TA-6) to 5000 years (TA-2 and TA-3), or an average of 2800 years. Tephra layers TA-1 and TA-2 were deposited at roughly the same time as a pair of layers in the lower part of a core from Davis Lake (*15*), about 40 km north of Mount St. Helens. Deposition of six younger layers at Davis Lake occurred every 1100 to 1400 years. At Mineral Lake (*20*), 20 km north of Davis Lake, four tephra layers were dated between 17,500 and less than 3700 radiocarbon years. On the basis of their ages and stratigraphic positions, they appear to correspond to certain tephra layers at the other lake sites. In all, the combined records for some 13 tephra layers at Fargher, Davis, and Mineral lakes indicate an average deposition interval of 2700 years over the 35,000-year time span. The data suggest that future ashfalls in western Washington are not likely to take place for at least a millennium.

The sources of the ejecta are, in the main, uncertain. Ash from Mount Mazama (Crater Lake) in Oregon, which erupted about 6700 years ago (*21*), is found at both Davis and Mineral lakes. It is widely distributed in the northwestern United States and in southwestern Canada (*6*). A layer of Mazama ash was not found at Fargher Lake, evidently because of deflation and disturbance caused by cultivation of the lake bed. Pyroclastic deposits on Mount Rainier and Mount St. Helens (*4, 5*) are only partly represented in the sediments of all three lakes. The ash from most of the eruptions, which was distributed eastward, would not likely have settled in the western lowland. At Mount St. Helens (*5*), the volcano nearest to Fargher Lake, pumice layer Cy, dated at about 36,000 ± 2000 radiocarbon years, may correspond with tephra layer TA-7 (Table 1), while any layer of set M, dated at between 18,560 ± 550 and 20,350 ± 500 years, may correlate with TA-1 and TA-2. Until the tephra layers can be shown to be related through more precise dating or by petrographic and chemical analyses, their sources of origin can only be suggested.

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11. In the cases of TA-1, TA-2, TA-3, TA-5, and TA-7, samples for dating are from 2.5 cm above to 2.5 cm below each layer; samples from above and below TA-4 and at the top of TA-6 are each 5 cm thick. Pooling of samples from multiple corings provided the material for dating and for petrographic and chemical study.
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7 July 1980; revised 28 August 1980

Calcite-Impregnated Defluidization Structures in Littoral Sands of Mono Lake, California

Abstract. *Associated locally with well-known tufa mounds and towers of Mono Lake, California, are subvertical, concretionary sand structures through which fresh calcium-containing artesian waters moved up to sites of calcium carbonate precipitation beneath and adjacent to the lake. The structures include closely spaced calcite-impregnated columns, tubes, and other configurations with subcylindrical to bizarre cross sections and predominantly vertical orientation in coarse, barely coherent pumice sands along the south shore of the lake. Many structures terminate upward in extensive calcareous layers of caliche and tufa. Locally they enter the bases of tufa mounds and towers. A common form superficially resembles root casts and animal burrows except that branching is mostly up instead of down. Similar defluidization structures in ancient sedimentary rocks have been mistakenly interpreted as fossil burrows.*

Sublacustrine deposits of calcareous tufa (sinter), which form pavements, mounds, and towers in alkaline lakes throughout the world, become exposed as evaporation reduces lake levels. Three modes of origin have been proposed for such tufa deposits: (i) physicochemical precipitation, (ii) biological precipitation by algae, and (iii) combined physicochemical and biological precipitation. Presently there is general agreement that the basic mechanism is physicochemical, with local algal activity influencing only form and surface texture. This view is supported by observations of tufa and closely related defluidization structures exposed on the south shore of Mono Lake.

Mono Lake is a shallow saline-alkaline remnant of much larger and deeper freshwater glacial lakes. It lies in Mono Basin, a closed structural depression at

0036-8075/80/1128-1009$00.50/0