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WIDESPREAD LATE GLACIAL AND POSTGLACIAL TEPHRA DEPOSITS FROM MOUNT ST. HELENS VOLCANO, WASHINGTON

By DONAL R. MULLINEAUX, JACK H. HYDE, and MEYER RUBIN,
Denver, Colo., Tacoma, Wash., Reston, Va.

Abstract.—Pumice layers composing four different groups of tephra beds (termed "sets"), whose stratigraphy, age, and trend away from Mount St. Helens are fairly well known, are potentially valuable stratigraphic markers in the northwestern United States and adjacent parts of Canada. All four tephra sets are less than about 18,000 yr old. The oldest set described (set S) is between about 18,000 and 12,000 yr old; the most extensive pumice layers of the set, however, probably are no more than about 13,000 yr old. Relatively voluminous layers in the next younger tephra unit (set J) probably range from slightly less than 12,000 to slightly more than 8,000 yr old; in the overlying set Y, the most extensive layers range from about 4,000 to 3,400 yr old. The largest tephra layers in the youngest tephra set described, set W, are apparently all about 450 yr old. All the extensive tephra deposits were carried chiefly east of Mount St. Helens, and the bulk of them form an arc which extends from north-northeast of the volcano clockwise around to the southeast.

Mount St. Helens, in southern Washington (fig. 1), has been an intermittent but prolific source of pyroclastic airfall deposits, called tephra, for more than 35,000 yr. The sequence of many tephra layers, which is being studied as part of an appraisal of volcanic hazards at Mount St. Helens, provides an excellent record of explosive eruptive activity. Some of these deposits are also useful marker beds for stratigraphic correlation and dating because they are distinctive and widespread. One pumice deposit erupted by Mount St. Helens, for example, has been identified in Mount Rainier National Park (Crandell and others, 1962) and in western Canada near Kamloops and Edmonton (Fulton and Armstrong, 1965; Westgate and others, 1970). The thicknesses and distribution of several other pumice deposits near Mount St. Helens suggest that they are similarly widespread and could serve as valuable marker beds in the northwestern United States and adjacent parts of Canada.

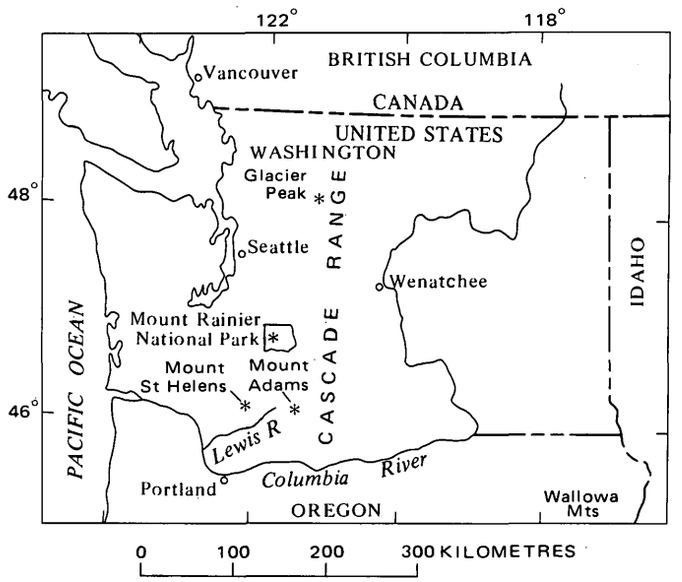

FIGURE 1.—Location of Mount St. Helens, southern Washington.

The content of ferromagnesian minerals in pumice erupted by Mount St. Helens has changed significantly from one eruptive episode to another on several occasions (table 1). As a result the layers can be grouped into several sets, each of which has a characteristic suite of Fe-Mg phenocrysts (Mullineaux and others, 1972). Each of these sets except the youngest contains more than one layer of tephra. A few layers are distinctive enough to be recognized individually and traced from one outcrop to another, but most layers are identifiable only as a part of a certain set. A single

TABLE 1.—*Age and* Fe-Mg *phenocryst content of tephra sets*

Set	Approximate ages [1] (radiocarbon years)	Fe-Mg phenocrysts	
		Predominant	Subordinant
T	150	Hypersthene, hornblende.	Augite.
W	1,150–450	----do----------	None.
B	2,500–1,600	Olivine, augite, hypersthene.	Do.
P	3,000–2,500	Hypersthene, hornblende.	Do.
Y	4,000–3,000	Cummingtonite, hornblende.	Biotite (in layer Yb).
J	<12,000, >8,000	Hypersthene, hornblende.	None.
S	<18,000, >12,000	Cummingtonite, hornblende.	Hypersthene.
Unnamed	37,600–18,000	Cummingtonite, hornblende, biotite.	Do.

[1] Years before 1950. Age of pumice here called set T determined from tree-ring counts by Lawrence (1954). Younger date for set W determined from tree-ring counts by Crandell (1971). All other dates are in radiocarbon years.

letter, such as Y, has been assigned to each set as a whole. Tephra layers that can be individually recognized and traced for some distance are further designated by adding a second letter—for example, layer Yn.

Selection of the letters used has no significance other than convenience. When the sets are arranged according to age, for example, the sequence of letters does not follow an alphabetical or other ordered sequence. The system we use arose during study of tephra in Mount Rainier National Park, where names for important marker beds were needed long before the tephra study was complete. The tephra layers recognized early in that study were known to be only a fraction of the total number of layers present, and no orderly sequence for all the tephra deposits could be established at that time. Instead, letters were assigned arbitrarily as needed, commonly from some word used in field descriptions. Thus, the letter Y was used for a yellow pumice, and W for a white one. Similarly, the second letter assigned to a distinctive layer within a set may be taken arbitrarily from field descriptions—for instance, layer Yn is a pumice bed in set Y that extends generally northeast of the volcano.

This report presents preliminary data on the stratigraphy, distribution, and age of four tephra sets, namely, sets S, J, Y, and W, which are expected to form recognizable marker beds over broad areas. The other tephra sets listed in table 1 either have been less fully studied or form less useful marker beds. Tephra units older than set S range in age from at least 37,600 to less than 20,000 radiocarbon years, but neither their stratigraphy nor their distributions have yet been determined. Set P, a preliminary description of which is presented in another report (Crandell and Mullineaux, 1973), is relatively thin and may be difficult to distinguish from ash beds from other volcanoes in the Cascade Range. Set B consists largely of scoria layers that are of relatively local extent. Set T contains only one moderately extensive pumice layer and has been described briefly in previous reports (Mullineaux, 1964; Mullineaux and Meier, 1965; Okazaki and others, 1972).

DESCRIPTION OF TEPHRA DEPOSITS

Tephra-set S

Set S consists chiefly of beds of yellow to brown pumice lapilli and ash with lesser amounts of lithic fragments. Ten km east-northeast of the present summit of Mount St. Helens, the set as a whole is as much as a metre thick and contains several separate lapilli beds (fig. 2). Irregularly stratified beds of chiefly ash- and lapilli-size pumice that make up the lower part of the set are more variable in thickness than most tephra layers around Mount St. Helens; these deposits may have been reworked after initially falling onto snow or ice. The middle part of the set contains at least three thin, relatively well defined beds of lapilli that are separated by even thinner ash beds. The upper part consists of two relatively coarse and thick lapilli layers. The lower of these, designated "Sg," commonly is 25–50 cm thick at 10 km from the volcano, and the upper, designated "So," is 10–20 cm thick.

Set-S tephra has been identified in virtually all directions from Mount St. Helens, but most of it lies in the quadrant extending from northeast to southeast of the volcano. Although one thin bed in the middle part of the set extends mainly southeast, the other well-defined layers in the set extend chiefly east-northeast from the volcano. The most voluminous beds of this set are the layers Sg and So, and they probably extend for considerable distances east and northeast of Mount St. Helens.

Close to Mount St. Helens, set S can be distinguished fairly readily in the field from younger pumice deposits; pumice in set S generally is lighter in color and finer grained than pumice in the overlying set J, and more weathered than pumice in set Y and younger deposits. Set S is less readily distinguished from older pumice deposits, and is identified in the field chiefly by its stratigraphic position under set J. It is separated stratigraphically from set J by lithic pyroclastic-flow deposits in some places, and elsewhere by lithic tephra and eolian material that commonly form a massive bed of silt and fine sand. Set S is separated from the next older pumiceous tephra unit by two beds of fine-grained lithic tephra and eolian material, each of which has a weak soil profile developed in it.

Ferromagnesian mineral suites further distinguish

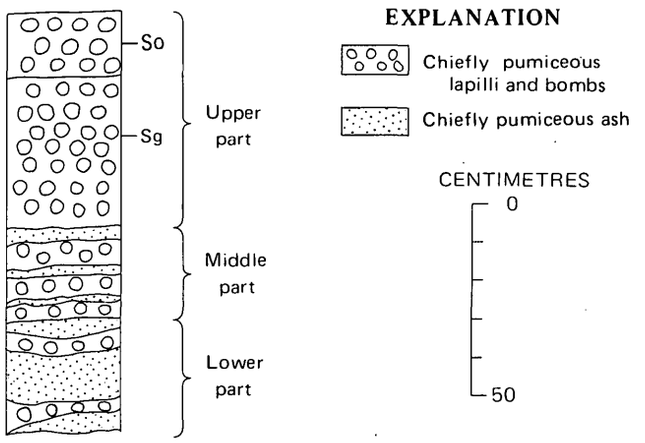

FIGURE 2.—Columnar section of set S, at a point about 10 km east-northeast of the summit of Mount St. Helens.

pumice in set S. The predominant Fe-Mg minerals in set-S pumice are cummingtonite and olive to brown hornblende, but pumice in this set typically also contains small amounts of hypersthene (table 1). The abundance of cummingtonite distinguishes set S from all younger pumice except that of set Y; set S can be distinguished from set Y by the presence of hypersthene, as well as by the character of its hornblende constituent, which is browner and has a higher refractive index than that found in the younger set. Likewise, the pumice in set S differs from most older pumice by the virtual absence of biotite, an abundance of brown rather than green hornblende, and the greater abundance of hypersthene.

Four radiocarbon dates for samples from pyroclastic-flow or lahar deposits that overlie layer So east of the volcano establish that set S is older than about 12,000 yr; stratigraphic positions of two of these dated samples are shown in figure 3. An age of less than 18,500 yr is indicated by a dated charcoal sample taken from another pyroclastic flow that underlies the set (fig. 3). One other dated charcoal sample suggests that part of the set is approximately 13,000 yr old; a radiocarbon date of 13,100±350 yr has been obtained for charcoal from a pyroclastic flow south of the volcano whose constituent pumice is like that in set S, and which underlies several thin beds of set-S pumice. This was a hot pyroclastic flow, which may have been erupted at the same time as some set-S tephra. Thus, the set-S layers above the dated pyroclastic flow, although they have not been correlated with individual layers elsewhere, show that at least part of the set is no more than about 13,000 yr old. At present, it seems likely that the voluminous layers Sg and So are about 13,000 yr old or perhaps even slightly younger.

Tephra-set J

Near Mount St. Helens, set J consists chiefly of reddish-brown to yellow pumice lapilli and small bombs. Southeast of the volcano three separate beds can be recognized in the set (fig. 4), and at least two beds can be distinguished to the northeast. Bedding in the set is obscure in most places, however, and we have not yet been able to trace individual layers from the southeast side of the volcano to the northeast.

Set J has been identified as a whole from north of the volcano clockwise around to the south. It is thickest in the quadrant that extends from the northeast to southeast; in those directions it is nearly a metre thick at a distance of about 10 km from the summit of Mount St. Helens and probably extends for considerable distances over a broad arc. Further southeast of Mount St. Helens, set-J pumice is as much as 20 cm thick at a distance of 40 km.

Near the volcano, pumice in set J commonly is darker and redder than pumice in sets S and Y. In addition, a brown oxidized zone is developed in the upper part of set J, and it commonly is separated from set Y by a thin discontinuous layer of charred vegetation.

The only common Fe-Mg minerals in set-J pumice are hypersthene and hornblende. Thus, this pumice differs markedly from that in sets S and Y in its

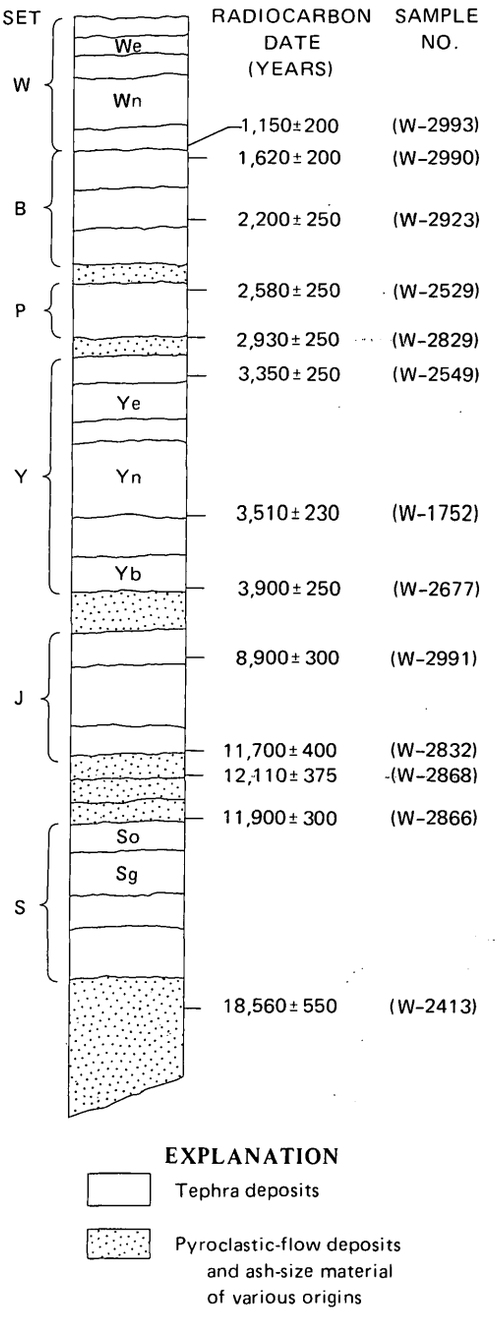

FIGURE 3.—Diagrammatic section showing stratigraphic positions of some key radiocarbon samples used to determine ages of tephra sets.

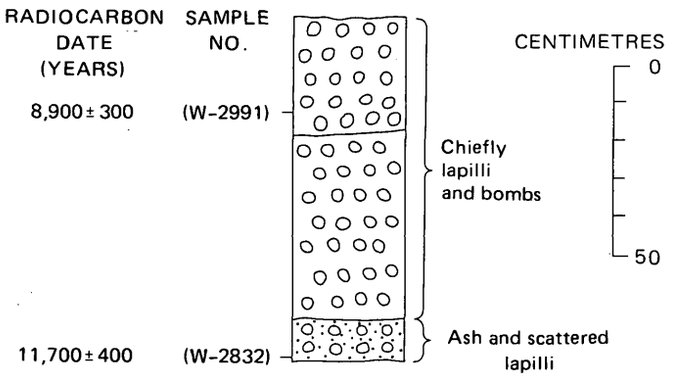

FIGURE 4.—Columnar section of set J, at a point about 10 km southeast of the summit of Mount St. Helens.

abundance of hypersthene and absence of cummingtonite. It is similar in mineral content to pumice in set W, but the hypersthene of set J has a lower refractive index (see "Tephra-set W"). In Fe-Mg mineral content and character of glass, it is also similar to pumice from Glacier Peak that is reported to be about 12,000 yr old (Fryxell, 1965); however, according to R. E. Wilcox and J. A. Westgate (oral commun., 1973), set-J pumice can be distinguished from that of Glacier Peak by their differing compositions of glass as determined by electron-probe methods.

Tephra beds in set J may have been the products of eruptions at widely spaced intervals throughout most of the period from slightly less than 12,000 yr to slightly more than 8,000 yr ago. A radiocarbon date of 11,700±400 yr for a sample from the basal bed of the set on the southeast flank of Mount St. Helens may approximate the eruption of that fine-grained layer (fig. 4). A date from the upper bed of set J there (fig. 4) shows that one coarse and thick pumice bed had been erupted about 9,000 yr ago, and another somewhat before that time. Two other dates from set-J pumice on the northeast flank of the volcano indicate that two more set-J eruptions occurred as late as about 8,430 (W-2702) and 8,300 (W-2587) yr ago. These two dates from the northeast flank, when compared to the one date in the upper layer of set J on the southeast flank of the volcano, also suggest that all the coarse and thick pumice on the northeast is younger than the uppermost coarse bed on the southeast side of the mountain. It has not yet been possible, however, to confirm their stratigraphic relation in the field.

Tephra-set Y

Set Y, the thickest and coarsest of the late glacial and postglacial tephra units, consists of many beds of white to yellowish-brown pumice and a few beds of lithic fragments. It includes more than a dozen discrete layers of pumice (fig. 5), two of which have been

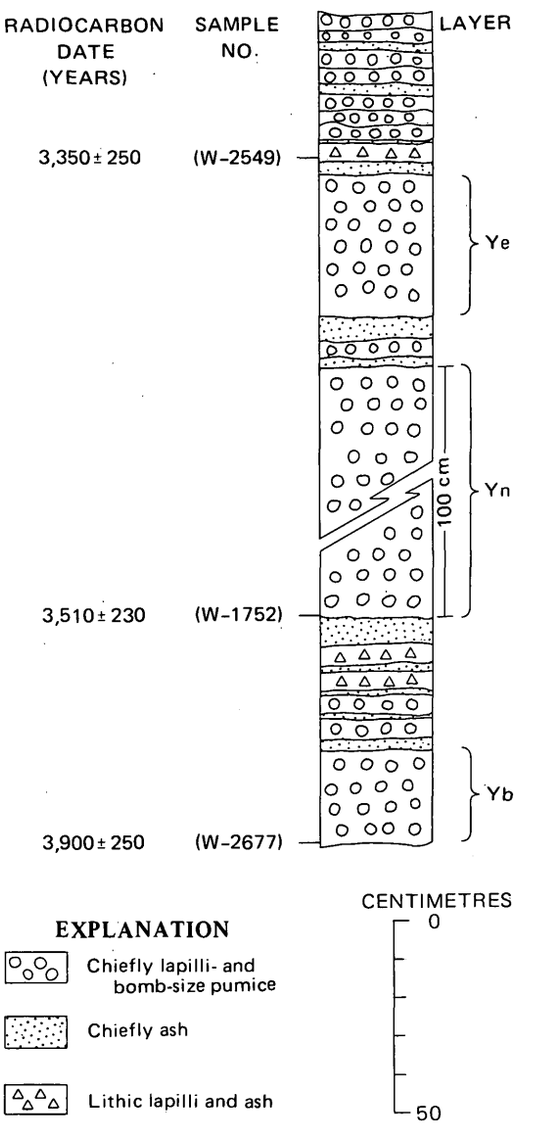

FIGURE 5.—Composite columnar section of set Y at a distance of about 10 km from the summit of Mount St. Helens. Thickness shown for layer Ye occurs east-southeast of the volcano; thicknesses for other layers are to the northeast.

found hundreds of kilometres from the source (fig. 6).

The layer designated Yn, the thickest and coarsest bed in the set, extends in a long narrow lobe that leads north-northeastward from the volcano (fig. 6). Within about 10 km of the mountain, it commonly consists of a metre or more of bombs and lapilli along the thickest, axial part of its lobe. At a distance of 80 km, layer Yn makes up a bed of lapilli and ash as thick as 30 cm in the southwestern part of Mount Rainier National Park, where it is the "layer Y" of Crandell, Mullineaux, Miller, and Rubin (1962). Still farther northeast, it has been identified near Kamloops in British Columbia (Fulton and Armstrong, 1965), and in Alberta where it is about 900 km from its

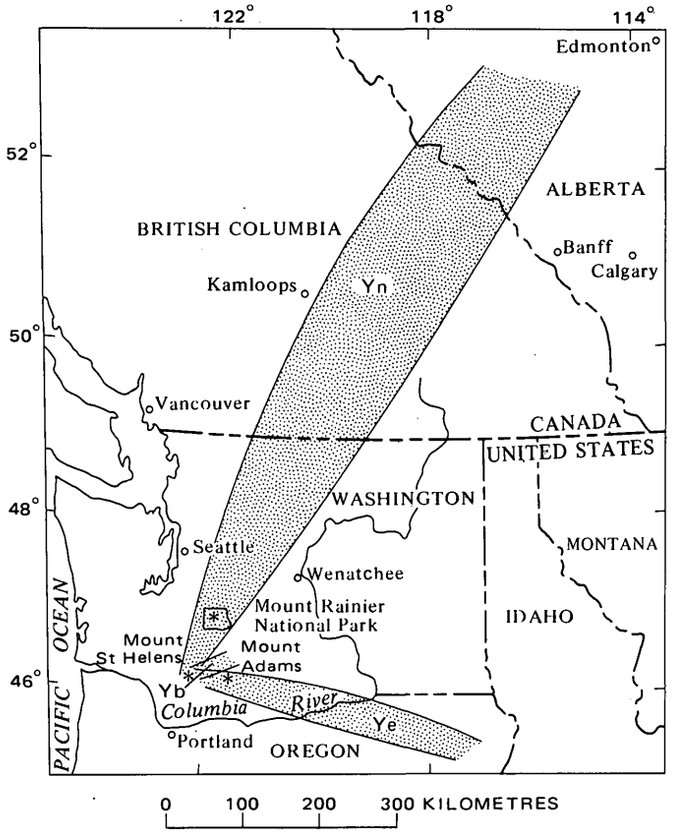

FIGURE 6.—Minimum distribution inferred from known occurrences of layers Yb, Yn, and Ye. Information from Crandell, Mullineaux, Miller, and Rubin (1962); Westgate, Smith, and Nichols (1970); and Borchardt, Norgren, and Harward (1973).

source (Westgate and others, 1970).

Layer Ye is a coarse thick bed that extends mainly east-southeast from the volcano (fig. 6). It is about 35 cm thick at a distance of 10 km from the summit, and as much as 20 cm thick at a distance of 50 km. Layer Ye probably is the 5-cm-thick "Mount St. Helens Y ash" identified in northeastern Oregon, at a distance of about 400 km from Mount St. Helens (Norgren and others, 1970; Borchardt and others, 1973).

A few other beds of set Y have also been found at considerable distances from Mount St. Helens. Layer Yb, for example, which lies at the base of the set northeast of the volcano, is as much as 5 cm thick at a distance of 50 km northeast of the mountain. In addition, at least two of the beds that are above layer Yn are ½–1 cm thick in Mount Rainier National Park at a distance of 80 km from their source (Mullineaux, 1974).

Set-Y pumice near Mount St. Helens is fairly easily distinguished from older pumice deposits by its relatively firm, unweathered condition. Set-Y pumice is stained yellowish brown, and this color distinguishes it from most younger pumice deposits, which are white. In addition, set-Y pumice differs from younger Mount St. Helens pumice and from other known tephras from Cascade Range volcanoes by its abundance of cummingtonite. Set-Y deposits far from the volcano might be differentiated from older cummingtonite-bearing tephras of Mount St. Helens by the absence of hypersthene in pumice fragments; however, because hypersthene is common as a contaminant in ash beds, recognition of ash beds of set Y may depend on their stratigraphic position. The Fe-Mg mineral content of most beds in set Y does not vary appreciably; layer Yb, however, contains small amounts of biotite (table 1).

Charcoal dated at about 4,000 and 3,000 radiocarbon years (fig. 3) underlies and overlies, respectively, set-Y pumice directly east of the volcano. Two other dates that bracket the two most extensive layers, Yn and Ye, indicate that they are between about 3,500 and 3,350 radiocarbon years old (fig. 3). Still other dates that are pertinent to the age of layer Yn include one of 3,500 yr from below layer Yn at Mount Rainier (Crandell and others, 1962); another of about 3,500 yr, regarded as from "the same stratigraphic position" as that same layer in Alberta (Westgate and others, 1970); and three dates of about 3,400 yr, two from below the layer and another from above it, in British Columbia (Fulton, 1971). Layer Yn originally was arbitrarily assigned an age of 3,200 yr on the basis of two limiting radiocarbon ages of about 3,500 and 3,000 yr (Crandell and others, 1962); the dates now available indicate that it is slightly older, perhaps about 3,400 radiocarbon years. However, curves that compare radiocarbon dates to calendar ages as indicated by bristlecone-pine tree rings suggest that organic material as young as about 3,600 calendar years or as old as about 4,000 calendar years could give a radiocarbon age of between 3,500 and 3,350 yr (Suess, 1970). Thus, the ages assigned to these tephra layers must be regarded as approximate, and the eruption of layers Yn and Ye might have been separated by a longer period of time than is indicated by the 3,500- and 3,350-year radiocarbon dates.

Tephra-set W

Set W consists mostly of a group of coarse white to light-gray pumice beds. The basal coarse bed of the set, however, is made up of relatively dense fragments of lapilli and ash (fig. 7). It is overlain by at least five pumice layers, two of which are known to extend many tens of kilometres from the volcano. Layer Wn, the coarsest and thickest pumice layer in the set, extends mostly to the northeast (fig. 8). At a distance of 10 km from Mount St. Helens, it consists chiefly of bombs and lapilli a metre or more thick; at a

distance of about 80 km, in the southeastern part of Mount Rainier National Park, the layer is as much as 8 cm thick and consists of small lapilli and ash. In the park, it is the "layer W" of Crandell, Mullineaux, Miller, and Rubin (1962).

Another relatively thick bed in the set, layer We (fig. 7), extends east of the volcano (fig. 8). It is about half a metre thick at a distance of 10 km from Mount St. Helens, and as much as 5 cm thick 50 km east of the volcano. This, or perhaps another, similar, bed of set W, is also 20–25 cm thick on the south flank of Mount St. Helens. The other pumice beds in the set are much thinner, and seem to be distributed mostly northeast and east of the volcano. Tephra of set W is known as far as 100 km northeast of Mount St. Helens (Mullineaux and Meier, 1965; Okazaki and others, 1972), and as far as 70 km east of the volcano (J. A. Norgren, written commun., 1971).

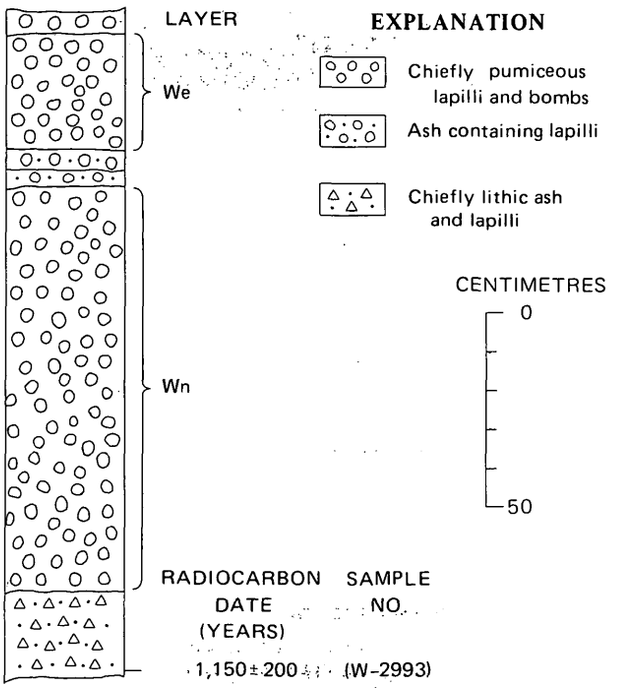

FIGURE 7.—Composite columnar section of set W at a distance of about 10 km from the summit of Mount St. Helens. Thickness shown for layer We occurs east of the volcano; thicknesses for other layers are to the northeast.

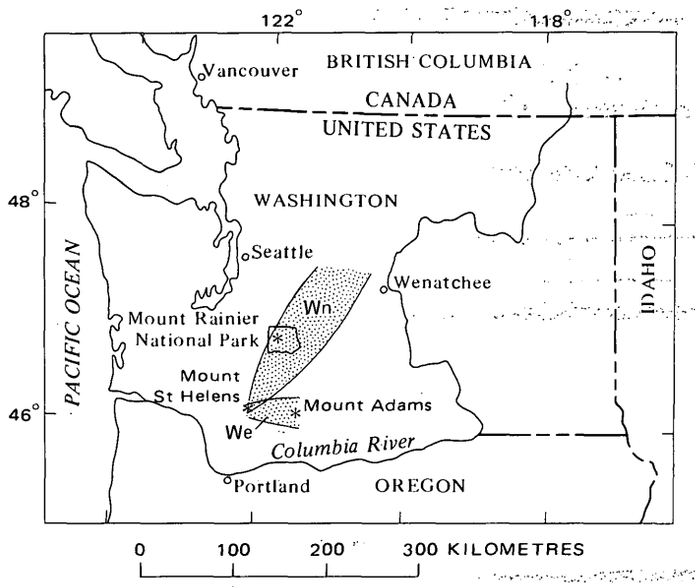

FIGURE 8.—Minimum distribution of layers Wn and We inferred from known occurrences

Set W is distinguished in the field from older pumice deposits of Mount St. Helens chiefly by color and stratigraphic position. It can also be readily differentiated from set Y by its hypersthene content and from pumice in set T by the absence of augite (table 1). Set W contains the same Fe-Mg mineral suite as set P (table 1), but generally is thicker and coarser. In addition the lowest refractive index of hypersthene in set W pumice is higher than 1.70, whereas that of hypersthene in set P is less than 1.70.

Set-W tephra beds appear to range from slightly more than 1,000 to about 450 yr old. A single charcoal sample from the basal coarse bed in the set has been dated as 1,150±200 yr old. Vegetation was reestablished on top of that basal bed before eruption of the overlying layer Wn, which has been dated as about 450 yr old by tree-ring counts (Crandell, 1971). Set W beds younger than layer Wn probably were erupted just shortly after layer Wn, for a tree as old as 435 yr has been found growing over layer We.

USE OF MOUNT ST. HELENS TEPHRA LAYERS FOR DATING AND CORRELATION

The tephras from Mount St. Helens should be especially useful for deciphering and dating glacial and volcanic sequences and for correlating those sequences from place to place. Because these tephras occur on and are interbedded with a wide variety of natural and artificial deposits, they can also be useful in geomorphic and archeologic investigations.

Tephra-set S in the Lewis River valley southeast of Mount St. Helens provides an example of application of these tephras to glacial studies. In this area, the middle and upper parts of set S occur on an outwash terrace formed during or shortly after the maximum stand of a valley glacier of Fraser age (Crandell and Mullineaux, 1973, p. A12). The lower part of the set is missing from the terrace, even though conditions for preservation seem to be favorable; thus, the outwash deposits presumably are younger than the lower part of the set, but older than the middle part. Close

dating of the tephra would provide a relatively precise date for the maximum stand of the glacier in the Lewis River valley. Moreover, determination of the distribution of various parts of the set on glacial deposits in nearby valleys would allow correlation of glacier positions from one valley to another. At progressively higher altitudes above valley floors eastward from Mount St. Helens, the upper beds of set S become discontinuous or absent altogether, and from their distribution it may be possible to determine approximately the extent of alpine glaciers at the time those tephra layers fell.

Knowledge of each of the younger tephra sets described can also be applied to glacial problems in the Cascade Range. Set-J tephra is a marker deposit that separates late Pleistocene from Neoglacial deposits wherever the tephra can be identified, and sets Y and W have been used to subdivide Neoglacial drift as far north as Mount Rainier National Park (Crandell and Miller, 1964). Discovery of set-Y tephra in the glaciated Wallowa Mountains of northeastern Oregon (Norgren and others, 1970; Borchardt and others, 1973) indicates that the tephra might be helpful in unraveling the Neoglacial sequence there.

The tephras may be very useful for determining the ages, especially the minimum limiting ages, of young lava flows, which do not commonly include carbon from which direct dates can be obtained. In many places in the Cascade Range of southern Washington, the four tephra sets described should allow subdivision of late glacial and postglacial lavas into at least four categories: those older than about 8,500 yr, those younger than 8,500 but older than 3,000–4,000 yr, others that are younger than 3,000 but older than about 500 yr, and still others that are less than about 500 yr old.

East of the Cascade Range, the Mount St. Helens tephra deposits provide information applicable to a variety of problems in the Columbia River basin. Three ash layers that are strongly similar to set-S tephra, for example, occur in the upper part of a widespread lacustrine fill in that basin. Confirmation of the three layers as part of set S, and closer dating of that tephra set, would provide a critical date for the geomorphic history of that region. Set-J tephra may be useful for unraveling the history of draining of the same lake and incision of the lake beds; tephra layers of sets Y and W have already been identified on younger deposits in the area (Fryxell, 1972).

Although the limits of distribution of these tephra sets are not yet known, the extent of a few layers such as Yn and Ye indicates that they could prove useful as much as several hundred kilometres from their source.

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