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Volcanic ash in organic-rich surficial uranium deposits of northeastern Washington and westernmost Nevada

by

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Abstract

Volcanic ash originating from eruptions of Mt. Mazama, Crater Lake, Oregon is identified at two new localities in the western United States. Diagnostic measurements include neutron activation analyses and refractive index measurements of separated glass shards, and petrographic observations of hornblende phenocrysts. The ash layers occur in organic-rich surficial uranium deposits and their identification provides a chronologic datum which aids ongoing studies of the sedimentary and paleoenvironmental history of the deposits. Subtle but analytically significant compositional differences between glass separates from the two localities, and distinct differences in the habit of hornblende phenocrysts suggest that the Washington locality contains ash from the climactic eruption of Mt. Mazama 6700-7000 y B.P., whereas the Nevada locality contains ash from an eruption that immediately preceded the climatic eruption.

Introduction

The climactic eruption of Mount Mazama at Crater Lake, Oregon, spread air-fall ash over much of the northwestern United States and southwestern Canada (Fig. 1). Numerous radiocarbon ages of organic material from within, or immediately above or below the ash indicate that the eruption occurred between 6700 and 7000 years ago (Sarna-Wojcicki et al., 1983). The wide distribution of the Mazama ash makes it a particularly useful time and stratigraphic marker for Holocene deposits, provided that it can be properly identified and correlated. Fortunately, the Mazama ash is readily distinguished from other widespread late Pleistocene and Holocene ashes on the basis of glass chemistry and refractive index, and phenocryst mineralogy (Powers and Wilcox, 1964; Wilcox, 1965; Borchardt et al., 1971; Sarna-Wojcicki et al., 1983). Sites where these measurements and/or radiocarbon dating have identified Mazama ash are plotted in Figure 1. Recognition of the Mazama ash and its use as a chronologic datum or stratigraphic marker at these sites has contributed to studies in geology, archaeology, palynology, and pedology.

In this report, two new sites of Mazama-like ash are identified using glass chemistry and refractive indices,and petrographic observations. The new sites are within the presently identified boundaries of the Mazama ash fallout (Fig. 1), and each of the new sites is within 25 km of a previously identified

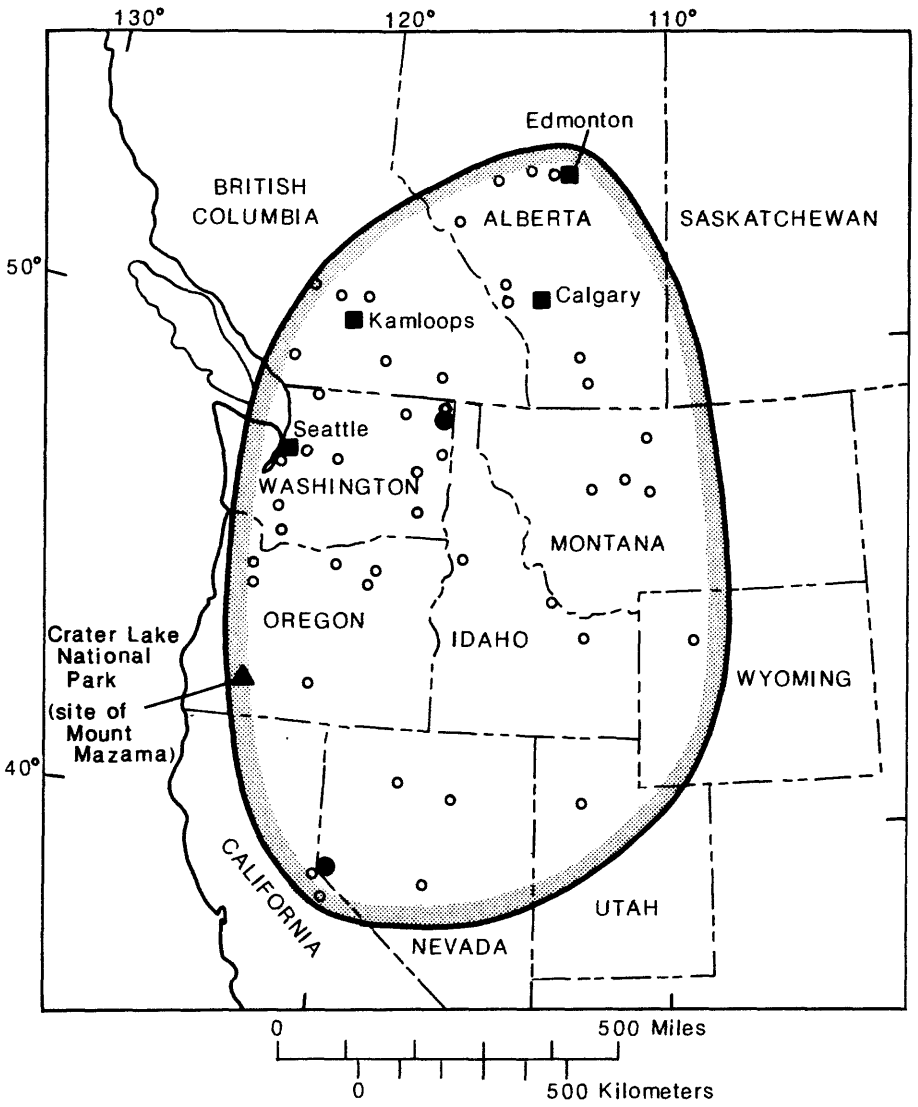

FIGURE 1.--The minimum areal extent of Mazama ash in the western United States and parts of Canada. Open circles mark some sites where the Mazama ash has been identified. Closed circles mark the two sites identified in this study. Figure modified from Sarna-Wojcicki and others, 1983.

site of Mazama-like ash of the appropriate age; one at Big Meadow, Washington (Mack et al., 1978), and the other at Osgood Swamp, California (Adam, 1967; Davis 1978). The organic-rich sediments which enclose the ash at each new site are of particular interest because they are anomalously uraniferous, and are the basis for ongoing studies of uranium in organic-rich surficial environments (Otton, 1984; Zielinski et al., 1985; Johnson et al., 1985). Uranium accumulations in such young surficial "bogs" belong to a new class of low radioactivity deposits that are a potentially significant resource for U worldwide (Culbert and Leighton, 1985). The positive identification of the contained volcanic ashes as the products of a dated eruption greatly enhances their utility as (now quantified) isochronous markers in the sedimentary and paleoenvironmental record.

Sample Locations and Descriptions

The ash layers are observed in piston cores and in auger cuttings taken at each site. The sampled cores (Fig. 2) were chosen for detailed analysis based on their lithologic diversity, and range of uranium content.

Site 1: Northeastern Washington

A single light tan volcanic ash layer is enclosed by organic-rich valley-bottom sediments along the drainage of the north fork of Flodelle Creek, Stevens County, Washington (SW 1/4 SW 1/4 sec. 33 T. 36 N., R. 42 E., Lake Gillette 7 1/2-minute quadrangle; elevation 3560 ft, 1085 m). A 5.1 cm diameter core of the sediments taken at the sample site is 292 cm long and bottoms in coarse to granular glacial-fluvial sand, deposited as glaciers retreated from the area approximately 12,000 yr B.P. Lithologically distinct intervals in the core range from peat to organic-rich silt, clay, and sand (Fig. 2) and contain 140 to 2800 ppm uranium, which correlates positively with organic content (Otton and Zielinski, 1985).

Site 2: Westernmost Nevada

A single light tan layer of volcanic ash occurs in organic-rich sediments that fill a broad valley fen near the headwaters of a small creek draining into south Zephyr Cove, Lake Tahoe, Douglas County, Nevada (center of sec. 1, T. 13 N., R. 13 E., Glenbrook 7 1/2- minute quadrangle, elevation 7520 ft, 2292

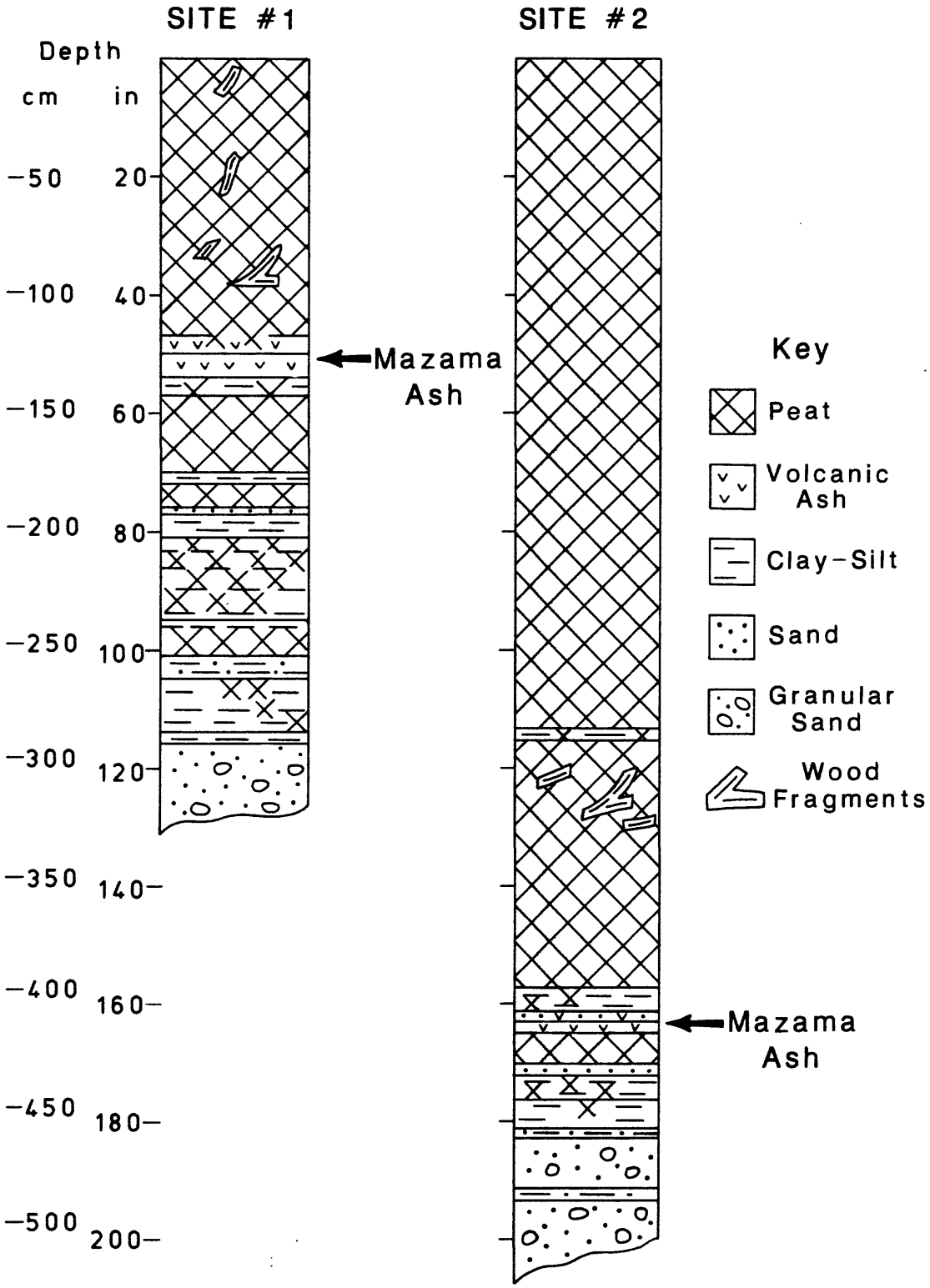

FIGURE 2.--Lithologic logs of the two sample cores. Site 1: northeastern Washington. Site 2: west central Nevada.

m). Uranium contents of lithologically distinct intervals of a 500-cm core range from 5 to 3100 ppm and again correlate positively with organic content (Otton, et al., 1985).

Analytical Methods

Approximately half of each ash-rich interval was sliced from the core and processed by standard methods to produce glass separates (Sarna-Wojcicki et al., 1979). Approximately 1 gram of each glass separate was submitted for instrumental neutron activation analysis (INAA; Gordon et al., 1968) at the U.S. Geological Survey reactor facility, Denver, CO. The INAA method was chosen because (A) it is nondestructive; (B) it generates high precision data for sodium, iron, and a wide variety of trace elements, and the combined data provide a geochemical "fingerprint" that can be used to distinguish ash layers (Borchardt et al., 1971, 1972; Izett et al., 1970, 1972; Izett 1981; Sarna-Wojcicki et al., 1979, 1980, 1983); and (C) previous INAA analyses of Mazama ash and other widespread late Quaternary ashes provide a reference data set for comparison (Borchardt et al., 1971; Sarna-Wojcicki et al., 1983). For the purpose of additional comparison we also submitted reference samples of previously identified 7000 y-old Mazama-like ash from Osgood Swamp in east-central California (Adam, 1967; Davis, 1978), and of Mazama ash and the 12,000 year old Glacier Peak ash from Creston Fen in east-central Washington (Powers and Wilcox, 1964; Mack et al., 1976).

Splits of glass separates were also measured for refractive index with the "focal masking" technique (Cherkasov, 1957; Wilcox, 1983), which allows measurement of refractive index variations within a population of grains.

Additional samples of the ash from each site were cleaned with H_2O_2 to remove organic material, and grain mounts of the very fine sand fraction were examined under oil at 200x and 400x magnification to determine the mineralogy of phenocrysts and the morphology of phenocrysts and shards.

Results and Discussion

INAA analyses

A comparison of the abundances of 20 measured elements indicates that the sampled glasses from sites 1 and 2 are analytically indistinguishable from their nearby reference samples of Mazama-like glass (Table 1). Most of the measured values from each site are also within two standard deviations of the

earlier reported mean values for near-source glasses of the Mt. Mazama eruption (Borchardt and others, 1971). The glasses from sites 1 and 2 are also clearly distinguished from the analyzed sample of Glacier Peak glass, especially on the basis of REE, Hf, Zr, Fe and Sc, all of which are 25-60 percent lower in the Glacier Peak glass.

The chemical data indicate small, but analytically significant, differences between the glasses from sites 1 and 2. In particular, the sample pair from site 2 and Osgood Swamp are approximately 50 percent richer in cobalt; 6-11 percent richer in iron, scandium, and thorium; and 8 percent poorer in sodium than the sample pair from site 1 and Creston Fen. All of these differences are significant compared to an estimated analytical precision of 2.5-3.5 percent (one sigma) for these elements, as determined by replicate analysis of standard rocks (J. R. Budahn, U.S. Geological Survey, written commun., 1985). Statistical calculations using the data of Table 1 indicate that the mean values of these elements in the site 2 - Osgood Swamp pair are different from the mean values for the site 1 - Creston Fen pair at the 95 percent confidence level (student's t test). With the possible exception of cobalt, the magnitudes of these apparent between-site variations are not great enough to cause confusion with most other late Quaternary ashes and are only documented by high-precision analyses. Possible causes of these small compositional differences include variable degrees of hydration, variable contamination of glass with microinclusions, and sampling of glass from different eruptive pulses of the Mt. Mazama eruption. With regard to the last possibility, a sequence of six separate layers of air-fall ash mapped near Crater Lake is attributed to separate pulses of the climactic eruption (Mullineaux and Wilcox 1980). In addition, a pre-climactic eruption at Crater Lake , Oregon about 7015 ± 45 y B.P. (Bacon, 1983) spread ash of Mazama-like composition over parts of northwestern Nevada and eastern California (Tsoyawata Bed of Davis, 1978, 1983, 1985).

Refractive index measurements

The refractive index of volcanic glass increases with the degree of hydration, and the observed range of refractive indices of a population of ash shards may relate to original chemical inhomogeneity or to variation in the degree of secondary hydration (Ross and Smith, 1961). Factors than can increase the rate of secondary hydration include smaller average grain size,

greater surface area (vesiculation) or greater alkalinity of migrating pore fluids (Wilcox, 1965). The Mazama ash is distinguished from other late Quaternary ashes on the basis of a generally higher refractive index and a wider range of refractive indices (Wilcox, 1965). The refractive indices of glasses from sites 1 and 2 agree very well with previously published values for Mazama glass (Fig. 3). There is a suggestion of a slightly higher average value and a greater range of values in the sample from site 2. This is confirmed by additional measurements of the nearby sample from Osgood Swamp (this study) and by a reported (maximum?) value of 1.511 from Osgood Swamp (Adam, 1967). Slightly lower abundances of sodium in the samples from site 2 and Osgood Swamp (Table 1) are also consistent with the observed loss of sodium that accompanies hydration of silicic glass (Lipman, 1965; Noble, 1967).

Petrographic Observations

Based on the chemical and refractive index data, the ashes from sites 1 and 2 clearly originated from Mt. Mazama, but perhaps from different eruptive pulses. Petrographic observations of hornblende phenocrysts were used to further investigate this hypothesis.

The 7000 y-old Mazama-like ash described by Adam (1967) at Osgood Swamp, CA (Table 1) was found by Davis (1978) to contain distinctive green laths of hornblende. Ashes containing this same green hornblende occur at several other localities in northwestern Nevada, and at some localities closely underly chemically similar ashes of the climatic eruption of Mt. Mazama (Davis, 1978, 1983). Davis named this lower ash the Tsoyawata Bed, which he later assigned to a precursor eruption of Mt. Mazama at 7015 $\pm$ 45 y (Davis, 1985).

Petrographic observations of the ashes from sites 1 and 2 indicated that green hornblende laths were present in the ash from site 2 (westernmost Nevada). The green hornblende occurs largely as clusters of microlites within glass shards, and may have contributed to the chemical differences between "glass" separates from sites 1 and 2. Likewise, contamination of site 2 glass with relatively abundant hornblende microlites could cause greater variability in both bulk chemistry (Davis, 1978), and refractive index (Fig. 3) of glass. In contrast, hornblende from site 1 (northeastern Washington) occurs largely as discrete, tabular, olive-green to brown phenocrysts, which are more typical

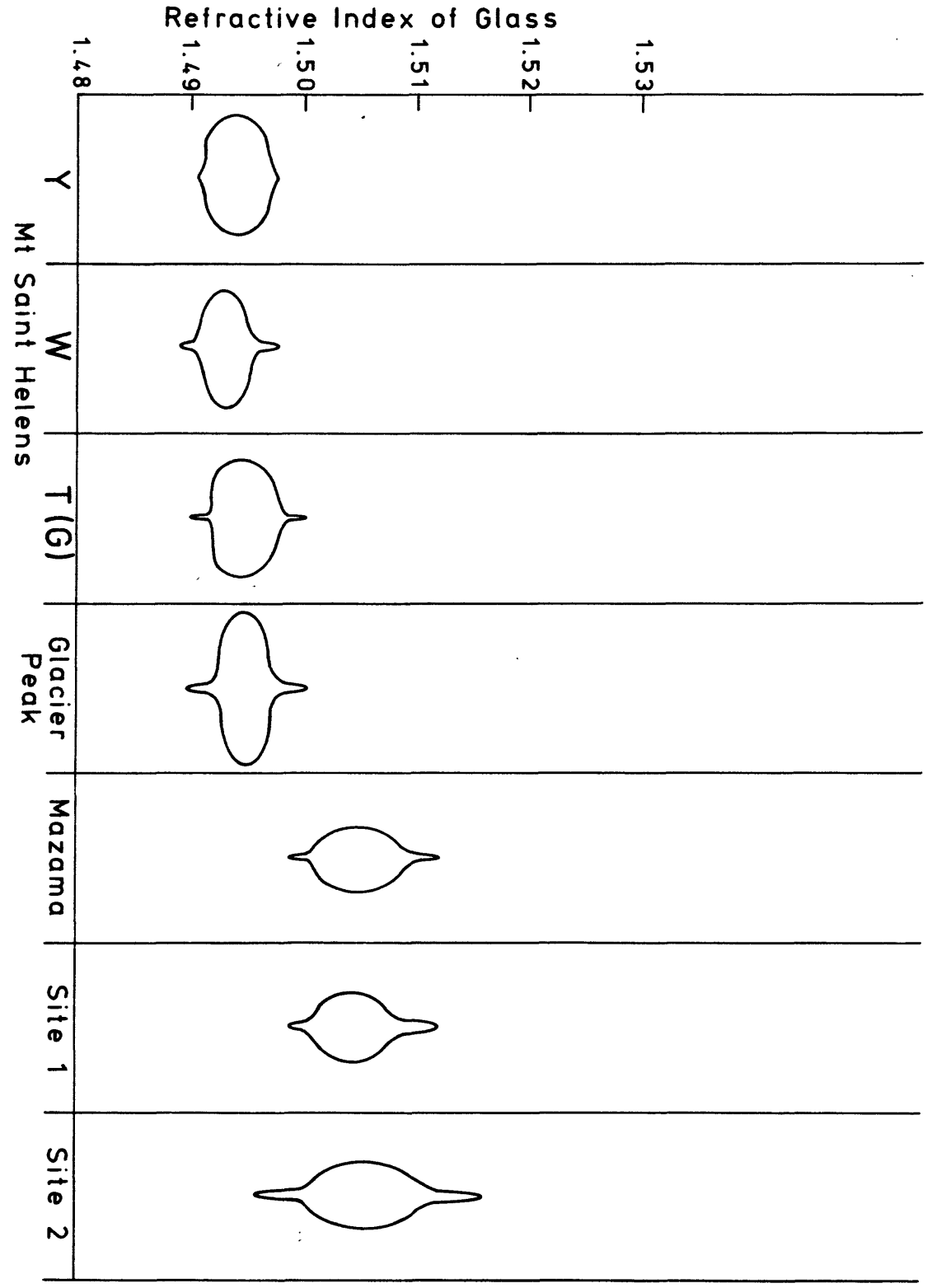

FIGURE 3.--Refractive indices of glasses from widespread late-Quaternary and Holocene ashes of the western United States, and of the two glasses of this study. Modified from Wilcox, 1965.

of hornblendes ubiquitous in ashes of the climatic eruption of Mt. Mazama (R. E. Wilcox oral communication, 1986).

Conclusions

Neutron activation analysis and refractive index measurements of glass separates confirm the identification of Mazama-like ash at two new localities in the western United States. The identification is based on a high degree of chemical similarity with nearby reference glasses of Mazama-like chemistry and age, and with previously analyzed glasses collected at the source area of Mazama ash.

Glass from the site in westernmost Nevada has a slightly higher and more variable refractive index than the glass sample from northeastern Washington, suggesting greater compositional heterogeneity or a greater degree of hydration. The same glass is also slightly enriched in Fe, Co and Sc, and slightly depleted in Na compared to the Washington sample, suggesting parentage in a different eruptive pulse of Mt. Mazama.

Petrographic observation of whole-ash from the Nevada site confirms the presence of small laths of distinctive green hornblende which occur as microlites in glass. This green hornblende, in combination with Mazama-like glass chemistry, is diagnostic of the Tsoyawata Bed of Davis (1978), which correlates with a pre-climactic eruption of Mt. Mazama about 7000 y B.P. (Davis, 1985). In contrast, tabular olive-green to brown hornblende phenocrysts from the Washington site are more typical of those observed in products of the climatic eruption of Mt. Mazama 6700 - 7000 y B.P.

The ash layers at these two new sites occur in organic-rich surficial uranium deposits and their identification provides a chronologic datum which aids ongoing studies of the sedimentary and paleoenvironmental record at these sites.

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References Cited

Adam, D. P. (1967). Late-Pleistocene and recent palynology in the central Sierra Nevada, California. In "Quaternary Paleoecology", (Cushing, E. J., and Wright, H. E. Jr., Eds.), Yale University Press, New Haven, Conn. pp. 275-301.

Bacon, C. R. (1983), Eruptive history of mount Mazama and Crater Lake Caldera Cascade Range, U.S.A. Journal of Volcanology and Geothermal Research, 18, 57-115.

Borchardt, G. A., Harward M. E. and Schmitt, R. A. (1971). Correlation of volcanic ash deposits by activation analysis of glass separates. Quaternary Research 1, 247-260.

Borchardt, G. A., Aruscavage, P. J. and Millard, H. T. Jr. (1972). Correlation of the Bishop Ash, a Pleistocene marker bed using instrumental neutron activation analysis. Journal of Sedimentary Petrology, 42, 301-306.

Cherkasov, Yu. A. (1957). Application of "focal screening" to measurement of indices of refraction by the immersion method. International Geology Review 1960, 2, 218-235.

Culbert, R. R., and Leighton, D. G. (in press). "Young" uranium deposits. In, "Unusual Uranium Deposits", (Gabelman, J., Ed.), Amer Assoc. of Petrol. Geologists Special Paper.

Davis, J.O. (1978). Quaternary Tephrochronology of the Lake Lahontan Area, Nevada and California. Nevada Archeological Survey Research Paper 7, 137 p.

Davis, J. O., (1983). Level of Lake Lahontan during deposition of the Trego Hot Springs Tephra about 23,400 years ago. Quaternary Research 19, 312-324.

Davis, J. O., (1985). Correlation of Late Quaternary tephra layers in a long pluvial sequence near Summer Lake, Oregon. Quaternary Research 23, 38-53.

Gordon, G. E., Randle, K., Goles, G. G. Corliss, J. B., Beeson, M. H., and Oxley, S. S.(1968). Instrumental activation analysis of standard rocks with high resolution x-ray detectors. Geochimica et Cosmochimica Acta 32, 369-396.

Izett, G. A. (1981). Volcanic ash beds: recorders of upper Cenozoic silicic pyroclastic volcanism in the western United States. Journal of Geophysical Research 86, 10200-10222.

Izett, G. A., Wilcox, R. E., Powers, H. A., and Desborough, G. A. (1970). The Bishop ash bed a Pleistocene marker bed in the western United States. Quaternary Research, 1, 121-132.

Izett, G. A., Wilcox, R. E., and Borchardt, G. A. (1972). Correlation of a volcanic ash bed in Pleistocene deposits near Mount Blanco, Texas, with the Guaje pumice bed of the Jemez Mountains, New Mexico. Quaternary Research, 2, 554-578.

Johnson, S. Y., Otton, J. K. and Macke, D. L. (in press). Latest Pleistocene to Holocene history of the north fork of Flodelle Creek drainage basin, Stevens County Washington: Ponding and the formation of surficial uranium deposits. Geological Society of America Bulletin.

Lipman, P. W. (1965). Chemical comparison of glassy and crystalline volcanic rocks. U.S. Geological Survey Bulletin 1201-D, pp. 1-24.

Mack, R. N., Bryant, V. M. Jr. and Fryxell, R. (1976). Pollen sequence from the Columbia Basin, Washington: Reappraisal of postglacial vegetation. The American Midland Naturalist, 95, 390-397.

Mack, R. N., Rutter, N. W. Bryant, V. M. and Valastro, S. (1978). Late Quaternary pollen record from Big Meadow, Pend Oreille County, Washington. Ecology, 59, 956-965.

Mullineaux, D. R., and Wilcox, R. E. (1980). Stratigraphic subdivision of Holocene air-fall tephra from the climactic series of Mount Mazama Oregon: (abs), American Geophysical Union Transactions 61, 66.

Noble, D. C. (1967). Sodium, potassium and ferrous iron contents of some secondarily hydrated natural silicic glasses. American Mineralogist, 52, 280-286.

Otton, J. K. (1984). Surficial uranium deposits in the United States of America. In "Surficial uranium deposits". (Toens, P. D., Ed.). IAEA, Vienna, Austria, 237-242.

Otton, J. K., Zielinski, R. A., and Been, J. M. (in press). Uranium in Holocene valley - fill sediments, and uranium, radon and helium in spring and surface waters, Nevada and California. Environmental Geology and Water Sciences.

Otton, J. K., and Zielinski, R. A. Movement and concentration of uranium in young, organic-rich sediments, Stevens County, Washington. Symposium on Concentration Mechanisms of Uranium in Geologic Environments, CREGU, Nancy, France, Oct. 1985, p 49-52.

Powers, H. A., and Wilcox, R. E. (1964). Volcanic ash from Mount Mazama (Crater Lake) and from Glacier Peak. Science, 144, 1334-1336.

Ross, C. S. and Smith, R. L. (1961). Ash-flow tuffs: their origin, geologic relations and identification. U. S. Geological Survey Prof. Paper 366, 81 p.

Sarna-Wojcicki, A. M., Bowman, H. R., and Russell, P. C. (1979). Chemical correlation of some late Cenozoic tuffs of northern and central California by neutron activation analysis of glass and comparison with x-ray fluorescence analysis. U.S. Geological Survey Professional Paper 1147.

Sarna-Wojcicki, A. M., Bowman, H. R., Meyer, C. E., Russell, P. C., Asaro, F., Michael H. Rowe, J. J., Baedecker Jr., P. A., and McCoy , G. (1980). Chemical analyses correlations and ages of late Cenozoic tephra units of east-central and southern California: U.S. Geological Survey Open-File Report 80-231.

Sarna-Wojcicki, A. M., Champion, D. E., and Davis, J. O. (1983). Holocene volcanism in the conterminous United States and the role of silicic volcanic ash layers in correlation of latest-Pleistocene and Holocene deposits. In "Late Quaternary Environments of the United States, Volume 2 The Holocene" (H.E. Wright Jr., Ed.). University of Minnesota Press, Minneapolis, p. 52-77.

Wilcox, R. E. (1965). Volcanic ash chronology. In "The Quaternary of the United States" (H. E. Wright, Jr., and D. G. Frey Eds.) Princeton University Press, pp. 807-816.

Wilcox, R. E. (1983). Refractive index determination using the central focal masking technique with dispersion colors. American Mineralogist. 68, 1226-1236.

Zielinski, R. A., Otton, J. K., Wanty, R. B., and Pierson, C. T. (in press). The geochemistry of water near a surficial, organic-rich uranium deposit, northeastern Washington State. Chemical Geology.

Table 1.--Elemental composition[1] of volcanic glasses sampled in this study, compared to reference glasses

	"Mazama" Creston Fen, WA.	Site #1, Flodelle Creek, WA	"Mazama[3]", Osgood Swamp, CA.	Site #2, Zephyr Fen, NV	Near-Source[2] Mazama Glasses (8) $\bar{X}$	$\pm s$	Glacier PK, Creston Fen, WA.
Na	3.76	3.70	3.47	3.41	3.44	0.17	3.00
Rb	52.8	51.2	49.5	47.4	50	9	53.5
Cs	3.02	3.04	2.99	2.87	3.9	0.8	2.46
Ba	762	757	759	745	660	80	654
La	20.3	20.2	20.5 (20.1)	20.6	21.5	2.2	15.2
Ce	44.9	42.5	44.1 (44.1)	42.9	44	3	30.9
Nd	22.3	21.8	21.0	20.4	29	5	11.9
Sm	4.46	4.45	4.42 (4.21)	4.38	5.0	0.4	1.95
Eu	0.89	0.88	0.91	0.93	0.89	0.09	0.53
Tb	0.62	0.61	0.57 (0.58)	0.60	0.83	0.15	0.24
Yb	2.24	2.35	2.25 (2.72)	2.20	3.5	0.7	0.98
Lu	0.35	0.35	0.32 (0.37)	0.33	0.56	0.08	0.16
Th	4.95	4.89	5.17 (5.58)	5.26	6.5	0.4	6.89
Hf	5.81	5.89	5.95	5.66	6.4	0.4	3.12
Zr	205	203	194	200	--	--	96
Ta	0.45	0.47	0.46	0.44	0.23	0.09	0.49
Co	2.25	2.10	3.15	3.49	2.6	0.4	1.14
Fe	1.39	1.36	1.54 (1.28)	1.51	1.48	0.09	0.70
Sc	5.39	5.36	5.81 (5.68)	5.69	6.4	0.4	2.25
Zn	38.6	39.6	36.7	--	--	--	23.9

[1]Analyses by Instrumental Neutron Activation (INAA). All values in ppm except for Na and Fe which are in percent. Estimated analytical precision ±1-5% (RSD)
[2]Reproduced from Borchardt et al., 1971.
[3]Values in parenthesis from Sarna-Wojcicki et al., 1983.