SUPPLEMENTAL MATERIAL

Sample collection. All samples were collected by the authors between 2016 and 2018. They are all pumice lapilli from four subplinian and Plinian fall deposits. ***Newberry Volcano.*** The Big Obsidian Flow period (~700 C.E.) of Newberry Volcano (Oregon, USA) erupted a volume of ~0.2 km^3 DRE (dense rock equivalent) divided approximately equally between initial pyroclastic fall deposits and final obsidian flow, with only 0.002 km^3 of pyroclastic flow deposit (McLeod and Sherrod, 1988). The estimated mass discharge rate is 2.8×10^7 kg/s (Rust and Cashman, 2007). The tephra deposit is typical of supblinian eruptions (Houghton and Wilson, 1989). Samples were collected in two ~2-m-thick pits separated by 1 km, and both located ~10.8 km E of the vent (43.705665°, -121.097255°) on or slightly off the ENE dispersal axis. Samples are crystal-poor to crystal-free rhyolite. ***Medicine Lake Volcano.*** The Plinian phase of the Glass Mountain eruption (1060±90 C.E.) of Medicine Lake Volcano (California, USA) deposited 0.09 km^3 DRE of fallout tephra with no evidence for pyroclastic density currents (Heiken, 1978). There is no estimate for the mass discharge rate for this eruption but given the similitude in volume and sedimentologic characteristics of the Plinian fall deposits with the Big Obsidian Flow tephra of Newberry, we estimate the mass discharge rate to be also ~10^7 kg/s. Samples were collected within a single layer towards the top of a several-meter section of the pumice-supported tephra fall deposit in a quarry about 2 km NNE of the vent (41.618356°, -121.495578°; Trafton and Giachetti, 2021), slightly off the NNE dispersal axis of the final phase of this eruption (Giachetti and Shea, in prep). Samples are crystal-poor rhyolite (Heiken, 1978). ***Mount Mazama.*** Both the Cleetwood and climactic eruptions of Mt Mazama occurred around 5,750 B.C.E. (Bacon, 1983). The Cleetwood phase initiated with a Plinian eruption that ejected 1.5 km^3 of magma and ended with the emplacement of a 0.6 km^3 obsidian flow. Estimated mass discharge rate is $2\pm1\times10^8$ kg/s (Young, 1990). It was followed weeks to tens of years later (Kamata et al., 1993) by the caldera-forming climactic eruption that ejected ~61 km^3 of dense rock equivalent magma (Buckland et al., 2020). Samples from these two eruptions were collected 46 km SE of the vent (42.704941°, -121.638693°) in a single pit 2.96 m in thickness. This pit is on the dispersal axis of the Cleetwood phase of the eruption (SE), but off the main dispersal axis for the climactic phase (NE). The Cleetwood sample was collected midway in the 122-cm section of Cleetwood tephra, whereas the climactic sample was collected within the upper 57 cm of the 171-cm climactic Plinian fall deposit, corresponding to the "Upper Pumice fall unit" as designed by Young (1990). This phase of the climactic eruption reached a mass discharge rate of $1.5 \pm 2.5 \times 10^9$ kg/s (Bacon, 1983). Both the Cleetwood and climactic samples collected are crystal-poor rhyodacite with no major chemical variations between rhyodacite components of the two eruptions (Bacon, 1983).

Lapilli selection. For each eruption, one hundred ~1-4-cm porous lapilli were randomly picked from the entire sample and then analyzed for volume and bulk and connected porosities. All 400 pyroclasts were then visually inspected using a stereomicroscope to search for evidence of sintering on their surface such as juxtaposed domains with sharply contrasting texture (e.g., porosity, vesicle size distribution, direction of elongation) and/or delineating fractures with ash and/or trapped lithics. To reduce the bias in interpreting textures, each pyroclast was inspected independently by three of the authors and was considered to be "extremely likely" to be an amalgamation of protopyroclasts if identified as such three times, and "most-likely" if identified as such twice. Three to four pyroclasts extremely likely to be an amalgamation of protopyroclasts, together with another 2-3 lapilli that appear homogeneous, were then arbitrarily selected from each eruption for Computed Tomography imaging and further textural analyses.

Measurement of volume and total and connected porosity. All 400 selected lapilli were rinsed and ultrasonicated in water, dried overnight in a furnace at 100 °C, and analyzed individually. Their volume, V, was determined either by the classical immersion method (Houghton and Wilson, 1989) or using a Microtrac PartAn^{3D} particle size analyzer (Trafton and Giachetti, 2021). The mass of each clast, M, was measured using a high-precision balance and the bulk (total) porosity calculated using $\varphi = M/(\rho V) \times 100$, where ρ is the density of the solid phase. The volume of solid and isolated pores was obtained using a Micromeritics AccuPyc II 1340 gas pycnometer in a 10, 35 or 100 cm^3 sample chamber, using high-purity helium as working gas. The connected porosity was then calculated. The density of the solid phase is 2.36±0.05 $g.cm^{-3}$ for Medicine Lake Volcano (Giachetti et al., 2020) and was measured by helium pycnometry on finely crushed powders from several clasts for all other eruptions (2.32±0.01 $g.cm^{-3}$ for Newberry, 2.38±0.01 $g.cm^{-3}$ for Cleetwood, and 2.43±0.01 $g.cm^{-3}$ for the Climactic phase of Mazama eruption). The connectivity, the ratio of connected to total porosity, is plotted in Figure 1 for all clasts and reported in Table 1 for pyroclasts further analyzed for their texture.

Computed Tomography and Scanning Electron Microscope. Twenty-eight samples appearing either texturally homogeneous or extremely likely to be an amalgamation of protopyroclasts were analyzed by X-Ray computed microtomography at the University of Texas High-Resolution X-ray Computed Tomography (CT) Facility. For all analyses, a NSI scanner was used with the following setup: Fein Focus Microfocal source, 100 kV, 0.125-0.2 mA, no filter, Perkin Elmer detector, 0.25-0.5 pF gain, beam-hardening correction = 0.1. Depending on the sample size, the resolution varied from 5.56 to 25.10 µm/voxel, resulting in a stack of 995 to 1,940 images per sample. The color balance of all the images of each sample was slightly altered to better highlight the different textures and produce the images shown in Figs. 1a-d. Thin sections of a subset of the samples were carbon-coated and analyzed using a Quanta 1000 Scanning Electron Microscope (SEM) at the University of Oregon Center for Advanced Materials Characterization in Oregon (CAMCOR). Both backscattered and secondary electrons were used at an acceleration of 25 kV and a working distance of about 1 cm. Images were acquired at a magnification between ×35 and ×1,700.

Protopyroclasts size distribution. As shown on Fig. 2, each pumice lapilli extremely likely to be an amalgamation is made of a few to thousands of textural domains, interpreted to be individual protopyroclasts separated by sharp or subtle boundaries. We measured protopyroclast size distributions in 2D on four samples, two samples from Medicine Lake Volcano (clast 8 and clast 86D, see Table 1 Supplementary material) and two from Newberry Volcano (clast 5 and clast 6) that exhibited a high number of protopyroclasts visible on the CT images. For each of the four samples, we used between 4 and 10 slices from the CT scans (corresponding to a single magnification for each sample) and 3 to 6 SEM images (3-6 magnifications), respectively. For each image, whether CT or SEM, we separated protopyroclasts manually using Adobe Photoshop (i.e., drew lines in between; Fig. 3A-B) and the area of each protopyroclast larger than 50 px^2 was then obtained using Fiji (ImageJ; Schneider et al., 2012). This procedure allowed us to analyze all protopyroclasts larger than ~4 µm in equivalent diameter, $d = 2 \times \sqrt{A/\pi}$, where A is the area of the object in μm^2. Protopyroclasts cut by the edge of the SEM image and those with an area larger than 1/100th of the area of the SEM image were not considered in the distribution (Shea et al., 2010). For each magnification, analyzed protopyroclasts were sorted based on their equivalent diameter into 20 regular logarithmic bins spanning 10^{-6} m to 10^{-2} m, producing for each magnification a distribution of N_A, which is the number density of protopyroclasts per unit area. In MATLAB, N_A distributions of all the magnifications were then merged into a single distribution for the whole sample using magnification cutoffs defined to minimize the change in N_A values at the shift from one curve to another (Shea et al., 2010). The distribution of N_A for each sample was then converted into a distribution of number density of protopyroclasts per unit volume, N_v, using the method of Sahagian and Proussevitch (1998) and plotted in Fig. 3c.

REFERENCES CITED IN SUPPLEMENTAL MATERIAL ONLY

Buckland, H.M., Cashman, K.V., Engwell, S.L. and Rust, A.C., 2020. Sources of uncertainty in the Mazama isopachs and the implications for interpreting distal tephra deposits from large magnitude eruptions. *Bulletin of Volcanology*, *82*(3), pp.1-17.

Giachetti, T., Hudak, M.R., Shea, T., Bindeman, I.N., and Hoxsie, E.C., 2020. D/H ratios and H_2O contents record degassing and rehydration history of rhyolitic magma and pyroclasts. Earth and Planetary Science Letters, 530, p.115909.

Houghton, B.F. and Wilson, C.J.N., 1989. A vesicularity index for pyroclastic deposits. Bulletin of volcanology, 51(6), pp.451-462.

Kamata, H., Suzuki-Kamata, K., and Bacon, C.R., 1993. Deformation of the Wineglass Welded Tuff and the timing of caldera collapse at Crater Lake, Oregon. Journal of volcanology and geothermal research, 56(3), pp.253-265.

MacLeod, N.S., and Sherrod, D.R., 1988. Geologic evidence for a magma chamber beneath Newberry Volcano, Oregon. Journal of Geophysical Research: Solid Earth, 93(B9), pp.10067-10079.

Rust, A.C., and Cashman, K.V., 2007. Multiple origins of obsidian pyroclasts and implications for changes in the dynamics of the 1300 BP eruption of Newberry Volcano, USA. Bulletin of Volcanology, 69(8), pp.825-845.

Sahagian, D.L., and Proussevitch, A.A., 1998. 3D particle size distributions from 2D observations: stereology for natural applications. Journal of Volcanology and Geothermal Research, 84(3-4), pp.173-196.

Schneider, C.A., Rasband, W.S. and Eliceiri, K.W., 2012. NIH Image to ImageJ: 25 years of image analysis. Nature methods, 9(7), pp.671-675.

Shea, T., Houghton, B.F., Gurioli, L., Cashman, K.V., Hammer, J.E., and Hobden, B.J., 2010. Textural studies of vesicles in volcanic rocks: an integrated methodology. Journal of Volcanology and Geothermal Research, 190(3-4), pp.271-289.

Trafton, K.R. and Giachetti, T., 2021. The morphology and texture of Plinian pyroclasts reflect their lateral sourcing in the conduit. *Earth and Planetary Science Letters*, *562*, p.116844.

Appendix A: Table 1: Data collected on samples from Medicine Lake, Newberry and Mount Mazama volcanoes. Y stands for macroscopic textural heterogeneity and N for none. Evidence of sintering as observed on the CT scan images has been qualitatively graded from – to ++ or classified as banded where heterogeneities form pervasive subparallel domains. Connectivity is the ratio of connected (open) to bulk (total) porosity. In the CT scans column header, "vx" is an abbreviation for voxel.

	sample ID	textural heterogeneity (Y/N)	evidence of sintering	mass (g)	pycnometer volume (cm^3)	external volume (cm^3)	equivalent diameter (mm)	density solid phase (g/cm^3)	bulk (total) porosity	connected (open) porosity	connectivity	CT scans resolution (µm/vx)
Medicine Lake	#1	Y	+	6.21	3.17	9.55	26.3	2.36	0.724	0.668	0.92	16.20
	#2	N	-?	1.98	0.90	3.43	18.7	2.36	0.755	0.738	0.98	13.30
	#3	N	++	1.39	0.77	2.12	15.9	2.36	0.721	0.636	0.88	12.90
	#4	Y	banded	2.09	1.49	3.02	17.9	2.36	0.707	0.508	0.72	12.10
	#5	Y	++	6.16	3.25	9.50	26.3	2.36	0.725	0.658	0.91	21.00
	#6	N	++	0.76	0.40	0.94	12.2	2.36	0.657	0.571	0.87	9.75
	#7	N	-	1.49	0.88	2.24	16.2	2.36	0.718	0.607	0.84	11.70
	#8	Y	++	0.82	0.65	1.42	13.9	2.36	0.756	0.545	0.72	9.96
	#86D	Y	++	7.96	5.09	15.43	30.9	2.36	0.781	0.670	0.86	25.10
Newberry	#1	N	+	6.29	3.30	14.07	29.9	2.32	0.807	0.765	0.95	17.68
	#2	N	-	0.98	0.57	2.46	16.8	2.32	0.828	0.767	0.93	9.29
	#3	N	-	5.55	3.20	15.86	31.2	2.32	0.849	0.798	0.94	18.29
	#4	Y	++	2.23	1.21	5.39	21.8	2.32	0.821	0.775	0.94	12.47
	#5	Y	++	0.91	0.57	1.84	15.2	2.32	0.788	0.689	0.87	8.26
	#6	Y	++	1.65	0.97	3.72	19.2	2.32	0.809	0.738	0.91	10.31
	#7	Y	++	0.71	0.45	1.54	14.3	2.32	0.801	0.705	0.88	7.51
Mazama - climactic	#1	Y	+	0.94	0.45	5.02	21.2	2.43	0.923	0.911	0.99	12.82
	#2	Y	++	1.20	0.56	2.18	16.1	2.43	0.774	0.745	0.96	11.73
	#3	N	+	0.40	0.14	1.05	12.6	2.43	0.842	0.867	1.03	8.86
	#4	Y	++	0.40	0.14	0.75	11.3	2.43	0.782	0.819	1.05	8.32
	#5	N	+?	1.72	0.93	3.93	19.6	2.43	0.820	0.762	0.93	11.24
	#6	N	-?	0.85	0.39	2.57	17.0	2.43	0.863	0.849	0.98	8.79
Mazama - Cleetwood	#7	N	-?	3.66	2.09	9.77	26.5	2.38	0.843	0.786	0.93	14.48
	#8	Y	++	0.25	0.14	0.53	10.0	2.38	0.801	0.734	0.92	5.56
	#9	N	+	0.50	0.34	0.87	11.8	2.38	0.758	0.604	0.80	6.67
	#10	N	-	0.59	0.40	1.23	13.3	2.38	0.798	0.672	0.84	6.93
	#11	Y	++	0.46	0.28	0.86	11.8	2.38	0.779	0.675	0.87	7.61
	#12	N	-	0.66	0.34	1.32	13.6	2.38	0.795	0.744	0.94	8.45