Reports

Mazama and Glacier Peak Pumice Glass: Uniformity of Refractive Index after Weathering

Abstract. *Weathering has had little differential effect on modal values of the index of refraction of pumice glasses from the eruptions of Mount Mazama and Glacier Peak thousands of years ago. Confidence is thus increased that the ranges of values for the index of refraction are reliable characteristics by which the two glasses may be distinguished from one another.*

Interest in the identification and chronology of layers of volcanic ash in the Pacific Northwest, particularly for use as time markers for stratigraphic horizons, has resulted in a series of papers on the characteristics and distribution of material ejected from vents in the Cascade Range (*1–4*). Correlation of these deposits is based on a combination of several field and laboratory criteria. One laboratory technique on which many of these studies have relied at least indirectly is measurement of the characteristic ranges and modal values of the index of refraction (n) of volcanic glass from each blanket of ejecta.

In our opinion, a serious question concerning reliance on refractive index values for such correlation has been the possibility that characteristic ranges of index may have been modified erratically by weathering, particularly by selective leaching of ionic constituents and by differential hydration of the glass, resulting from exposure to different environments at different localities.

To assess the influence of different weathering environments on the refractive index of glass from the main eruptions of Mount Mazama (6600 years ago) and of Glacier Peak (about 12,000 years ago), samples of pumice and coarse ash were collected along transects representing the wide range of climate over which the ejecta may be found. Morphologic development of soil horizons, formed during as much as 12,000 years of weathering over areas of diverse climate and topography, has proceeded with little differential effect on refractive index values except, perhaps, for the case of glass from podzolic A2 horizons.

Alteration of the index in artificial glasses due to selective addition or subtraction of various types of ions is implied by Morey (*5*), and change of values due to hydration of volcanic glass has been reported (*6*). Differential hydration, especially, might be suspected in glass from the eruptions of Mount Mazama (at Crater Lake) and Glacier Peak, for fallout of ash from these volcanoes extended over enormous areas (*3*) of diverse topography and climate.

The nature and intensity of weathering to which any sample of ejecta has been subjected are dependent on two basic circumstances: the conditions under which the sample was deposited, and the weathering to which it subsequently has been exposed.

Although pumice and ash fell indiscriminately over the landscape, the deposits characteristically have been preserved best in caves and rock-shelters (where samples may have remained essentially dry), on lee slopes of hills and on valley floors (where deposits have been subjected to alternate wetting and drying), and in bogs (where samples may have been continually beneath the water table).

Deposition of volcanic ejecta in dry caves and burial of layers of ejecta by other sediments provide significant protection from weathering, but where pumice and ash are exposed at the surface and are subjected to alternate wetting and drying, no such shielding is present and weathering is represented by the development of soil profiles. Samples for evaluating the effects of weathering therefore were taken from sites at which fragments of ejecta occur throughout the soil profile.

Weathering of deposits at or near the surface reflects the collective effect of the same complexly interrelated factors which control development of soil profiles. These factors are summarized by Jenny (*7*) in the equation:

$$s = f\,(p, t, c, o, r, \ldots)$$

in which development of soil profile characteristics (s) is considered to be a function of parent material (p), time (t), climate (c), organisms (o), topographic relief (r), and other variables which may be either local or as yet unrecognized. For the Mazama and Glacier Peak pumice and ash, composition of the glass parent material and maximum time available for weathering are essentially constant within each blanket of ejecta. The last three of these factors, largely controlled by the Cascade Range and its rain shadow, vary from site to site, and collectively comprise the weathering environment. Although it is obvious that finite values seldom can be placed on all (or even most) of these factors, it is equally obvious that the effectiveness, or intensity, of weathering environments differs qualitatively from one area to another. The variables may exist in an almost limitless number of combinations, but consideration of a few representative environments is permitted by the fact that, in any given area, the distribution of well-drained zonal soils reflects an effective suite of these combinations which has resulted in a group of morphologically similar weathering profiles. Hence it might be expected that the greatest differences in the nature and effectiveness of weathering would be found in areas where environmental differences, as reflected qualitatively in vegetation zones and in the morphology of associated zonal soil profiles, are found to be greatest. Within such areas, the greatest deviation from zonal weathering regimes might be expected to occur in intrazonal situations such as those resulting at poorly drained sites.

Accordingly, samples for laboratory study were collected from five well-drained sites along each of the two transects (Fig. 1) extending from cool, wet mountain slopes in the vicinity of Crater Lake and Glacier Peak, through representative intermediate environments, to hot, dry desertic flats on the adjacent Columbia Plateau (Table 1). Samples were also collected from poorly drained sites at the extreme ends of both transects. In each case, the texture of the sample (ranging from pumice near the vent to coarse ash at the ends of the transects) and its proximity to Glacier Peak or Mount Mazama greatly reduced the possibility of inadvertent collection of material from other source vents. At each site, local vegetation, microtopography, drainage, and morphology of the soil profile developed on parent material from which the sample was taken were recorded.

Data for local temperature and precipitation were obtained from nearby weather stations or extrapolated from the closest available stations. Because the maximum duration of weathering is constant for glass from each eruption, and because analyses available to date (*2*) suggest that there is little variation in the chemical composition of glass samples from each of the ejecta blankets, it was considered likely that any variations in index of refraction would reflect variations in weathering affected by local climate, microrelief, and vegetation. At two sites, samples were taken vertically through podzol profiles to determine whether differential weathering within major morphologic horizons of the solum had significantly affected the index of refraction. Because the podzol A2 horizons were discontinuous, and because A horizons in areas toward the more arid portions of the transects generally were mixed with loess, most samples were taken from B and C horizons.

Before examination under the microscope, duplicate samples were cleaned, one set physically and the other set chemically. For physically cleaned samples, 5 grams of crushed pumice were sieved to segregate the 140-to-300-mesh fraction, then scrubbed ultrasonically in distilled water. For chemically cleaned samples, organic matter was removed from the crushed pumice with hydrogen peroxide, and iron oxides were removed with sodium citrate and sodium dithionite by procedures modified slightly from those of Jackson (*8*) and Mehra and Jackson (*9*) by Kittrick and Hope (*10*). After further sorting with a 300-mesh, wet sieve, both sets of samples were dried on filter paper; then the glass was concentrated through heavy-liquid separations (*11*) with acetylene tetrabromide and carbon tetrachloride (specific gravity, 2.4). Chemical cleaning greatly facilitated determination of the index of refraction, and it reduced values by approximately 0.001 (*12*).

Measurements of refractive index were made with a Leitz Dialux-Pol microscope by the focal-masking techniques of Cherkasov as adapted by Wilcox (*13*); these techniques permit measurements to be made with a sensitivity of 0.001 when white light, controlled temperature, and high-dispersion index oils are used. Glass shards were examined on a microscope slide beneath a cover slip, flooded with immersion oil of known index. Under the microscope, shards near the center of the field were observed individually; by the three focal-masking techniques, the modal refractive index of each shard, relative to the wavelength of sodium light, was recorded. Each shard then was tallied in one of three classes: $n_{\text{glass}} > n_{\text{D oil}}$, $n_{\text{glass}} = n_{\text{D oil}}$, or $n_{\text{glass}} < n_{\text{D oil}}$. This procedure was usually repeated in each oil for 300 grains. After each count of 100 grains, the stage temperature was checked and recorded.

After three lots of 100 glass shards had been counted and assigned to their respective categories of refractive index, the number of grains in each category was averaged. The figures which resulted provide the percentage of grains with refractive index greater than, equal to, or less than the refractive index of the immersion oil with respect to the wavelength of sodium light (590 nanometers). This procedure was repeated on the same glass sample for no less than two, and often for four, consecutive immersion oils. A total of approximately 26,000 individual determinations of refractive index and an equal number of controlled estimates were made in this manner.

On the basis of these observations,

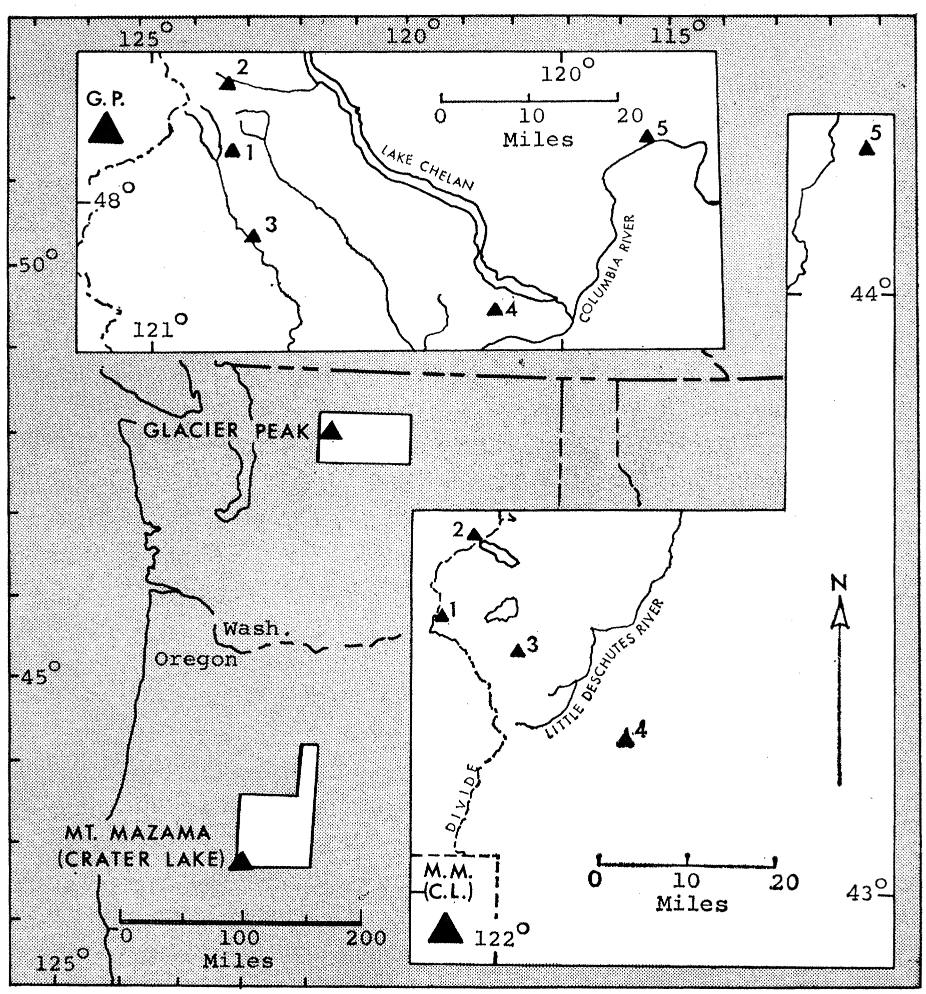

Fig. 1. Locations of sites from which samples of pumice from the Mount Mazama and Glacier Peak eruptions were collected.

Table 1. Characteristics of extremes of weathering environments from which pumice glass was sampled for studies of refractive index.

Collecting locality	Elevation (m)	Mean annual tempera-ture (°C)	Mean annual precipi-tation (cm)	Vegetation zone	Zonal soil
			Glacier Peak transect		
GP-1	~1830	6	152	*Abies amabilis/Tsuga heterophylla*	Podzolic
GP-2, GP-3, GP-4	*	*	*	*	*
GP-5	340	10	25	*Artemesia tridentata/ Agropyron spicatum*	Desertic
			Mount Mazama transect		
M-1	1692	5	152	*Abies amabilis/Tsuga heterophylla*	Podzolic
M-2, M-3, M-4	*	*	*	*	*
M-5	937	9	23	*Juniperus occidentalis*	Desertic

* Intermediate characteristics.

the ranges of modal refractive index of physically cleaned glass, collected from the B and C soil horizons at well-drained sites along the sample transects, were found to be 1.501 (+) to 1.504 for the Glacier Peak pumice, and 1.510 to 1.512 for that from Mount Mazama. For chemically cleaned samples (Fig. 2), the ranges were 1.501 to 1.503 and 1.510 to 1.511, respectively. These values remain essentially constant for samples of glass derived from pumice fragments collected at each station along the two transects, despite the extremes of weathering environment represented. Modal values for glass from poorly drained sites also fall within these limits. Thus it is evident both that there has been little difference in the effects of topography, climate, or vegetation at the collecting site on the refractive index of Mazama and Glacier Peak pumice glass collected from the lower soil horizons, and that these glasses may be distinguished from each other by refractive index, despite their obviously different weathering histories. Hence reliance on use of the index of refraction for identification of these glasses is justified (*2*).

Comparable studies have not yet been made on glass from samples of fine ash collected at greater distances from the two source vents, but closely controlled estimates of modal refractive index for such finely divided glass shards are now available for more than 50 samples. These samples have been collected from layers of ash buried within or below C horizons of the present solum, at sites distributed throughout most of the known areas of fallout; all show refractive indices in the range displayed by the pumices.

Although no gross correlation exists between refractive index of the glass and the weathering environment to which the glass has been exposed, care should be taken to sample from B and C horizons rather than from the A2 horizon, for at one site Mazama glass from a podzol A2 horizon shows a modal refractive index 0.006 lower than samples from the underlying B horizon. Whether this is a general occurrence is not yet known. Similar effects appear in a paired A2-B sample of Glacier Peak ejecta, but interpretation is complicated by advanced weathering and mixing with shards of glass which stratigraphically may be shown to be younger than the Glacier Peak material. In practice, this suggested limitation presents little difficulty. Sampling of Glacier Peak and Mazama ash for correlation of surficial deposits or archeological materials has seldom been dependent on samples from the thin, discontinuous podzolic A2 horizons and usually has involved sampling from thicker B and C horizons or from layers buried well beneath the solum. Given the consistently distinctive values for modal range of refractive index of these glasses in the latter two cases and accessory evidence such as associated phenocrysts (*2*), stratigraphic or physiographic relationships (*3*), and TiO_2 contents (*4*), the possibility becomes extremely small that ejecta layers from Glacier Peak or Mount Mazama need be confused.

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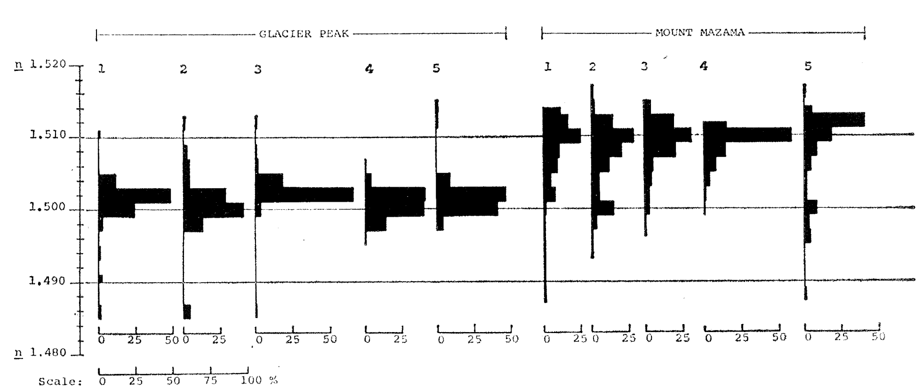

Fig. 2. Ranges of values of the index of refraction of chemically cleaned samples of pumice glass collected from the lower soil horizons of well-drained sites along the transects. Small amounts of glass with low indices of refraction may represent contaminants from other volcanoes.

References and Notes

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