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COMPOSITIONAL VARIATIONS OF THE CLIMACTIC ERUPTION OF MOUNT MAZAMA

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Mount Mazama, the ancestral mountain that now contains Crater Lake, is probably the best known of the Cascade volcanoes and illustrates better than any other the compositional variations that characterize the Quaternary rocks of the southern part of the range. As Williams (1942) has shown, the volcano grew to its full height during a long period of eruption of uniform pyroxene andesite. In the later stages of its evolution, more siliceous andesites, dacites, and rhyodacites were discharged from a semicircular arc of vents around the northern slopes close to the present rim of Crater Lake. The composition of the lavas along this fissure varies systematically from rhyodacite and dacite along the central portion (Llao Rock and the Cleetwood and Redcloud flows) to andesite at the two extremities (Hillman Peak and the Watchman on the west and Sentinel Rock on the east). At the same time, dacite domes were extruded near the eastern base and basaltic cinder cones broke out over a wide area, mainly around the lower northern slopes.

The products of the great eruption that led to formation of the caldera closely resemble, at least in bulk composition, the contrasting rocks of the preceding stage. The rhyodacite pumice that makes up the first pumice fall and most of the glowing avalanche deposits is very similar to the obsidian of the earlier domes along the northern arc of vents, while the basic hornblende scoria that was erupted at the close of the eruption closely resembles in its bulk chemical composition the basaltic lavas of the earlier satellite cones around the base. Finally, the volcano reverted to andesite lavas with the post-caldera activity that formed Wizard Island.

Variations such as those in the products of the climactic eruption of Mount Mazama have been reported from other caldera-forming eruptions (Lipman and others, 1966; Katsui, 1963; Rittman, 1962), but none of these show the abrupt change from acid pumice to basic scoria seen at Crater Lake. The spectacular section of the glowing avalanche deposit at The Pinnacles (figure 1) shows the change especially well. A sudden transition from white dacite pumice to dark brown hornblende scoria occurs within a vertical distance of less than two feet. There is no evidence that this change marks a break in the continuity of the eruption. The contrasting magmas must have been discharged continuously from a compositionally inhomogeneous magma reservoir beneath the volcano.

In order to relate the nature of this change to the eruptive sequence, analyses have been made of a series of samples of the air-fall pumice and glowing avalanche deposits. Two analyses were made for each sample, one of the bulk rock and another of its glass. The analytical results, recalculated on a water-free basis, are presented in table 1 and summarized graphically in figure 2.

The most obvious conclusion to emerge from this data is that the gross features of the series are to a large degree the result of differences in the abundance and composition of phenocrysts; the variation in the glass is much smaller than that of the total rock. Total-rock SiO_2, for example, drops almost 15 percent from the air-fall pumice to the basic scoria, while the glass in the same samples differs by only about 6 percent.

The crystal content varies widely from one sample to the next, but there is a much greater average abundance of crystals in the basic scoria than in the dacite pumice. The plagioclase of the pumice is mostly labradorite zoned to oligoclase; in the scoria it is somewhat more basic - labradorite or bytownite zoned to andesine. In most pumice samples, hypersthene is the most common dark mineral, but augite is also present and hornblende is common. Pyroxenes are much less important in the basic scoria than is hornblende, which in some samples constitutes nearly half of the volume. Some of the hornblende crystals

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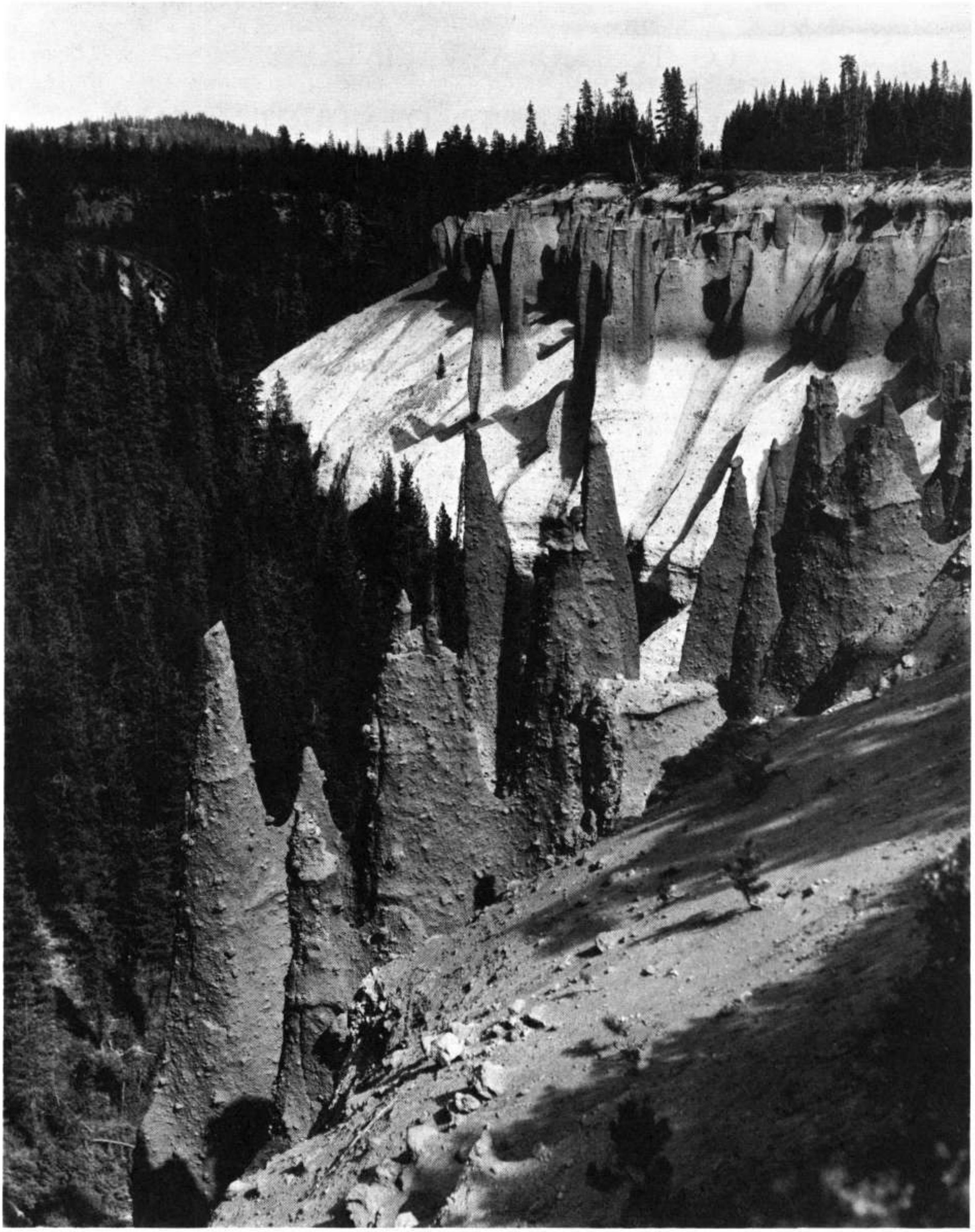

Figure 1. The Pinnacles, Crater Lake National Park.

View of glowing avalanche deposits in Sand Creek. Pumice was erupted at the later stages of the climactic eruption of Mount Mazama and changed composition abruptly from rhyodacite (light colored pumice in lower section) to crystal-rich hornblende scoria (dark colored layer at top of section). (Oregon State Highway Dept. photograph 5301.)

Table 1. Chemical composition of products of the climactic eruption of Mount Mazama.

	1	1g	2	2g	3	3g	4	4g	5	5g	6	6g
SiO_2	72.07	73.65	70.71	72.70	70.25	71.82	69.70	72.30	57.36	67.89	56.53	67.25
TiO_2	0.48	0.37	0.54	0.49	0.58	0.49	0.57	0.51	1.05	0.67	0.76	0.81
Al_2O_3	15.04	14.52	15.00	14.48	15.21	15.07	15.46	14.46	18.46	16.08	19.96	16.74
Fe_2O_3	1.18	0.49	1.80	1.12	2.08	1.33	2.09	-	3.58	1.79	2.78	1.36
FeO	1.39	1.52	1.05	0.84	1.14	0.89	0.94	2.20	2.80	1.62	2.82	2.31
MnO	0.03	0.02	0.04	0.03	0.07	0.06	0.04	0.02	0.08	0.07	0.15	0.07
MgO	0.28	0.22	0.55	0.31	0.61	0.44	0.61	0.32	3.71	0.87	3.80	1.03
CaO	1.67	1.16	2.40	1.78	2.33	1.91	3.00	1.45	7.17	3.29	8.29	2.80
Na_2O	5.07	5.08	5.07	5.10	4.93	5.02	4.87	5.63	4.18	5.21	3.84	5.41
K_2O	2.72	2.92	2.77	3.09	2.68	2.89	2.65	3.05	1.30	2.24	0.99	2.04
P_2O_5	0.06	0.04	0.08	0.06	0.11	0.07	0.08	0.06	0.30	0.25	0.07	0.19

1. Earliest air-fall pumice
2. Basal pumice deposit in Sand Creek
3. White pumice 15 feet above the creek bed at The Pinnacles
4. Gray pumice 25 feet above the creek bed at The Pinnacles
5. Dark basic scoria 35 feet above the creek bed at The Pinnacles
6. Dark basic scoria at top of section at The Pinnacles

NOTE: All analyses recalculated on water-free basis. For each sample the composition is given for the total rock and glass (indicated by 'g'). (Analyses by Ken-ichiro Aoki, Tohoku University, Japan.)

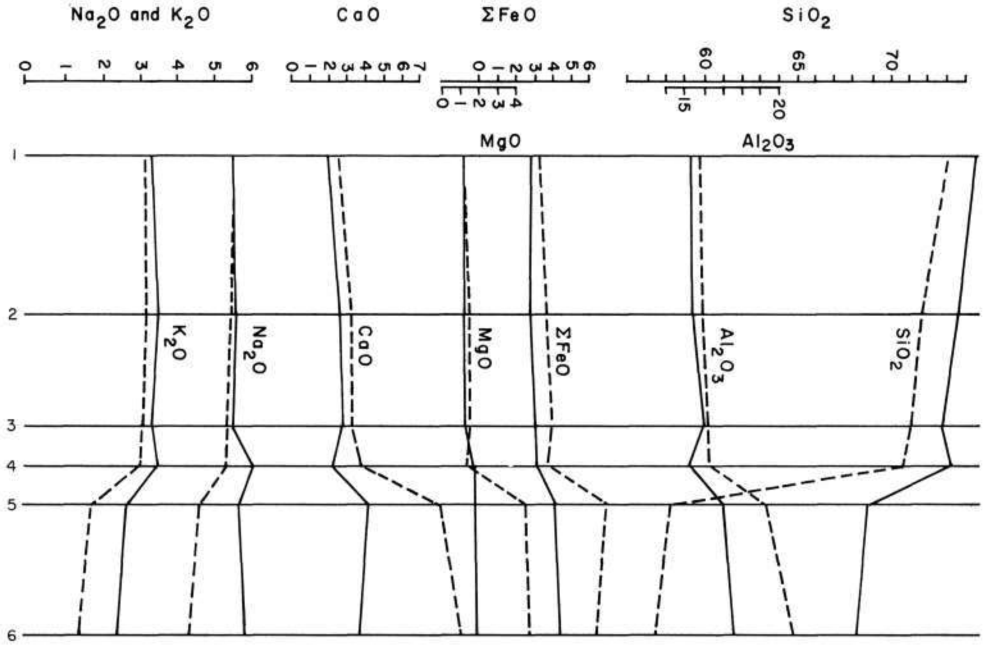

Figure 2. Variation of major elements in the ejecta of the climactic eruption of Mount Mazama. Oxide weight percent on a water-free basis is plotted against the approximate stratigraphic position of the sample in the section at The Pinnacles. Broken line refers to total-rock and solid line to glass.

contain small grains of olivine.

There is no evidence of resorption of the crystals of either unit, although some of the plagioclase of the dacite pumice is extremely porous and resembles that of partially fused plutonic xenoliths that were among the debris discharged toward the close of the eruption (Taylor, 1967).

The compositional differences of the glass fractions, even though they are less marked than those of the total rock analyses, are significant. They appear to require moderately strong vertical zoning of the liquid in the magma chamber before the eruption. Passing downward to deeper levels in the chamber, there was a decrease of silica and alkalis and an increase of calcium, iron, and magnesia. The greatest part of this variation was compressed within a narrow vertical interval corresponding to the visible transition from white dacite pumice to dark basic scoria.

An interesting feature of this variation is the reversal of slope that is seen in the variation curves for SiO_2, Al_2O_3, CaO, Na_2O, and K_2O. These inflections are confined to the glass and do not appear in the corresponding bulk compositions. The complementary nature of the SiO_2 and Al_2O_3 and of the CaO and alkalis suggests that the transition zone may have been diffusion controlled and related in some way to the equilibrium relations of each liquid to plagioclase. It is clear, of course, that many factors such as temperature and pressure gradients, distribution of water, and relative movement of crystals and liquid must have influenced the compositional variations, but our meager knowledge of the effects of these factors on the physical and chemical behavior of silicate liquids rules out a better interpretation at this time.

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