

Sanidine from the Mesa Falls Tuff, Ashton, Idaho

ABHIJIT BASU¹ AND CHARLES J. VITALIANO

Indiana University, Bloomington, Indiana

Abstract

K-feldspar crystals from different horizons and localities in the Mesa Falls member of the Yellowstone Tuff, in the vicinity of Ashton, Idaho, are unzoned and unaltered. Calculated formulae of representative crystals, based on electron-microprobe analysis, permit classification of all as sanidine, near $Or_{61.5} Ab_{27} An_{1.5}$ in the ternary feldspar diagram. X-ray diffraction studies suggest a uniformity of cell dimensions and high albite-high sanidine series structural state. Optical data are in agreement with this classification. The data lead to the conclusion that all sanidine phenocrysts in the Mesa Falls Tuff appear to have crystallized in the magma chamber during a single epoch prior to eruption. Eruptions from the magma chamber occurred in pulses to produce the different horizons in the tuff.

Introduction

Alkali feldspar crystals constitute the major phenocryst component of an airfall crystal-rich layer in the Mesa Falls Tuff, the middle member of the Yellowstone Group (Christiansen and Blank, 1972, p. B3). The unit crops out in the vicinity of Ashton, Idaho, and mechanical erosion continually affords an abundant supply of crystals which accumulate at the break in slope in several easily accessible outcrops (e.g. along U.S. Highway #191). Microscopic examination shows that the feldspar crystals are mainly sanidine. They are unaltered and unzoned and readily amenable to optical and chemical study. This and the lack, until recently², of any detailed information in the literature on the material from this occurrence prompted us to study the sanidine. We have prepared this note on the basis of eight samples collected and kindly provided us by Mr. David Doherty of Wayne State University.

The airfall tuff

The zone which contains the sanidine crystals is part of the Mesa Falls Tuff, the middle member of the

Yellowstone Group, of Pleistocene age (Christiansen and Blank, 1972, p. B6). The phenocryst-bearing layer is as much as 15 m thick in the type locality, a road cut on U.S. Highway 20 and 91 (see Hamilton, 1965, p. C5, fig. 3). There it rests on a thin layer of loess. It crops out in several additional but smaller road cuts along the highway, is present in the cliffs at Mesa Falls on the Henry Fork, and is exposed in a quarry about 6.8 km north of Ashton as well (Christiansen and Blank, 1972, p. B7). Locations of individual samples are given in the appendix.

The sanidine crystals are white to colorless, subhedral to euhedral and reportedly attain a length in excess of 1 cm (Christiansen and Blank, 1972, p. B6). The crystals selected for study are clear and transparent, and despite a whitish dusty appearance on the surface of some, microscope examination failed to reveal any alteration products. Refractive indices were determined for several crystals from each sample. In addition to the crystals selected for refractive index determination, eight moderate-size single-feldspar phenocrysts were handpicked at random from each of the original samples. Each selected grain was divided into two parts, one to be used for X-ray powder diffraction and the other for electron microprobe analysis.

Optical data

The selected crystals were crushed and sized to -100 +120 mesh and studied by immersion method. The refractive index of the matching liquid was immediately checked by means of the Abbe refractometer (sodium light source) and adjusted, where neces-

¹ Present address: Harvard and Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge Massachusetts 02138

² Recently, Friedman *et al.*, (1974) have studied the oxygen isotopic composition of the sanidine crystals from the volcanic rocks in Yellowstone National Park. Among the results they presented are two determinations on sanidine crystals from the Mesa Falls Tuff dated at 1.2 m.y. The values for $\delta^{18}O$ given for the two are +4.0 and +4.1 respectively. A K/Ar age of 1.2 m.y. has been determined by J. D. Obradovich (written communication to Christiansen and Blank, 1972).

sary, to 25°C. The β index, determination of which presented some slight difficulty, was checked in each instance by using several different orientations in addition to the nearly centered Bx_a figure. The optical data are given in Table 1.

Electron probe microanalysis

The portion of the grains set aside for chemical analyses were mounted with epoxy in small sleeves, carbon coated, and analyzed with an ETEC Auto-probe. For each sample, several random single spots were analyzed in order to obtain an average composition. An acceleration potential of 15 kV was used with a sample current of about 0.022 μ A, and the effective beam diameter was about 1–2 microns. A counting time of 10 seconds was used for each element for the nine element analyses. Data were reduced on an on-line PDP-11 computer with the GEO-WHIZ program (Finger and Hadidiacos, 1971, 1972), using β factors calculated as per Bence and Albee (1968) and α factors from Albee and Ray (1970) for the standards used. The general procedure at the electron microprobe laboratory of the Department of

Geology, Indiana University, was followed. Details of the procedure are given in Klein (1974).

Average analyses for each of the eight samples are given in Table 1 along with the chemical formulae and the calculated molecular proportions Or, Ab, and An. The latter values when plotted on a ternary diagram cluster closely in the sanidine field near the border between sanidine and soda sanidine (see also Barth, 1969, p. 44).

X-ray study

X-ray data were obtained by means of a Phillips goniometer using Ni-filtered CuK-radiation. X-ray powder diffractograms were obtained from each sample with three oscillatory scans at $\frac{1}{4}^\circ 2\theta$ per minute from 60° to $20^\circ 2\theta$ using a chart speed of $\frac{1}{4}$ inch per minute. Each corrected peak position³ of the feldspars, if unaffected by interfering lines and agree-

³ Pure semiconductor grade crystalline silicon metal (as supplied by Jarrel Ash, JM 424, spec-impurity <3 ppm) was used as an internal standard. Its unit cell parameter (D. R. Waldbaum: personal communication) is 0.543093 ± 0.000008 nm at 25°C.

TABLE 1. Optical properties and electron microprobe analyses of Mesa Falls Tuff sanidine

| | IP-1 (avg. of 3) | IP-2 (avg. of 2) | IP-3 (avg. of 3) | IP-4 (avg. of 3) | ILP-4 (avg. of 4) | ILP-6 (avg. of 3) | ILP-9 (avg. of 3) | ILP-25 (avg. of 3) |
|---------------------------------------|---------------------|---------------------|---------------------|---------------------|----------------------|----------------------|----------------------|-----------------------|
| SiO ₂ | 66.34 | 66.26 | 66.28 | 66.16 | 66.07 | 66.28 | 66.75 | 67.36 |
| Al ₂ O ₃ | 18.52 | 18.50 | 18.51 | 18.54 | 18.36 | 18.64 | 18.41 | 18.76 |
| FeO* | 0.13 | 0.08 | 0.13 | 0.08 | 0.01 | 0.08 | 0.09 | 0.08 |
| MgO | 0.00 | 0.01 | 0.00 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 |
| CaO | 0.24 | 0.33 | 0.31 | 0.34 | 0.26 | 0.22 | 0.31 | 0.35 |
| Na ₂ O | 3.84 | 4.09 | 3.98 | 3.96 | 3.92 | 4.25 | 3.97 | 3.93 |
| K ₂ O | 10.31 | 10.09 | 10.32 | 10.05 | 10.16 | 10.14 | 9.91 | 9.97 |
| MnO | 0.05 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.03 | 0.01 |
| TiO ₂ | 0.05 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.03 | 0.01 |
| Total | 99.48 | 99.37 | 99.45 | 99.15 | 99.11 | 99.66 | 99.50 | 100.47 |
| α | 1.5167 | 1.5176 | 1.5168 | 1.5182 | 1.5185 | 1.5182 | 1.5191 | 1.5182 |
| β | 1.5203 | 1.5203 | 1.5204 | 1.5226 | 1.5219 | 1.5220 | 1.5215 | 1.5208 |
| γ | 1.5217 | 1.5214 | 1.5216 | 1.5236 | 1.5226 | 1.5231 | 1.5226 | 1.5221 |
| 2V(-) | 17° | 9° | 8° | 10° | 16° | | 11° | 19° |
| Numbers of ions on the basis of 8 (0) | | | | | | | | |
| Si | 3.01 | 3.01 | 3.01 | 3.01 | 3.01 | 3.00 | 3.02 | 3.02 |
| Al | 0.99 | 0.99 | 0.99 | 0.99 | 1.00 | 1.00 | 0.98 | 0.99 |
| Ca | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 |
| Na | 0.34 | 0.36 | 0.35 | 0.35 | 0.35 | 0.37 | 0.35 | 0.34 |
| K | 0.60 | 0.59 | 0.60 | 0.59 | 0.59 | 0.59 | 0.57 | 0.57 |
| Mole percent | | | | | | | | |
| Or | 63 | 61 | 62 | 61 | 62 | 61 | 61 | 61 |
| Ab | 36 | 37 | 36 | 37 | 37 | 38 | 38 | 37 |
| An | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 2 |

*Fe recalculated as FeO

ing within $0.03^\circ 2\theta$ between each scan, was averaged for the three scans and tabulated. Miller indices were assigned according to Wright and Stewart (1968) and Borg and Smith (1969). Usually more than 20 unique reflections were obtained for each sample.

A relatively precise method of approximating Al/Si order-disorder involves the estimation of the relative structural state of an alkali feldspar from its refined unit cell parameters (see Smith, 1974, for details). Luth (1974) developed a set of equations involving the b and c cell edges and the α^* and γ^* angles (reciprocal cell) to estimate the proportion of Al in the various T sites. We have used these equations to obtain an estimate of Al/Si order-disorder of the sanidine phenocrysts from the Mesa Falls Tuff.

Unit cell parameters were refined by a least-squares method using a program written by Burnham (1962), and modified by Waldbaum (1973, personal communication). The program was adapted and further updated by Hazarika (1974, personal communication) for use in Indiana University's CDC 6600 computer. Depending on the quality of the peaks they were weighted on a scale from one to three. As none of the feldspars showed a $131\text{--}1\bar{3}1$ split only monoclinic solutions were sought. Estimated Al occupancy in the various tetrahedral sites, Δbc values, and variances of each of the above quantities were calculated from the refined cell parameters using a program written by Mr. M. Hazarika (1975, personal communication).

Refined cell dimensions of all the crystals (Table 2) are nearly the same, and none of them appear to be abnormal. The near constant values of cell volumes ($\bar{X}_{\text{vol}} = 705.44\text{\AA}^3$; $\sigma_{\text{vol}} = 1.10\text{\AA}^3$) suggest a constancy in composition. The b and c cell edges indicate that these crystals belong to the high albite-high sanidine series of the alkali feldspars. Calculations using equa-

tions derived by Luth (1974, revised, 1975, personal communication) also show that these feldspars have highest structural states with a mean Δbc (Stewart and Ribbe, 1969) of $0.53 \pm .03$. As might be expected, maximum disorder is evidenced from the estimated Al occupancy of the $T_1(0)$ site in all the crystals ($26.1\% \pm 1.3\%$, Table 2).

Discussion

Optical properties, chemical compositions, and structural states of the sanidine crystals in all the eight samples suggest that they are almost identical. Individual oxides of the major cations vary within ± 1 percent, refractive indices do not vary more than 0.0024; and standard deviation of percentages Al occupancy at the $T_1(0)$ site is only 1.3. All the crystals studied are high-sanidine and the Or:Ab ratio of approximately 59:41 (estimated from $\bar{2}01$ peak positions, refined values of a and cell volumes) is in agreement with the results obtained through microprobe analyses (K:Na = 62:38).

The similarity of the physical and chemical properties of the sanidine phenocrysts collected from different locations and different stratigraphic levels of the Mesa Falls Tuff is remarkable. This similarity suggests that the physicochemical conditions, including pressure, temperature, chemical composition, and probably the activities and chemical potentials of the major cations in the magma at the time of crystallization of these phenocrysts remained fairly constant. It is likely that all the sanidine phenocrysts crystallized more or less together in the magma chamber before being extruded in pulses to produce the tuffs of the different horizons and localities in the Mesa Falls Tuff from which the samples were collected.

TABLE 2. Cell dimensions and order parameters of Mesa Falls Tuff sanidines

| | IP-1 | IP-2 | IP-3 | IP-4 | ILP-4 | ILP-6 | ILP-9 | ILP-25 |
|----------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| a (\AA) | 8.409(4)* | 8.419(3) | 8.415(7) | 8.430(4) | 8.434(2) | 8.426(2) | 8.436(4) | 8.436(6) |
| b (\AA) | 13.008(2) | 13.007(2) | 12.994(1) | 12.996(1) | 13.006(1) | 13.008(1) | 13.015(2) | 12.995(1) |
| c (\AA) | 7.166(2) | 7.166(1) | 7.168(4) | 7.171(2) | 7.169(1) | 7.170(1) | 7.170(2) | 7.170(3) |
| β° | 116.05(2) | 116.03(1) | 116.10(4) | 116.21(2) | 116.07(1) | 116.06(1) | 116.08(2) | 116.08(3) |
| $V(\text{\AA}^3)$ | 704.2(5) | 705.2(3) | 703.9(12) | 704.9(1) | 706.4(2) | 706.0(3) | 707.1(4) | 705.9(8) |
| Δbc | 0.515(20) | 0.519(14) | 0.564(5) | 0.577(12) | 0.538(9) | 0.540(7) | 0.525(14) | 0.575(12) |
| Al % in $T_1(0)$ | 25.8(5) | 26.0(3) | 28.2(1) | 28.9(3) | 26.9(2) | 27.0(2) | 26.2(4) | 28.7(3) |
| n^{**} | 22 | 24 | 18 | 23 | 22 | 25 | 23 | 22 |

* Estimated standard deviation in parentheses
 ** Number of reflections used in cell refinement

Appendix: sample documentation

- IP-1 From Quarry (7½ min. Ashton Sheet). From bottom of quarry. This material contains pumice fragments up to 4" in size. It is poorly sorted and crudely crossbedded.
- IP-2 1' below base of pumice breccia layer.
- IP-3 Road cut on Hwy 90-127 (See: Hamilton, 1965, Fig. 3, p. C-5) 2' below base of top pumice breccia. Good cross-bedding.
- IP-4 (8-22-3b) Road cut on Hwy 90-127 (same locality as IP-3).
- ILP-25 Sand and Gravel Quarry, Ashton Quadrangle, one-half mile north of the Snake River, just east of Highway 191. From the top of the exposure.
- ILP-9 Same location; from middle of exposure.
- ILP-4 Same location; from middle of exposure.
- ILP-6 Same location; base of exposure.

Acknowledgments

We wish to express our sincerest thanks to David Doherty, formerly at Wayne State University, for supplying the sanidine samples, our appreciation to Dr. J. Mitra of New York University for his encouragement to one of us (A.B.) and acknowledge our indebtedness to Dr. Cornelis Klein, Jr. of Indiana University for use of the X-ray and electron microprobe facilities in his laboratory. The electron microprobe and X-ray diffraction equipment were obtained by joint funds from N.S.F. grants GA-37109 (Klein) and GY-10055 (Klein) respectively and the Indiana University Foundation. The electron microprobe analyses were covered by N.S.F. Grant GA-36186 (Klein).

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Manuscript received, October 14, 1975; accepted for publication, February 4, 1976.