DISCUSSION

CALCIUM CONTENTS, Na_2O:K_2O RATIOS, AND WATER CONTENTS OF THE PAINTBRUSH AND TIMBER MOUNTAIN MAGMAS

DONALD C. NOBLE

Department of Geological Sciences,
Harvard University, Cambridge, Massachusetts 02138

In a recent paper Lipman (1966) has inferred the water pressures that obtained during the final stages of intratelluric crystallization of several compositionally zoned silicic pyroclastic magmas, principally by comparing the normative Ab–Or–Q proportions of chemically analyzed whole-rock (in some instances essentially quenched melt) material with the corresponding proportions of ternary minima determined experimentally for water-saturated melts in the system $NaAlSi_3O_8$–$KAlSi_3O_8$–SiO_2–H_2O at different total pressures (Tuttle and Bowen, 1958). Particular attention was given to the composition of the most silicic parts of the resultant ash-flow units (table 1). Similar treatments have been made by Christiansen and Lipman (1966), Lipman, Christiansen, and O'Connor (1966), and by several other workers.

Unfortunately, there are very few quantitative data now available on the location of the boundary curves, and of the liquid fractionation curves beyond the critical end points of boundary curves that do not reach the Ab-Or sideline, in the SiO_2- and water-saturated system $CaAl_2Si_2O_8$–$NaAlSi_3O_8$–$KAlSi_3O_8$ as a function of total pressure. (See Stewart and Roseboom (1962) for a discussion of phase relations in the ternary feldspar system.) Because of this, it is presently impossible, even in the most favorable circumstances, to make even semiquantitative estimates of magmatic water content from normative An–Ab–Or–Q proportions of even relatively calcium-poor rhyolites.

Lipman (1966) states (p. 811-812): "As the quartz-feldspar field surface in the quartz and three-feldspar tetrahedron shifts toward the three-feldspar surface with increasing water pressure (Tuttle and Bowen, 1958; Stewart, 1958), projection of an analysis that contains appreciable An onto the Ab–Or–Q face of the tetrahedron will yield an erroneously low water-pressure value". This, however, refers to the changes in quartz-alkali feldspar proportions rather than to effects of the alkali feldspar-plagioclase cotectic on Ab–Or proportions in quartz-saturated melts. The only other considerations of calcium are calculations of normative anorthite content and conclusions that the rocks, for example, "closely approximate the experimental system", the inference being that the effects of the anorthite present will not seriously affect the results obtained.

The effects of small amounts of calcium are, however, far from minor. Consider the boundary curve in the system $CaAl_2Si_2O_8$–$NaAlSi_3O_8$–$KAlSi_3O_8$ at 5000 bars water pressure which from the data of Yoder, Stewart, and Smith (1957) lies at a very low angle to the Ab–Or join. If, for example, a cotectic of similar orientation were passed through the groundmass composition of the rhyolitic Topopah Spring rocks (fig. 1), it would intersect the Ab–Or joint at approximately Ab_{70}. Steeper lines of liquid descent, which may obtain under other conditions, will give more Or-rich compositions, and under certain conditions lines of liquid descent might conceivably curve toward the Or apex, intersecting the Ab–Or sideline at compositions of lower Ab:Or ratio than that of the parental anorthite-containing melt. Saturation water pressures inferred directly from the Tuttle-Bowen data for the different Ab:Or ratios range from several hundred to 5000 bars![1]

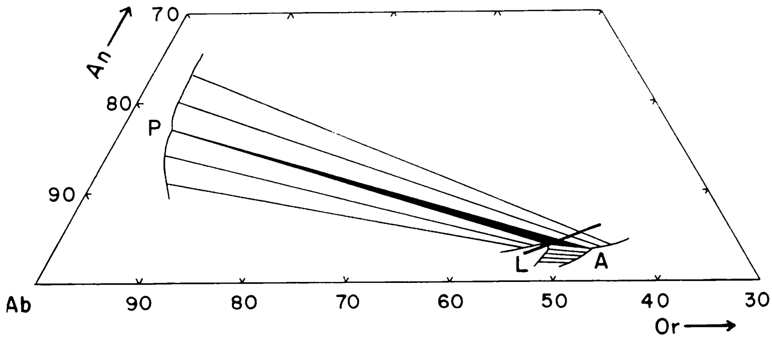

Fig. 1. Portion of an isothermal isobaric section in the system Ab–Or–An (silica and water saturated) showing a possible orientation of the three-phase triangle (solid black) plagioclase (P)-alkali feldspar (A)-liquid (L) indicating possible feldspar-liquid phase relations in the phenocryst-poor rhyolitic Topopah Spring magma prior to the beginning of eruption from the Topopah Spring magma chamber. A portion of a possible isobaric boundary curve for this system is projected (heavy line) onto the section.

Lipman (1966, p. 314, footnote) claims a precision of ±100 bars in reading water pressures[2] from the diagram of Tuttle and Bowen; the accuracy he believes to be somewhat less. From this statement the present writer infers that, although the absolute partial pressures of water derived are not too accurate, Lipman believes that the relative differences in water pressure of the magmas, and especially closely related ones such as those that produced the Topopah Spring Member and the overlying Yucca Flat Member-Tiva Canyon Member sequence (table 1), are known with considerable accuracy. Lipman (1966) further develops this idea on pages 824 and 825, where he states: "Late ash-flow magmas from both the Paintbrush and Timber Mountain Tuffs appear to have crystallized

[1] By no means all the effects of the addition of anorthite to the system Ab–Or–Q are considered in the present discussion.

[2] It may be well (compare, Lipman, 1966, p. 824, lines 10-13; Lipman, Christiansen, and O'Connor, 1966, p. F44, column 2, lines 22-37) to emphasize that it is the *water content* of the melt rather than the partial pressure of water in the melt per se that can be correlated with the amount of depression of the liquidus surface and shifting of the minimum, et cetera, on the addition of water to feldspar-quartz systems. Variations in total pressure will have a much more subordinate effect.

TABLE 1

Major extra-caldera ash-flow units of the Paintbrush and Timber Mountain volcanic centers*

Formation	Member	Lithology and relative volume
Timber Mountain Tuff (Pliocene)	Ammonia Tanks Member	Very large-volume sheet in most localities grading from rhyolite at the bottom to quartz latite at the top
	Rainier Mesa Member	Very large-volume sheet grading progressively from rhyolite at the bottom to quartz latite at the top
Paintbrush Tuff (Miocene)	Tiva Canyon Member	Large-volume sheet grading abruptly from crystal-poor rhyolite at the bottom to crystal-rich quartz latite at the top
	Yucca Mountain Member	Small-volume sheet of crystal-poor rhyolitic tuff
	Pah Canyon Member	Small-volume sheet of crystal-rich quartz latitic tuff
	Topopah Spring Member	Large-volume sheet grading abruptly from crystal-poor rhyolite at the bottom to crystal-rich quartz latite at the top

* Compiled from data given by Orkild (1965), Lipman, Christiansen, and O'Connor (1966), Byers and others (1968), and other sources.

and differentiated at higher water pressures than initially erupted magma. In the Paintbrush Tuff the earlier Topopah Spring Member apparently had a water pressure of about 600 bars whereas the later Yucca Mountain and Tiva Canyon Members had water pressures of about 1200 bars. . . . Possibly the long-term relations reflect progressively increasing depth resulting from cooling and crystallization at the top of the magma chamber". In sum, he considers that the small but real compositional differences between the rhyolitic rocks of, for example, the Topopah Spring Member and the later Yucca Mountain-Tiva Canyon sequence are due entirely, or at least in very large part, to differences in pre-eruption water pressure (content) of the magma.

A somewhat different explanation appears to be preferable. Rocks of the lower crystal-poor rhyolitic part of the Topopah Springs Member contain about 0.5 weight percent CaO (Lipman, Christiansen, and O'Connor, 1966, table 1), most of which must be in the groundmass, whereas available analyses (Lipman, 1966, table 1; Lipman and Christiansen, 1964; Byers and others, ms) indicate that rocks of the phenocryst-poor lower part of the Tiva Canyon Member, as well as the underlying and probably genetically related rhyolitic Yucca Mountain Member, originally contained less than half that amount of CaO. There thus appears to be no reason to postulate different water contents for the two units. The somewhat higher average Na_2O:K_2O ratio of the Tiva Canyon-Yucca Mountain rhyolites compared to that of the rhyolitic Topopah Springs rocks (Lipman, 1966) can reasonably be explained solely by the difference in normative anorthite content.

The differences in phenocryst mineralogy between the rhyolitic rocks of the two units are consistent with the above interpretation. Whereas the Topopah Springs rocks contain abundant plagioclase, by far the dominant phenocryst mineral in the rhyolitic Tiva Canyon-Yucca Mountain rocks is alkali feldspar. It thus seems likely that in the case of the rhyolitic Tiva Canyon-Yucca Mountain tuffs either (a) the three-phase (2-feldspars plus liquid) field had terminated or (b) the equilibrium sodium-rich feldspar phase had become anorthoclase or sodic sanidine prior to the onset of eruptive activity.

Similar relations appear to exist between the rhyolitic tuffs of the Rainier Mesa and Ammonia Tanks Members of the Timber Mountain Tuff (table 1). The most silicic tuffs of the later Ammonia Tanks Member appear to have slightly higher Na_2O:K_2O ratios than do the most silicic of the tuffs of the earlier Rainier Mesa Member (Lipman, 1966), although the present writer considers that insufficient data are now available, particularly on the Ammonia Tanks tuffs, to demonstrate this conclusively. The data available (Byers and others, ms) also tend to suggest that the groundmass material of the most silicic Ammonia Tanks flows may contain appreciably less CaO than does groundmass material of comparable Rainier Mesa tuffs. Less equivocal information is provided by phenocryst assemblages (Byers and others, 1968; Lipman, 1966). Plagioclase is virtually absent from the most silicic tuffs of the Ammonia

Tanks Member whereas it comprises roughly 20 to 50 percent of the feldspar in the rhyolitic tuffs of the Rainier Mesa Member.

The Tiva Canyon and Ammonia Tanks Members were erupted after the emplacement of the Topopah Springs and Rainier Mesa Members, respectively (table 1). In light of the presently available data, it would seem not unreasonable to suggest that the rhyolitic parts of both the Tiva Canyon and Ammonia Tanks Members represent more highly differentiated portions of the same magmas from which the rhyolitic tuffs of the Topopah Spring and Rainier Mesa sheets were derived. Such differentiation presumably took place after the eruption of the Topopah Spring and Rainier Mesa Members.

References

Byers, F. M., Jr., Carr, W. J., Christiansen, R. L., Lipman, P. W., Orkild, P. P., and Quinlivan, W. D., ms., Geology of the Timber Mountain caldera area, southern Nevada: U.S. Geol. Survey Prof. Paper, in preparation.

Byers, F. M., Jr., Orkild, P. P., Carr, W. J., and Quinlivan, W. D., 1968, Timber Mountain Tuff, southern Nevada, and its relation to cauldron subsidence: Geol. Soc. America Mem. 110, in press.

Christiansen, R. L., and Lipman, P. W., 1966, Emplacement and thermal history of a rhyolite lava flow near Fortymile Canyon, southern Nevada: Geol. Soc. America Bull., v. 77, p. 671-684.

Lipman, P. W., 1966, Water pressures during differentiation and crystallization of some ash-flow magmas from southern Nevada: Am. Jour. Sci., v. 264, p. 810-826.

Lipman, P. W., and Christiansen, R. L., 1964, Zonal features of an ash-flow sheet, the Piapi Canyon Formation, southern Nevada: U.S. Geol. Survey Prof. Paper 501-B, p. B74-B78.

Lipman, P. W., Christiansen, R. L., and O'Connor, J. T., 1966, A compositionally zoned ash-flow sheet in southern Nevada: U.S. Geol. Survey Prof. Paper 524-F, p. F1-F47.

Orkild, P. P., 1965, Paintbrush and Timber Mountain Tuff of Nye County, Nevada: U.S. Geol. Survey Bull. 1224-A, p. A44-A51.

Stewart, D. B., and Roseboom, E. H., Jr., 1962, Lower temperature terminations of the three-phase region plagioclase-alkali feldspar liquid: Jour. Petrology, v. 3, p. 280-315.

Tuttle, O. F., and Bowen, N. L., 1958, Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$–$KAlSi_3O_8$–SiO_2–H_2O: Geol. Soc. America Mem. 74, 153 p.

Yoder, H. S., Stewart, D. B., and Smith, J. R., 1957, Ternary feldspars: Carnegie Inst. Washington Year Book 56, p. 206-214.