THE AMERICAN MINERALOGIST, VOL. 51, MAY–JUNE, 1966

COMPOSITIONAL VARIATIONS OF PLAGIOCLASE FELDSPAR FROM A BASALTIC LAVA FLOW

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ABSTRACT

A detailed study of the Rock Creek basalt flow reveals significant relationships between chemical composition of the plagioclase feldspar and texture. The An content of the groundmass plagioclase varies inversely with size and directly with the amount of associated glass. The rate of cooling, after extrusion, determined the composition of the groundmass plagioclase. The plagioclase phenocrysts, averaging 20 percent more calcic than the corresponding groundmass plagioclase, are intratelluric.

INTRODUCTION

At the present time no detailed information is available concerning the variation in composition of any one mineral or the compositional variation of a mineral present in two distinct sizes (*i.e.*, phenocryst and groundmass crystals) in a lava flow. In order to obtain such information a study has been completed concerning the variation in composition of groundmass and phenocryst plagioclase from a thick porphyritic flow (250 to 470 feet), the Rock Creek flow, of the Columbia River Basalt in west-central Idaho (Bond, 1963).

Samples were collected from five measured sections of the Rock Creek flow and the phenocryst and groundmass plagioclase in each sample were concentrated separately with a Frantz Isodynamic separator after crushing and screening. The composition of the plagioclase, expressed as mole per cent An content, was determined by the glass fusion method (Foster, 1955). In addition, the textural relationships in each sample were studied with thin sections, with special emphasis on determination of the size of the groundmass plagioclase and the amount of associated glass so as to obtain an index of the rate of cooling for each sample. The factors that determine the texture of any igneous rock include the rate of cooling, bulk chemical composition, composition with regard to hyperfusibles, and pressure. The similarity in average composition of the plagioclase phenocrysts from all samples suggests that the first-formed crystals of plagioclase represent crystallization from the same melt. There is no evidence to indicate that the bulk chemical composition changed during crystallization. The content of hyperfusibles and the effect of pressure during crystallization are hard to appraise, but it seems likely that the influence of pressure was small because of the crystallization at the surface. Therefore, the rate of cooling, after extrusion, was the primary factor in determining the final texture. However, in small areas variations in volatile constituents and pressure may have influenced the rate of cooling and

TABLE 1. COMPOSITIONAL AND TEXTURAL DATA OF PLAGIOCLASE FROM THE ROCK CREEK FLOW

Sample Number	An Content Phenocryst	An Content Groundmass	Average Size (width in mm) of Groundmass Crystals	Per Cent Glass
W-1	60.0	37.5	0.12	7
W-3	61.5	54.5	0.04	48
W-4	61.5	53.0	0.04	45
W-5	63.5	48.5	0.07	27
W-6	59.5	51.0	0.04	57
W-7	67.0	54.0	0.07	7
W-8	67.5	39.5	0.09	17
W-9	64.5	50.0	0.07	23
W-10	62.0	52.0	0.04	35
W-11	60.0	43.5	0.09	28
W-12	62.5	56.0	0.06	53
SKC-1	62.0	40.0	0.09	5
SKC-2	61.5	37.0	0.08	8
SKC-3	63.5	36.0	0.09	8
SKC-4	62.0	40.0	0.07	17
SKC-6	61.5	56.5	0.02	62
SKC-7	63.0	57.0	0.02	67
SKC-8	62.0	42.0	0.07	17
SKC-9	63.0	50.5	0.03	53
SKC-10	61.0	44.0	0.04	32
SKC-11	73.0	48.0	0.04	20
SK-1	63.5	43.5	0.06	8
SK-2	62.0	41.5	0.08	10
SK-3	62.0	40.0	0.08	6
SK-4	63.0	49.0	0.04	35
SK-5	62.0	47.5	0.07	8
SK-7	63.0	53.0	0.02	38
SK-8	62.0	51.0	0.03	47
SK-9	63.0	47.5	0.06	12
SK-10	63.5	54.0	0.03	47
SK-11	61.5	52.0	0.04	35
SK-12	62.0	53.0	0.07	41
SK-13	62.0	51.0	0.03	43
R-1	63.5	43.0	0.13	5
R-2	64.0	45.0	0.13	5
R-3	64.0	41.5	0.13	5
R-4	64.0	44.5	0.12	5
R-5	65.0	52.0	0.11	8
R-6	63.5	45.5	0.10	5
R-7	60.5	45.0	0.09	5
R-8	62.0	56.5	0.03	52
R-9	62.0	50.5	0.04	30
R-10	61.5	51.5	0.03	57
R-11	61.5	50.5	0.04	28
S-1	62.0	45.0	0.08	7
S-2	64.0	43.5	0.09	10
S-3	67.0	43.0	0.09	5
S-4	65.0	46.0	0.10	5
S-5	66.0	52.0	0.07	38
S-6	63.0	55.0	0.06	45
S-8	63.5	49.5	0.09	7
S-9	62.5	48.0	0.06	12
S-10	66.0	55.0	0.05	51
S-12	62.5	51.5	0.03	20
S-13	62.5	50.0	0.02	47
S-14	62.5	52.0	0.03	17
S-15	62.5	59.0	0.02	51

hence the final texture. The average width of the groundmass plagioclase was determined by micrometer ocular measurements on two thin sections per sample. The percentage of associated glass was estimated from two thin sections per sample by comparison with standard percentage charts. To check the relative accuracy of these above determinations, each thin section was ranked in order of increasing size of the groundmass plagioclase and the amount of associated glass by projection from a 35 mm slide projector. In all samples, excellent agreement was obtained by both methods. The results of these determinations are summarized in Table 1.

Results and Discussion

The composition of the groundmass plagioclase ranges from An_{36} to An_{59} and shows no systematic spatial variation vertically or laterally

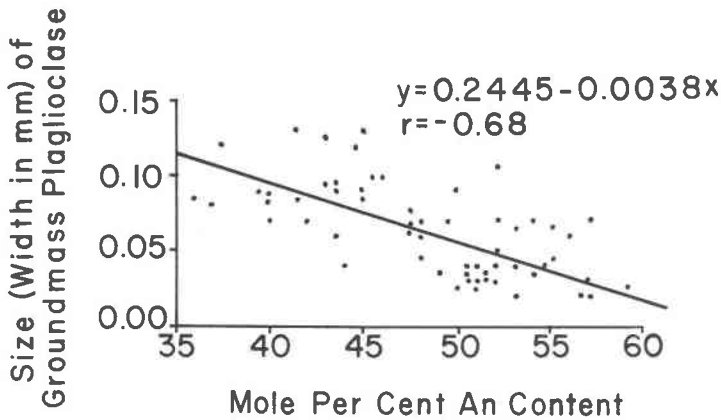

FIG. 1. Variation of mole per cent An content of the groundmass plagioclase samples with size (width) of the groundmass plagioclase (y = equation of the line and r = linear correlation coefficient). Each point represents a sample.

through the flow. Marked correlations exist, however, between the An content and crystal size of the groundmass plagioclase (Fig. 1) and between the An content of the groundmass plagioclase and the amount of associated glass (Fig. 2). As the An content of the groundmass plagioclase increases, the size of the crystals decreases ($r = -0.68$), and the amount of associated glass increases ($r = +0.75$). In addition, a marked degree of negative correlation ($r = -0.79$) exists between the proportion of associated glass and the size of the groundmass plagioclase crystals.

The plagioclase phenocrysts range in composition from $An_{59.5}$ to An_{73}, with 98 per cent of the samples in the interval $An_{59.5}$ to $An_{67.5}$. Textural relationships and composition (the phenocrysts average 20 per cent more calcic than the corresponding groundmass plagioclase) suggest that the plagioclase phenocrysts are intratelluric and crystallized at depth under conditions of slow cooling, before the crystallization of the groundmass plagioclase. The relationship of the size of the groundmass plagioclase and proportion of associated glass indicates that there were variations in the rate of cooling after extrusion of the magma. In samples representing conditions of relatively slow cooling the proportion of glass is small and the average size of the groundmass plagioclase is relatively large. Conversely, small groundmass plagioclase crystals, formed under condition of rapid cooling, are found in samples containing a large amount of glass.

Rock Creek samples representing rapid cooling, inferred from the small

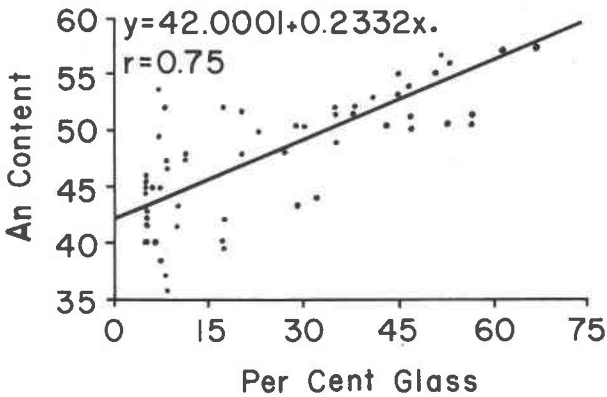

FIG. 2. Variation of mole per cent An content of the groundmass plagioclase samples with per cent glass (y=equation of the line and r=linear correlation coefficient). Each point represents a sample.

crystal size and abundant glass, possess groundmass plagioclase of high An content (An_{50} to An_{59}) whereas those that cooled more slowly contain groundmass plagioclase of low An content (An_{36} to An_{50}). With regard to the plagioclase phenocrysts, no significant relationship was found to exist between the composition and the rate of cooling, as indicated by the proportion of glass.

The relationship between compositional variations of the groundmass and phenocryst plagioclase and cooling history, as indicated by textural features, during crystallization of the Rock Creek flow can best be explained by reference to the plagioclase phase diagram in Fig. 3 (Bowen, 1913). In this simplified scheme all components of the Rock Creek magma are neglected except plagioclase. The temperatures indicated on the phase diagram do not imply the temperatures of crystallization of the magma of the Rock Creek flow.

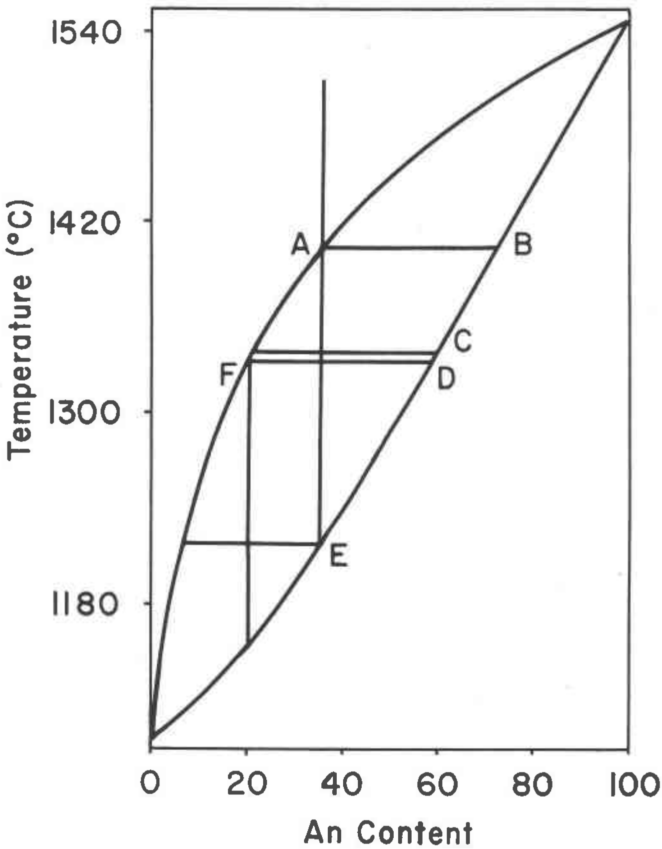

FIG. 3. The phase relationships of the plagioclase feldspars (A = composition of the simplified hypothetical Rock Creek magma. B = composition of the most calcic plagioclase phenocryst (An_{73}), C = composition of the most sodic plagioclase phenocryst ($An_{59.5}$), D = composition of the most calcic groundmass plagioclase (An_{59}), E = composition of the most sodic groundmass plagioclase (An_{36}), and F = composition of the hypothetical Rock Creek magma after extrusion to the surface).

When the temperature of the hypothetical Rock Creek magma of composition A intersected the liquidus, the first plagioclase to crystallize had a composition of An_{73}, the composition of the most calcic plagioclase phenocryst (B in Fig. 3). As cooling continued more sodic crystals of plagioclase crystallized and some of the earlier more calcic crystals were converted to more sodic composition by reaction with the melt. The relatively small range of composition of the majority of the Rock Creek plagioclase phenocrysts suggests that, for the most part, close approach to equilibrium between the crystals and the melt was attained during crystallization. Weak zoning in many of the phenocrysts indicates, however, that equilibrium between the melt and crystals was not maintained throughout the crystallization of the plagioclase phenocrysts.

At this stage, when composition of the plagioclase phenocrysts was about An_{63} (average An content of all phenocryst samples), the magma and its phenocrysts, in the form of a crystal mush, were extruded to the surface. Cooling was immediately accelerated, and the phenocryst formation halted. The composition of the melt at this stage was probably close to An_{20}, point F on the liquidus curve of Fig. 3, and the groundmass plagioclase crystals that formed initially, after or during extrusion of the magma, had an An content of approximately 59 per cent (point D). As cooling proceeded, crystals more and more sodic in composition crystallized and some of the earlier more calcic crystals reacted with the melt and became more sodic. The final composition of the groundmass plagioclase was therefore dependent upon the rate of cooling after extrusion. In groundmass samples which reflect a rapid rate of cooling (small size of the groundmass plagioclase and larger amounts of associated glass), the An content of the groundmass plagioclase is high. The high An content of these groundmass plagioclases is evidently the direct result of the rapid cooling. On the other hand, the samples that show evidence of crystallization under conditions of slower cooling (groundmass plagioclase crystals are relatively large and are associated with small amounts of glass) contain groundmass plagioclase of low An content. Under these conditions of slow cooling the early-formed groundmass crystals of composition approximately An_{59} were able to react with the melt and were converted in composition to more sodic forms. Therefore, the slower the rate of cooling, the more sodic are the final groundmass plagioclase crystals.

Conclusions

In summary, the important features of the plagioclase from the Rock Creek flow may be stated. The composition of the groundmass plagioclase crystals (An_{36} to An_{59}) varies inversely with their size and directly with the amount of associated glass. Therefore, the variation of An content of the plagioclase groundmass crystals is due primarily to the variation in the rate of cooling under conditions of fractional crystallization. The composition of the plagioclase phenocrysts is more calcic than the corresponding groundmass (98 per cent in the interval $An_{59.5}$ to $An_{67.5}$) and does not show any relationship to the amount of associated glass. The first formed crystals, the plagioclase phenocrysts, crystallized at depth under conditions of slow cooling which allowed close approach to equilibrium. At a later stage the magma was extruded to the surface and variations in the accelerated cooling rate produced the compositional variations found in the groundmass plagioclase crystals.

Acknowledgments

The author wishes to thank The Society of the Sigma Xi for financial support of this study. Thanks are also extended to R. K. Sorem, Washington State University, who critically read the manuscript and offered helpful suggestions during the investigation.

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