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TRANSITIONAL-PRIMITIVE BOUNDARY IN CALCIC PLAGIOCLASE

DAVID J. MOSSMAN, *Department of Geology, University of Otago, Dunedin, New Zealand.*

ABSTRACT

Variation of reciprocal angle γ^* with respect to α refractive index in four specimens of plagioclase from Greenhills, Bluff Peninsula, Southland, New Zealand, suggests a discontinuity rather than a flexure in unit cell geometry between $An_{90.5-93.0}$. This break, which probably represents the boundary between transitional anorthite and primitive anorthite, is also indicated by plotting γ^* against mol percent anorthite after the manner proposed by Doman *et al.*, (1965). The occurrence of two structurally distinct types of plagioclase on opposite sides of the proposed break is supported by single crystal X-ray study of the Greenhills plagioclases.

INTRODUCTION

Smith (1960) indicated a hiatus in the optical properties of low-temperature calcic plagioclase at $An_{90\pm3}$ but cautioned that its closer characterization will require precise optical measurement and chemical determinations. More recently, Doman *et al.*, (1965) suggested that this hiatus might be demonstrated by plots of reciprocal angle γ^* versus molecular percent anorthite and of γ^* versus refractive index in a manner analogous to their postulated structural discontinuities at An_{33} and An_{50}; however, due to insufficient data in the transitional anorthite region, they were uncertain whether the hiatus is a flexure or a discontinuity. Work carried out by the author provides substantiating evidence for a discontinuity of the type suggested by Doman *et al.*, (1965) close to An_{92}.

METHOD

Samples of practically unzoned calcic plagioclase were extracted from four samples of eucrite from Greenhills, Bluff Peninsula, Southland, New Zealand, and from one sample of anorthosite from the Stillwater Complex. Three of the Greenhills samples are from a layered series of rocks, and one is from a pegmatitic eucrite dyke. Essential data on the plagioclases are given in Table 1. Alkalis were determined by flame photometry, calcium by atomic absorption. Absolute amounts of calcium may be about 0.5 percent low due to interference of aluminum with calcium in the latter technique (Angino and Billings, 1967). In all five specimens partial analyses were duplicated and the mean of each pair used to calculate percentage anorthite. Reproduceability is approximately one percent anorthite.

Detailed optical and X-ray measurements were made on the plagioclases. The refractive index α was determined directly on six grains in each sample by single variation method on a four-axis universal stage. Although the range in α recorded from the grains within each sample is slightly larger than the probable error of measurement, a minimum of zoning is indicated. Thin section observation and inspection of X-ray powder films confirm minimal zoning of the plagioclase. Determination of percent anorthite according to Slemmons' (1962) curves for twinned grains of plutonic plagioclase, suggests anorthite

TABLE 1. SUMMARY OF X-RAY, OPTICAL AND CHEMICAL DATA ON PLAGIOCLASE FROM FOUR SAMPLES OF EUCRITE FROM GREENHILLS AND AN ANORTHOSITE FROM THE STILLWATER COMPLEX

Specimen	O.U. 14328	24591	24592	24594	24593
CaO	14.80	16.03	16.93	17.15	17.46
Na_2O	2.24	1.18	0.92	0.87	0.82
K_2O	tr	not detected	tr	tr	tr
An	78.0	88.3	91.1	91.6	92.2
Ab	22.0	11.7	8.9	8.4	7.8
Or	—	—	—	—	—
Est. % An (Slemmons method)	n.d.	91	92	93	93
α	1.5675	1.5705	1.5711	1.5720	1.5725
Overall range in α	0.0010	0.0015	0.0010	0.0010	0.0010
% An recalc. from avg. α refract. index curve Doman et. al., (1965)	80.0	88.0	89.5	92.0	93.2
γ^*	87.43	87.21	87.22 & 87.25 (repeat)	87.40	87.35
$B=2\theta_{1\bar{1}\bar{1}}-2\theta_{\bar{2}01}$	n.d.	0.74	0.74	0.75	0.75

KEY: *O.U. No.* — *Source of plagioclase*

O.U. No.	Source of plagioclase
14328	anorthosite, Stillwater complex
24591	layered series eucrite, Greenhills
24592	layered series eucrite, Greenhills
24594	pegmatitic eucrite dyke, Greenhills
24593	layered series eucrite, Greenhills

contents slightly greater than those found by partial analysis. The mol percent anorthite values when recalculated from the average α refractive index curve of Doman *et al.*, (1965) are closer to the chemical analyses; these recalculated values (see Table 1), supplied by Dr. S. W. Bailey, are used in Figure 2 to give a valid comparison with the data of Doman *et al.*, (1965).

For each plagioclase a minimum of 23 X-ray reflections, recorded by a 114.6 mm diameter Debye-Scherrer camera and corrected for film shrinkage, were used in the determination of unit cell parameters. Reciprocal angle γ^* was determined using a computer program for a least squares refinement of unit cell parameters (Evans *et al.*, 1963). The calculated powder data for bytownite given by Borg and Smith (1968) differ appreciably from the ASTM data on bytownite and because the former are probably superior they were used to calculate γ^* for the Stillwater specimen. The standard deviation of γ^* is less than one minute after ten cycles of least squares refinement. Replicate measurements of X-ray reflections on different samples of the same material (*e.g.* O.U. 24592, Table 1) suggest that the error in measurement is about 0°10′. Diffractometer measurements of the function $B=2\theta_{1\bar{1}\bar{1}}-2\theta_{\bar{2}01}$ (Smith and Gay, 1958) were carried out on the Greenhills plagioclases; results are compatible with a low temperature structural state, that is, with slow cooling and/or low temperatures of crystallization.

RESULTS

A plot of the α refractive index of the plagioclases against molecular percentage anorthite on Smith's (1960) graph reveals no unequivocal break in the transitional region; however, the variation of α with γ^* can be interpreted as delineating a structural break near An_{92} (Figure 1). On Figure 1 there is a small discrepancy between the plot of O.U. 24592 (An_{91}) and the calibration point of Doman *et al.*, (1965) for An_{90}. However, the difference between $\alpha = 1.5711$ for O.U. 24592 and $\alpha = 1.5720$ for M (Doman *et al.*, 1965) lies within the probable error of measurement as does the difference in γ^*. Doman *et al.*, (1965) give their estimated error of measurement of γ^* as less than 0°10′. The difference in γ^* for their sample M (87.13°) and O.U. 24592 (87.235) lies within that error of measurement, and is compatible with the possibility that sample M despite its phenocryst origin within a lava flow is a low temperature structural form. Probably the same is true of their sample U. Indeed a number of workers have found that volcanic plagioclases of this composition verge on a low structural state (Wenk *et al.*, 1968).

The proposed discontinuity in unit cell geometry near An_{92} is further suggested by locating the samples on the plot of γ^* versus mol per-

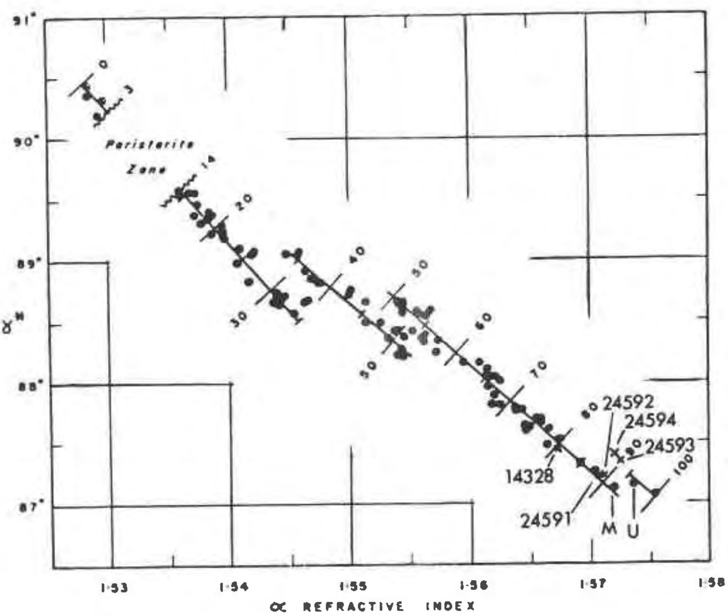

FIG. 1. Variation of reciprocal angle γ^* against refractive index α measured on the same grain after Doman *et al.*, (1965). Locations marked "x" refer to the Stillwater plagioclase and the four plagioclases from Greenhills.

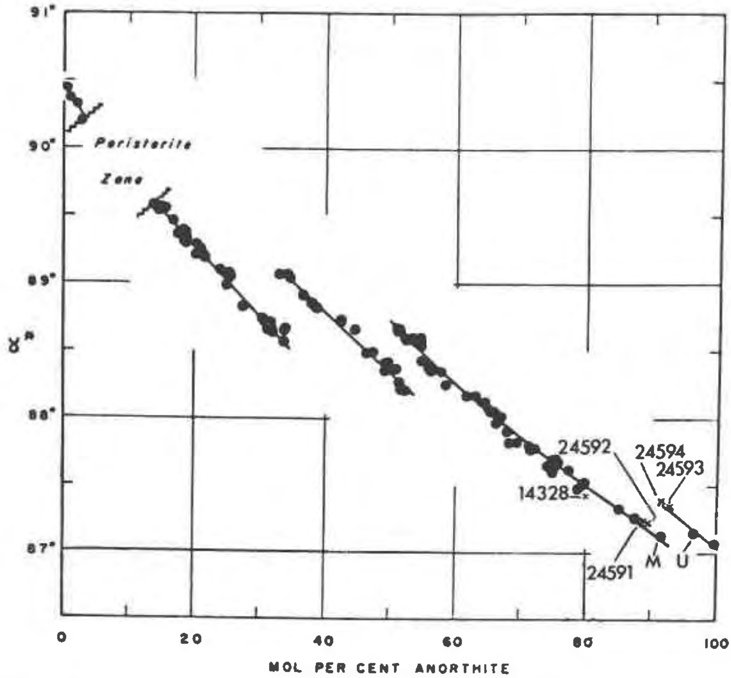

FIG. 2. Plot of reciprocal angle γ^* against individual grain composition determined optically (after Doman *et al.*, 1965). Locations marked "x" refer to the Stillwater plagioclase and the four plagioclases from Greenhills.

cent anorthite determined optically presented by Doman *et al.*, (1965) (Figure 2). Allowing for a 1 percent error in determination of mol percent anorthite present data indicate that this discontinuity occurs between $An_{90.5-93.0}$. In this compositional range the difference in γ^* between the adjacent linear segments appears to be less than the angle, about 0.5°, which separates adjacent segments at An_{33} and An_{50}.

According to Ribbe and Megaw (1962) sharp, medium "*c*" and "*d*" reflections are present in primitive anorthite whereas in transitional anorthite these reflections are diffuse. Careful comparison of X-ray powder photographs of the Greenhills plagioclases O.U. 24591 and O.U. 24593 which lie on either side of the proposed structural discontinuity using Borg and Smith's (1968) calculated reflections for transitional and primitive anorthite does not demonstrate conclusively two structurally distinct types. However, a faint reflection at about 13.00° 2θ, which according to Borg and Smith (1968. p. 1717) is $\overline{1}\overline{1}1$, the most intense ($I_{\text{INT}}=9.0$) "*c*" or "*d*" type reflections in anorthite, is visible in the powder photograph of the proposed primitive plagioclase O.U. 24593 but not in that of the transitional plagioclase O.U. 24591. Untwinned grains of each of these two specimens were selected for single crystal X-ray study. The grains were mounted along the *c*-crystallographic axis and in each instance *hk*1 Weissenberg photographs were taken with 48-hour exposures. The "*c*" and "*d*" reflections in the photographs of the two Greenhills specimens tend to be more distinct in the suggested primitive plagioclase O.U. 24593 than in the transitional plagioclase O.U. 24591, thus substantiating the concept of a structural break between the two.

Conclusions

Variation of reciprocal angle γ^* with respect to α refractive index in four specimens of plagioclase from Greenhills suggests a discontinuity rather than a flexure in unit cell geometry between $An_{90.5-93.0}$. This break, which probably represents the boundary between transitional anorthite and primitive anorthite is also indicated by plotting γ^* against mol percent anorthite after the manner proposed by Doman *et al.*, (1965). The occurrence of two structurally distinct types of plagioclase on opposite sides of the proposed break is supported by single crystal X-ray study of the Greenhills plagioclases.

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