OBSERVATIONS ON ORDER-DISORDER RELATIONS OF NATURAL PLAGIOCLASE

IV. Order-disorder Relations in Plagioclase of the White Mountain and New Hampshire Magma Series

By

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Introduction

This paper presents data derived from the measurement of order-disorder relationships in plagioclase feldspars from a typical epizone magmatic province. The specimens for this examination were collected from the White Mountain and New Hampshire magma series occurring in New Hampshire. This area has been studied in detail by Billings (1928, 1945), Chapman and Williams (1935), Kingsley (1931), Williams and Billings (1938), La Freniere (1957), and many others. However, none of these studies investigated the order-disorder relationships of plagioclase feldspars. The writers believed that the approach outlined in Part I of this paper could be applied to such a well known area to provide additional information about these magma series and also test the versatility and reliability of the ordering index method.

The White Mountain magma series is a group of alkaline intrusives occurring in a north-northwesterly trending belt extending from southern New Hampshire to Mt. Monadnock in north-eastern Vermont. This series intruded Lower Devonian and older metamorphic rocks, as well as intrusive rocks of the New Hampshire (Upper Devonian) and Oliverian (Devonian) magma series (La Freniere(1957)), probably during the Permian or Triassic periods.

Billings (1945) suggests that the primary magma was gabbroic and that during its intrusion, blocks of country rock were either stoped or

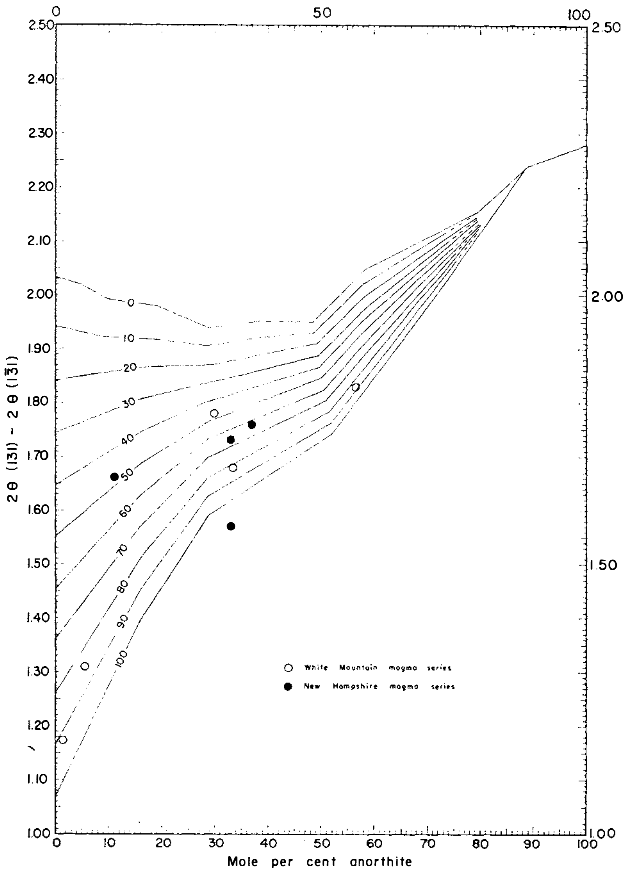

Figure 1. Intermediacy indices for $2\theta(131)-2\theta(1\bar{3}1)$ versus plagioclase composition in molecular percent anorthite. The indices based on data given in Part I of this report.

collapsed into the magma, and that ring fractures, developed near the top of the chamber, penetrated to the Earth's surface forming dikes. The stoped material was then assimilated, contributing to the final granitic phase. In this phase, granitic stocks rather than ring dikes were formed. Because of this association of stocks with earlier formed ring dikes and cauldron subsidences, Buddington (1959, p. 680) has classified the White Mountain magma series as epizonal.

The program of study consisted of optical determinations, as prescribed by Slemmons (1962), and X-ray diffraction measurements

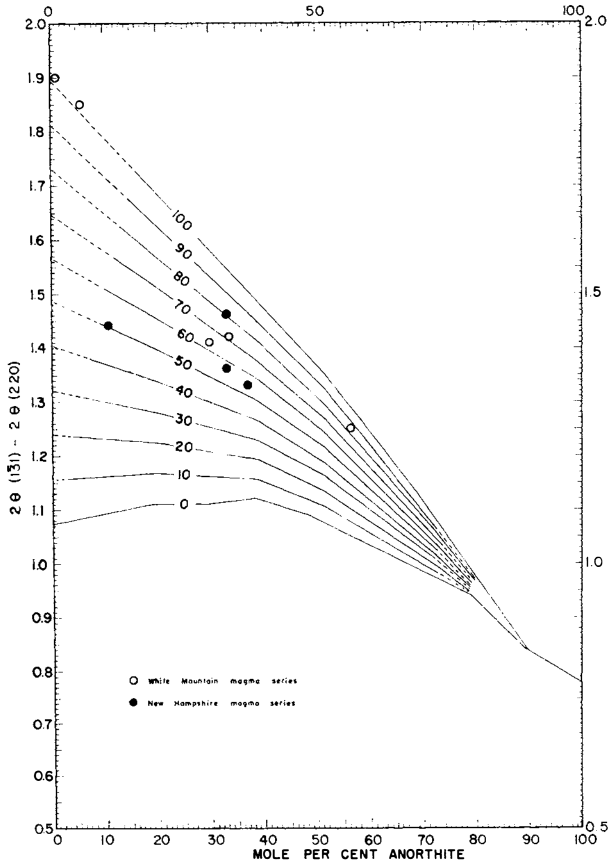

Figure 2. Intermediacy indices for $2\theta(1\bar{3}1)-2\theta(220)$ versus plagioclase composition in molecular percent anorthite. The indices based on data given in Part I of this report.

of plagioclase feldspars occurring in the New Hampshire and White Mountain magma series. The writers are indebted to R. E. Stoiber and J. B. Lyons of Darmouth College for contributing the specimens and thin sections used by G. F. La Freniere in his study of contact metamorphic zones in this area.

Discussion of data

The optical study included universal stage measurements for twin law, composition, and $2V_x$. Twenty-five complete twin axis measure-

Table 1. X-ray Diffraction and Selected Optical Data for Specimens from White Mountain and New Hampshire Magma Series, New Hampshire.

Spec. no.	Collection no., spec. description, and series designation	AVG. comp. An %	$2V_x$	X/Ta	Y/Ta	Z/Cp	Twin law	$2\theta(131)-2\theta(1\bar{3}1)$	$2\theta(1\bar{3}1)-2\theta(220)$	Years to cool to 475 °C
1	NH/Wi–1–56 Winnipesaukee quartz diorite (N.H. magma series)	37	88	87	68	19	albite	1.76	1.33	8
2	NH/Wi–12–56 Winnipesaukee quartz diorite (N.H. magma series), from xenolith in syenite, Red Hill area	33	86	89.8	16	18	albite-$A1aB$	1.73	1.36	0.13[1]
3	NH/Wi–5–56 Ames monzodiorite dike (White Mt. magma series) in Winnipesaukee quartz diorite	30		29	62	21	Carlsbad-albite	1.78	1.41	8
4	NH/Wi–8–56 Xenolith of Winnipesaukee quartz diorite (N.H. magma series) in Red Hill syenite dike (White Mt. magma series)	32	86	87	16.5	15	albite-$A1aB$	1.57	1.46	425
5	NH/Wi–9–56 (H–4–56 of Figure 4) Syenite from Red Hill dike (White Mt. magma series)	33.5	93	88	73	15	albite-$A1aB$	1.68	1.42	665
6	NH–Pw–9–56 Gabbro (White Mt. magma series)	56.5	101	76	64		albite	1.83	1.25	470
7	NH/F–1–56 Kinsman quartz monzonite (N.H. magma series) associated with the Franconia breccia	11	82	88.5	8	10	albite-$A1aB$	1.66	1.44	8
8	NH/F–3–56 (B) Conway granite (White Mt. magma series) stock intruding Franconia breccia (N.H. magma series)	0–2	96	87	74.5	17.5	albite	1.17	1.90	1000
9	NH/F–4–56 Conway granite	1–11	91	76.7	16	9.5	Carlsbad	1.31	1.85	1000

[1] Specimen 2 was not plotted since it could not be established that the cooling time corresponds exactly with specimen NH | Wi–12–56.

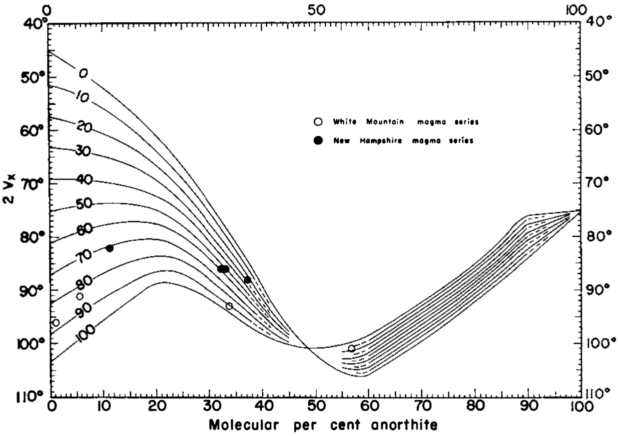

Figure 3. Intermediacy indices for angle of $2V_x$ versus plagioclase composition in molecular percent anorthite. The indices based on data in Part I of this report.

ments and ten X-ray diffraction analyses were completed. One sample, NH/Wi–7–56, was rejected because the X-ray pattern was diffuse and could not be read accurately. X-ray diffraction and selected optical data for the nine specimens are recorded in Table 1. The Intermediacy Indices (see Part I of this paper for definition) for each method are given in Table II. The average index tends to be internally consistent with the exception of the indices assigned for $2V_x$. These average about ten units too low, which may indicate that minor future readjustment

Table 2. Intermediacy Indices.

Spec. No.	X-ray methods		Optical Methods		Weighted average
	$2\theta(131)-2\theta(1\bar{3}1)$	$2\theta(1\bar{3}1)-2\theta(220)$	$2V_x$	Orien-tation	
1	62	54	50	65	54
2	77	56	50	—	63
3	47	63	—	—	55
4	100+	80	60	—	84
5	82	71	55	—	74
6	86	84	85	85	85
7	48	50	71	—	58
8	92	100	88	100+	95
9	84	100	83	—	90

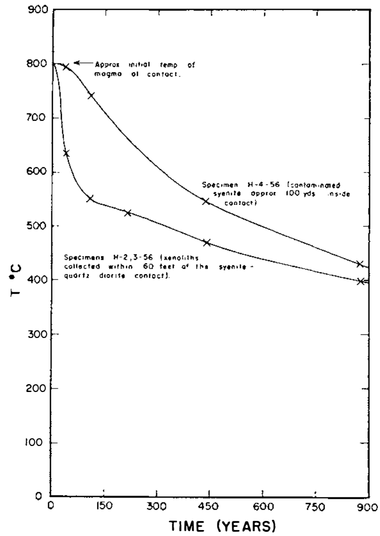

Figure 4. Cooling curves for syenite intrusion, after LA FRENIERE (1956).

may be required for the $2v_x$ curves for hypabyssal plagioclase of composition An 0–40.

The cooling times in Table 1 were determined from curves (Figure 4) prepared by La Freniere (1957). He derived these curves from those of Larson and Lovering. The temperature of 475 °C was chosen as a basis of reference because: *a*) it is within 20 °C of the temperature where the greater number af La Freniere's cooling curves begin to stabilize, and, *b*) it is assumed that the ordering processes ceased before magmas have cooled to this temperature. The intermediacy index of each specimen (Table II) was plotted against the time required for it to cool to 475 °C (Figure 5). From this it became apparent that the more ordered specimens, Nos. 9 and 8, cooled more slowly than the less ordered speciments, Nos. 4, 5, and 6; furthermore, specimens Nos. 1 and 3, with the lowest ordering indices, cooled more rapidly than any of the others.

Conclusions

Any conclusions drawn from the data derived from this study are limited by the small number of samples. The writers feel, however, that there is a definite relationship between the order-disorder of the

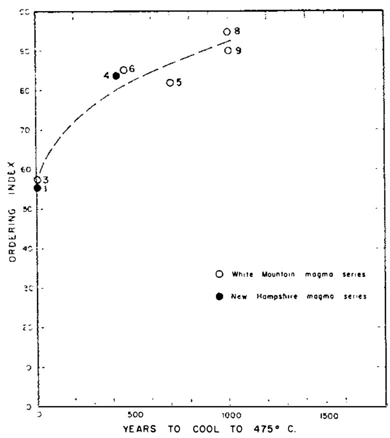

Figure 5. Intermediacy (ordering) indices versus years to cool to 475 °C. Note that the more ordered specimens have a longer cooling history. See text for explanation.

specimens and their cooling history. It is apparent from Figure 5, that the cooling rate of the more ordered forms is greater than that of the disordered forms, suggesting that ordering is a function of time. The importance of the cooling rate is further supported by the fact that with the exception of sample No. 6, the initial magma temperatures for all the plotted specimens were approximately 800 °C (La Freniere (1957)). This indicates that for these rocks the order-disorder relations in the plagioclase are produced by variable cooling rates rather than by variable temperatures of crystallization.

When the specimes of both magma series were plotted against the cooling time to 475 °C, both series formed the same curve, though their times of intrusion were widely separated. This could indicate similar cooling histories, which suggest that the New Hampshire magma series is also epizonal or that reheating by plutons of the White Mountain magma series has modified the older granitic rocks. Though the ultimate comparison of the two magma series should require additional evidence, it would appear that order-disorder relationships can provide an additional method for the description and comparison of intrusive bodies.

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