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Extinction angles of synthetic intermediate albites

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Abstract

Extinction angles of synthetic intermediate albites measured on a universal stage are extrapolated to low albite and analbite. The extinction angle on (010) plates, $X' \wedge$ trace (001), decreases linearly with $2\theta(131)$–$2\theta(1\bar{3}1)$ and hence with structural state from 19.9° for maximum low albite to 7.7° for analbite. The extinction angle on (001) plates, $X' \wedge$ trace (010), increases from 2.8° for low albite to 8.1° for analbite.

Introduction

Whereas the extinction angles on (010) and (001) cleavage plates of natural low albite are well established, only few data exist for high albite or analbite, and no data at all have been reported for intermediate albites. This is due to the rare natural occurrence of intermediate to high albite of pure Na-feldspar composition, and due to the small grain size and lamellar twinning of synthetic albites which are thus only rarely suitable for optical measurements. Nevertheless, it was possible to measure the extinction angles of a few small untwinned crystals found in the synthetic Na-feldspars prepared by Raase and Kern (1969) and Raase (1971).

Previous data

Of the extinction angles on (010) and (001) reported for low albite and largely disordered albite (Table 1), those for low albite are rather uniform. The best values seem to be those of Crawford (1966, and personal communication 1976) on the very pure Tiburon albite, and those of Burri *et al.* (1967) calculated from selected optic orientation data of plagioclase and extrapolated to pure Na-feldspar composition. For largely disordered Na-feldspars, the data show significant discrepancies which may be partly due to measurement errors, particularly for synthetic Na-feldspar, and partly to a degree of disorder less than maximum, causing the extinction angle on (010) to be too high and that on (001) too low.

Procedure

The extinction angles of Na-feldspars synthesized by Raase and Kern (1969) and Raase (1971) were measured in grain mounts on a universal stage. The albite crystals or cleavage fragments were checked for their orientation and twinning. The extinction on (010), *i.e.* the angle between the vibration direction of the fast ray X' and the trace of the (001) cleavage, was measured only on untwinned crystal plates lying on their (010) face. The extinction on (001) was measured as the angle between X' and the twinning plane (010) of albite twins lying on the (001) face. The albites were usually tabular parallel to (010), and therefore more measurements could be made of the extinction on (010) than on (001). The standard deviation of the arithmetic mean for the extinction on (010) is about 0.3–0.6° and for the extinction on (001) about 0.3–1.0°. Single measurements in very small crystals sometimes deviate up to 4° from the arithmetic mean.

Results

Table 2 and Figure 1 show the results of the extinction measurements on 11 specimens of synthetic Na-feldspar with different thermal histories and thus with varying degrees of Al/Si order. The extinction angles on (010) and on (001) are plotted *versus* the X-ray powder line separation $2\theta(131)$–$2\theta(1\bar{3}1)$ for Cu$K\alpha$, which is a good indicator of the structural state (Stewart and Ribbe, 1969). An approximately linear relation between $2\theta(131)$–$2\theta(1\bar{3}1)$ and the extinction on (010) and on (001) is obtained (Fig. 1). For both data sets, linear and higher-order polynomials were calculated by the method of least-squares regression (Table 3). For the extinction on (001), the linear equation gives the best fit on the basis of Gauss' criterion. For the extinction on (010),

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Table 1. Extinction angles $X' \wedge$ trace (001) on (010) plates and $X' \wedge$ trace (010) on (001) of low albite and largely disordered Na-feldspar (high albite or analbite)

Reference	Location	Low albite Extinction angle on (010) (degrees)	Low albite Extinction angle on (001) (degrees)	High albite or analbite Extinction angle on (010) (degrees)	High albite or analbite Extinction angle on (001) (degrees)
Spencer 1937	Amelia Kodarma	18.8 19.5		8	
Tuttle and Bowen 1950	Amelia + synthetic	20	3	9	0-2
Schneider 1957	Schmirntal	20		7-8	
Crawford 1966, pers. comm. 1976	Tiburon	20.5	3.2		
Burri, Parker, and Wenk 1967		20.3	3.4	9.3	5.2
This work		19.9 esd 0.8	2.8 esd 0.9	7.7 esd 0.8	8.1 esd 0.9

the third-order polynomial fits slightly better than the linear equation, but the error and the small number of the measurements do not allow proof of a third-order relation. Therefore, only the first-order regression lines are drawn in Figure 1. The extrapolation of the regression lines to maximum-disordered analbite yields nearly the same value for the extinction on (010) and (001), *i.e.* 7.7±0.8° and 8.1±0.9°, whereas the extrapolation to maximum-ordered low albite yields 19.9±0.8° for the extinction on (010) and 2.8±0.9° for the extinction on (001).

Discussion

The results show that the extinction angles on (010) and (001) are both approximately linearly dependent on $2\theta(131)-2\theta(1\bar{3}1)$, and thus on the structural state (Fig. 1). A linear relation with $2\theta(131)-2\theta(1\bar{3}1)$ has also been reported for the optic axial angle $2V$ of synthetic Na-feldspars (Raase and Kern, 1969). The optic axial angle should be more suitable for a precise determination of the structural state of a Na-feldspar because of its large range of variation (~ 50°), but the measurement of the extinction on (010) will also give valuable estimates.

The extrapolated extinction angles for maximum low albite and analbite agree in general with previous data (Table 1). However, a discrepancy occurs for the extinction on (001), which extrapolates to about 8° for analbite, whereas Tuttle and Bowen (1950) reported 0–2° for synthetic 'high albite' and Burri *et al.* (1967) calculated an angle of 5.2° for three heated natural albites and one synthetic Na-feldspar. The very low extinction angle for the synthetic albite determined by Tuttle and Bowen (1950) cannot yet be explained. A misidentification of the optic orientation of the small synthetic crystals might have happened. Stewart (1974) hypothesized that the extinction on (001) of completely disordered high albite could be zero, mainly on the basis of Tuttle and Bowen's data. However, symmetry considerations do not require the extinction on (001) to be closer to zero in analbite than in low albite. The lattice angles α and γ also both show a greater departure from 90° in analbite than in low albite, if observed at room temperature. The extinction angle on (001) in fact increases from low albite to analbite. The value of 5.2°

Table 2. Extinction angles $X' \wedge$ trace (001) on (010) plates and $X' \wedge$ trace (010) on (001) of synthetic Na-feldspars in relation to $2\theta(131)-2\theta(1\bar{3}1)$ for Cu$K\alpha$ radiation

Specimen	X'∧(001) on (010) (degrees)	X'∧(010) on (001) (degrees)	2θ(131)-2θ(1$\bar{3}$1) (degrees)
I 5 +)	9.2 (3)	7.1 (3)	1.88
I 1 +)	9.6 (3)	7.4 (5)	1.85
V 48 †)	10.3 (4)	7.25(5)	1.81
V 33 *†)	11.9 (3)	6.8 (3)	1.76
I 12 +)	10.6 (5)	5.8 (3)	1.735
V 36 *†)	13.1 (4)	5.8 (7)	1.65
V 34 *†)	14.1 (5)	4.5 (5)	1.57
V 13 +)	14.6 (4)	5.6 (6)	1.41
IV 30 +)	16.9 (6)	n.d.	1.29
III 47 *+)	18.4 (6)	3.5 (5)	1.22
V 8 *†)	19.7 (6)	3.7 (9)	1.17

Parenthesized figures represent the estimated standard deviation in terms of least units cited for the value to their immediate left.

+) Specimen from Raase and Kern (1969)
†) Specimen from Raase (1971)
*) Lattice constants are reported in the above cited papers.

Table 3. Equations relating the extinction angles to the line separation $2\theta(131)-2\theta(1\bar{3}1)$ calculated by the method of least-squares regression

$$2\theta(131) - 2\theta(1\bar{3}1) = a_0 + a_1\varepsilon + a_2\varepsilon^2 + a_3\varepsilon^3$$

ε	a_0	a_1	a_2	a_3	r^2	estimated mean square error
X'∧(001) on (010)	2.54 esd 0.06	-0.0714 esd 0.0043			0.969	0.00239
	2.60 esd 0.31	-0.081 esd 0.045	0.0003 esd 0.0016		0.969	0.00268
	0.13 esd 1.51	0.47 esd 0.34	-0.040 esd 0.024	0.0009 esd 0.0006	0.978	0.00220
X'∧(010) on (001)	0.66 esd 0.14	0.165 esd 0.024			0.850	0.0112

calculated by Burri *et al.* (1967) for the extinction on (001) of "high albite" may still be low, because the heated albite samples from Schneider (1957) and Marfunin (1960), upon which their calculations are essentially based, may contain potassium from the furnace atmosphere (Brown, 1967). Potassium in albite will reduce the extinction on (001) significantly, because alkali feldspar with about 40 percent Or is monoclinic, and thus has an extinction on (001) of 0° (Orville, 1967).

The extinction angle on (010) of analbite is obtained as 7.7° by extrapolation, slightly lower than that reported by some other authors (see Table 1). A value of 9° was reported by Tuttle and Bowen (1950) on "high albite" synthesized at 800°C. At this temperature the Na-feldspar will not crystallize in the completely disordered form (MacKenzie, 1957) and, therefore, the extinction on (010) of the form with maximum disorder (analbite) should be somewhat lower than 9°. The value of 9.3° calculated by Burri *et al.* (1967) for heated natural Na-feldspars may also be high, because it is not proven that these feldspars disordered completely on dry heating.

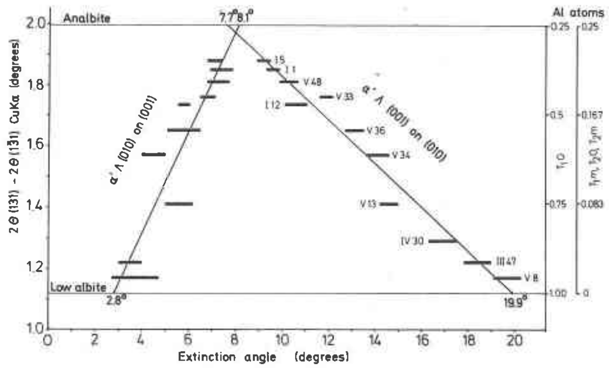

Fig. 1. Relation between the extinction angle on (010) and on (001), respectively, and the line separation $2\theta(131)-2\theta(1\bar{3}1)$ for $CuK\alpha$. At the right, Al contents have been estimated assuming a linear relation to $2\theta(131)-2\theta(1\bar{3}1)$. The extinction angles for analbite and maximum low albite are extrapolated from least-squares regression lines. The albite end-member values of $2\theta(131)-2\theta(1\bar{3}1)$ are taken from Stewart and Wright (1974). The length of the error bars is twice the standard deviation.

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