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ROLE AND CONVENIENCE OF LATTICE ELEMENTS FOR DERIVING Si, Al DISTRIBUTION IN ALKALI FELDSPAR

RIASSUNTO. — Vengono valutate le possibilità di stima della distribuzione (Si, Al) tra le posizioni centro-tetraedriche dei feldspati alcalini mediante elementi reticolari tenendo conto che $t_1O + t_1m + t_2O + t_2m = 1$ e $t_2O = t_2m = t_2$. Risultano possibili due tipi di procedimento che mediante diagrammi di appropriati elementi reticolari conducono rispettivamente a una stima diretta o indiretta di t_1O e t_1m, quest'ultima attraverso la determinazione di $t_1O + t_1m$ e $t_1O - t_1m$. Tra i procedimenti del primo tipo, si possono considerare i diagrammi $Tr[011]/Tr[1\bar{1}0]$ e $Tr[0\bar{1}1]/Tr[110]$ per determinare rispettivamente t_1O e t_1m, e inoltre i diagrammi $Tr[1\bar{1}0]/t_1O$ e $Tr[110]/t_1m$ proposti da KROLL (1973) e ora rivisti per la scelta dei termini estremi di riferimento. Per quanto teoricamente corretti, nella pratica questi procedimenti non appaiono convenienti poichè, tra vari svantaggi, in essi sussiste ambiguità tra sostituzione (K, Na) e distribuzione (Si, Al). Nel metodo proposto da KROLL (1973), inoltre, per un dato valore di $Tr[1\bar{1}0]$ o $Tr[110]$ e per una data composizione, sussiste anche indeterminazione nella valutazione di t_1O o t_1m tra differenti cammini di ordinamento. Per quanto riguarda i metodi del secondo tipo, tra i vari diagrammi esaminati per stimare $t_1O + t_1m$ in pratica appaiono convenienti soltanto i grafici b/c (STEWART e RIBBE, 1969) e b^*/c^* (SMITH, 1968). Per la stima di $t_1O - t_1m$ si hanno maggiori alternative. Il diagramma $\{Tr[011] - Tr[0\bar{1}1]\}/\{Tr[110] - Tr[1\bar{1}0]\}$, rigorosamente dipendente da $t_1O - t_1m$, appare conveniente. Il diagramma $\cos\alpha/\cos\gamma$ (BLASI, 1978) può anche essere usato a questo scopo, e a causa dei valori che α e γ assumono nei feldspati alcalini, esso può essere sostituito dal diagramma più semplice α/γ, le cui implicazioni sono simili a quelle del diagramma α^*/γ^*, proposto da SMITH (1968) e da STEWART e RIBBE (1969). Questi quattro metodi forniscono valori di $t_1O - t_1m$ praticamente coincidenti tra loro, e molto prossimi a quelli ottenibili dalle distanze $<T \cdot O>$ per i feldspati alcalini triclini di cui sono state risolte le strutture.

ABSTRACT. — The possibilities of estimating Si, Al distribution among the *T*-site in alkali feldspar by using lattice elements and taking into account that $t_1O + t_1m + t_2O + t_2m = 1$ and $t_2O = t_2m = t_2$ are here evaluated. Two kinds of procedure founded on plots of appropriate lattice elements are found to be possible, and enable t_1O and t_1m to be estimated directly or indirectly, the latter by determining $t_1O + t_1m$ and $t_1O - t_1m$. Among the procedures of the first kind, there are the plots of $Tr[011]$ vs. $Tr[1\bar{1}0]$ and $Tr[0\bar{1}1]$ vs. $Tr[110]$ for deriving t_1O and t_1m, respectively. There are also the plots of $Tr[1\bar{1}0]$ vs. t_1O and $Tr[110]$ vs. t_1m proposed by KROLL (1973) and now revised for the reference values of the extreme end-members of alkali feldspars. Although theoretically correct, in practice these procedures do not appear convenient because, among various disadvantages, they involve ambiguity between the K, Na substitution and the Si, Al distribution. In addition, in the method proposed by KROLL (1973) for a given value of $Tr[1\bar{1}0]$ or $Tr[110]$ and for a given composition, there is also an indeterminacy in the estimate of t_1O or t_1m among different paths of ordering. For procedures of the second type, among the different diagrams investigated for estimating $t_1O + t_1m$, only the plots of b vs. c (STEWART and RIBBE, 1969) or b^* vs. c^* (SMITH, 1968), in practice appear to be convenient.

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For estimating $t_10 - t_1m$ there are more possibilities. There is the plot of $\{Tr[011] - Tr[0\bar{1}1]\}$ vs. $\{Tr[110] - Tr[1\bar{1}0]\}$, which is rigorously dependent on $t_10 - t_1m$. The plot of $\cos\alpha$ vs. $\cos\gamma$ (BLASI, 1978) can also be used and, because of the values of α and γ in alkali feldspar, can be replaced by the simpler plot of α vs. γ, the latter yielding similar implications to the plot of α^* vs. γ^* proposed by SMITH (1968) and STEWART and RIBBE (1969). These four procedures give values of $t_10 - t_1m$ that practically coincide with each other, and are very near to those obtainable from the $<T\text{-}O>$ distances for the triclinic alkali feldspars whose structure has been determined.

Introduction

In the crystal lattice of alkali feldspar it is possible to identify lattice elements whose changes are influenced by the Al contents of the T-sites according to the following relationships:

$$k_1 + k_2t_10, \quad k_3 + k_4t_1m, \quad k_5 + k_6(t_10 + t_1m), \quad k_7 + k_8(t_10 - t_1m),$$

where k_i are numerical coefficients, t_10 and t_1m indicate the Al contents of the T_10 and T_1m sites, when adopting KROLL's (1973) notation, which uses for this purpose the code of the appropriate T-site in the lower case. From appropriate combinations of lattice elements dependent on the Al contents of T-sites according to the aforementioned expressions, further parameters whose changes are still linearly dependent on the Al contents of T_1-sites can be derived.

Taking into account that in alkali feldspar $t_10 + t_1m + t_20 + t_2m = 1$ and $t_20 = t_2m = t_2$, an appropriate utilization of lattice elements may allow an estimate of the Si, Al distribution among the T-sites to be made which, theoretically, can be obtained in two different ways. The first leads to a direct measure of t_10 and t_1m, while the second leads to their indirect measure, obtained from the determination of $t_10 + t_1m$ and $t_10 - t_1m$.

Since, in practice, the two different procedures did not turn out to be equivalent, this paper will discuss the role and convenience of lattice elements involved in the determination of the T-site occupancies in alkali feldspar.

Alkali feldspar end-members

When inspecting ordering by lattice elements in a given alkali feldspar, knowledge of the T-site occupancies and of the unit-cell parameters for the reference end-members is required. These end-members identify standard (K, Na)-series and allow the two extreme ordering paths, known as one-step and ideal two-step, to be defined.

The reference end-members for which $t_10 = t_1m = t_20 = t_2m = 0.25$ define

the topochemically monoclinic series, high sanidine-high albite, HS-HA for short, whose members have actual monoclinic symmetry for $0.4 \leqslant N_{or} \leqslant 1$, and actual triclinic symmetry for $0 \leqslant N_{or} \leqslant 0.4$.

The end-members for which $t_10 = 1$ and $t_1m = t_20 = t_2m = 0$ define the topochemically triclinic series, low microcline-low albite, LM-LA for short, whose members have actual triclinic symmetry.

The one-step trend corresponds to the path leading from the HS-HA end-members to the LM-LA end-members. The ideal two-step trend corresponds to the path which leads from HS-HA to LM-LA passing through end-members for which the T-site occupancy is expressed by $t_10 = t_1m = 0.5$ and $t_20 = t_2m = 0$. This Si, Al distribution is proper to the topochemically monoclinic theoretical series called by SMITH (1974) theoretical low sanidine — Na-exchanged theoretical low sanidine, LS — Na-exch. LS for short ([1]). The members of this series should have actual monoclinic symmetry for $0.4 \leqslant N_{or} \leqslant 1$ and actual triclinic symmetry for $0 \leqslant N_{or} \leqslant 0.4$, on the analogy of the members of corresponding composition in the series with complete Si, Al disorder.

The existence of a natural K-feldspar with a Si, Al distribution equal to that assumed for LS is controversial; however, a large number of K-feldspars approximate to this ideal model. PRINCE, DONNAY and MARTIN (1973), from a refinement of the neutron scattering factors, obtained 0.50 Al in T_1 and 0.0 Al in T_2 for the Himalaya orthoclase. SMITH (1974) reported that this specimen was not the same as theoretical low sanidine, and that it was a domain-twinned microcline. Furthermore, STEWART and WRIGHT (1974) suggest arguments for the existence of monoclinic K-feldspars more highly ordered than the Himalaya specimen.

A Si, Al distribution equal to that assumed for Na-exch. LS has never been found in Na-feldspars. However, the Na-exchanged products of some K-feldspars, e.g. Na-exch. Spencer U and Na-exch. Spencer B obtained by WRIGHT and STEWART (1968), have unit-cell parameters that approximate to this ideal.

For a full description of all observed types of Si, Al distribution, in addition to the end-members HS, LM, LA, and HA, it is convenient to involve LS and Na-exch. LS, irrespective of their actual occurrence. For HS, LM, LA, and HA, the unit-cell parameters proposed by SMITH (1974) or by STEWART and WRIGHT (1974) can be used, while for LS and Na-exch. LS, on the basis of available structural data, it appears justified to assume: $b_{LS} = b_{LM}$, $c_{LS} = c_{LM}$, $\alpha_{LS} = 90°$, $\gamma_{LS} = 90°$, $b_{Na\text{-}exch.LS} = b_{LA}$, $c_{Na\text{-}exch.LS} = c_{LA}$, $\alpha_{Na\text{-}exch.LS} = \alpha_{HA}$, $\gamma_{Na\text{-}exch.LS} = \gamma_{HA}$. As regards cell edge a, its change with ordering is trivial but does exist; for the sake of simplicity, in line with SMITH (1974), it was assumed that $a_{LS} = a_{HS}$ and $a_{Na\text{-}exch.LS} = a_{HA}$. Any assumption for β is disregarded, since this angle is not required in the analysis that follows.

([1]) For the potassic end-member, MEGAW (1974) suggests arguments for retention of the term « ideal orthoclase ».

Direct estimate of $t_1 0$ and $t_1 m$

For this purpose, two rectangular plots can be used, one of which is constructed with two lattice elements dependent on $t_1 0$, and the other with two lattice elements dependent on $t_1 m$.

Since the Al contents encountered along the lattice translations $Tr[110]$ and $Tr[1\bar{1}0]$ are $Al_{Tr[110]} = 2 - 2t_1 m$ and $Al_{Tr[1\bar{1}0]} = 2 - 2t_1 0$ (KROLL, 1973), and the Al contents along $Tr[011]$ and $Tr[0\bar{1}1]$ are $Al_{Tr[011]} = 2 - t_1 0$ and $Al_{Tr[0\bar{1}1]} = 2 - t_1 m$ (BLASI, 1978), the plots of $Tr[011]$ vs. $Tr[1\bar{1}0]$ and $Tr[0\bar{1}1]$ vs. $Tr[110]$ are indicated for deriving $t_1 0$ and $t_1 m$, respectively.
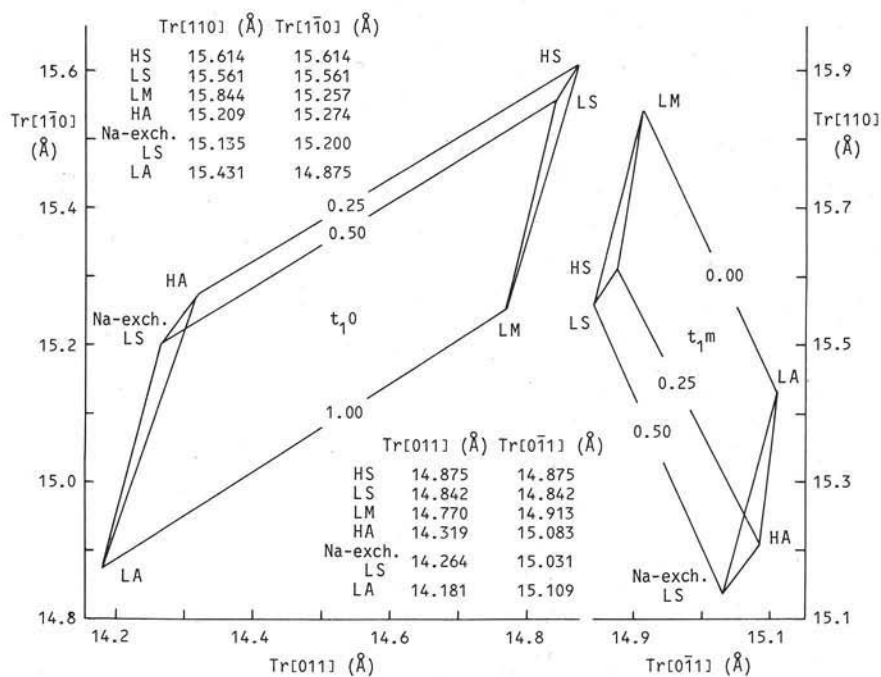

Fig. 1. — Plots of $Tr[011]$ vs. $Tr[1\bar{1}0]$ and $Tr[0\bar{1}1]$ vs. $Tr[110]$. For calculating the relevant lattice translations, use was made of the unit-cell parameters proposed by Smith (1974) for high sanidine (HS), low microcline (LM), low albite (LA), and high albite (HA), and on the basis of these, the lattice constants for theoretical low sanidine (LS) and Na-exchanged theoretical low sanidine (Na-exch. LS) were derived, as explained in the text.

Fig. 1 shows these two plots constructed with the values of the lattice translations along [110], [1$\bar{1}$0], [011], and [0$\bar{1}$1], obtained for the end-members involved by using the following relationships: $Tr[110] = \sqrt{(a^2 + b^2 + 2ab\cos\gamma)}$, $Tr[1\bar{1}0] = \sqrt{(a^2 + b^2 - 2ab\cos\gamma)}$, $Tr[011] = \sqrt{(b^2 + c^2 + 2bc\cos\alpha)}$, and $Tr[0\bar{1}1] = \sqrt{(b^2 + c^2 - 2bc\cos\alpha)}$. Use was made of the unit-cell parameters proposed by SMITH (1974) for HS, LM, LA, and HA and, on the basis of these, the lattice
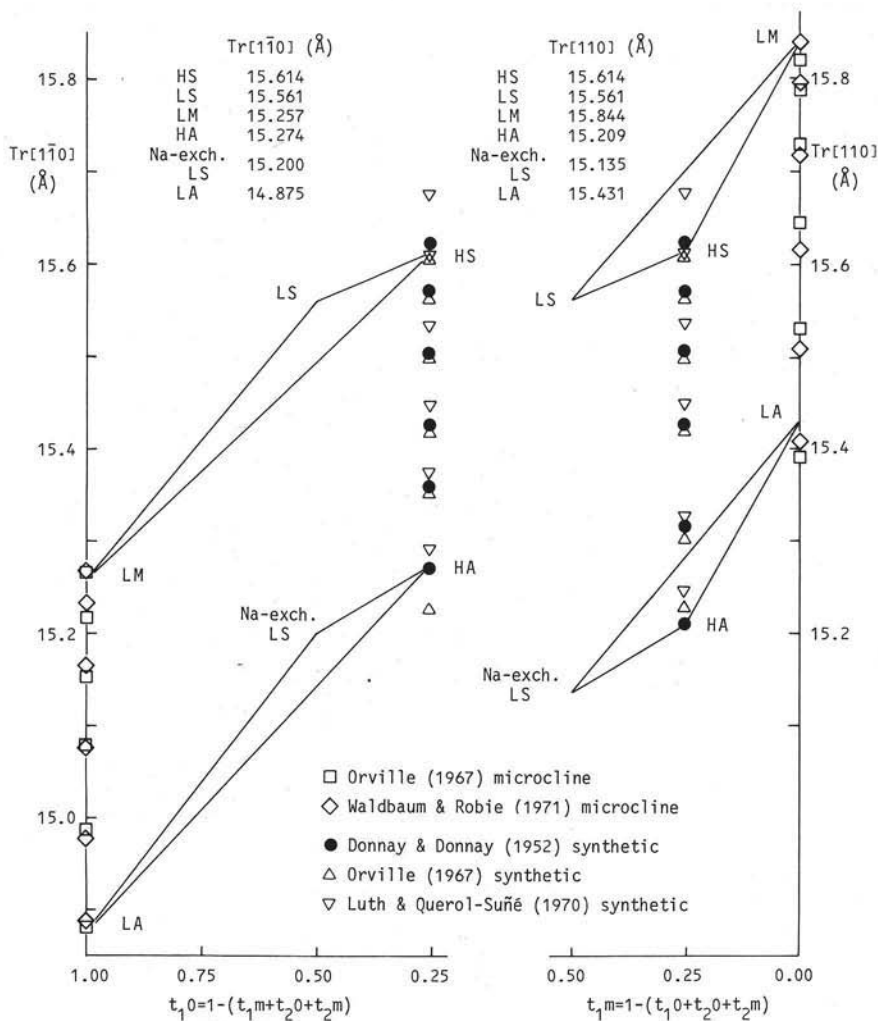
Fig. 2. — Plots of $Tr[1\bar{1}0]$ vs. t_10 and $Tr[110]$ vs. t_1m by Kroll (1973) revised for choice of the reference values for the extreme end-members of alkali feldspars. The values for the involved lattice translations are the same as those given in Fig. 1. Maximum and minimum ordering was assumed for the members in the low and high temperature (K, Na)-series plotted at intervals of 0.2 N_{or}. The re-refinements of Wright and Stewart (1968) on the data of Donnay and Donnay (1952) were used.

constants for LS and Na-exch.LS were derived in the way indicated in the previous section.

For a direct measure of t_10 and t_1m in alkali feldspar, KROLL (1973) also proposed two plots in which he had calibrated $Tr[1\bar{1}0]$ vs. t_10 and $Tr[110]$ vs. t_1m, respectively. In addition, he announced the extension of this method to ternary feldspars and plagioclases (cf. BAMBAUER, KROLL, NAGER and PENTINGHAUS, 1974; KROLL, 1976).

In accordance with SMITH (1974), the original plots proposed by KROLL (1973)

for alkali feldspars have been revised in Fig. 2 for choice of the end-members by using the same values of $Tr[110]$ and $Tr[1\bar{1}0]$ as those involved in Fig. 1.

The plots in Figs. 1 and 2, for correct utilization, must be contoured for composition.

Contouring for composition

Two different sets of isopleths must be reconstructed for the two extreme trends of ordering in both diagrams in Figs. 1 and 2.

Considering first the contouring for the one-step trend, (K, Na)-series with maximum and minimum ordering are necessary, possibly together with (K, Na)-series with known intermediate ordering in the one-step trend.

On the basis of the non-partial (K, Na)-series at the moment available, along the joins LM-LA and HS-HA, linear contouring for composition appears unsatisfactory, while non-linear contouring is made difficult because of the discrepancies between the values of the lattice translations in the members of equal composition and structural state, and because of the present impossibility of giving them a proper weight. There remains the possibility of reducing the values of the lattice translations for the members of the available (K, Na)-series to the same scale as the values of the lattice translations for the relevant extreme end-members, and of then drawing the isopleths for the points corresponding to the mean values of the appropriate lattice translations for the members of equal composition and structural state. However, in these circumstances in the members of the sanidine-high albite series there was the drawback that for composition $0.4 \leqslant N_{or} \leqslant 1$, although $\gamma = 90°$, $Tr[110]$ is significantly different from $Tr[1\bar{1}0]$.

For the sake of illustration, the values of $Tr[110]$ and $Tr[1\bar{1}0]$ for the non-partial (K, Na)-series at present available have been plotted in Fig. 2 at intervals of 0.2 N_{or}, assuming maximum and minimum ordering for the low and high temperature series, respectively. These values have been calculated by using the lattice constants derived from the regression equations recalculated by LUTH (1974) for the different series.

As regards contouring for the ideal two-step trend, in addition to (K, Na)-series with maximum and minimum ordering, (K, Na)-series with $t_1 = 0.5$ and $t_2 = 0$ are necessary, possibly together with (K, Na)-series with known intermediate ordering in the ideal two-step trend. In addition to the aforementioned (K, Na)-series with an assumed maximum and minimum ordering, at present only the ion-exchanged P50-56F series (WRIGHT and STEWART, 1968) is available, for which however the starting material is an orthoclase with optics and lattice constants indistinguishable from those of Spencer C.

From the foregoing, a contouring for composition or, as an alternative, an extrapolation of the unit-cell parameters along an expected ion-exchange path to the pure end-member, with the data so far available, does not appear completely reliable.

Estimate of t_1O+t_1m and t_1O-t_1m

For this purpose, two rectangular plots can be used, which are constructed with a pair of lattice elements or of appropriate combinations of them, dependent on $t_1O + t_1m$ and $t_1O - t_1m$, respectively.

In order to obtain values of $t_1O + t_1m$, use can be made of the plot of b vs. c, which yields the structural indicator $\Delta(bc)$ (STEWART and RIBBE, 1969; STEWART and WRIGHT, 1974; STEWART, 1975). For the same purpose, according to SMITH (1968; 1974), in all circumstances in which it may be useful, the plot of b^* vs. c^* can be used, and this gives the structural indicator $\Delta(b^*c^*)$.
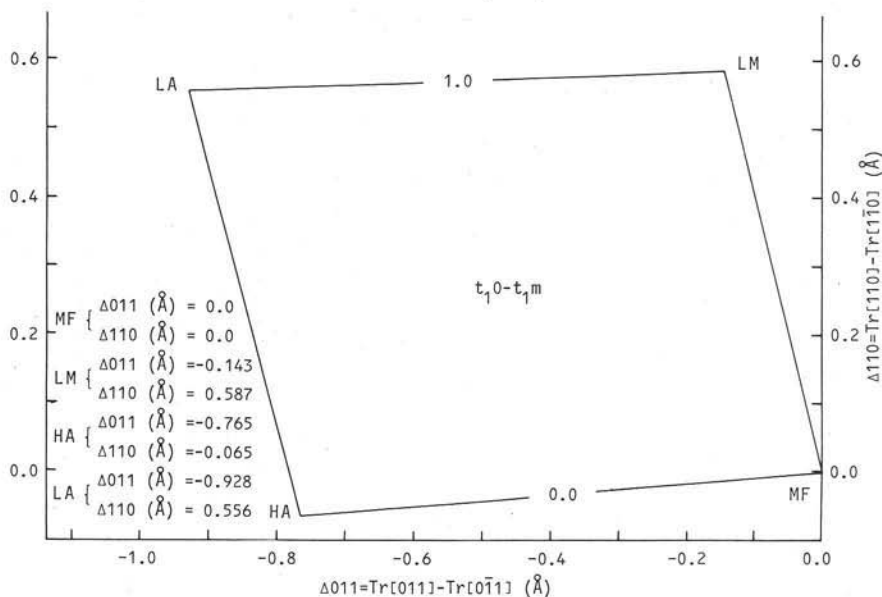

Fig. 3. — Plot of $\{Tr[011]\text{-}Tr[0\bar{1}1]\}$ vs. $\{Tr[110]\text{-}Tr[1\bar{1}0]\}$, or $\Delta 011$ vs. $\Delta 110$, for short. The values for the relevant lattice translations are given in Fig. 1. As explained in the text, the values of $\Delta 011$ and $\Delta 110$ are given only for the end-members MF (monoclinic feldspars), LM, LA, and HA.

Theoretically, there are other possibilities for deriving $t_1O + t_1m$, which in practice do not appear convenient. In fact, the diagrams inspected with lattice elements, or appropriate combinations of them, dependent on $t_1O + t_1m$, show geometrical shapes that do not permit clear enough contouring for deriving the sum of the Al contents of the T_1O and T_1m sites.

Scrutiny of the possibilities for deriving $t_1O - t_1m$ offers more numerous alternatives. The plot of $\{Tr[011] - Tr[0\bar{1}1]\}$ vs. $\{Tr[110] - Tr[1\bar{1}0]\}$, or $\Delta 011$ vs. $\Delta 110$ for short, is rigorously dependent on $t_1O - t_1m$. In fact, the Al contents influencing the two parameters $\Delta 011$ and $\Delta 110$ involved in this diagram are equal to $-(t_1O - t_1m)$ and $2(t_1O - t_1m)$, respectively. Fig. 3 shows the diagram of $\Delta 011$ vs. $\Delta 110$, which has a geometrical shape suitable for good linear contouring for $t_1O - t_1m$.

TABLE 1

Values of $t_1 0 - t_1 m$ derived from lattice elements for selected triclinic alkali feldspars

sample	$t_1 0 - t_1 m$ from the plots of				sample	$t_1 0 - t_1 m$ from the plots of			
	Δ011 vs. Δ110 (†)	cosα vs. cosγ	α vs. γ	α* vs. γ*		Δ011 vs. Δ110 (†)	cosα vs. cosγ	α vs. γ	α* vs. γ*
K-feldspars (Stewart and Wright, 1974)					synthetic albites (Martin, 1970)				
Stewart 3b	0.185	0.185	0.185	0.185	1277	0.154	0.154	0.154	0.153
Spencer H	0.224	0.224	0.224	0.224	1216 (¶)	0.182	0.182	0.182	0.180
Stewart 4b	0.282	0.282	0.282	0.281	1219 (¶)	0.194	0.194	0.194	0.193
Spencer E	0.289	0.290	0.289	0.289	393	0.206	0.206	0.206	0.205
P23.4	0.298	0.298	0.298	0.297	330	0.310	0.309	0.309	0.308
Fox E	0.383	0.384	0.383	0.383	321	0.425	0.423	0.423	0.423
Wright 211	0.589	0.589	0.588	0.588	1310	0.492	0.491	0.491	0.491
SH-C	0.741	0.741	0.741	0.741	402	0.539	0.538	0.538	0.538
White 1	0.795	0.796	0.796	0.795	391	0.557	0.557	0.557	0.557
P63-1-Mi	0.910	0.911	0.911	0.910	1298	0.642	0.641	0.641	0.642
T116	0.914	0.915	0.915	0.914	384	0.760	0.759	0.759	0.760
WC 4-15	0.940	0.941	0.941	0.940	455	0.792	0.791	0.791	0.792
MP-3Mi	0.952	0.953	0.953	0.952	382	0.890	0.889	0.889	0.891
Blue Mtn	1.003	1.004	1.004	1.003	383	0.917	0.916	0.916	0.918

(†) Δ011 = Tr[011] − Tr[0$\bar{1}$1]; Δ110 = Tr[110] − Tr[1$\bar{1}$0].
(¶) "Highly metastable" specimen.

Taking into account that the Al content influencing cosγ is equal to $t_1 0 - t_1 m$, and that influencing cosα is given by a complicated function closely approximate to $- (t_1 0 - t_1 m) 3/4$, the plot of cosα vs. cosγ can be used for estimating $t_1 0 - t_1 m$ (BLASI, 1978). Because of the values of α and γ in alkali feldspars, this plot can be replaced by the simpler diagram of α vs. γ. The use of the latter is equivalent to the use of the plot of α^* vs. γ^*, which yields the structural indicator $\Delta(\alpha^* \gamma^*)$ (SMITH, 1968, 1974; STEWART and RIBBE, 1969; STEWART and WRIGHT, 1974; RIBBE, 1975 b; STEWART, 1975).

The four procedures mentioned for deriving $t_1 0 - t_1 m$ have been compared by using most of the triclinic K-feldspars quoted by STEWART and WRIGHT (1974), many of the albites synthesized by MARTIN (1970), and all the triclinic alkali feldspars whose structures have so far been published along with the lattice constants. Since more than a few percent of components in solid solution other than Or and Ab cause essentially identical changes in cell dimensions as does Si, Al disorder in pure alkali feldspar end-member (SMITH, 1974; STEWART and WRIGHT, 1974), the anorthoclase used for structure analysis by DE PIERI and QUARENI (1973) will not be considered here.

The values of $t_1 0 - t_1 m$ have been obtained by the calculation procedure devised by BLASI (1977). The unit-cell parameters proposed by SMITH (1974) for HS, LM, LA, and HA have been used. Incidentally, in the plot of Δ011 vs. Δ110, the lattice elements for LS and Na-exch.LS are not necessary, because Δ110$_{LS}$ = Δ110$_{HS}$, Δ110$_{Na-exch.LS}$ = Δ110$_{HA}$, Δ011$_{LS}$ = Δ011$_{HS}$, and because between Δ011$_{Na-exch.LS}$ and Δ011$_{HA}$ there exists only a trivial difference of 0.002 Å.

Table 1 shows that for the K-feldspars quoted by STEWART and WRIGHT (1974),

TABLE 2

Values of t_10-t_1m derived from lattice elements and from $<T\text{-}O>$ distances for triclinic alkali feldspars used in structure determinations

reference	sample	t_10-t_1m from the plots of				t_10-t_1m from the $<T\text{-}O>$ distances	
		Δ011 vs. Δ110 (†)	cosα vs. cosγ	α vs. γ	α* vs. γ*	Smith's method, 1974	Ribbe's method, 1975a
Brown and Bailey (1964)	low microcline (Pellotsalo)	0.977	0.979	0.979	0.978	0.954	0.977
Finney and Bailey (1964)	low microcline (Pontiskalk)	0.955	0.957	0.957	0.956	0.917	0.938
Bailey (1969)	int. microcline (Spencer U)	0.373	0.374	0.374	0.373	0.378	0.396
Ribbe and Gibbs (1975)	int. microcline (K-235)	0.171	0.170	0.170	0.169	0.164	0.162
Ferguson et al. (1958); Ribbe et al. (1969)	low albite (Ramona)	1.013	1.012	1.012	1.016	1.023	1.046
Wainwright and Starkey (1968) (¶)	low albite (Tiburon)	0.983	0.983	0.983	0.985	0.986	1.008
Wainwright and Starkey (unpublished) (§)	high albite (heated Tiburon?)	0.061	0.061	0.061	0.058	0.078	0.077
Ferguson et al. (1958); Ribbe et al. (1969)	high albite (heated Amelia)	-0.009	-0.009	-0.009	-0.009	0.031	0.031
Prewitt et al. (1976)	high albite (synth.) T=24°C	0.005	0.005	0.005	0.002	0.039	0.038
do.	do. T=350°C	0.023	0.024	0.024	0.023	0.047	0.046
do.	do. T=600°C	0.024	0.024	0.024	0.026	0.039	0.038
do.	do. T=750°C	0.028	0.028	0.028	0.030	0.047	0.046
do.	do. T=950°C	0.023	0.024	0.024	0.026	0.016	0.015
do.	do. T=1090°C	0.008	0.008	0.008	0.008	0.016	0.015
do.	do. T=1105°C	0.003	0.003	0.003	0.003	0.016	0.015
Wright and Stewart (1968)	Na-exch. K-feldsp. (Spencer U)	0.297	0.297	0.297	0.295	—	—
do.	Na-exch. K-feldsp. (Spencer B)	0.031	0.030	0.030	0.030	—	—

(†) Δ011=Tr[011]−Tr[0$\bar{1}$1]; Δ110=Tr[110]−Tr[1$\bar{1}$0].
(¶) Lattice constants from Wainwright and Starkey (unpublished), quoted in Smith (1974).
(§) $<T\text{-}O>$ distances and lattice constants quoted in Smith (1974).

and the albites of MARTIN (1970), the values of t_10-t_1m obtained with the four above procedures practically coincide. For the alkali feldspars used in structure determinations, Table 2 enables the same to be said and further shows that the values of t_10-t_1m obtained by using lattice elements are very close to those calculated with the $<T\text{-}O>$ distances according to the methods proposed by SMITH (1974) and by RIBBE (1975 a) ([2]).

([2]) For the Spencer U specimen, STEWART (1975) calculated $\Delta(\alpha^*\gamma^*) = 0.35$ by using the approximate formulae of Luth quoted in the former's paper and based on the lattice constants proposed by STEWART and WRIGHT (1974) for HS, LM, LA, and HA. With the same unit-cell parameters used by STEWART (1975) the rigorous method proposed by BLASI (1977) gives an actual value of $\Delta(\alpha^*\gamma^*) = 0.379$, which is closer to that obtainable from the $<T\text{-}O>$ distances.

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TABLE 3
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Extreme values of t_1O and t_1m derived from the plots of $Tr[1\bar{1}0]$ vs. t_1O and $Tr[110]$ vs. t_1m for selected triclinic alkali feldspars

sample	t_1O	t_1m	sample	t_1O	t_1m
K-feldspars (Stewart and Wright, 1974) (†)			synthetic albites (Martin, 1970)		
Stewart 3b	0.492÷0.602	0.258÷0.419	1277	0.372÷0.486	0.215÷0.323
Spencer H	0.534÷0.635	0.257÷0.417	1216 (¶)	0.445÷0.546	0.236÷0.355
Stewart 4b	0.538÷0.638	0.220÷0.357	1219 (¶)	0.436÷0.538	0.224÷0.336
Spencer E	0.563÷0.658	0.228÷0.371	393	0.427÷0.531	0.212÷0.318
P23.4	0.578÷0.669	0.229÷0.373	330	0.489÷0.582	0.177÷0.265
Fox E	0.637÷0.715	0.205÷0.334	321	0.568÷0.646	0.144÷0.216
Wright 211	0.750÷0.804	0.135÷0.219	1310	0.620÷0.689	0.127÷0.191
SH-C	0.851÷0.883	0.089÷0.145	402	0.637÷0.703	0.105÷0.157
White 1	0.897÷0.919	0.077÷0.125	391	0.675÷0.734	0.115÷0.172
P63-1-Mi	0.975÷0.980	0.045÷0.072	1298	0.744÷0.791	0.098÷0.147
T116	0.964÷0.972	0.036÷0.058	384	0.821÷0.854	0.062÷0.093
WC 4-15	0.985÷0.988	0.032÷0.051	455	0.836÷0.866	0.047÷0.071
MP-3Mi	0.985÷0.988	0.023÷0.037	382	0.925÷0.938	0.032÷0.047
Blue Mtn	1.025÷1.020	0.011÷0.018	383	0.938÷0.949	0.021÷0.032

(†) Values obtained assuming N_{Or}=1.0.
(¶) "Highly metastable" specimen.

<div align="center">

Discussion and conclusions
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The plots of $Tr[011]$ vs. $Tr[1\bar{1}0]$ and $Tr[0\bar{1}1]$ vs. $Tr[110]$ (Fig. 1) involve an ambiguity between K, Na substitution and Si, Al distribution, which could be removed by performing a contouring for composition. However, as previously seen, this does not appear easily feasible with the data available at the moment.

In addition to this difficulty, the shape of the diagrams does not allow a significant enough distinction to be made between the two extreme trends of ordering and, furthermore, changes in $Tr[011]$ and $Tr[0\bar{1}1]$ with t_1O and t_1m respectively are very slight for a given composition.

As regards the diagrams of KROLL (1973), not even a contouring for composition would permit unequivocal determination of the Al contents. In fact, for a given value of $Tr[1\bar{1}0]$ and $Tr[110]$ and for a given composition, these diagrams involve an indeterminacy in the estimate of t_1O and t_1m, due to the circumstance that the representative point of a given alkali feldspar can be plotted on every straight line included between those that define the two extreme paths of ordering.

When the above extreme straight lines attain the maximum distance apart, the indeterminacy reaches its highest point. Under these circumstances, for a pure potassic composition in the diagrams of Fig. 2 for a single value of $Tr[1\bar{1}0]$, there are infinite values of t_1O in the 0.36÷0.50 range, and for a single value of $Tr[110]$ there are infinite values of t_1m in the 0.25÷0.40 range.

For the same alkali feldspars as in Table 1, for the purpose of illustration, Table 3 shows the pairs of values for t_1O and t_1m that define the indeterminacy intervals obtained by using the plots in Fig. 2. Pure potassic composition was assumed

for the K-feldspars. This simplification involves an error that may be significant in each value of each pair of $t_1 0$ or $t_1 m$, but is unimportant as regards the indeterminacy ranges.

The necessity of an aprioristic knowledge of the ordering path renders this procedure non-autonomous. According to KROLL (1973) some indirect information on the ordering path is provided by the plot of b vs. γ of MÜLLER (1969). In it, however, there is ambiguity between K, Na substitution and Si, Al distribution, as in other diagrams not considered here, which use lattice elements whose changes with ordering are expressed by relationships dependent on Al contents different in the abscissae and ordinates.
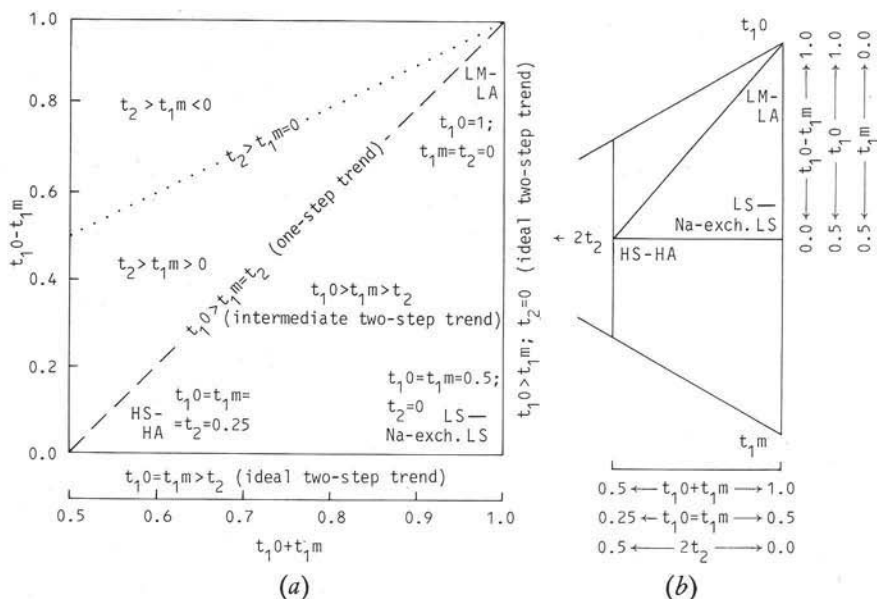

Fig. 4. — Relationships between (a) the rectangular plot of $(t_1 0 + t_1 m)$ vs. $(t_1 0 - t_1 m)$, devised by Smith (1974) in the form $\Delta(b^* c^*)$ vs. $\Delta(\alpha^* \gamma^*)$, and (b) the triangular plot of $t_1 0$, $t_1 m$, and $t_2 0 + t_2 m = 2 t_2$, subsequently proposed by Stewart and Wright (1974).

For evaluation of $t_1 m$, the plot $Tr[110]$ vs. $t_1 m$ also involves an indeterminacy in the two-step trend between the first stage and a part of the second one.

For all these reasons, the methods aiming at an estimate of the Si, Al distribution by determining directly $t_1 0$ and $t_1 m$ do not appear convenient, although theoretically correct.

While, in the determinative plots for $t_1 0$ and $t_1 m$, one-step and two-step trends are distinguishable, in the determinative plots for $t_1 0 + t_1 m$ and $t_1 0 - t_1 m$ this distinction does not appear. It is shown only by using these two plots simultaneously. Alternatively, it can be obtained by a rectangular plot of $(t_1 0 + t_1 m)$ vs. $(t_1 0 - t_1 m)$ (Fig. 4 a) such as that proposed by SMITH (1974) for $\Delta(b^* c^*)$ vs. $\Delta(\alpha^* \gamma^*)$, or by a triangular plot such as that subsequently proposed by STEWART and WRIGHT (1974),

having as vertices t_10, t_1m, and $t_20 + t_2m = 2t_2$. The latter plot is reset in Fig. 4 b in order to show that it includes the diagram in Fig. 4 a.

Referring only to the simpler rectangular plot in Fig. 4 a, it is worth to point out that, above the dashed line, there are no structural states possible or usual in natural or synthetic alkali feldspars. Upon and under this straight line there is an infinite number of paths along which the Si, Al distribution may occur in alkali feldspars.

The plot in Fig. 4 a can be constructed with the data obtained by any one of the procedures previously identified in order to estimate $t_10 + t_1m$ and $t_10 - t_1m$, and the results achieved are those that most approximate to those provided by the similar plot of $(t_10 + t_1m)$ vs. $(t_10 - t_1m)$, obtained by the $<T\text{-}O>$ distances through structure determinations.

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