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Feldspars from the Meldon aplite, Devonshire, England

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SUMMARY. Chemical analyses of nine K-feldspars and thirteen albites, along with their optical, physical, and X-ray data are presented. The obliquity values $\Delta = 12\cdot5(d_{131}-d_{1\bar{3}1})$ of the K-feldspars are found to be independent of the contents of silica and volatiles in the rocks. The role of temperature as the primary factor affecting the obliquity values is stressed. The relationship between the (An+Ab) content of the potassic phase of K-feldspars and $2V_\alpha$ is shown diagrammatically.

THE Meldon aplite, near Okehampton, Devonshire, is a soda-lithia aplite dyke about 20–5 m in thickness, occurring 1 km north-west of the main Dartmoor granite. Albite, quartz, mica, and K-feldspar are the essential minerals and elbaite, topaz, fluorite, apatite, and petalite are the accessory minerals of the aplite. The aplite is divided into three types: the 'blue aplite', a marginally chilled facies which approaches albitite in composition, the 'white aplite' which is unmetasomatised and contains (in order of abundance) albite, quartz, and lepidolite, and the 'brown aplite' which is moderately to strongly metasomatised (autometasomatism) and contains larger amounts of lepidolite and quartz than the other types and may also contain notable amounts of elbaite, topaz, fluorite, and apatite. The aplite is cut by two types of thin (2–7 cm) veins: one type, the 'pegmatite veins', consist of K-feldspar, quartz, lepidolite, albite, and elbaite; the second type, the 'pegmatitic veins', consist of K-feldspar, lepidolite, quartz, albite, topaz, and petalite. In addition the aplite contains synmagmatic as well as postmagmatic metasomatic megacrysts of K-feldspar. The brown aplite is richer in volatile components such as fluorine, boron, and water than the other two types. The veins are richer in volatiles than the aplite types. The 'pegmatitic veins' are richer in total volatiles ($F_2+H_2O+B_2O_3$) than the 'pegmatite veins'. A major paper dealing with the petrogenesis of the Meldon aplite is in preparation.

Chemistry. Nine K-feldspars and thirteen albites were separated and chemically analysed: conventional wet methods were mainly used, but for the low values of Fe_2O_3, MnO, and TiO_2 in these feldspars the more sensitive X-ray fluorescence techniques were employed; the latter method was also used for the determination of rubidium, caesium, barium, and strontium. The major alkalis were determined flame photometrically; lithium was sought in each case but could not be detected.

The albites show a very restricted range of chemical composition (table I). Their CaO content ranges from 0·26 to 0·92 %, their anorthite content thus ranging from

TABLE I. *Data for the albites*

	MN.57	M.15	MN.52	MO.1	MN.56	MN.75	MN.11	MN.69	MN.63	M.A.R.	MN.61	MN.117	MN.10B
SiO_2	67·34	67·89	68·18	68·40	68·15	67·35	67·03	67·16	67·16	68·56	67·36	68·40	67·57
TiO_2	0·01	nil	nil	0·10	0·01	0·25	nil	0·20	0·08	0·01	nil	nil	nil
Al_2O_3	20·19	19·79	20·00	19·11	20·30	19·85	20·65	19·92	20·01	19·05	20·18	19·50	19·96
Fe_2O_3	0·05	0·04	0·07	0·04	0·07	0·03	0·03	0·05	0·05	0·06	0·06	0·04	0·03
MgO	0·16	0·07	0·04	0·10	0·08	0·10	0·08	0·05	0·08	0·09	0·09	0·09	0·07
BaO	0·04	0·02	0·03	0·02	0·04	0·06	0·03	0·03	0·02	0·03	0·02	0·04	0·03
CaO	0·70	0·66	0·34	0·60	0·26	0·58	0·50	0·59	0·32	0·53	0·33	0·42	0·92
SrO	0·02	0·01	0·03	nil	0·03	nil	0·03	0·03	0·02	0·01	0·02	0·03	0·03
Na_2O	11·55	11·00	11·24	11·00	11·40	11·26	11·10	11·40	11·50	10·50	11·50	11·20	10·80
K_2O	0·24	0·31	0·36	0·30	0·23	0·30	0·23	0·57	0·23	1·22	0·20	0·60	0·60
Rb_2O	0·01	0·01	0·01	0·01	0·01	0·02	0·01	0·03	0·02	0·04	0·03	0·02	0·02
Cs_2O	0·01	0·02	0·02	0·01	0·02	0·03	nil	nil	0·07	nil	0·07	0·01	0·01
H_2O^+	0·05	0·07	0·07	0·08	0·08	0·06	0·05	0·07	0·14	0·07	0·09	0·03	0·08
H_2O^-	0·03	0·03	0·02	0·05	0·05	0·04	0·03	0·05	0·06	0·04	0·02	0·03	0·05
Sum	100·40	99·92	100·43*	99·82	100·73	99·93	99·77	100·15	99·76	100·21	99·97	100·41	100·17
Ab	95·09	94·65	95·82	95·09	97·05	95·08	95·92	93·61	96·70	98·85	96·75	93·58	91·66
An	3·47	3·37	1·89	3·05	1·42	2·86	2·63	2·94	1·65	2·68	1·70	2·16	4·64
Or	1·44	1·98	2·29	1·86	1·53	2·06	1·45	3·45	1·65	7·47	1·55	4·26	3·70
α	1·532	1·531	1·528	1·529	1·528	1·529	1·528	1·527	1·531	1·530	1·529	1·531	1·532
γ	1·541	1·541	1·537	1·539	1·538	1·539	1·538	1·538	1·539	1·540	1·538	1·539	1·541
$2V_\gamma$	80°	80°	81°	79°	79°	80°	79°	78°	79°	77°	80°	79°	81°
D	2·626	2·626	2·626	2·624	2·624	2·625	2·625	2·624	2·624	2·622	2·624	2·625	2·629
$\Delta 2\theta$†	1·10°	1·15°	1·18°	1·15°	1·10°	1·13°	1·10°	1·15°	1·13°	1·15°	1·10°	1·10°	1·15°

(Table 1 *cont.*):

Number of ions on a basis of 8 oxygen

	MN.57	M.15	MN.52	MO.1	MN.56	MN.75	MN.11	MN.69	MN.63	M.A.R.	MN.61	MN.117	MN.10B
Si	2·944	2·982	2·969	2·995	2·968	2·945	2·941	2·938	2·953	3·000	2·949	2·982	2·959
Al	1·040	1·025	1·027	0·986	1·029	1·023	1·068	1·027	1·037	0·983	1·042	1·010	1·031
Fe^{3+}	0·002	0·002	0·002	0·002	0·002	0·001	0·001	0·002	0·002	0·002	0·002	0·002	0·001
Ti	0·003	nil	nil	0·003	0·003	0·082	nil	0·066	0·027	0·001	nil	nil	nil
ΣR^{iv}	3·989	4·009	3·998	3·986	4·002	4·051	4·010	4·033	4·019	3·986	3·993	3·994	3·991
K	0·013	0·017	0·020	0·017	0·013	0·017	0·013	0·032	0·013	0·068	0·011	0·034	0·034
Na	0·979	0·936	0·949	0·934	0·962	0·955	0·944	0·967	0·980	0·891	0·976	0·947	0·917
Ca	0·033	0·031	0·017	0·028	0·012	0·027	0·024	0·028	0·015	0·025	0·015	0·020	0·043
Rb	tr.	tr.	tr.	tr.	tr.	0·001	tr.	0·001	0·001	0·001	0·001	0·001	0·001
Cs	tr.	0·001	0·001	tr.	0·001	0·001	nil	nil	0·002	nil	0·002	tr.	tr.
Ba	0·001	tr.	0·001	tr.	0·001	0·001	0·001	0·001	tr.	0·001	tr.	0·001	0·001
Sr	0·001	tr.	0·001	nil	0·001	nil	0·001	0·001	0·001	tr.	0·001	0·001	0·001
Mg	0·011	0·005	0·003	0·007	0·005	0·007	0·005	0·003	0·005	0·006	0·006	0·006	0·005
ΣX‡	1·038	0·990	0·993*	0·986	0·995	1·009	0·988	1·033	1·017	0·992	1·012	1·010	1·002

MN.57, MN.75, MN.11, MN.69, M.A.R., and MN.10B: Albites from the 'white aplite'.
MN.52, MN.56, MN.63, and MN.61: Albites from the 'brown aplite'.
M.15 and MN.117: Albites from the 'blue aplite'.
MO.1: Albite from the pegmatitic vein.
* Also MnO 0·02 %, 0·001 atom per 8 oxygen. † $2\theta_{131}-2\theta_{1\bar{3}1}$. ‡ K+Na+Ca+Rb+Cs+Ba+Sr+Mg.

1·42 to 4·64 %. No relation between the CaO content of the aplite and that of their albites could be found: this is attributed to metasomatism, including CaO metasomatism in the brown aplite, which has affected large parts of the aplite.

TABLE II. *Data for the K-feldspars*

	M.5	M.3	RA.4	MK.2	MN.21	MO.3	MN.61	MN.52	MN.62
SiO_2	64·72	64·63	64·17	63·97	64·25	64·27	64·20	64·41	65·42
Al_2O_3	18·70	19·21	19·62	19·48	19·40	19·30	19·96	19·06	18·38
Fe_2O_3	0·03	0·04	0·08	0·03	nil	0·02	0·03	0·13	0·03
MgO	0·06	0·05	0·04	0·07	0·07	0·02	0·02	0·02	0·02
CaO	0·40	0·21	0·18	0·35	0·25	0·06	0·09	0·09	0·14
BaO	0·20	0·04	0·06	0·07	nil	0·06	0·03	0·10	0·03
Na_2O	1·48	1·63	2·03	1·94	2·90	1·68	2·49	1·80	2·75
K_2O	14·20	13·71	13·38	13·70	12·60	14·20	12·80	13·57	12·80
Rb_2O	0·38	0·45	0·34	0·51	0·27	0·46	0·35	0·58	0·41
Cs_2O	0·09	0·04	0·13	0·04	0·13	0·04	0·18	0·20	0·07
H_2O^+	0·13	0·14	0·09	0·10	0·13	0·11	0·04	0·18	0·10
H_2O^-	0·05	0·04	0·02	0·04	0·03	0·06	0·05	0·07	0·03
Sum	100·44	100·19	100·14	100·30	100·03	100·28	100·24	100·21	100·18
Or	85·52	84·78	81·98	82·05	74·51	85·49	78·30	84·14	76·35
Ab	12·52	14·13	17·45	16·24	24·15	14·21	21·25	15·41	22·96
An	1·96	1·09	0·57	1·71	1·34	0·30	0·45	0·45	0·69
$(Ab+An)^*_K$	5	1	6	2	5	1	6	4	6
α	1·516	1·518	1·517	1·520	1·518	1·518	1·517	1·518	1·517
γ	1·526	1·528	1·528	1·530	1·529	1·529	1·528	1·529	1·527
$2V_\alpha$	56°	52°	56°	52°	56°	51°	58°	53°	57°
Δ†	0·02	0·00	0·02	0·03	0·03	0·00	0·00	0·00	0·01
Number of ions on a basis of 8 oxygen									
Si	2·972	2·962	2·946	2·940	2·944	2·955	2·935	2·960	2·993
Al	1·012	1·038	1·062	1·056	1·048	1·046	1·076	1·032	0·998
Fe^{3+}	0·001	0·002	0·003	0·001	nil	0·001	0·001	0·004	0·001
ΣR^{iv}	3·985	4·002	4·011	3·997	3·992	4·002	4·012	3·996	3·992
K	0·832	0·802	0·784	0·802	0·736	0·833	0·747	0·800	0·747
Na	0·132	0·145	0·181	0·173	0·258	0·150	0·220	0·160	0·244
Ca	0·020	0·011	0·006	0·017	0·014	0·003	0·004	0·004	0·007
Rb	0·011	0·013	0·010	0·015	0·008	0·014	0·010	0·017	0·012
Cs	0·002	0·001	0·003	0·001	0·003	0·000	0·004	0·004	0·002
Ba	0·003	0·001	0·001	0·001	nil	0·001	0·001	0·003	0·001
Mg	0·004	0·003	0·003	0·005	0·005	0·001	0·001	0·001	0·001
ΣX‡	1·004	0·976	0·988	1·014	1·024	1·002	0·987	0·989	1·014
D	2·558	2·568	2·566	2·586	2·595	2·570	2·593	2·575	2·593

MN.21, MN.62, and MN.61: Metasomatic megacrysts.
MK.2, MO.3, and M.3: K-feldspars from the pegmatitic veins.
M.5 and MN.52: K-feldspars from the simple pegmatites.
RA.4: Primary megacryst.
* (Ab+An) in the potassic phase.
† $\Delta = 12{\cdot}5(d_{131}-d_{1\bar{3}1})$.
‡ K+Na+Ca+Rb+Cs+Ba+Mg.

The K-feldspars show a greater variation. Their (An+Ab) content varies from 14·48 to 25·49 %. The megacrysts in the aplite contain higher (Ab+An) content (from 21·70 to 25·49 %) than the K-feldspars from the veins, which contain from 14·48 to 17·95 % (Ab+An). The lower (An+Ab) content of the K-feldspars from the veins is due to the relatively higher content of volatiles, which imparted greater mobility to the (An+Ab) content, some of which moved out to form small grains at or close to the margins of such crystals.

The average anorthite content of the albites of the volatile-poor white aplite is 3·09 % whereas the average anorthite content of the albites from the volatile-rich brown aplite is only 1·67 %. Chemical studies of the two types of aplites show no significant difference in the CaO content of the two groups. The lower average anorthite contents of the albites from the brown aplite is due to the partitioning of the CaO content between the volatile phase and the crystallizing albite phase. The CaO in the volatile phase subsequently crystallized in fluorite and apatite, which occur with albite in the brown aplite.

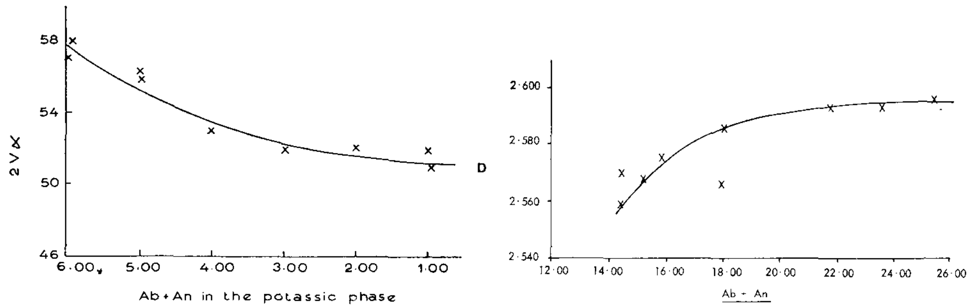
The compositions of the potassic phases of the K-feldspars were determined by X-ray diffraction, using Cu-$K\alpha$ radiation, according to the procedure modified by Orville (1958) from the method devised by Bowen and Tuttle (1950). The values $\Delta 2\theta$ (20$\bar{1}$) feldspar—(101)$KBrO_3$ were used to estimate the composition from the determinative data of Orville (1960, 1963). The results are included in table II.

The megacrysts contain the highest amount of (An+Ab) in their potassic phases followed by the pegmatite veins and the pegmatitic veins. This order corresponds with increasing amounts of volatiles like F_2, B_2O_3, and K_2O. The increasing amounts of volatiles impart greater mobility to the (An+Ab) phase and cause it to exsolve from the potassic phase.

The obliquity values, $\Delta = 12{\cdot}5(d_{131}-d_{1\bar{3}1})$, of Goldsmith and Laves (1954*a*) were determined on smear mounts using Cu-$K\alpha$ radiation. All the samples were found to be practically monoclinic. Eskola (1951), Goldsmith and Laves (1954*b*), and Dietrich (1962) have regarded high amounts of volatiles and silica along with temperature as factors contributing to high obliquities. In the present case although K-feldspars formed in the presence of high and varying amounts of volatiles and silica, their obliquities range from 0·00 to 0·03 only. In addition the authors referred to above consider rapid cooling and higher temperatures to be causes of decrease in obliquities. The K-feldspars in the Meldon aplite have crystallized as a result of slow cooling to form large crystals, so rapid cooling as a cause of nil to very low obliquity values can be ruled out. Therefore, the only factor that remains is temperature, which is regarded as the chief factor controlling obliquities. Since in the evolution (in the sense of progressive crystallization) of most rocks the contents of volatiles and silica increase concurrently with decreasing temperatures, therefore obliquity values, silica, and volatiles may often all increase with decreasing temperature. But volatiles and silica of themselves are of little consequence in controlling the obliquity values.

The values of $2\theta(131)-2\theta(1\bar{3}1)$ for albites were measured from the diffraction pattern obtained by using Cu-$K\alpha$ radiation. All the albites, even those from the chilled edges, were found to belong to the low structural state. $2\theta(131)-2\theta(1\bar{3}1)$ ranges from 1·10 to 1·18, and when plotted against the anorthite content of the albites does not show any systematic variation for albites coming from different parts of the aplite, which crystallized under moderately variable conditions of temperature.

Physical and optical properties. The specific gravities (accuracy ±0·05), optic axial angles (accuracy ±0·05), and refractive indices (accuracy ±0·001) of the feldspars are presented with their chemical analyses. The very restricted range of chemical composition and corresponding values of refractive indices and specific gravities (except for K-feldspar) do not justify the construction of variation diagrams. However, in the case of the K-feldspars the optic axial angle increases with the increasing amount of (An+Ab) content in the potassic phase (fig. 1). The variation diagram is a



FIGS. 1 and 2: Fig. 1 (left). Variation of $2V_\alpha$ with (Ab+An) in the potassic phase. Fig. 2 (right). Variation of density with (Ab+An) in the bulk K-feldspar.

concave curve that flattens out towards the lower values of the optic axial angles. In no instance is the obliquity enough to affect 2V appreciably; Rb and Cs may have a measurable effect but the data are not numerous enough to test this.

The specific gravities of the bulk K-feldspars are plotted against their (Ab+An) content in the fig. 2. Two values fall off this curve, one above and the other below, because they contain, respectively, greater and less anorthite content than the comparable sample points on the curve. Since the content of the anorthite molecule falls rapidly with decreasing amounts of (Ab+An), the curve bends sharply downwards towards the lower end. The specific gravities of these bulk feldspars are higher than the ordinary K-feldspars in the same composition range; this is due to the presence of notable amounts of rubidium and caesium.

Conclusions. The present work shows that temperature is the primary factor while the content of SiO_2 and volatiles are of secondary importance in determining the obliquity values of K-feldspars. The composition of the potassic phase is determined by the concentration of volatiles during crystallization. The greater the amount of volatiles, the lower the amount of (Ab+An) held in solid solution by the potassic phase.

The low An content of albites from the volatile-rich brown aplite as compared to the albite from the volatile-poor white aplite is considered to be due to the partitioning of the CaO content between the volatile phase and the crystallizing albite phase.

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REFERENCES

Bowen (N. L.) and Tuttle (O. F.), 1950. The system $NaAlSi_3O_8$–$KAlSi_3O_8$–H_2O. *Journ. Geol.* **58**, 489–511 [M.A. **11**–325].

Dietrich (R. V.), 1962. K-feldspar structural states as petrogenetic indicators. *Norsk Geol. Tidsskr.* **42**, 394–414 [M.A. **16**–462].

Eskola (P.), 1951. Around Pitkäranta. *Ann. Acad. Sci. Fennicae*, ser. A.3, no. 27 [M.A. **11**–471].

Goldsmith (J. R.) and Laves (F.), 1954*a*. The microcline-sanidine stability relations. *Geochimica Acta*, **5**, 1–19 [M.A. **12**–333].

—— —— 1954*b*. Potassium-feldspars structurally intermediate between microcline and sanidine. Ibid. **6**, 100–18 [M.A. **12**–527].

Orville (M. P.), 1958. Feldspar investigations. *Carnegie Inst. Washington, Year Book*, **57**, 206–9.

—— 1960. Powder X-ray methods for determination of (Ab+An) content of microcline. *Bull. Geol. Soc. Amer.* **71**, 1939–40 (abstr.).

—— 1963. Alkali ion exchange between vapor and feldspar phases. *Amer. Journ. Sci.* **261**, 201–37 [M.A. **16**–435].

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