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ASPECTS OF ALKALI FELDSPARS IN CORNUBIAN GRANITES

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The alkali feldspars in Cornubian granites are micro- and cryptoperthites in which the sodic phase is low albite and the potassic phase may be monoclinic orthoclase or triclinic microcline. Optical and X-ray studies indicate that while microcline appears to be rare in or absent from the biotite granites of the Scilly Isles, Land's End, Carnmenellis, St Austell and Hingston Down, it is more common in the biotite granites of Godolphin, Bodmin Moor and Dartmoor and in the Li-mica granites of Tregonning and St Austell. It is restricted to one area in the Bodmin Moor outcrop. Since inversion of monoclinic to triclinic K-feldspar and exsolution are complex processes in which low-temperature fluids are crucial, it is expected that both occurred during the subsolidus recrystallization stage and that in some areas the intrusion of Li-mica granite was a significant factor in influencing temperatures.

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INTRODUCTION

K-bearing feldspar is the second most abundant mineral phase in the Cornubian granites, contributing more than 30% to the biotite-bearing varieties. Nevertheless, little has been published about it, although its structure may provide an indicator of the cooling history of the rock. Occasional references to microcline appear in the Survey Memoirs and in papers about the granites, details apparently being confined to those by MacKenzie and Smith (1962) and Hawkes (in Edmonds *et al.*, 1968), both relating to Dartmoor, and by Halliday (1980) in connection with mineralization in south-west Cornwall.

Our work was initiated to ascertain more about the mineral and to see whether its properties could add usefully to knowledge of the Cornubian plutons as has been done by, for example, Ragland (1970), Parsons and Boyd (1971), Parsons (1980), and

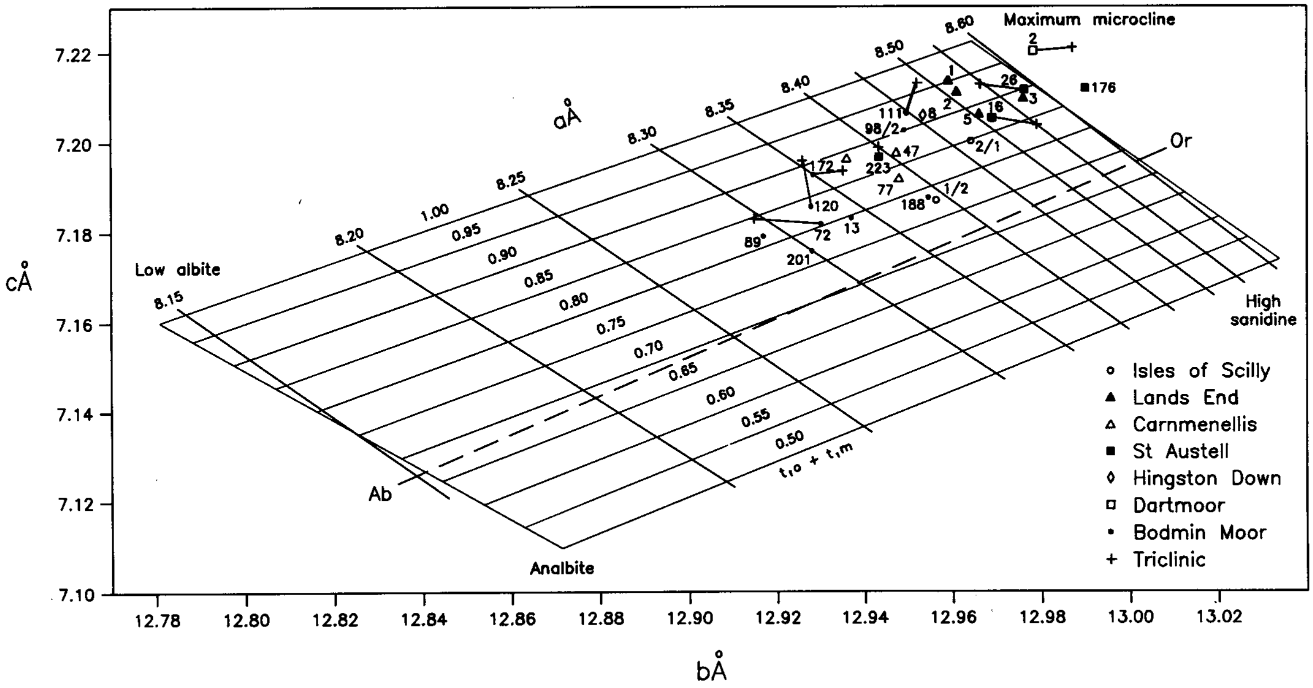

Figure 1: b-c plot for alkali feldspars (Wright and Stewart 1974) showing Cornubian specimens. Approximate Or-Ab boundary from specimen P50-56F (Wright and Stewart 1968).

Iball and Hubbard (1982) for granite and syenite complexes. Specimens have been re-analysed and earlier conclusions (Edmondson, 1970) (Edmondson, 1970) re-examined in the light of recent research.

TECHNIQUES

In addition to literature surveys and carrying out examinations and measurements of 2Vγ by standard optical methods, the alkali feldspars were hand-separated from 18-30 mesh fractions and then crushed to between 2-5μ m for X-ray powder analysis. The X-ray determinations were made on smears of the powders, using CuKα radiation with a Ni filter and a fluorite internal standard, and scanning the range 20°-55° 2θ.

Crystal symmetry was determined from the 131 and 131 reflections between 29° and 31° 2θ, a single sharp peak indicating monoclinic orthoclase alone and a double peak indicating both orthoclase and triclinic microcline. Between these extremes, mixtures show a broad, diffuse peak, as discussed by Parsons and Boyd (1971).

The degree of `triclinicity' was calculated from Goldsmith and Laves' (1954) 'obliquity equation' where Δ (obliquity) = 12.5(d131 - d131) and has a value of 0 in monoclinic and 1 in fully triclinic alkali feldspar crystals. Interference between the 131 relfections

TABLE 1: Alkali feldspars from Cornubian granites: Compositions, optic axial angles, obliquities and some cell dimensions.

Specimen	Rock	Composition											
Type	Or	Ab	An	2Vγ	Δa	d$\bar{2}$01	a	b	c	α	β	γ	
Isles of Scilly													
ES 1/2 m*	B	76.3	21.9	1.3	55.3	-	4.203	8.539	12.956	7.187	90	116.06	90
ES 2/1 m	C	65.9	51.6	2.4	51.6	-	4.253	8.653	12.964	7.2	90	116.21	90
Land's End													
EL 1 m	B	78.7	20.9	0.4	63.3	-	4.245	8.597	12.959	7.214	90	116.22	90
EL 2 m	C	76.9	21.9	1.2	61.7	-	4.247	8.612	12.961	7.211	90	115.35	90
EL 3 m	B	81.7	18.3	n.f.	61.9	-	4.221	8.619	12.976	7.21	90	116.14	90
EL 5 m	C	76.6	25	1.3	56.8	-	4.247	8.623	12.967	7.207	90	116.02	90
Carrnmenellis													
A 47 m	B(3)#	55.7	36.4	8	61.7	-	4.239	8.608	12.947	7.198	90	116.1	90
A 77 m	B(2)	59.9	34.9	5.3	61.5	-	4.241	8.6	12.948	7.192	90	116.07	90
A104 m	B(1)	60.8	33.4	5.8	64.3	-	4.226	8.592	12.936	7.197	90	115.82	90
St Austell													
E 176 m	B	60	34.9	5.2	61.5	-	4.235	8.605	12.99	7.212	90	116.07	90
E 223 m	D	69.5	29.3	1.2	81.6	-	4.227	8.591	12.943	7.197	90	115.96	90
------- t					n.d	0.188	4.227	8.573	12.943	7.198	90.03	116.14	89.17
E 26 m	E	66.8	32	1.3	50.8	-	4.221	8.598	12.976	7.211	90	115.93	90
------- t					74.7	0.275	4.221	8.572	12.966	7.213	90.04	116.08	89.43
E 16 m	F	64.2	31.6	4.2	51.4	4.221	8.557	12.969	7.205	90	116.09	90	
------- t					79.6	0.413	4.223	8.551	12.979	7.204	90.08	116.13	88.8
Hingston Down													
ED 8 m	C	77.9	20.6	1.4	62	-	4.228	8.645	12.953	7.205	90	116.22	90
Dartmoor													
ED 2 m	B	62.1	37.6	0.5	63.5	4.251	8.607	12.978	7.22	90	116.16	90	
------- t					78	0.363	4.251	8.598	12.987	7.221	90.03	116.19	88.92
Bodmin Moor													
EB 13 m	B	80	19.5	0.5	63.1	-	4.227	8.6	12.937	7.183	90	115.94	90
EB 89 m	B	81.5	17.7	1.9	62.9		4.197	8.514	12.917	7.179	90	116.07	90
EB 98/2 m	B	64.4	31.2	4.4	62.2	-	4.227	8.58	12.949	7.203	90	116.08	90
EB 188 m	B	83.4	14.6	2	63.6	-	4.214	8.536	12.954	7.188	90	116.1	90
EB 201 m	C	85.4	14.3	0.3	62.5	-	4.199	8.504	12.928	7.176	90	116.01	90
EB 72m	B	73.2	24.9	1.9	62.1	-	4.203	8.574	12.93	7.182	90	116.03	90
------- t					74.5	0.213	4.225	8.532	12.915	7.188	90.27	116.25	89.13
EB 111 m	B	71.3	25.4	3.3	65	-	4.226	8.571	12.949	7.206	90	116.2	90
------- t					78.8	0.475	4.225	8.571	12.952	7.213	90.2	116.29	89
EB 120 m	B	61.8	34	4.2	n.d.	-	4.205	8.532	12.928	7.186	90	115.94	90
------- t					77.3	0.488	4.205	8.537	12.926	7.196	90.15	115.99	88.75
EB 172 m	B	75.5	23	1.5	60	-	4.211	8.563	12.928	7.193	90	115.83	90
------- t					76.7	0.638	4.211	8.557	12.935	7.194	90.26	115.93	88.58

Compositions in %, angles in degrees, dimensions in Ǻ. Rock types from Exley and Stone (1982). * = monoclinic, t = triclinic. # type numbers from Ghosh (1934).

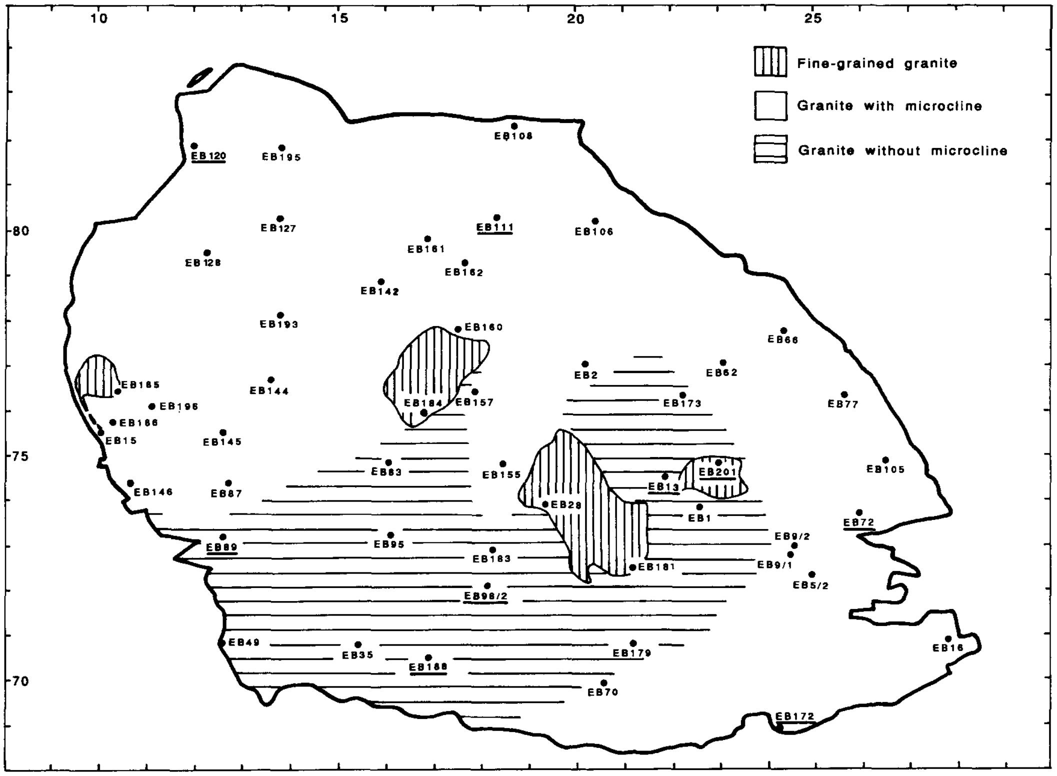

Figure 2: Map of Bodmin Moor granite showing distribution of microcline and locations of specimens in Table 1 (underlined) and Table 2.

of microcline and albite was corrected by subtracting from the combined value the measured magnitude of the unobscured albite 131 reflection, which is of intensity to the 131 reflection (Smith, 1956; Smith and Yoder, 1956).

Unit cell parameters were calculated by a method based on the least squares refinement of measured 2θ values (Wright and Stewart, 1968; Appleman and Evans, 1973). Causes of error include approximations in the refinement mathematics, overlap in the 131 and 1$\bar{3}$1 peaks (and in other pairs) in mixtures of monoclinic and triclinic phases, and their tendency to merge as the obliquity value of the triclinic mineral falls below about 0.2. Such errors are not easily evaluated and error values quoted here are based on the maximum values of Wright and Stewart. The b and c cell dimensions are decided by Si:Al order, regardless of overall feldspar composition, and are therefore indicative of structural states. These parameters were plotted on the b:c diagram (Figure 1) of Stewart and Wright (1974).

The powders from which the X-ray smears were made were also used for the chemical determination of K_2O, Na_2O and CaO by flame photometry and atomic absorption spectrometry.

RESULTS

General

References to the alkali feldspars of south-west England granites range from those in the Geological Survey's Memoirs to more detailed accounts in Austin (1960), Stone and Austin (1961), Exley and Stone (1964; 1982), Booth (1966; 1968), Stone (1979), Dangerfield and Hawkes (1981), Hawkes (1982), Exley et al., (1983) and Floyd et al., (1993). The chief features are summarised here. Megacrysts range from 1 to 2 cm in length in fine-grained granites, through the average of 3 to 4 cm in coarse-grained granites, to extreme examples 15 to 17 cm long. Apparently euhedral or subhedral, they actually have irregular margins which may be embayed, lobate or zig-zag against their neighbours. Usually twinned on the Carlsbad Law, their composition planes are often stepped or curved, and they have exsolved on a scale varying from sub-microscopic to coarsely perthitic. Grains of each of the other minerals in the rock may be enclosed, often lying in concentric zones. Included quartz is anhedral, frequently strain-free and without trains of inclusions, while included plagioclase is usually subhedral, normally-zoned, with a clear albite rim. Core compositions of such plagioclase usually correspond with those of discrete plagioclase in the rocks but may be slightly more calcic. Groundmass crystals of alkali feldspar average about 1 mm in length in fine-grained granites and about 3 mm in coarse-grained granites. They are sub- to anhedral and more equidimensional than megacrysts. Otherwise they are similar, although perhaps having fewer zonally-arranged inclusions and more irregular margins which often penetrate between and partially envelop adjacent grains.

Potassic phase

Wright and Stewart (1968) used the b and c cell dimensions to define the structural states of potassic phases of alkali feldspars, whose compositions they had adjusted by means of alkali exchange techniques. We have added other criteria to their definitions. Thus, in compositions more potassic than Or_{37} (where Or represents the conventional $KAlSi_3O_8$ 'molecule''), 'orthoclase' has a monclinic structure recognisable by X-rays, an absence of grid-twinning, an average 2V value between 44°and 70° and an obliquity of $\Delta = 0$. 'Intermediate microcline' has a recognisably triclinic X-ray pattern, grid twinning present at least patchily, average $2V\gamma$ value between 70° and 80° and an obliquity $(\Delta)>0$ but <1.

Least squares refinements of the b and c dimensions of 24 alkali feldspars (see below) plotted on Figure 1 show that they are intermediate between orthoclase and maximum microcline, the monoclinic phase being orthoclase and the triclinic phase being intermediate microcline by our definitions. Perhaps monoclinic specimens plot nearer to the orthoclase-albite boundary than the monoclinic-triclinic mixtures and there is some overlapping, probably because of distortion resulting from additional ions in the lattice and interference from reflections of included grains of other minerals. A few potassium-rich specimens

TABLE 2: Alkali feldspars from Bodmin Moor Optic axial angles (degrees).

Granite type	Specimens	Measurements	Mean 2Vy	Standard deviation
Fine-grained	5	10	62.4	3
No microcline	15	47	62.2	1.1
With microcline:				
Megacrysts	8	18	56.6	1.2
2V 60-67°	18	36	63.3	1.8
2V 67°	21	43	74.9	4.1

plot towards the sodic (albite) end of the diagram and vice versa; this will be referred to later.

It is well established that the b and c cell dimensions reflect the ordering of Al and Si, a measure of which is given by the occupancy of T1 tetrahedral sites. The statistical probability of this is shown as $(t_1o + t_1m)$ in Figure 1. The a dimension, however, which may be obtained from the d spacing of $\bar{2}01$, is related to the proportions of alkali ions. Ideally, as noted by Orville (1967), Wright and Stewart (1968) and others, variation in a, composition and certain physical properties should be related and, as Wright and Stewart have shown, in laboratory-prepared material this may be so. However, in naturally-occurring feldspars inconsistencies are usual and have been remarked upon by various authors from Laves (1952) and Smith (1961) onwards. Wright and Stewart (1968) decided that such feldspars were 'anomalous' (p.40), describing them as having [a(observed) - a(estimated from b and c)] > 0.02 Å, then commented (p.71) on the 'surprisingly large number' of natural feldspars falling into this category. Subsequently, however (Stewart and Wright, 1974), they recognised the importance of strain, defining a as the 'index of strain' and the strain 'threshold' as $\Delta a > 0.05$ Å.

Using the values of a from Table 1 and Figure 1, most of the feldspars in our study are 'strained' according to this definition, the same conclusion being reached if Or contents are calculated from %Or content = $-92.19\ (2\theta_{-201}) + 2031.77$ (Wright 1968, Table 4) or if $2V\gamma$ are derived from $2V\gamma = -0.274\ (\%Or) + 102.66$ (Rankin 1967, p. 416).

Structural states determined by the 'three peaks equation' method of Wright (1968), were also examined and were A to give dimensions which differ by no more than 0.005 Å from those obtained by the least squares refinement method, thereby providing a useful check.

Sodic Phase

The sodic phase occurs in domains which cover the range from cryptoperthite (visible under the microscope as clear streaks in a more or less cloudy host), through stringlets, films and rods, to braids and patches. We detected no systematic distribution of these, either within individual granite outcrops or over the southwestern peninsula as a whole. In thickness, sodic areas range from about 0.004 mm to 0.5 mm and in length from about 0.1 mm to 0.6 mm. Although the majority thin towards the margins of the host crystal, some cross the boundary and link with neighbouring plagioclase either in adjacent perthite or in discrete crystals. This plagioclase is in optical continuity and is clearly part of the perthite. Other patches, often more irregular and of variable size, have different optical orientations and are of different origin (Exley and Stone, 1964, Figure 3). Some small irregular grains of plagioclase may also occur with random orientation near the margins of megacrysts (Exley and Stone, 1964, Figure 2).

The boundaries of all these sodic phases are irregular on the fine scale although sharp pleated and sutured boundaries like those illustrated by Parsons (1978, Figure 8) have not been seen.

Structurally, the only phase is low albite and its composition, though covering the full albite range (An_{O-10}), is usually An_{4-5}. The lamellae are sub-parallel to (100) of the host crystal, crossing twin planes and persisting to the margins of enclosed grains. Twinning is even and undisturbed, unlike that in discrete plagioclase where it is often wedge-shaped and bent within crystals which are distorted or broken and re-sealed.

DISTRIBUTION

Regional

Accounts of the petrography and evolution of the Comubian granites have been given by Exley and Stone (1964; 1982), Exley et al., (1983) and Floyd et al., (1993). The most common type is coarse, usually megacrystic rock composed of alkali feldspar (ca. 30%), oligoclase (ca. 22%), quartz (ca. 34%), biotite (ca. 6%), muscovite (ca. 4%), tourmaline (ca. 1%), apatite and other minerals (ca. 1%). Fine-grained granite modally resembles coarse granite, but muscovite exceeds biotite and plagioclase composition is close to the albite-oligoclase boundary. Other varieties will be mentioned where appropriate. The outcrops fall into two groups. (Granite 'types' are those of Exley and Stone (1982)).

Granites with little microcline

Isles of Scilly

The islands are almost entirely composed of the coarse (Type B) and fine (Type C) biotite granites and microcline seems to be absent (Barrow, 1906; Osman, 1928; Jones, 1963; Dangerfield and Hawkes, 1981; Stone and Exley, 1989). Analyses of each type (Table 1) indicate the presence of the monoclinic phase only. Compositions determined chemically show that feldspar from the coarse-grained rock (specimen ES1/2), is more potassic than that from the fine-grained variety (ES2/1), contrary to what would be expected from Figure 1.

Land's End

This outcrop also comprises Types B and C. Two notes identify microcline: one by Reid and Flett (1907) saying that `microcline is very rarely to be seen', and one by Goode et al., (1987) and Goode and Taylor (1988) referring to small amounts in greisened or mineralized specimens. This phase is not mentioned by Booth (1966) nor by Booth and Exley (1987). We have examined two specimens from each granite variety and all proved to be orthoclase (Table 1).

Carnmenellis

This outcrop is mainly of Type B granite with a little Type C. Ghosh (1934) divided the former into three textural varieties which were reduced to two by Chayes (1955) and Al-Turki and Stone (1978), and increased to six by Leveridge et al., (1990). Both the earlier Falmouth and Truro Memoir (Sheet 352, Hill and MacAlister, 1906) and Austin (1960), refer to both microcline and orthoclase, but microcline is not noted by Ghosh (1934) or the later Falmouth Memoir (Leveridge et al.„ 1990). We examined specimens from Ghosh's three textural varieties; all were monoclinic and similar in both structure and composition.

St Austell

The eastern part of this mass consists of coarse-grained biotite granite (Type B) and small amounts occur among the Li-mica varieties in the western part. Microcline has not been reported from any of these (Ussher et al.„ 1909; Richardson, 1923; Exley, 1959; Hill and Manning, 1987). The single Type B specimen we examined (Table 1) contained only orthoclase and showed the compositional inversion noted in the Scilly Isles minerals.

Hingston Down and Kit Hill

These are two small, poorly exposed outcrops between Bodmin Moor and Dartmoor, and little has been published about them. Reid et al., (1911) and Bull (1982) do not mention microcline and the specimen we examined from Hingston Down was orthoclase.

Granites with more microcline

Godolphin

This outcrop consists of fine-grained Type C biotite granite. Although Reid and Flett (1907), Flett and Hill (1946) and Stone (1975) make no mention of microcline, Stone (1965) identified it in many specimens and Goode et al., (1987) and Goode and Taylor (1988) refer to occurrences related, like that at Land's End, to alteration. We have not analysed any material.

Tregonning

This outcrop, contiguous with that of Godolphin, consists of medium-grained, non-megacrystic Li-mica granite (Type E) or topaz granite (Hill and Manning, 1987). Microcline was not recorded in the earlier Survey Memoirs, nor by Stone (1975; 1984) but has been seen in thin section by us and by Stone (1965), by Goode et al., (1987) and by Goode and Taylor (1988). We have not carried out any X-ray examinations.

St Austell

The western part of the outcrop is occupied by granite characterised by Li-mica (Types D and E) or fluorite (Type F), with small amounts of biotite granite (Exley, 1959; Hill and Manning, 1987; Manning and Hill, 1990). Most authors do not refer to microcline, although Exley (1959) made a brief mention. However, our detailed optical work on some 200 specimens shows that it is common in the Li-mica and fluorite granites, but absent from the biotite granites, as stated earlier. X-ray examinations of the three western granite types confirm the presence of microcline (Table 1). Like the Scilly Isles and St Austell biotite granites, the least potassic plot at the potassium-rich end of Figure 1.

Dartmoor

The granite here is biotite-bearing and both coarse (Type B) and fine (Type C) occurs. Geological Survey Memoirs (Ussher, 1902; Reid et al., 1912; Ussher, 1912; 1913) do not refer to microcline and the only mention in the later Memoir (Edmonds et al.,, 1968) casts doubt on its presence, as does Hawkes (1982). However, it has been found among detrital minerals (Brammall, 1928), in the south-western area (Knox and Jackson, 1990) and by us, and MacKenzie and Smith (1962) believed it to be present in specimens analysed by them.

Bodmin Moor

This is described last because, while we have relied on the literature and a few specimens for information about the other plutons, we have carried out a comprehensive survey of Bodmin Moor. The outcrop consists of coarse biotite granite (Type B) with several exposures of fine granite (Type C). 138 specimens were examined by microscope and of these 50 were selected for 2V measurements (Table 2) and 9 of the 50 for X-ray analysis (Table 1). Microcline was not mentioned in their Memoirs by Reid et al., (1910) or Reid et al., (1911), but was noted by Ghosh (1927) as being fresher than plagioclase and present in both coarse and fine granites.

In our preliminary examination we did not identify microcline either in the four small areas of fine granite or in the south-central area of coarse granite. Microcline was found in the outer part of the outcrop, however (Figure 2) and the structural states of the feldspars examined by X-ray (Table 1) are consistent with the presence or absence of grid-twinning revealed by the microscope in material from these areas. $2V\gamma$, however, is variable. Thus, although $2V\gamma$ values are consistent in the fine-grained granite (mean 62.4°, standard deviation 3.0°) and in the coarse 'no microcline' granite (mean 62.2°, standard deviation 1.1°), they cover a wide range in the 'with microcline' granite. This range can be separated into megacrysts and some groundmass feldspars with $2V\gamma$ between 56.6° (s.d. 1.2°) and 63.3° (s.d. 1.8°) (ie orthoclase) and the remaining groundmass feldspars with a mean $2V\gamma$ of 74.9° (s.d. 4.1°) and an obliquity of 0.213 to 0.638 (ie microcline). The occurrence of microcline is thus restricted to certain groundmass feldspars and is absent from all the megacrysts and from the groundmass of a large part of the outcrop (Table 2).

DISCUSSION

Symmetry in alkali feldspars results from the configuration of the Al, Si-0 framework and the relationship of K, Na and Ca (and substituting cations) to it. On cooling not only does the ordering of potassic phases change by a redistribution of Si and Al and corresponding adjustments of bonding, so that it becomes triclinic rather than monoclinic, but the potassic and sodic phases unmix. Experimentally, the temperature range over which these changes occur has been shown to be approximately 750° to 400°C at low pressures, depending on the bulk composition. However, conditions in cooling rocks involve several variables, including strain and fluids.

In some circumstances strain is external to the crystals, eg. as a result of shearing stress, but in most plutonic rocks it is internal, resulting from the contrasting cell dimensions of adjacent potassic and sodic areas. Release of this strain is a major factor in the development of micropores, which cause the turbidity commonly seen in alkali feldspars and facilitate diffusion of ions and fluids.

This process results in the extensive and relatively coarse development of triclinic microcline associated with areas. of albite, ie the change from homogeneous alkali feldspar, through cryptoperthite, to microperthite (Parsons, 1978; David and Walker, 1990; Worden et al., 1990).

Fluids are important agents in these processes and in most granites are probably late-magmatic. Where maximum microcline occurs, their effects start at about 450° to 400°C (Parsons and Brown, 1984; 1986), although Wright (1967) and Zyryanov (1977) have put it as low as 375° (± 50°C or ± 25°C respectively). Moreover, the efficacy of aqueous fluids is enhanced by the presence of F (Snow and Kidman, 1991).

Ordering of the potassic phase is influenced by several factors, of which composition is one. Parsons and Boyd (1971) suggest that whether the magma is peralkaline or peraluminous (which may vary with differentiation), could predispose the eventual presence of orthoclase or microcline, but probably more important is the Na:K ratio of the feldspars themselves. Ferguson (1979) argues that bond strengths in sodic and potassic feldspar cause the former to retain its triclinic symmetry from high to low temperature, while the latter readjusts. He argues further that pure $KAlSi_3O_8$ does not invert and that there is a low-temperature series between monoclinic orthoclase, through intermediate microcline, to fully ordered triclinic maximum microcline. This is governed by the proportion of the albite molecule in the original feldspar, a lower Na:K ratio making low-temperature orthoclase more likely and a higher ratio increasing the likelihood of maximum microcline, a concept accepted by Parsons and Brown (1984). While Ferguson (1979) thus resists the idea that orthoclase in low-temperature rocks is a metastable form, his bond-strength theory does not explain the mixtures of orthoclase and microcline commonly found.

The development of the alkali feldspars in slowly-cooled rocks is not a function of the cooling rate alone (Parsons and Brown, 1984) and is complicated by subsolidus reactions, especially where extensive exsolution and general recrystallization takes place. This, with accompanying metasomatism, is probably why some of our specimens plot anomalously on the structure diagram (Figure 1).

The evidence from the Cornubian biotite granites, other than Bodmin Moor, illustrates this complexity, reinforcing the conclusion of Parsons and Brown (1984) that 'stranded' orthoclase will commonly occur in such rocks, which are peraluminous, contain significant concentrations of OH and F, cooled slowly and underwent substantial subsolidus recrystallization (eg. Stone, 1979; 1984).

The detailed study of Bodmin Moor is more instructive. As described, the outer parts form an incomplete ring in which microcline occurs in a typically variable fashion, while in the inner area the coarsely microperthitic feldspar is orthoclase. There are several possible explanations.

One is that, because of differentiation, the inner, microcline-free granite is more aluminous than the outer, inhibiting microcline (Parsons and Boyd, 1971). This is not supported by chemical evidence; the inner granite has Al_20_3: $K_2O + Na_2O + CaO = 1.715$ 0.059 and the outer a ratio of 1.695 ± 0.083. Secondly, in addition to the inner granite having a higher K-feldspar: plagioclase ratio, also due to differentiation (Selwood et al., in press), the feldspars themselves had a higher Or:Ab ratio and, with one exception, this is borne out by the compositions in Table 1. This would favour the Ferguson (1979) and Parsons and Brown (1984) structural predisposition concept. A third possibility is that, being central, the area maintained a temperature higher than that of inversion, while its surroundings first cooled slowly but then rapidly, in effect 'freezing' the monoclinic structure. This effect could well be linked to intrusion of the Li-mica granite (Type E or 'topaz granite') which normally contains microcline, is volatile-enriched, is associated with the main mineralization stage in Cornubia and was emplaced 10 to 20 mA after the biotite granites (Halliday, 1980; Jackson et al., 1982; Darbyshire and Shepherd, 1987; Bristow, 1992). At St Austell it caused extensive alteration of biotite granite and is thought to underlie much of the western outcrop (Manning and Hill, 1990; Floyd et al., 1993). In addition to the occurrence at Tregonning, small amounts have been found in south-west Dartmoor (Knox and Jackson, 1990) and, in view of its connection with mineralization, there is probably more below the present erosion level generally. In this case, it is conceivable that an unexposed intrusion may underlie the south-central area of Bodmin Moor and have delayed cooling, or re-heated the rocks, thus preserving the orthoclase.

Alkali feldspar megacrysts formed during the late- to post-magmatic stage of the evolution of the granites if they are of metasomatic origin *(eg.* Stone and Austin, 1961; Exley and Stone, 1964; Booth, 1968; Edmonds et al., 1968; Stone, 1979, 1983; Hawkes, 1982; Exley et al., 1983; Booth and Exley, 1987; Goode et al., 1987). However, a number of authors have recently described them as being magmatic (eg. Vernon, 1986; Manning and Hill, 1990; Leveridge et al., 1990), as did earlier authorities. This issue is complex, but our results, indicating that megacrysts have not inverted to microcline, suggest that they owe more to late metasomatic growth than to a long magmatic history.

CONCLUSIONS

This study shows that the potassic phase in perthitic feldspars in Cornubian granites may be either monoclinic or triclinic but, with the exception of Bodmin Moor, it is not known whether these phases are preferentially distributed in the outcrops. It is believed that both ordering and exsolution were dependent on the fluid-rich post- and late-magmatic stages of consolidation when recrystallization was taken place and that the intrusion of Li-mica granite into biotite granite was significant because of its thermal effect. There is also evidence suggesting that the Or:Ab ratio of the feldspars was an important influence on inversion. There seems to be a good case for additional detailed work and this could take advantage of electron microscopy techniques, following the lead of Parsons and co-workers (eg. Parsons and Brown, 1984).

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