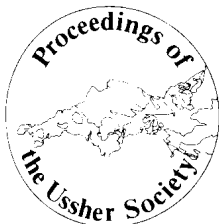


Read at the Annual Conference of the Ussher Society, January 1988

Behaviour of trace-alkali and other elements at Tregonning granite - pelite contacts

MAURICE STONE and NABIL T.I. AWAD

Stone, M. and Awad, N.T.I. 1988. Behaviour of trace-alkali and other elements at Tregonning granite - pelite contacts. Proceedings of the Ussher Society, 7, 47-51.



Pelitic hornfels of the Mylor Slate Formation in contact with Li-mica granites of the Tregonning - Godolphin pluton show marked, though localized, trace alkali and fluorine metasomatism. Other elements, including Sn, La, Ce, U, Th and Zn, show smaller but significant additions to the contact hornfels. New data reported here reveal differential behaviour of Cs and the other trace alkali elements. The timing of metasomatism in relation to the crystallization history of the granite and the evolution of an initial F-poor fluid phase becoming richer in F with progressive crystallization is discussed. A comparison with the Porthmeor (biotite granite) contact and the nature of transformation of biotite at Tregonning granite contacts has a bearing on the genesis of the Li-mica granites themselves.

M. Stone and N.T.I. Awad, Department of Geology, University of Exeter, Exeter, Devon EX4 4QE.

Introduction

Extreme differentiation of some granite magmas has produced rocks enriched in several less common elements such as Li, Rb, Cs, F, Nb and Sn and a fluid phase capable of transporting these elements into the adjacent country rocks. Within the Cornubian batholith such extreme differentiates are the Li-mica granites which show marked enrichment in these elements and have extremely low K/Rb values (Exley and Stone 1982).

This paper examines the extent of metasomatism in pelitic hornfels adjacent to the Li-mica bearing Tregonning granite. This is a medium-grained aphyric zinnwaldite - albite - topaz granite (Type E of Exley and Stone 1982) occupying most of the outcrop of the Tregonning - Godolphin pluton and capped and flanked by a roof-complex of layered lepidolite-bearing leucogranites, aplite and pegmatite (Stone 1975). It is well-exposed along the coast between Praa Sands (GR: SW585275) and the Megiliggarr Rocks (GR: SW611266) where its contacts with the pelitic hornfels of the Mylor Slate Formation are readily accessible. This Formation is also well-exposed along the coast between Marazion (GR: SW520305) and the Loe Bar (GR: SW642242) where it is composed predominantly of striped pelitic slates with siltstones and some sandstone horizons.

Earlier work by Bowler (1958) demonstrated large increases in the trace alkali elements and F at the contacts. For example, Cs increases from 10 to amounts between 70 and 260ppm and F from several hundred ppm to amounts between 2000 and 4000ppm and occasionally to over 2wt%. Bawden (1962) reported an increase in B from 140-460ppm in non-metasomatized rocks to over 1500ppm at the granite contacts. The apparent transformation from biotite to Li-mica at contacts (Stone 1963) has been confirmed by recent microprobe studies (Stone et al. 1988). A more systematic study by Chesher (1971) showed marked contact enrichment in Sn as well as the trace alkali elements and F together with an overall enrichment of Zn and Pb in the inner aureole.

Analytical data presented here were obtained by XRF and wet methods (F, Li and Fe²⁺) as briefly described in Stone et al. (1988). REE analyses were obtained by ICP spectrometry at the Royal Holloway and Bedford New College. Statistics were calculated with the aid of the Minitab package and Fortran 77 programs written by one of us (MS) using a Prime 750 computer at the University of Exeter.

Chemical data and statistical appraisal

In an ideal study, samples would be collected from a single lithology that could be traced from a granite contact to outside its aureole. In practice, complex folding and varied lithology of the

Mylor Slate Formation prevent this. Three broad categories of sample came from (a) immediate contacts, both vertical and horizontal, (b) the inner aureole - a zone extending from 2cm to 10m from the contact, and (c) localities outside this (i.e. more than 10m from contacts extending to several km). Of course, difficulties arise in trying to match recrystallized hornfels at or near contacts with striped pelitic slates situated some distance away. In order to reduce chemical variation resulting from unrecognized original variation (i.e. "background noise") samples with unusually high or low SiO₂ and Al₂O₃ were omitted, leaving 57 with SiO₂ contents of 55-70wt% and Al₂O₃ contents of 13-24wt% (limits arbitrarily chosen). Of course, other sources of original variation will add further background "noise" to real metasomatic variation, but patterns that stand out above this are likely to be significant.

Marked departure of oxide/element data from the normal distribution was tested using the Kolmogorov - Smirnov one sample test (Table 2, col. 1). Several elements have a normal distribution although normality is improved in most cases by a lognormal transformation. However, some elements, like Cu, Sn an U, follow neither distribution so that non-parametric statistics are preferable and mainly used here.

Comparisons between the means of the three initial sample categories, a, b and c, using the Mann-Whitney test (Table 2, cols 2, 3 and 4) reveal important differences (significant at the 0.01 probability level) in the trace alkali elements and several others including Sn and U. In addition F, As, Ce, La, Th and Zn show significant differences between category c and the other two.

Real systematic variation more than 10m away from contacts cannot be distinguished from background, hence this study is concerned with effects at or close to the contacts. A closer study of metasomatism in the inner aureole is obtained by dividing the second category (b) into three separate groups giving five "distance" groups altogether (Table 1). These represent distance ranges from granite contacts as follows: (1) 0-2cm, (2) 2-25cm, (3) 25-50cm, (4) 50-1000cm and (5) over 1000cm. Homogeneity was tested using the Kruskal-Wallis H test (the non-parametric analysis of variance). Results (Table 2, col. 5) demonstrate considerable inhomogeneity in all those elements marked by an asterisk: these are the mobile elements. Again, most important are the trace alkali elements, F, the light REE, Sn, Zn, U and Th.

Chemical variation

The (Spearman Rank) correlation matrix of the mobile elements (Table 3) shows marked positive correlation and hence association between the trace alkali elements and F (as indicated by previous

Table 1: Average analysis from politic rocks of the Mylor Slate Formation

	1	2	3	4	5
Wt. %					
SiO ₂	60.88	60.95	60.68	61.91	61.16
TiO ₂	0.95	0.9	0.97	0.97	0.91
Al ₂ O ₃	18.72	18.62	19.57	19.62	18.32
Fe ₂ O ₃	1.65	1.37	1.76	1.52	1.96
FeO	5.25	5.86	5.43	5.19	5.34
MgO	2.07	2.12	2.19	2.08	2.38
CaO	0.81	1.03	0.42	0.35	0.8
Na ₂ O	1.93	2.59	1.23	1.2	1.76
K ₂ O	4.46	3.99	4.36	4.33	3.27
P ₂ O ₅	0.16	0.12	0.12	0.11	0.14
F	0.96	0.86	0.24	0.26	0.18
ppm					
As	64	46	39	42	17
Ba	348	375	534	513	433
Ce	111	101	97	95	72
Cr	139	141	150	143	124
Cs	205	99	53	48	15
Cu	23	26	22	9	26
Ga	22	20	20	19	18
La	65	56	49	50	42
Li	1415	923	358	310	157
Mn	1009	904	925	931	723
Nb	23	17	19	17	18
Ni	81	88	73	66	62
Pb	27	18	19	20	21
Rb	1458	872	342	304	162
Sn	26	9	10	9	6
Sr	67	87	57	60	82
Th	12	11	11	10	9
U	8	4	3	8	1
V	116	111	117	114	118
Y	49	43	44	38	43
Zn	272	237	216	188	116
Zr	221	198	223	213	202
K/Rb	38	61.8	109.8	124.2	169
Rb/Sr	59.2	11.4	7.8	6.1	3.1
Ce/Y	2.33	2.39	2.22	2.57	1.71
Ti/Zr	26.1	27.7	26.4	27.5	28.4

1. Average contact sample, n=14.
2. Average sample 2-25 cm from contact, n=10.
3. Average sample 25-50 cm from contact, n=13.
4. Average sample 50-1000 cm from contact, n=9.
5. Average sample > 1000 cm from contact, n= 11.

work) and their marked association with La, Ce, Th and Sn. Of the major oxides, only K₂O (not shown) has marked positive correlation with Th and Sn in that group, in addition to V, Ga and Al₂O₃, (suggesting a K-feldspar grouping). Other element (or oxide) associations (not shown in Table 3) include TiO₂ and V (a common association in sedimentary rocks) and Zr and Y (probably reflecting an association with the HREE). The association of trace alkali elements and others shown in Table 3, and referred to here as the trace-alkali suite, is one commonly observed in the granites. Only Th is not associated with these elements but with the 'ferric' elements (Fe, Mg, Ca) in the granites. R-mode cluster analysis of the data (not shown here), based upon the Spearman Rank correlation coefficient, isolates the trace alkali suite into a distinct cluster, although the trace alkali elements form a strong subcluster of their own. A typical relation between the elements of this suite is illustrated by that between Li and Rb (Fig. 1): this shows a linear spread of data consistent with a true genetic association and illustrates a marked enrichment in the two sample groups close to the granite contact compared with those slightly further away. The overall increase in both Li and Rb (and other elements of the trace-alkali suite) at the granite contact is consistent with marked metasomatism of limited extent. High negative correlation is sparse, but that between Fe₂O₃ and FeO reflects an increase in oxidation as the granite contact is approached.

Table 2: Results of statistical tests

	1 K-S	2	3 Mann-Whitney U	4	5 H
K ₂ O	0.091	-	-	-	9.77
P ₂ O ₅	0.181	-	-	-	10.28
F	0.305*	-	*	*	20.34*
As	0.102	-	*	*	21.14*
Ba	0.066	*	-	-	18.21*
Ce	0.096	-	*	*	20.12*
Cs	0.227*	*	*	*	39.28*
Cu	0.227*	-	-	-	5.9
La	0.107	*	*	-	15.23*
Li	0.314*	*	*	*	40.55*
Nb	0.173	*	-	-	13.23
Pb	0.242*	-	-	-	2.65
Rb	0.304*	*	*	*	39.77*
Sn	0.244*	*	*	*	15.94*
Th	0.124	-	*	*	11.69
U	0.322*	*	*	*	33.64*
Zn	0.153	-	*	*	21.41*

Critical values

p=0.05 0.180 9.49

p=0.01 0.216 13.28

1. Kolmogorov-Smirnov statistic for test against normal distribution. 2, 3, 4. Tests between means of initial categories a and b, a and c, and b and c respectively.

5. H-value from Kruskal-Wallis test. Starred values indicate rejection of the Null hypothesis at the 0.01 probability (p) level. - result not significant at or below the 0.01 level in cols 2, 3 and 4.

Selected data from the five sample groups of Table 1 are plotted as group (i.e. distance) - concentration variation diagrams in Fig. 2. The 95 percent confidence limits are based upon the pooled standard deviation. Owing to departures from normality these limits are approximate in some cases, but give a rough visual indication of significance of trends. The patterns for Rb (Fig. 2(i)), Cs and Li show continuous enrichment from groups 1 to 3 (i.e. up to 50cm from the contact) although Cs enrichment extends further into the aureole. F shows a more abrupt enrichment up to 25cm (Fig. 2(ii)) whilst that of Sri (Fig. 2 (v)) is confined to the contact zone itself (up to 2cm). Zn (Fig. 2 (iv)) shows a continuous increase towards the contact whilst several elements, including Th and Cr, like Mn (Fig. 2 (iii)) show apparent increases but have large variances that result in marked overlapping of (parametrically determined) confidence intervals. An overall increase in the aureole is possible in the case of Mn, although the decrease in group 5 could reflect original differences. La, Ce and Ga are also enriched in the contact zone (group 1) and appear to show a continuous increase from group 5 to the contact. Other elements, like Zr, Sr, V, Pb and Cu, show no marked changes. U shows an overall increase at the contact but the pattern is irregular. K/Rb shows a marked but continuous decrease from outside the inner aureole as the contact is approached (Table 1), whereas the increase in Rb/Sr only becomes marked within 2cm of the contact. Ce/Y, like Ti/Zr, remains nearly constant except in group 5.

Tricotahedral micas

The increase in trace alkali elements and F at contacts with the zinnwaldite- and lepidolite-bearing granites of the TregonningGodolphin pluton must be taken up principally by the micas, particularly biotite. Petrographic evidence (Stone *et al.* 1988, Table V). Data for two traverses in a single polished section are summarized in Table 6, cols 1 and 2. Rb, Cs and F all show marked increases within 15mm of the contact. The triotahedral

Table 3: Spearman rank correlation matrix of selected elements

	F	Ce	Cs	La	Li	Rb	Sn	Th	U
Ce	<u>0.36</u>								
Cs	<u>0.65</u>	<u>0.7</u>							
La	<u>0.35</u>	<u>0.65</u>	<u>0.7</u>						
Li	<u>0.7</u>	<u>0.58</u>	<u>0.88</u>	<u>0.51</u>					
Rb	<u>0.7</u>	<u>0.59</u>	<u>0.88</u>	<u>0.56</u>	<u>0.94</u>				
Sn	<u>0.29</u>	<u>0.28</u>	<u>0.52</u>	<u>0.37</u>	<u>0.51</u>				
Th	<u>0.32</u>	<u>0.4</u>	<u>0.54</u>	<u>0.46</u>	<u>0.56</u>	<u>0.64</u>	<u>0.47</u>		
U	<u>0.35</u>	<u>0.47</u>	<u>0.59</u>	<u>0.33</u>	<u>0.6</u>	<u>0.62</u>	<u>0.44</u>	<u>0.39</u>	
Zn	<u>0.29</u>	<u>0.45</u>	<u>0.51</u>	<u>0.38</u>	<u>0.46</u>	<u>0.5</u>	<u>0.23</u>	<u>0.29</u>	<u>0.52</u>

Underlined values are significant at the 0.01 probability level.

mica in the hornfels at the contact is a zinnwaldite, indistinguishable from that in the adjacent granite. Two further specimens (cols 3 and 4) taken further from the contact illustrate the extent of change: Rb₂O increases by a factor of 6, Cs₂O by 4, whilst F increases by more than 12 times. The biotite of col. 4 provides the (almost) non-metasomatized background although compared with a specimen collected from above the Porthmeor contact (Table 6, col. 6), all the Tregonning aureole samples show some enrichment in Rb and F (and probably Li).

REE data

Small but significant increases in both La and Ce determined by XRF suggest that the LREE as a whole increase as the contact is approached. The near-constant Ce/Y ratio points to an overall small increase in the REE, approximately maintaining the original LREE/HREE slope, but at a slightly higher level, as in the case of Mylor pelites in the Land's End granite aureole (Mitropoulos 1982). ICP analyses of 5 samples (Table 4) give closely similar chondrite-normalized patterns. No clear enrichment trend is apparent when these specimens are arranged according to distance from contacts. Clearly, there are insufficient samples for a statistical appraisal of the data and a comparison with the XRF results. However, 2 samples (0290 and 0294) taken 3cm apart from a single hand specimen show an overall small increase in the direction of the granite contact. Both show increases in total REE compared with the slate sample (0244) from outside the aureole (Table 4). These 3 analyses are plotted in Fig. 3. Slopes (Ce_N/Yb_N) compared with those of the less regular data from the Mylor pelites of the Land's End granite aureole, although the latter show marked uniform enrichment

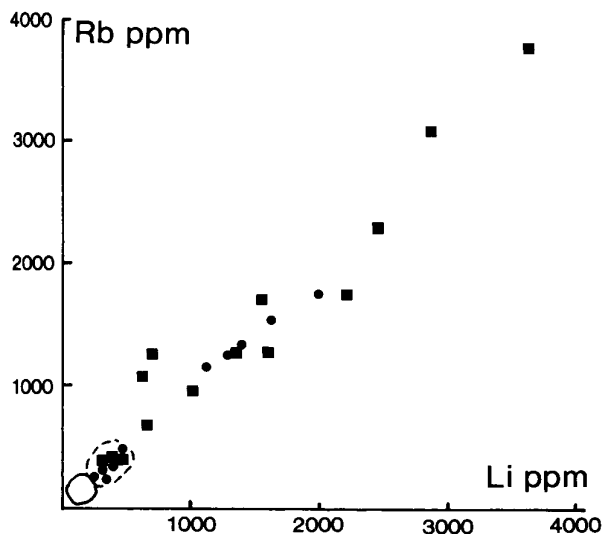


Figure 1. Rb ppm - Li ppm diagram. Group 1- filled squares; group 2 filled circles; field of groups 3 and 4 marked by dashed line; solid line encloses field of group 5.

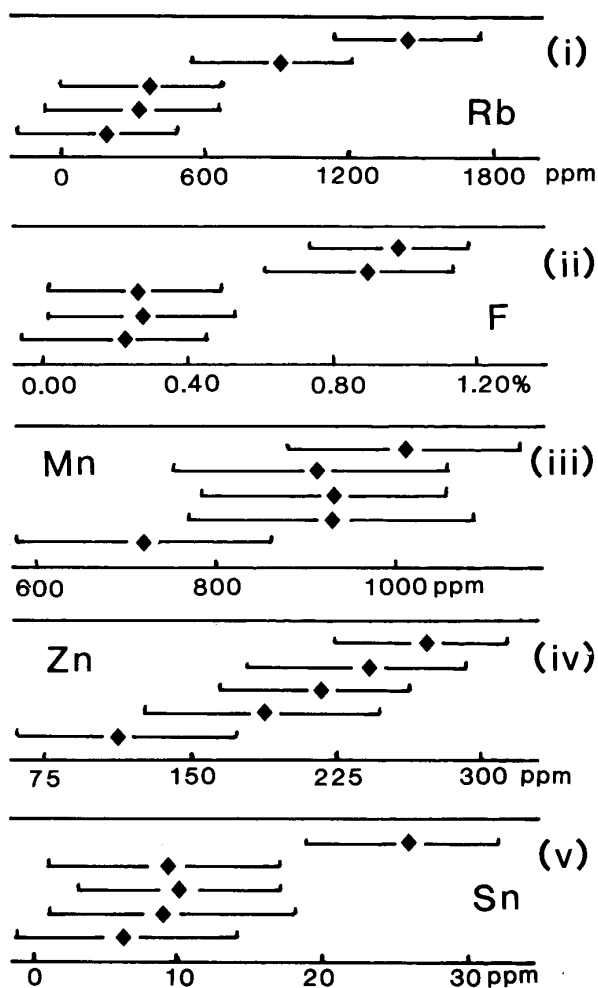


Figure 2. Concentration - group (distance) diagrams for Rb, F, Mn, Zn and Sn. Groups 1 to 5 arranged vertically with group 1 at the top. Confidence intervals about means obtained from the Minitab Analysis of Variance output. Means indicated by filled diamonds.

attributed to hydrothermal metasomatism (Mitropoulos 1982). The Mylor pelites are depleted in the HREE compared with the Brioverian pelites that are believed to have been the source rocks for the Carnmenellis granite (Charoy 1986), but are enriched in the HREE relative to the biotite granites. Presumably, the very low REE contents of the Li-mica granites compared with the biotite granites result in the marked differences between the REE contents of the Land's End and Tregonning granite aureoles. Indeed, the features highlighted by these data are the mobility of the REE in contact metasomatism and their increase towards the granite contact despite the low REE contents of the Li-mica granites.

Discussion and conclusions

The mobile elements at Tregonning granite - hornfels contacts are those that form a distinct cluster and show significant inhomogeneity in both the Kruskal-Wallis and Mann-Whitney tests. They comprise Li, Rb, Cs, F, Ce, La, As, Zn, Sn, U and Th, and constitute the trace alkali suite of this paper.

Fig. 2 and Table 1 show differential movement of elements in the trace alkali suite. For example, Cs has a 'background' value of 15ppm in group 5 (Table 1, col. 5), although a more typical value of c. 10ppm occurs in Mylor pelites far removed from the aureole.

Table 4: REE analyses of Mylor slates.

	1	2	3	4	5
Spec. No.	290	294	244	277	229
La	38.11	36.53	34.15	38.69	33.72
Ce	84.1	80.31	74.7	85.05	76.02
Pr	9.44	8.81	8.63	9.65	8.86
Nd	35.08	33.69	31.8	35.39	32.95
Sm	6.85	6.4	6.26	6.9	6.57
Eu	1.27	1.37	1.32	1.28	0.86
Gd	5.79	5.34	5.27	5.62	5.55
Dy	4.69	4.49	3.69	4.39	4.35
Ho	0.97	0.95	0.76	0.92	0.92
Er	2.63	2.6	1.92	2.5	2.38
Yb	2.76	2.66	2.12	2.74	2.44
Lu	0.46	0.44	0.37	0.46	0.42
Total REE	192.15	183.59	170.79	193.63	175.04
CeN/YbN	7.89	7.81	9.12	8.04	8.06

1 and 2. Hornfels 2-3 and 5-5.5 cm, respectively, from upper contact, sea stack, Legereath zawn.

3. Slate 2 km from contact, Porthleven.

4 and 5. Hornfels 91 cm from contact and contact hornfels, respectively, Megiliggarr Rocks.

Significant enrichment occurs up to c. 10m from the contact although the major enrichment (x 14) occurs in the contact zone itself (col. 1). Increases for Li (x9) and Rb (x9) are less and the overall increases do not extend as far into the aureole as that of Cs, perhaps suggesting that the poorly hydrated Cs ion has moved with greater ease than the other trace alkali ions (Floyd 1967). Other elements of the trace alkali suite, except F and Sri, also show general enrichment in the aureole, although at much lower levels. F (x5) is only enriched below c. 25cm from the contact whilst Sri (x4) enrichment is apparently confined to c. 2cm of the contact.

The timing of metasomatism in relation to crystallization of the granite can be surmised as follows. Crystallization in the Tregonning granite can be compared directly with that in the simple Qz - Ab-Or- H₂O - F system (Manning 1981). The present composition of the granite lies close to the estimated 'ternary' eutectic so that almost simultaneous anhydrous crystallization of quartz and two alkali feldspars probably occurred over a very small temperature interval. Such crystallization resulted in the abundant release of a fluid ('volatile') phase, F-poor at first

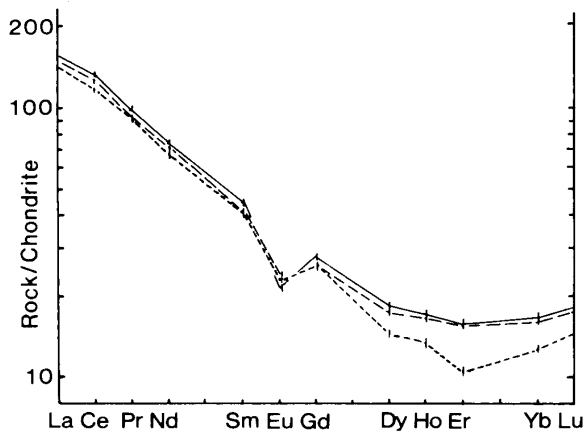


Figure 3. Chondrite normalized REE patterns of data in Table 4, using the chondrite values of Evensen *et al.* (1978). Solid line = 0290 (col. 1); long dashes = 0294 (col. 2); short dashes = 0244 (col. 3).

owing to retention of F in the melt, but becoming richer in F as more fluid was released from the finally crystallizing magma or as the melt evolved into a highly 'saline' fluid (Stone 1984). Metasomatism was probably superimposed upon a slightly earlier metamorphism at the time of emplacement and early crystallization, before a fluid phase was released from the crystallizing magma.

The earlier H₂O-richer high-energy fluids were capable of transporting most of the mobile elements, in particular, the trace alkali elements which, owing to low ionic potentials, were probably carried as hydrated ions. Cs, having the lowest potential, is the least hydrated of the alkali ions and was carried further than Rb and Li which show little difference in enrichment patterns with distance from the contact. The build-up of high F contents in the crystallizing granite resulted in some grain boundary movement of the major alkali elements within the granite (Stone 1984) and the fluid phase became richer in F with continuing crystallization and falling temperature resulting in a marked enrichment of F and Sri in the contact hornfels (group 1) only: it is implied that Sn was carried as a fluoride complex.

A useful comparison can be made with similar hornfels that overlie the roof zone of the small Porthmeor pluton (GR:

Table 5: Mylor pelites, Porthmeor Cove.

	1	2	3	4	5
Spec.No.	0341A	0341B	344	345	346
wt%					
SiO ₂	57.29	57.56	59.52	57.76	60.6
TiO ₂	0.87	0.9	0.84	0.84	0.77
Al ₂ O ₃	18.78	19.51	17.67	18.32	16.51
Fe ₂ O ₃	1.37	1.14	0.89	0.98	0.98
FeO	5.96	6.24	6.24	6.28	6.26
MgO	3.18	3.39	3.39	3.15	2.97
CaO	1.34	1.22	1.12	0.52	1.09
Na ₂ O	1.87	1.49	1.4	0.85	1.11
K ₂ O	4.5	4.48	4.35	5.68	4.86
P ₂ O ₅	0.17	0.17	0.08	0.06	0.05
F	0.56	0.42	0.18	0.25	0.21
ppm					
As	4	9	3	15	n.d.
Ba	432	524	528	569	627
Ce	85	91	69	85	69
Cr	135	142	118	124	110
Cs	95	96	62	110	81
Cu	n.d.	n.d.	64	32	n.d.
Ga	21	19	18	18	18
La	58	68	58	48	42
Li	590	492	348	386	316
Mn	1151	1220	1114	669	1009
Nb	20	15	18	13	18
Ni	139	136	116	134	102
Pb	7	5	1	3	4
Rb	633	480	241	360	216
Sn	13	12	3	33	11
Sr	88	92	70	70	84
Th	10	11	9	11	8
U	2	2	2	2	1
V	125	125	110	105	96
Y	45	47	36	38	34
Zn	69	58	54	42	45
Zr	184	179	186	196	180
K/Rb	59	77.5	149.8	131	186.8
Rb/Sr	7.2	5.2	3.4	5.1	2.6
Ce/Y	1.9	1.9	1.9	2.2	2
Ti/Zr	28.3	30.1	27.1	25.7	25.6

1. Contact (to 2 mm), Porthmeor granite dome.

2.2- 4 cm above roof of dome.

3, 4, 5. 100, 220 and 440 cm above roof of Porthmeor granite dome.

Table 6: Trioctahedral micas in Mylor Pelites near contacts

	1	2	3	4	5	6
Spec.No.	516	516	202	203	341	346
	Zinn	Bi	Bi	Bi	Bi	Bi
SiO ₂	46.19	38.49	35.94	35.29	35.96	34.63
TiO ₂	0.46	1.44	2.42	2.19	2.48	2.62
Al ₂ O ₃	21.45	22.92	19.83	20.69	19.03	18.76
tFeO	10.46	18.63	19.43	20.49	18.32	18.84
MnO	0.61	0.54	0.14	0.23	0.19	0.34
MgO	0.36	1.36	7.4	7.19	9.64	9.38
Na ₂ O	0.2	0.27	0.24	0.21	0.36	0.28
K ₂ O	10.16	9.56	9.06	8.44	9.51	9.41
Rb ₂ O	0.8	0.57	0.2	0.13	0.22	tr
Cs ₂ O	0.18	0.05	0.09	0.04	0.06	0.04
F	7.31	4.68	1.39	0.55	1.29	0.23
Total	99.36	99.55	96.14	95.46	98.06	94.43
N=	2	6	5	3	4	7

I & 2. Contact and 3-15 mm from contact, respectively, Lesceave Por, Praa Sands. (from Stone *et al* 1988, Table 5).

3 & 4. 25 and 60 cm, respectively, from contact with small pendant, Rinsey.

5 & 6. Contact and 3m from contact, respectively, Porthmeor Cove (Land's End pluton).

N = number of points analysed, Zinn = zinnwaldite, Bi = biotite.

SW425376). This is composed of megacrystic biotite granite (Type B of Exley and Stone 1982) but, like the Tregonning granite, has undergone differentiation in situ (Stone and Exley 1984). The data of Table 5 show similar trace alkali and F patterns in the contact hornfels as in the Tregonning aureole, but on a much reduced scale. At 4.4m above the upper contact the pelitic hornfels show some enrichment in the trace alkali elements compared with the 'background' (Table 1, col. 5), but as in the Tregonning aureole, Cs maintains a much higher relative value compared with the other two alkali elements, suggesting again that it is capable of being carried further. F is enriched only at the contact (to c. 4cm), beyond which, it rapidly falls to background values. Zn, Y, Ce, La and perhaps V, Pb, Ni and Cr may show small increases towards the contact, but as the data represent individual analyses no statistical comparison can be made and it is likely that some of these elements will have large variances. Sn has no clear trend of enrichment at the contact: this almost certainly results from both the lower Sn content of a less well-fractionated granite compared with the Tregonning granite and, related to this, a much lower F content in the melt and the evolved fluid. The greater extent of trace alkali movement compared with F is also revealed by the micas (Table 6, cols 5 and 6). However, even at the actual contact, the trioctahedral micas in the hornfels are biotites.

Implications for the genesis of Li-mica granites include the evidence for subsolidus transformation of biotite (siderophyllite) to zinnwaldite at the Tregonning contacts and the absence of Li-mica granite at Porthmeor. The former was used by Stone (1975, 1984) as part of the evidence for subsolidus transformation of biotite granite to Li-mica granite and the latter as evidence that Li-mica granite cannot be derived from biotite magma by differentiation. The alternative hypothesis that the aphyric Li-mica granites were derived by metasomatism followed by remobilization is preferred.

Acknowledgements. Grateful thanks go to Messrs T.C. Hopkins and D. Plant for help in the use of the Camebax WD/ED microprobe in the Geology Department of the University of Manchester, to Mr J. Merefield of the Geology Department, University of Exeter for the chemical data for the rocks and to Dr. C.S. Exley for reading the manuscript.

References

- Bawden, M.G. 1982. The boron content of some Cornish rocks. *Proceedings of the Ussher Society*, 1, 11-13.
- Bowler, C.M.L. 1958. The distribution of alkalis and fluorine across some granite-killas and granite-greenstone contacts. *Abstracts of the Proceedings of the Conference of Geologists and Geomorphologists working in SW England. Royal Geological Society of Cornwall*, 20-21.
- Charoy, B. 1986. The genesis of the Cornubian batholith (South West England): the example of the Carnmenellis pluton. *Journal of Petrology*, 27, 571-604.
- Chesher, S.E. 1971. The metasomatic effect of the intrusion of the Tregonning-Godolphin granite into the Mylor slates, south Cornwall. *Unpublished Ph.D. Thesis, University of Exeter*.
- Evensen, N.M., Hamilton, P.J. and O'Nions, R.K. 1978. Rare-earth abundances in chondritic meteorites. *Geochimica et Cosmochimica Acta*, 42, 1199-1212.
- Exley, C.S. and Stone, M. 1982. Hercynian intrusive rocks. In: Sutherland, D.S. (ed) *Igneous Rocks of the British Isles*. John Wiley, Chichester, 287-320.
- Floyd, P.A. 1967. The role of hydration in the spatial distribution of metasomatic cations in the Land's End aureole, Cornwall. *Chemical Geology*, 2, 147-156.
- Manning, D.A.C. 198 L The effect of fluorine in liquidus phase relations in the system Q-Ab-Or with excess water at 1 kb. *Contributions to Mineralogy and Petrology*, 76, 205-215.
- Mitropoulos, P. 1982. REE patterns of the metasedimentary rocks of the Land's End granite aureole (south-west England). *Chemical Geology*, 35, 265-280.
- Stone, M. 1963. Lithium in the Tregonning-Godolphin granite. *Proceedings of the Ussher Society*, 1, 50-53.
- Stone, M. 1975. Structure and petrology of the Tregonning-Godolphin granite, Cornwall. *Proceedings of the Geologists' Association*, 86, 155-170.
- Stone, M. 1984. Textural evolution of lithium mica granites in the Cornubian batholith. *Proceedings of the Geologists' Association*, 95, 28-41.
- Stone, M. and Exley, C.S. 1984. Emplacement of Porthmeor granite pluton, west Cornwall. *Proceedings of the Ussher Society*, 6, 42-45.
- Stone, M., Exley, C.S. and George, M.C. 1988. Compositions of trioctahedral micas in the Cornubian batholith. *Mineralogical Magazine*, 52, 175-192.