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METASTABLE FELDSPARS OF ARCHEAN AGE IN THE MEGGISI LAKE GRANITE, WABIGOON BELT, ONTARIO

SHAHÉ F. SABAG*

W. G. Wahl Limited, 350 Bay Street, Toronto, Ontario M5H 2S6

ROBERT F. MARTIN

Department of Geological Sciences, McGill University, 3450 University Street, Montreal, Quebec H3A 2A7

ABSTRACT

The cell parameters of microcline and sodic plagioclase (15 pairs) from the seriate unit, Meggisi Lake granite (Wabigoon belt, northwestern Ontario) provide evidence of metastability in both minerals. The plagioclase, now An_2 and slightly disordered in most cases, is not magmatic but seems to be the result of an albitization reaction that almost reached completion. More calcic compositions occur in the groundmass of two specimens and as relics, in grains included in microcline (microprobe determinations). The coexisting microcline invariably is relatively well ordered; on the whole, however, the microcline samples do not define a structurally well-equilibrated lot. Anomalies do not affect *a*, but rather *b* and *c* cell edges; some anomalies may reflect Al in T_2 positions inherited from a plagioclase precursor, in agreement with petrographic signs of a replacement origin for much of the microcline. Other anomalies suggest a departure in stoichiometry of the microcline toward SiO_2. The seriate granite may be a metasomatic envelope around the core zone of equigranular granodiorite to quartz monzonite. In spite of the Archean age of the complex, opportunities have not arisen to anneal the metastable feldspars in the metasomatic assemblage that formed as the Meggisi Lake pluton was intruded and cooled.

Keywords: granite, Archean, microcline, plagioclase, cell dimensions, anomalies, metasomatism, Wabigoon belt, Ontario.

SOMMAIRE

Les paramètres réticulaires de quinze paires microcline + plagioclase sodique du granite à texture sériée du complexe du lac Meggisi (ceinture Wabigoon, au Nord-Ouest de l'Ontario) indiquent l'existence de métastabilité dans les deux minéraux. Le plagioclase, présentement An_2 et légèrement désordonné dans la plupart des cas, n'est pas primaire mais semble résulter d'une réaction d'albitisation presque complète. On trouve des compositions plus calciques dans la matrice de deux échantillons et à l'intérieur de cristaux de microcline (déterminations à la microsonde). Le microcline coexistant est relativement bien ordonné; toutefois, dans l'ensemble, le microcline ne définit pas une population structurale homogène. Les anomalies n'affectent pas le paramètre *a*, mais plutôt *b* et *c*; dans certains cas, l'anomalie pourrait indiquer, en position T_2, la présence d'aluminium hérité d'un plagioclase antérieur. Ceci concorde avec les indices, observés dans la majeure partie du microcline de ces roches, d'une origine par remplacement. Dans d'autres cas, l'anomalie serait due à un excédent de SiO_2 dans le microcline. Le granite à texture sériée constituerait une enveloppe métasomatique autour d'un coeur de granodiorite et de monzonite quartzifère équigranulaires. En dépit de l'âge archéen du complexe, il ne semble pas y avoir eu d'occasion d'éliminer par recuit les feldspaths métastables métasomatiques formés lors de la mise en place et du refroidissement du pluton du lac Meggisi.

Mots-clés: granite, archéen, microcline, plagioclase, paramètres réticulaires, anomalies, métasomatisme, ceinture Wabigoon, Ontario.

INTRODUCTION

The Wabigoon belt in the Superior province (Archean) of northwestern Ontario is a "granite - greenstone" terrane characterized by an assemblage of metavolcanic, metavolcaniclastic and minor metasedimentary units intruded by plutons of massive and foliated granitoid rocks (Mackasey *et al.* 1974, Blackburn 1982). W. M. Schwerdtner and coworkers have recently recognized the importance of gigantic gneiss diapirs more than 50 km in diameter in this part of the Canadian Shield (Schwerdtner *et al.* 1979, Schwerdtner & Lumbers 1980). These diapiric megastructures, which mainly contain foliated to gneissic tonalite to granodiorite, consist of a number of phases, "many of which are distinctly porphyroblastic or have other typically metamorphic textures" (Schwerdtner *et al.* 1979). Crescentic plutons of massive to foliated diorite to granite were then emplaced *between* the diapiric structures and the envelope of supracrustal rocks; lithologically similar batholiths later cut the central part of the diapiric complexes. We present here data on the feldspar mineralogy of the Meggisi Lake

*Present address: Algonquin Mercantile Corporation, Suite 200, 931 Yonge Street, Toronto, Ontario M4W 2H7

pluton, a typical example of the younger, crescentic bodies.

One key question in understanding the evolution of the Wabigoon volcanic-plutonic belt concerns an account of the time span involved between the emplacement of the gneiss diapirs and that of the younger massive to foliated plutons. Birk & McNutt (1981) used the Rb–Sr method to show that the emplacement of the younger plutons in the belt occurred, on average, 2568 Ma ago and spanned less than 35 Ma [$(^{87}Sr/^{86}Sr)_0$ = 0.7007 ± 0.0005]. Although the Meggisi Lake pluton, the subject of this study, was not sampled by Birk & McNutt, the Taylor Lake composite pluton, very similar in all respects and located only 2 km to the north (Fig. 1), was included in their survey. The emplacement of the Taylor Lake pluton, characterized by six intrusive units that range from granodiorite to microgranite and by an autometasomatic (deuteric) overprint, occurred 2584 ± 31 Ma ago, during the Kenoran orogeny. Pooling of the data on several such younger plutons with information of similar precision on the

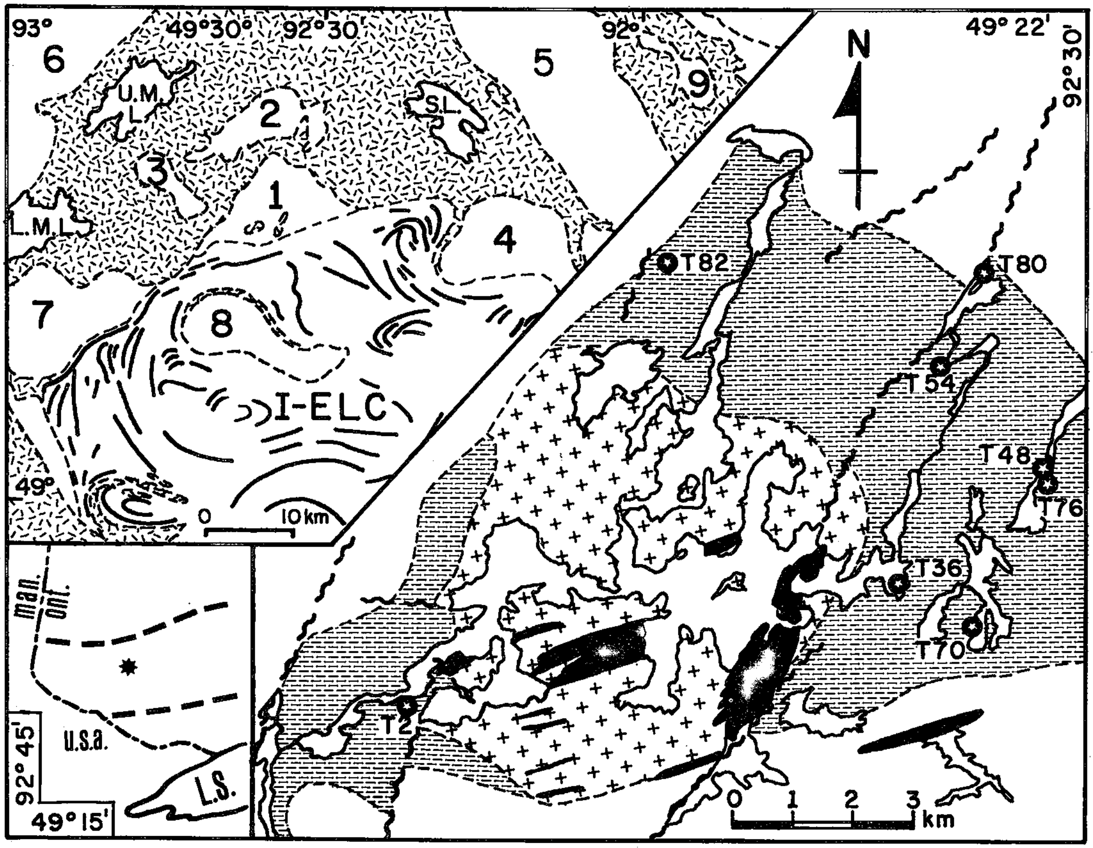

FIG. 1. Simplified geological map of the Meggisi Lake pluton, adapted from Blackburn (1981), showing the core zone (+ + +) of equigranular hornblende–biotite granodiorite to quartz monzonite, largely surrounded by the seriate phase (horizontal dashes). The plutonic complex was mapped by S. F. Sabag. In the southeastern corner, the seriate granite is transitional into gneissic to foliated tonalitic and granodioritic rocks of the Irene - Eltrut lakes diapiric complex, although the contact is shown as a line. The host rocks to the north and west are submarine high-magnesium metabasaltic rocks of the Wapageisi Group. Very large enclaves of such mafic rocks are shown in black. Stars: specimens mentioned in this study. Meggisi Lake occupies a large part of the core zone of the pluton. Top inset: relationship to surrounding rocks. I-ELC Irene - Eltrut Lakes diapiric complex, shown with regional trend lines of foliation (after Schwerdtner *et al.* 1979). Stippled pattern: supracrustal rocks, including metavolcanic suite. S.L. Stormy Lake, U.M.L. Upper Manitou Lake, L.M.L. Lower Manitou Lake. 1 Meggisi Lake pluton, 2 Taylor Lake pluton, 3 Scattergood Lake pluton, 4 Beak Lake pluton, 5 Mennin batholith, 6 lobe of the Atikwa-Lawrence-Doré complex, 7 Vickers Lake pluton, 8 Entwine Lake pluton, 9 Raleigh Lake pluton. Bottom inset: approximate location of study area with reference to the boundaries of the Wabigoon belt, the Ontario — Manitoba and Ontario — U.S.A. boundaries and Lake Superior (L.S.).

syntectonic gneiss diapirs led Birk & McNutt (1981) to conclude that the separation of these intrusive events in the Wabigoon belt is beyond the resolution of the Rb–Sr method.

Interestingly, it now seems that the results of Birk & McNutt (1981) do not represent the timing of *magmatic* crystallization. Davis *et al.* (1982) found a U–Pb zircon age of 2695 ± 3.6 Ma for the Taylor Lake pluton. This suggests that the Rb–Sr system and, by implication, the host minerals for these elements (dominantly the feldspars), remained open during the cooling of the huge Irene - Eltrut lakes diapiric complex. An alternate explanation might be that the system was regionally reset approximately 125 Ma after emplacement of the complex and the discordant plutons.

In the light of the importance of autometasomatic phenomena, open-system behavior and the discordance in the age determinations by the two methods, we present here the results of an investigation of the feldspar mineralogy of one typical crescentic pluton. The Meggisi Lake body, which cuts the Irene - Eltrut lakes diapiric complex, is located approximately 47 km SSE of Dryden and 60 km W of Ignace, Ontario. Our combined electron-microprobe and X-ray-diffraction investigation is designed to characterize the composition and degree of Si–Al order of the coexisting K- and Na-rich feldspars and to relate these properties to petrogenetically significant environmental factors, in the hope of shedding light on the evolution of these post-diapir plutons.

The Meggisi Lake pluton is lenticular and approximately 20 km across at its widest point. The pluton was emplaced along the contact between tonalitic migmatite of the Irene - Eltrut lakes diapiric complex to the south and high-Mg metabasalts of the Wapageisi Group to the north. The pluton occupies the southeastern portion of the Meggisi Lake sheet (between 49°15′ and 49°22′30″ N, 92°30′ and 92°45′ W: Blackburn 1981). An early, equigranular core of hornblende–biotite granodiorite, which carries abundant xenoliths of metavolcanic rocks, is almost completely surrounded (Fig. 1) by a younger seriate granite that is the focus of this report. Also encountered are very small intrusive bodies and dykes of quartz-feldspar porphyry that contain xenoliths of the seriate phase. Full descriptions of the rocks in the area are provided by Blackburn (1981).

Petrography of the Seriate Granite

The seriate granite is characterized by extreme heterogeneity in grain size and mineral abundances (Fig. 2). Quartz and microcline form the coarsest grains. Plagioclase, quartz, microcline and ferromagnesian silicates and accessory minerals are set in an aplitic groundmass containing quartz, microcline and sodic plagioclase. The groundmass typically accounts for 10% of the rock, but may attain 40% near the contacts. An average specimen of seriate granite contains 50 vol. % plagioclase, 27% quartz, 15% microcline and 8% ferromagnesian and accessory minerals. Modes of all specimens examined are reported by Sabag (1979, Appendix A3).

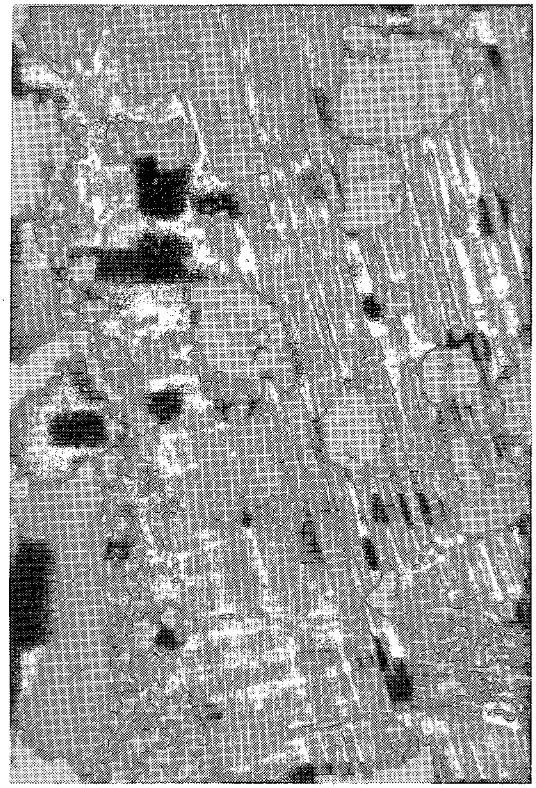

FIG. 2. Typical textural development in the seriate granite, specimen T80. Field of view 4 mm. Note the large range in grain size characteristic of this rock and the high concentration of anhedral sodic plagioclase grains in the microcline "phenocryst".

Quartz glomerophenocrysts range from 0.5 to 3 cm across, but these commonly are granulated into rods and ribbons of anhedral strained grains. Inclusions of titanite, plagioclase and biotite are common in the quartz grains. The *plagioclase* crystals are equant to somewhat lath-shaped, and attain 3 mm across. These grains typically contain a distinct normally zoned euhedral core, on which occur additional zones that define a normal or oscillatory pattern. The zoning gives a record of magmatic crystallization, but the compositions no longer are original (see below). The margin of the zoned grains characteristically is irregular. Inclusions of biotite, magnetite and titanite, visible near the rim, are lacking in the core. Microcline, interpreted to be a product of local replacement, commonly occurs in irregular patches throughout the grains of plagioclase. "Phenocrysts" of *microcline* are equant and invariably poikilitic (Fig. 2), and may merge into irregular intergranular concentrations of K-feldspar in the groundmass. The smaller grains are anhedral and free of inclusions, but the "phenocrysts" contain laths of plagioclase (altered core, fresh rim, as shown in Fig. 2) and biotite, magnetite and titanite inclusions. Microcline grains commonly exhibit Carlsbad twinning and an excellent cross-hatched pattern of albite- and pericline-twinned domains, and are very slightly perthitic. Zones of myrmekite occur commonly in the discrete grains of plagioclase near microcline. The seriate granite is relatively leucocratic: *biotite* (< 5 vol. %) constitutes the most abundant mafic mineral. Accessory phases are epidote, titanite, magnetite and apatite. Hornblende, ubiquitous in the more mafic core-zone of the Meggisi Lake intrusive complex, is lacking in the seriate granite. Ilmenite is not found in the Meggisi Lake suite.

Pegmatite and aplite dykes are more abundant in the seriate phase than in the granodioritic core. In the southwestern part of the pluton (Fig. 1), the seriate phase shows a more prominent fabric and enhanced flattening of crystals, and generally *grades* into the banded tonalitic and granodioritic gneisses to the south. Quartz veins and pegmatite dykes are common in this transition zone.

Composition of the Seriate Granite

In terms of the modal proportion of the dominant minerals plagioclase, quartz and K-feldspar, and assuming that all the plagioclase is more calcic than An_5, the seriate-textured unit ranges from quartz diorite ($n = 2$) to granodiorite ($n = 27$) to granite ($n = 3$), in terms of the IUGS classification (Streckeisen 1976). In view of the microprobe data on the composition of plagioclase (see below), this assumption of An > 5 would appear justified. However, bulk-rock compositions (Table 1) show that the rock names deduced are somewhat misleading. On the basis of twenty specimens whose composition was determined (Sabag 1979, Appendix A5), the seriate granite varies surprisingly little, from 69.8 to 73.3% SiO_2, 14.7 to 15.9% Al_2O_3, 1.2 to 2.2% CaO, 4.9 to 5.5% Na_2O and 2.1 to 3.3% K_2O. The twenty specimens analyzed thus probably contain a very sodic plagioclase, on average, as part of the calcium is bound in the accessory phases. A large proportion of the volume of each plagioclase grain in these rocks must be close to albite in composition, such that the rocks should more properly appear in the field of granite. On the basis of the analytical data in Table 1 and the results quoted by Sabag (1979), the average seriate granite contains 27.8% normative quartz, 0.8% corundum, 16.4% K-feldspar, 43.6% albite and 8.7% anorthite; the average differentiation index thus is 87.8, a value that is beyond the range normally encountered in granodiorites.

TABLE 1. BULK COMPOSITION OF SPECIMENS OF THE SERIATE PHASE, MEGGISI LAKE PLUTON, NORTHWESTERN ONTARIO

	T2	T54	T70	T76	T80
SiO_2 wt.%	72.44	71.95	71.70	71.41	70.59
TiO_2	0.17	0.16	0.14	0.21	0.20
Al_2O_3	15.39	15.13	15.52	15.80	15.35
Fe_2O_3	0.80	0.54	0.56	0.80	0.30
FeO	0.53	0.55	0.55	0.55	1.17
MnO	0.02	0.04	0.01	0.03	0.02
MgO	0.33	0.34	0.40	0.42	0.73
CaO	2.03	1.72	1.91	2.19	2.14
Na_2O	5.50	5.11	5.19	5.00	5.25
K_2O	2.47	2.97	2.48	2.42	2.39
P_2O_5	0.06	0.05	-	0.03	-
L.O.I.	0.42	0.53	0.49	0.54	0.67
Total	100.16	99.09	98.95	99.40	98.81

X-ray-fluorescence data; analyst: S.F. Sabag.

Electron-Microprobe Data on Minerals

Plagioclase

Most plagioclase grains are concentrically zoned. Core compositions encountered range from An_{44} to An_{18}; in the somewhat more mafic, hornblende-bearing rocks in the centre of the pluton, the core zone of the plagioclase generally is more calcic than in the seriate granite. Core-to-rim traverses of zoned plagioclase grains in two representative specimens of the seriate phase (T36 and T48; see Fig. 1 for specimen location) indicate ranges of $An_{21} \rightarrow An_{18}$ and $An_{26} \rightarrow An_{16}$, respectively. Also, compositions from the seriate phase are more tightly clustered than is found in plagioclase of the hornblende-bearing rocks. Analyses of small zoned plagioclase grains included in the microcline "phenocrysts" yield compositions from core to rim in the range $An_{30} \rightarrow An_{14}$. Small grains of intergranular plagioclase yield compositions in the range $An_{11} \rightarrow An_{15}$; films of sodic plagioclase in microcline perthite contain 1% An. Sabag (1979) provided an extended discussion of the microprobe results.

K-feldspar

All the K-feldspar grains ($n = 25$) that have been analyzed by electron microprobe are very pure; the average composition is $Ab_0An_{0.5}Or_{99.5}$. All contain small quantities of calcium (0.01 to 0.25% CaO) but virtually no sodium. The larger grains contain more Ca ($An_{0.8}$) and Na ($Ab_{0.5}$) than do intergranular and interstitial grains. The poikilitic K-feldspar grains are slightly *more* calcic in the vicinity of plagioclase inclusions.

Biotite

The seriate phase contains an aluminous biotite of composition $(K_{0.89}Na_0Ca_{0.01})(Mg_{1.35}Fe^{2+}_{0.84}Mn_{0.03}Fe^{3+}_{0.36}Al_{0.32}Ti_{0.10})_{\Sigma 3.00}(Al_{1.12}Si_{2.88})_{\Sigma 4.00}O_{11}(OH)_2$. This composition is the average of thirteen determinations made on five specimens. The average composition of biotite in the early phase (n = 26) is virtually identical in all respects: $(K_{0.93}Na_0Ca_{0.01})(Mg_{1.38}Fe^{2+}_{0.91}Mn_{0.02}Fe^{3+}_{0.34}Al_{0.27}Ti_{0.09})_{\Sigma 3.01}(Al_{1.11}Si_{2.89})_{\Sigma 4.00}O_{11}(OH)_2$; however, it coexists with hornblende. One unusual feature of these biotite compositions is the absence of sodium, as was seen to be the case for the K-feldspar.

X-RAY-DIFFRACTION STUDIES

Unit-cell parameters of the coexisting plagioclase and K-feldspar in six specimens of the seriate-textured unit (locations shown in Fig. 1) are listed in Table 2. These data, obtained for coarse grains of microcline (termed phenocrysts and abbreviated P in Table 2) and adjacent groundmass assemblages (abbreviated G in Table 2), are computed from cor-

TABLE 2. CELL DIMENSIONS OF COEXISTING FELDSPARS IN SELECTED SPECIMENS OF THE MEGGISI LAKE GRANITE

		a(Å)	b(Å)	c(Å)	α(°)	β(°)	γ(°)	V(Å³)	Δ2θ	#	α*(°)	β*(°)	γ*(°)	Δ	ψ(°)
T2	P1	8.5760	12.9684	7.2209	90.675	115.960	87.707	721.46	0.009	44	90.366	64.045	92.222	0.933	
		0.0006	0.0010	0.0005	0.008	0.007	0.006	0.07			0.009	0.007	0.007		
		8.1419	12.7756	7.1549	94.225	116.612	87.822	663.57	0.007	24	86.364	63.469	90.321		1.150
		0.0008	0.0019	0.0006	0.011	0.008	0.008	0.09			0.017	0.008	0.008		
T2	G	8.5763	12.9608	7.2218	90.688	115.960	87.661	721.13	0.010	40	90.373	64.046	92.267	0.952	
		0.0008	0.0009	0.0006	0.009	0.008	0.009	0.08			0.010	0.007	0.009		
		8.1410	12.7785	7.1563	94.245	116.616	87.857	663.74	0.010	43	86.325	63.463	90.271		1.178
		0.0007	0.0013	0.0006	0.010	0.007	0.008	0.08			0.009	0.007	0.008		
T54	P1	8.5753	12.9620	7.2229	90.628	115.941	87.818	721.42	0.011	48	90.363	64.064	92.121	0.897	
		0.0007	0.0012	0.0006	0.010	0.006	0.009	0.08			0.009	0.006	0.009		
		8.1402	12.7620	7.1575	94.193	116.599	87.862	663.07	0.016	32	86.380	63.479	90.293		1.153
		0.0016	0.0027	0.0011	0.030	0.014	0.018	0.15			0.020	0.014	0.016		
T54	P2	8.5759	12.9693	7.2205	90.611	115.923	87.820	721.74	0.010	49	90.380	64.081	92.127	0.906	
		0.0007	0.0013	0.0006	0.008	0.007	0.009	0.08			0.008	0.007	0.009		
		8.1381	12.7891	7.1574	94.238	116.618	87.802	664.15	0.013	35	86.360	63.464	90.338		1.145
		0.0012	0.0014	0.0008	0.011	0.012	0.014	0.11			0.011	0.012	0.013		
T54	G	8.5871	12.9637	7.2233	90.616	115.932	87.699	722.54	0.010	39	90.434	64.071	92.259	0.975	
		0.0009	0.0012	0.0006	0.008	0.007	0.008	0.08			0.008	0.007	0.008		
		8.1466	12.7788	7.1549	94.165	116.608	87.913	664.20	0.009	28	86.386	63.467	90.249		1.164
		0.0008	0.0014	0.0007	0.012	0.009	0.012	0.09			0.012	0.009	0.011		
T70	P1	8.5819	12.9667	7.2268	90.666	115.942	87.689	722.55	0.012	54	90.383	64.063	92.245	0.950	
		0.0008	0.0012	0.0007	0.010	0.008	0.009	0.09			0.010	0.008	0.009		
		8.1420	12.7808	7.1608	94.199	116.630	87.835	664.31	0.020	28	86.387	63.450	90.319		1.142
		0.0015	0.0037	0.0015	0.030	0.019	0.024	0.20			0.027	0.019	0.020		
T70	G	8.5783	12.9707	7.2222	90.646	115.912	87.712	722.20	0.012	35	90.393	64.092	92.229	0.948	
		0.0012	0.0016	0.0010	0.013	0.011	0.012	0.12			0.014	0.011	0.013		
		8.1517	12.7873	7.1491	94.087	116.609	87.953	664.58	0.021	27	86.453	63.463	90.244		1.143
		0.0016	0.0044	0.0018	0.026	0.026	0.022	0.27			0.030	0.026	0.026		
T76	P1	8.5798	12.9683	7.2189	90.628	115.935	87.792	721.77	0.010	55	90.376	64.070	92.150	0.912	
		0.0007	0.0009	0.0006	0.008	0.006	0.008	0.07			0.008	0.006	0.009		
		8.1431	12.7766	7.1590	94.232	116.666	87.785	663.78	0.019	32	86.376	63.417	90.356		1.135
		0.0016	0.0022	0.0012	0.018	0.017	0.015	0.16			0.028	0.017	0.015		
T76	P2	8.5758	12.9686	7.2184	90.618	115.919	87.772	721.48	0.011	53	90.396	64.085	92.177	0.930	
		0.0007	0.0010	0.0005	0.009	0.006	0.009	0.07			0.009	0.006	0.010		
		8.1451	12.7780	7.1534	94.196	116.590	87.786	663.96	0.009	32	86.415	63.493	90.378		1.115
		0.0007	0.0012	0.0008	0.011	0.008	0.010	0.08			0.009	0.008	0.008		
T76	G	8.5767	12.9609	7.2143	90.697	115.848	87.649	721.11	0.010	29	90.365	64.159	92.274	0.952	
		0.0014	0.0011	0.0009	0.011	0.010	0.010	0.12			0.011	0.010	0.010		
		8.1487	12.8093	7.1467	94.045	116.487	88.381	666.00	0.009	33	86.287	63.558	89.794		1.334
		0.0008	0.0013	0.0006	0.012	0.010	0.010	0.09			0.012	0.010	0.010		
T80	P1	8.5815	12.9642	7.2168	90.627	115.943	87.823	721.44	0.009	38	90.362	64.062	92.116	0.894	
		0.0007	0.0010	0.0008	0.010	0.008	0.009	0.08			0.009	0.008	0.009		
		8.1375	12.7894	7.1585	94.293	116.620	87.797	664.16	0.011	41	86.300	63.463	90.314		1.172
		0.0007	0.0011	0.0007	0.011	0.009	0.009	0.08			0.011	0.009	0.009		
T80	P3	8.5788	12.9630	7.2175	90.621	115.948	87.793	721.17	0.010	41	90.383	64.057	92.152	0.916	
		0.0009	0.0013	0.0008	0.011	0.008	0.009	0.09			0.011	0.008	0.009		
		8.1368	12.7878	7.1576	94.261	116.641	87.794	663.84	0.012	28	86.338	63.442	90.332		1.154
		0.0012	0.0020	0.0011	0.016	0.012	0.012	0.11			0.015	0.012	0.010		
T80	G	8.5757	12.9593	7.2219	90.637	115.923	87.649	721.22	0.011	27	90.434	64.081	92.304	0.991	
		0.0017	0.0017	0.0009	0.015	0.010	0.016	0.14			0.014	0.010	0.016		
		8.1397	12.7854	7.1570	94.257	116.622	87.795	664.01	0.013	50	86.343	63.461	90.335		1.152
		0.0010	0.0016	0.0008	0.012	0.008	0.009	0.09			0.012	0.008	0.009		
T82	P1	8.5800	12.9658	7.2211	90.569	115.927	87.828	721.93	0.011	54	90.423	64.076	92.138	0.928	
		0.0006	0.0012	0.0006	0.010	0.007	0.009	0.08			0.010	0.007	0.009		
		8.1372	12.7822	7.1588	94.269	116.611	87.770	663.86	0.011	31	86.341	63.473	90.358		1.146
		0.0009	0.0013	0.0009	0.015	0.011	0.011	0.11			0.014	0.012	0.010		
T82	G	8.5820	12.9571	7.2165	90.622	115.885	87.695	721.35	0.011	28	90.427	64.118	92.260	0.972	
		0.0011	0.0017	0.0011	0.019	0.014	0.013	0.13			0.018	0.013	0.013		
		8.1389	12.8015	7.1493	94.204	116.541	88.025	664.59	0.021	30	86.286	63.527	90.109		1.239
		0.0020	0.0055	0.0013	0.026	0.018	0.028	0.26			0.024	0.018	0.026		

represents the number of indexed powder-diffraction lines used in the cell refinement (program of Appleman & Evans 1973). Each specimen is split into two or three subsamples; the symbols P and G stand for phenocryst and groundmass, respectively. Each subsample contains two feldspars. Data for the K-feldspar are listed on the first line, associated errors on the second line, data for the plagioclase on the third line and associated errors on the fourth line. Δ is the obliquity of the microcline in each subsample, and is defined as $12.5(d_{131} - d_{1\bar{3}1})$; ψ is the value of the 131 indicator of the plagioclase in each subsample; it is defined as $2\theta_{131} - 2\theta_{1\bar{3}1}$ (Cu$K\alpha_1$ radiation). The indicator of goodness of fit Δ2θ is expressed in degrees.

TABLE 3. COMPOSITIONAL AND STRUCTURAL INDICATORS INFERRED FROM CELL CONSTANTS OF MICROCLINES, MEGGISI LAKE SERIATE GRANITE

		Or(a)	*Or(V)*	a^*(Å^{-1})	*Orb*c**	Δbc	$\Delta\alpha^*\gamma^*$	$t_1 0$
T2	P1	0.957	0.957	0.12979	1.006	0.982	0.990	0.986
	G	0.958	0.947	0.12979	0.988	1.006	1.010	1.008
T54	P1	0.955	0.955	0.12977	1.004	1.011	0.942	0.976
	P2	0.957	0.965	0.12974	1.018	0.977	0.941	0.959
	G	0.984	0.989	0.12959	1.009	1.010	0.993	1.001
T70	P1	0.971	0.989	0.12968	1.027	1.027	0.997	1.012
	G	0.963	0.979	0.12970	1.028	0.986	0.987	0.986
T76	P1	0.966	0.966	0.12970	1.005	0.968	0.953	0.961
	P2	0.957	0.957	0.12974	1.007	0.964	0.962	0.963
	G	0.959	0.946	0.12966	0.986	0.954	1.015	0.984
T80	P1	0.970	0.956	0.12968	0.985	0.963	0.940	0.951
	P3	0.964	0.948	0.12973	0.983	0.970	0.953	0.961
	G	0.956	0.950	0.12976	0.993	1.010	1.015	1.013
T82	P1	0.967	0.970	0.12968	1.010	0.989	0.937	0.963
	G	0.972	0.953	0.12962	0.976	0.978	0.995	0.987

The six specimens of seriate granite (see Fig. 1 for locations of sampling sites) are split into two or three subsamples; the symbols P and G stand for phenocryst and groundmass, respectively. *Or(a)*: Or content, in mol. fraction, calculated on the basis of the a cell edge (see text). *Or(V)*: Or content based on cell volume. *Orb*c**: Or content inferred from the b^* - c^* plot. Δbc is calculated using the program of Blasi (1977), as is $\Delta\alpha^*\gamma^*$; average errors for these 15 refinements are ±0.006 and ±0.005, respectively. $t_1 0$: Al occupancy of the $T_1 0$ site in these microclines. In normal microclines, Δbc (= $t_1 0 + t_1 m$) > $\Delta\alpha^*\gamma^*$ (= $t_1 0 - t_1 m$).

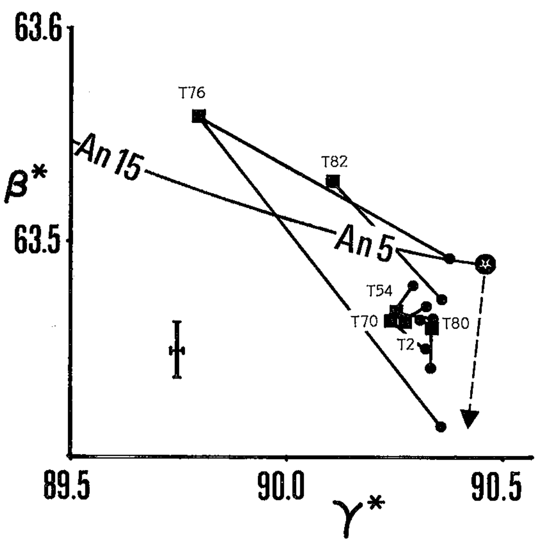

FIG. 3. Plot of β^* *versus* γ^* for the sodic plagioclase in the six specimens of seriate granite studied. Curved line: ordered plagioclase. Dashed line shows the direction of increasing Si-Al disorder. The dots represent the sodic plagioclase in the microcline; a large proportion of this fraction consists of the anhedral inclusions poikilitically enclosed in the "phenocrysts" of microcline. The square symbol represents the sodic plagioclase in the matrix. The error bars are an average of the fifteen determinations. Star: ordered pure albite.

rected and indexed diffraction peaks (film technique, Guinier–Hägg focusing camera, synthetic spinel internal standard) using the program of Appleman & Evans (1973). Calculated structural and compositional indicators (Table 3) were derived from the raw data for the fifteen pairs of feldspars.

Plagioclase

The cell parameters of the sodic plagioclase in the groundmass and in the microcline phenocrysts reflect the volumetrically most abundant plagioclase in a given subsample; the refinement is based on a c = 7 Å cell. The range of compositions in the zoned grains is restricted, as demonstrated in the microprobe traverses mentioned above, obtained for representative specimens T36 and T48. No evidence was found of two sets of plagioclase diffraction peaks in any of the subsamples, nor of unusual broadening of peaks owing to marked heterogeneities in composition or structural state (or both).

The data for plagioclase are best analyzed in terms of a plot of the reciprocal angles β^* *versus* γ^* (Fig. 3). The tieline in each case links the matrix plagioclase to the *dominant* sodic feldspar composition in the microcline phenocryst. Note from Table 2 that in three cases, two microcline phenocryst assemblages differing only in grain size were X-rayed; in Figure 3, both data-points are shown linked to a common point for the matrix.

The *groundmass* plagioclase in T76 and T82 is distinctly more calcic than that in the other specimens (An_{13} and An_6 as opposed to An_2 or An_3); also, these points are in a slightly anomalous position with respect to the locus of well-ordered albite and oligoclase structures in the β^* - γ^* plot. The microcline phenocrysts in T76 and T82 contain a distinctly more sodic plagioclase (An_2) than the groundmass; these examples of sodic plagioclase define a large span in structural state that encompasses the phenocryst and groundmass plagioclase of the other specimens.

The β^* - γ^* plot shown in Figure 3 is but a small portion of the diagram shown by Smith (1974, Fig. 7–44). In the context of the full diagram and in the light of unpublished information on the albitization of plagioclase (*e.g.*, in the feldspathic rocks of the Montgenèvre ophiolitic suite, western Alps: R. F. Martin, in prep.), the anomalous positions of the matrix plagioclase in T76 and T82 can be attributed to the incomplete albitization of a more calcic plagioclase (*e.g.*, andesine). Such intermediate products of an incomplete reaction probably define a curvilinear path linking the original composition (to the left of T76 and T82 in Fig. 3) and pure, ordered albite.

The cluster of data points in the compositional range An_2 - An_3 is displaced from the "ordered" plagioclase curve in the direction of increasing Si–Al disorder. Eberhard (1967) has shown that the presence of small amounts of Ca in the plagioclase structure greatly retards the process of Si–Al ordering; this may explain why these feldspars are not perfectly ordered. It is possible that the present composition of the matrix plagioclase in T2, T54, T70 and T80 also arose by processes of albitization; the precursor plagioclase in these cases may have been less calcic than that which gave matrix plagioclases T76 and T82, so that the product approached more closely pure albite in the time available for reaction. Note that T82 comes from the northern contact, adjacent to basic metavolcanic rocks (Fig. 1). Additional data, bearing on possible transitional, somewhat more mafic seriate rocks, could perhaps shed light on the steps followed in the reaction. The dominant compositions of plagioclase in these rocks clearly are not magmatic; they are inconsistent with the compositions expected in granitoid rocks whose bulk composition lies in the primary field of crystallization of plagioclase. In spite of the Archean age of the Meggisi Lake granite, opportunities for complete Si-Al ordering of these structures and complete transformation to pure albite, *e.g.*, during a later orogeny, clearly have not arisen.

A powder-diffraction study provides information concerning the average structure in the small volume of sample chosen; the beam of an electron microprobe provides point analyses of plagioclase, sampled away from inclusions of calcium-bearing breakdown minerals (*e.g.*, epidote) to minimize spurious results. The two methods of analysis thus are complementary, and both should be used. Unfortunately, the range of plagioclase compositions recorded by microprobe (Sabag 1979, Table P2) cannot be compared directly with XRD determinations, as these were made on different specimens. The most calcic composition of plagioclase in the matrix indicated in Figure 3, An_{12}, agrees with the range of compositions determined by microprobe, An_{11} to An_{15}. However, the matrix plagioclase in the other specimens is distinctly more sodic. The discrepancy in An content suggests that the electron beam may have interacted with calcium-bearing breakdown minerals intimately associated with these grains. In the case of sodic feldspar films in microcline perthite, microprobe determinations are consistent with the XRD data perhaps because this albite never was very much more calcic, and thus is not associated with calcium-bearing breakdown phases.

K-feldspar

The cell parameters *b, c,* α^* and γ^* serve to define the structural indicators $\Delta(bc)$ and $\Delta(\alpha^*\gamma^*)$, and hence t_1O, the proportion of Al in the T_1O position in the K-feldspar structure. By definition, t_1O = 1.00 in fully ordered microcline; one might well expect this value to have been attained in plutonic rocks of Archean age. The composition of the K-rich feldspar can be inferred 1) from the *a* cell edge, which is relatively insensitive to structural state, 2) from a *b* — *c* plot contoured for *a,* and 3) from a plot of the reciprocal cell dimensions *b* versus c**. These data lead to an evaluation of strain in the lattice of K-feldspar in the six specimens of Meggisi Lake seriate granite selected for study.

The *a* cell edge of the microcline (Table 2) ranges from 8.5753 to 8.5871 Å; the average standard error associated with this dimension in the fifteen datasets is 0.0009 Å. It is possible to obtain a value of N_{Or}, the mol fraction of Or, from *a* using an expression derived from the K-rich portion of the microcline - low albite series of Orville (1967): $N_{Or} = -19.926 + 2.43506\,a$ (W.C. Luth, pers. comm. 1970). Values of N_{Or} based on *a* range from 0.955 to 0.984 (Table 3). Judging from its *a* dimension, microcline in the groundmass is not systematically richer (or poorer) in Or than that in the phenocryst.

Lattice strain that results from coherency between sodium- and potassium-rich domains in a perthite is reflected in an anomalously short predicted *a* dimension of the K-rich feldspar, based on position in the *b* - *c* quadrilateral. An arbitrary limiting value in Δa (= $a_{obs} - a_{pred}$) of 0.05 Å (Stewart & Wright 1974, Fig. 9) is usually considered in the definition of such an anomalous K-rich feldspar. In an expanded view of part of the *b* - *c* quadrilateral (Fig. 4), the groundmass K-feldspar in specimens T76 and

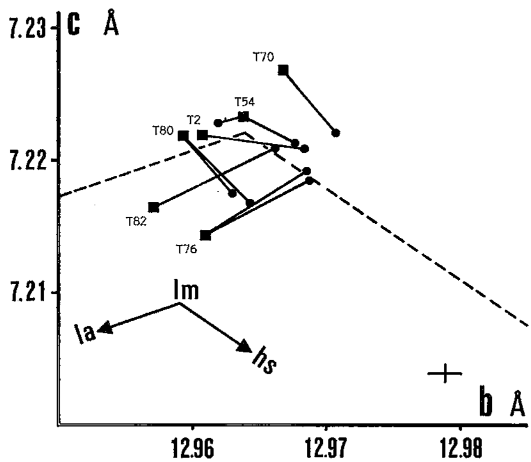

FIG. 4. Plot of *b versus c,* showing the location of the fifteen data points with respect to the low microcline (lm) corner. The direction of the low albite (la) and high sanidine (hs) corners is also shown, as is an average of the error bars in the fifteen determinations. Symbols as in Figure 3.

T82 plots in an unexpected position away from the low microcline corner. Values of Δa in both cases attain the limiting case of 0.05 Å. Note that T76 and T82 are the specimens in which the groundmass plagioclase was found aberrant. The position of these two data-points for groundmass microcline in Figure 4, significantly displaced toward low albite, cannot be attributed to a higher Na content, as 1) N_{Or} values inferred from a or from V (see below) show no signs of apparent Na enrichment in T76 and T82, and 2) the groundmass microcline in two typical specimens was found to be devoid of Na (microprobe analyses).

The samples of groundmass microcline in the four other specimens are offset from the phenocryst microcline in the direction of increasing apparent degree of order. As the ordering reaction is surface-controlled, such a structural difference between phenocryst and groundmass feldspar might not be unexpected in a much younger rock. Taken at face value, the surprising degree of scatter among points in Figure 4, apparently a reflection of a range of t_1O values from 0.951 to 1.013 (Table 3), suggests that structural equilibrium has *not* been attained, both within and between the six specimens analyzed.

The data points for microcline (groundmass *and* phenocryst) in specimen T70 plot in an anomalous position, outside the $b - c$ quadrilateral. Such a shift could reflect substitution of a large cation in the K-feldspar [*e.g.*, Rb-for-K or Fe-for-Al substitutions (Martin 1971, Fig. 2)]. However, T70 is not pegmatitic, nor is it unusually iron-rich. Values of a in T70 (Table 3) show no evidence of Rb-for-K substitution. The anomalies in T70, which in fact imply that Δa is a negative quantity, may thus also reflect structural effects rather than compositional variables.

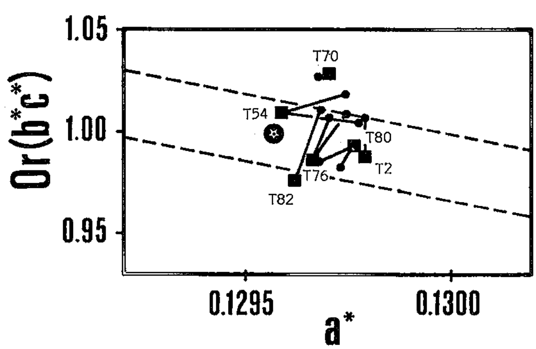

FIG. 5. Plot of a^* *versus* Or (b^*c^*), showing the location of the fifteen data points for microcline with respect to the limits (dashed lines) of unstrained K-feldspar. Symbols as in Figure 3, with the exception of the star, which represents end-member microcline.

The cell volume is usually considered to reflect composition of a K-rich feldspar more accurately than a, which is apparently prone to strain-related anomalies of both signs. Compositions based on V, calculated for the fifteen samples of microcline studied (equation of Stewart & Wright 1974), range from 0.946 (T76 groundmass) to 0.989 (Table 3). The values are surprisingly close to those deduced from a alone, suggesting that there are in fact no anomalies involving a in the K-feldspar of the Meggisi Lake suite. In turn, this suggests that the groundmass microcline in T76 and T82 (Fig. 4) is anomalous in its b and c dimensions.

Smith (1974, Fig. 7-27) proposed a different diagram to gauge the extent of structural anomalies: a^* (in Å^{-1}) is plotted as a function of Or(b^*c^*), the Or content deduced from the $b^* - c^*$ quadrilateral. Values of Or(b^*c^*), calculated with the expression of Blasi (1977) and listed in Table 3, range from 0.976 to 1.028. Note that with some exceptions (Fig. 5), these values of Or agree more closely with compositions measured by microprobe than values of Or based on a or V. Most points fall within the arbitrary limits for normal (*i.e.*, unstrained) K-rich feldspars (Fig. 5). On this diagram, a strained K-feldspar in coherent intergrowth with albite would be expected to plot off-scale toward a lower value of Or(b^*c^*). The anomalies in T70 and in one phenocryst sample of T54 are thus not due to a coherent intergrowth with sodium feldspar, nor would such a cause be expected in view of the age, the degree of deformation and the original plutonic nature of the Meggisi Lake granite body.

Although a^* seems to have a value very close to that expected, thirteen out of fifteen samples of microcline are anomalous in that they plot outside the $b^* - c^*$ quadrilateral (not shown). The microcline in T70 (phenocryst and groundmass), as in Figure 4, shows the maximum departure in c^*, which is 0.00012 Å^{-1} too short; b^* is 0.00043 Å^{-1} too long in the matrix microcline in T82. Internal variability and the anomalous positions suggest that both b^* and c^* are anomalous in these samples of microcline. Insofar as a and a^*, which reflect the proportion of Na and K, are not aberrant, we must conclude that the anomalies involve structural variables related to the distribution of Si and Al.

DISCUSSION

The approach used here provides information on the *average* K-feldspar and plagioclase structures in a given specimen selected for study. Even though a typical sample, as mounted for X-ray-diffraction analysis, weighs between 2 to 2.5 mg and thus occupies less than 1 mm^3, there is a possibility that the two variables that affect the cell constants, composition and degree of Si–Al order, are not homogeneous properties of the feldspars in this small volume, leading to diffuse diffraction-maxima. For example, the groundmass plagioclase may well be zoned, as indicated by microprobe scans described above. Keeping in mind these words of caution, however, the reader should note that in the data for K-feldspar, cell edges are determined with a precision close to 1 in 10000; for plagioclase, the average precision attained is only slightly inferior to this level, suggesting that the extents of compositional zoning and structural heterogeneities are minimal.

The structural anomalies in microcline, reflected principally in *b* and *c* rather than *a*, can be explained by considering how the distribution of Al and Si affects *b* and *c*. In an admittedly simplistic approach, Stewart & Ribbe (1969) proposed that *b* and *c* (unlike *a*) vary significantly in length with degree of Si–Al order because of the following different sequences of tetrahedral cations encountered along [010] and [001]: T_1O, T_1m, $2T_2O$ and $2T_2m$ along *b*, T_1O, T_1m and one of T_2O or T_2m along *c*. The mean *T*–O bond-lengths vary from 1.604 Å (Si–O) to 1.643 Å ($Si_{3/4}Al_{1/4}$–O, as in a completely disordered feldspar) to 1.759 Å (Al–O), according to one model (Ferguson 1980). As one T_1O and one T_1m are in common to both paths through the microcline, an anomaly in *b* and *c* must reflect the relative importance of the T_2 set of positions. It is true that results of structure refinements of well-ordered microcline, summarized by Ferguson (1980), indicate very low concentrations of Al in these two positions, such that in ordinary low microcline, the mean T_2O–O and T_2m–O bond-lengths would both be very close to 1.604 Å.

As a *possible* explanation of the anomalous values of *b* and *c* found in some samples of microcline, we propose that small amounts of Al statistically occupy T_2O and T_2m positions. Three larger-than-usual T_2 sites would thus be encountered along *b versus* one along *c*, and the resulting cell would be expanded along *b* and somewhat less so along *c* (*e.g.*, T54 and T70 in Fig. 4). Such a pattern of Si–Al distribution may reflect 1) more Al than expected in ideal $KAlSi_3O_8$ owing to small amounts of structurally bound Ca, and 2) a relict disordered Si–Al distribution if the microcline was once a plagioclase (see below).

The other type of anomaly, illustrated by matrix microcline in T76 and T82 (Fig. 4), in which both *b* and *c* are shorter than expected, could possibly reflect more in the structure than expected, presumably balanced by a deficiency in the alkali position. This small excess of Si, distributed over T_1m, T_2O and T_2m, would lead to sufficient shortening of the mean T_1m–O, T_2O–O and T_2m–O bond-lengths to account for the anomaly. Unfortunately, only in high-temperature calcic plagioclase has this phenomenon of departure from stoichiometry toward SiO_2 been documented properly (Bruno & Facchinelli 1974). Careful crystal-structure studies will be needed to test the proposals made here concerning the cause of shortening in *b* and *c*.

The composition and degree of Si–Al order of both plagioclase and microcline can be used to extract petrogenetic information concerning the origin of the seriate granite at Meggisi Lake. (1) The zoned crystals of plagioclase were more calcic than they presently are; they have been almost completely albitized, presumably at temperatures in the realm of greenschist-facies metamorphism. (2) An *average* composition of 2 to 3% An characterizes matrix and phenocrysts of four of the six specimens studied; compositional or structural equilibrium was not attained in any of these. These results, which are not compatible with the point determinations of composition by microprobe (on samples not available for XRD analysis) suggest that the volume occupied by the relics of the original plagioclase is small in the six specimens studied. (3) In the case of T76 and T82, the matrix plagioclase was albitized, but it is significantly more calcic than in the other specimens, suggesting a more calcium-rich original matrix (owing to admixed mafic volcanic xenoliths or, in a more extreme view, to the fact that the whole rock once was a basic volcanic rock). Note that T82 was collected very close to the contact with the metabasic host rocks. (4) The lack of equilibration among the plagioclase components of T76 and T82 and the lack of structural and compositional convergence onto ordered An_0 among the other specimens imply a relatively short-lived series of deuteric adjustments that possibly accompanied the cooling of the central body of early-emplaced equigranular granodiorite to quartz monzonite. Also a possibility, in view of the discrepancy between Rb–Sr (*i.e.*, feldspar) and U–Pb (*i.e.*, zircon) systems in the neighboring Taylor Lake stock and elsewhere in the Wabigoon belt, is a separate event 125 Ma after the emplacement of the small plutons. This could be related to reactivation of the huge Irene - Eltrut lakes diapiric complex. (5) The presence of "phenocrysts" of strikingly grid-twinned microcline in the seriate granite implies initial formation of K-feldspar as a monoclinic phase, and thus crystallization at a temperature higher than approximately 450° C (*e.g.*, Smith 1974, Fig. S–1). The monoclinic K-feldspar seems to have formed in part by *in situ* replacement of a pre-existing plagioclase. The bulk composition of the rocks is not consistent with the crystallization of phenocrysts of K-rich feldspar as a liquidus phase. Petrographic evidence suggesting a replacement origin for the "phenocrysts" [*e.g.*, large, strikingly poikilitic grains of microcline, irregular outline, projections and anastomosing network of K-feldspar extending into groundmass; highly irregular and embayed margins of the small lath-shaped grains of plagioclase in the groundmass, "synneusis" texture produced by selective removal of material along fronts that cut across grain boundaries, patchy pseudomorphism by microcline (Sabag 1979)] is also mentioned by Schwerdtner *et al.* (1979) and Birk *et al.* (1979) in descriptions of other plutonic complexes in the Wabigoon belt. The conversion of the monoclinic K-feldspar to ordered microcline was successful, but the rate of cooling of the affected rocks must have been too rapid to allow these structures to anneal properly, leading to persistence of structural anomalies indicative of a plagioclase precursor and (more tentatively) of nonstoichiometric compositions apparently enriched in Si.

The initial $^{87}Sr/^{86}Sr$ ratio determined on the neighbc ing Taylor Lake stock, 0.7005 (Birk & McNutt 1981), as well as the range in $\delta^{18}O$ values measured on a representative suite of four specimens from the same body (7.7 – 8.9°/oo: Longstaffe & Birk 1981), are consistent with ultimate derivation of these small batches of granitic magma by the anatexis of buried basaltic material previously enriched slightly in ^{18}O during an episode of low-temperature alteration. The feldspar data suggest that the seriate granite, which does not have an igneous texture, forms a metasomatic envelope around the central stock at Meggisi Lake; the rocks affected by K,Na metasomatism were the banded gneisses on the southern side (a transition zone in fact was noted in the field: see caption to Fig. 1) and metabasic rocks of the Wapageisi Group to the north. These metasomatic adjustments may represent the attempted conversion, at amphibolite- and greenschist-range temperatures, of the host rocks to compositions in equilibrium with fluids released during the crystallization of the central stock. The conversion is considered only partly successful because of the persistence of Ca-bearing albite, locally of oligoclase and andesine, and of scatter and structural anomalies among the microcline samples analyzed. Such metastable features could have been removed by annealing had the area been reheated; this may provide an argument against a younger event of regional importance 125 Ma after emplacement.

The overall crescentic shape of such plutonic complexes as at Meggisi Lake may reflect the outer shape of the metasomatic envelope, which developed around an igneous core of anatectically reactivated crustal material as it rose along the interface between the major diapiric structures and the metabasic rocks of the adjacent greenstone belt. Mafic xenoliths in this envelope may represent "digested" metabasic wallrocks, whereas those in the igneous core may represent a residuum left over after partial melting of a basic source (Sutcliffe 1978).

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