Observations on some features of the Heemskirk Granite

by M. P. McClenaghan

PREVIOUS WORK

The mapping of the original Zeehan map sheet (Blissett and Gulline, 1962) did not subdivide the Heemskirk granite. Blissett (1962) described the Heemskirk granite as an adamellite with a pink variety which merged gradually into white or cream-coloured varieties. More detailed work followed in the mid 1960's by Brooks in association with Heier and Compston (Brooks and Compston, 1965; Heier and Brooks, 1966; Brooks, 1966). This work was principally a Rb/Sr isotope study but also included the geochemistry of the granite. Although three granite types were recognised the work does not appear to have involved detailed mapping of the granite body. The eastern part of the body was described as red granite which had a zone of irregular and diffuse mixing with white granite to its west. The white granite was subdivided into series A and B, with the former consisting of equigranular coarse white granite and the latter of porphyritic varieties containing greater amounts of biotite and altered xenoliths. The white series B granite occured in the northern part of the body, and the boundary between it and the series A white granite could be placed only approximately. Heier and Brooks (1966) considered that the white granite was highly differentiated, had intruded first, and had then been modified by a magmatic vapour phase. The parent magma then intruded as a second phase and formed the red granite.

The first detailed mapping of the granite body was done by Klominsky (1972) who subdivided the body mainly into white and red granite types with coarse and medium to fine-grained varieties of both. Klominsky concluded that the white granite intruded the red, contra to the conclusion of Heier and Brooks (1966). More recently Hajitaheri (1984) carried out a study on the Heemskirk granite which concentrated on the geochemistry, mineralisation and fluid inclusions of the granite, mostly in the southern part of the body. He also considered that the white granite intruded the red granite.

RECENT WORK

Mapping of the Heemskirk granite as part of the revision of the Zeehan map (Brown et al., 1994) has used similar granite-type divisions to those used by Klominsky (1972), but all boundaries shown on the map are based on new mapping. The most significant boundary appears to be between the red and white granites (fig. 1); this can be mapped very accurately for most of its length and is in close agreement with the boundary produced by Klominsky

(1972). The way the contact follows the contours indicates that the surface between the two granite types is almost horizontal, and suggests that the white granite is not far below the surface over a large part of the area of red granite in the east of the granite mass. Contact features at the boundary, such as chilling of the white granite and concentrations of quartz-tourmaline nodules in the white granite, indicate that the white granite is later, which is in agreement with the conclusions of Klominsky (1972) and Hajitaheri (1984).

The main field criteria used to distinguish the white and red granite types was the colour of the K-feldspar, which is generally a distinct pink in the red granite whereas in the white granite it is a creamy or buff colour. The appearance of the mica was also found to be useful, with the red granite usually having abundant small flakes of fresh looking, shiny black biotite, whereas the mica in the white granite is generally less abundant and occurs as larger dull greenish flakes. The white granite also has a more altered appearance, has a more diverse texture, and has more abundant quartz-tourmaline nodules and patches.

The southeastern part of the body is dominantly very coarse-grained to coarse-grained red granite, with the remaining parts of the red granite having a complex distribution of fine- to coarse-grained and very coarse-grained granite. The finer granite varieties generally have small phenocrysts of feldspar and quartz. Both sharp and gradational contacts between fine-grained and coarse-grained granite occur. It was not possible, in the time available, to map more than a small part of these textural variations but the impression was gained that Klominsky's conclusion that the red granite consists of many horizontal sheet-shaped intrusions is correct. In several areas down-hill traverses passed from coarse-grained granite to fine-grained granite with a sharp boundary, and then going further down the hill the fine-grained granite passed gradationally to a coarse-grained granite which was underlain by fine-grained granite, again with a sharp contact. The fine-grained granite, at the sharp contacts with the coarse-grained granite, is very rich in quartz-tourmaline nodules, suggesting that there was an accumulation of volatiles in these zones. These features are consistent with the intrusion of sheets into space formed by subsidence within a cauldron-type structure as suggested by Klominsky (1972).
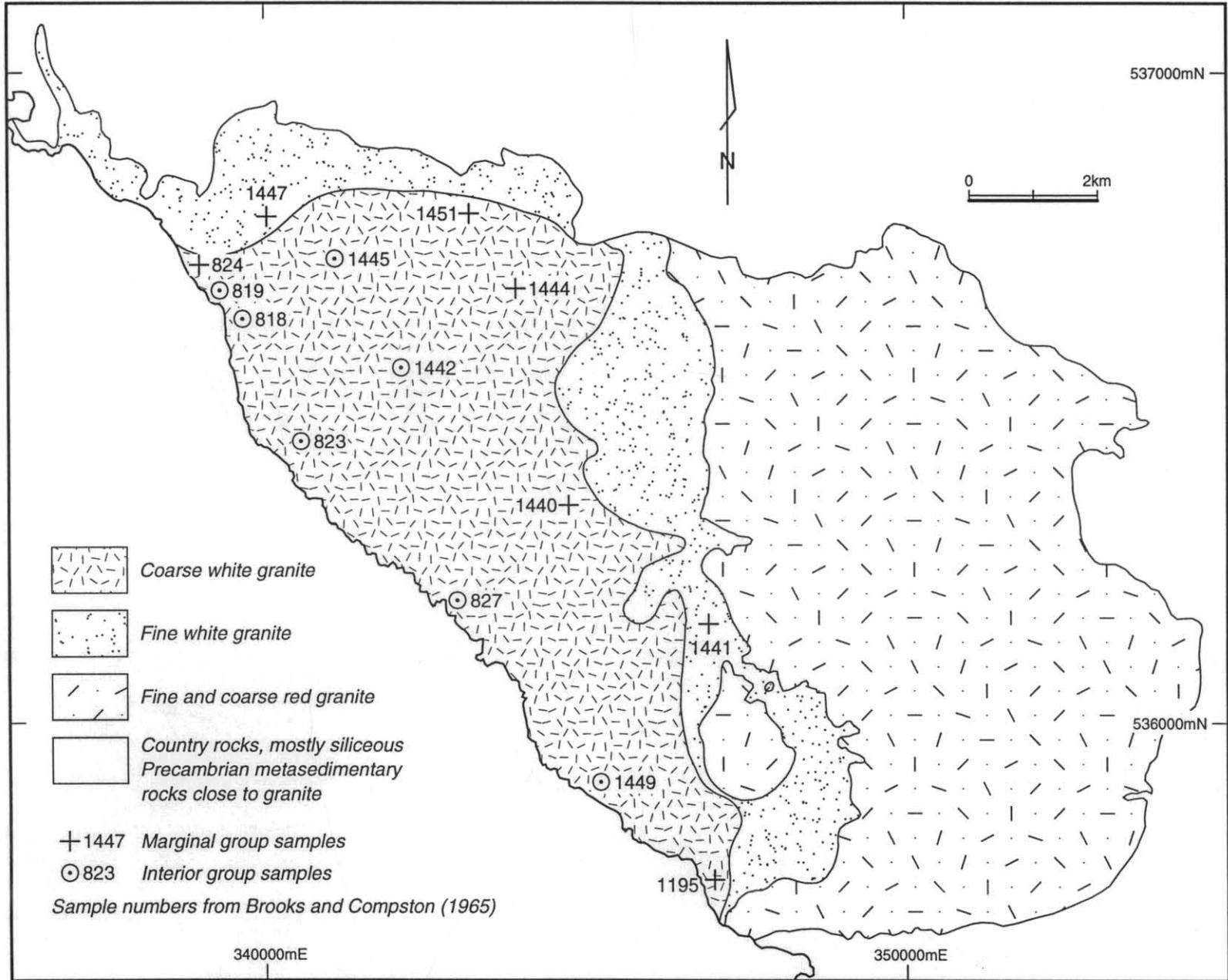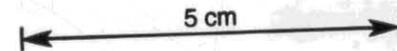
Figure 1. Geological sketch map of the Heemskirk Granite showing the distribution of the main granite types and the localities for the samples analysed for isotope composition.

Legend:

- *Coarse white granite*
- *Fine white granite*
- *Fine and coarse red granite*
- *Country rocks, mostly siliceous Precambrian metasedimentary rocks close to granite*
- $+$ 1447 *Marginal group samples*
- $\odot$ 823 *Interior group samples*

Sample numbers from Brooks and Compston (1965)

Thin quartz-tourmaline veins are common along joints and are particularly abundant near the boundary with the white granite and where the white granite can be inferred to be present at moderate depth. Occasional larger patches and dykes of quartz-tourmaline also occur. Prominent photo-lineaments are present in the area of the red granite and appear to be following the joints and veins.

The white granite has been divided into finer grained and coarser grained varieties, with the finer generally in the outer part of the white granite body adjacent to the red granite and in the north adjacent to the country rock. The texture in both the white granite types is variable. The coarse white granite is dominantly equigranular, whereas the finer white granite ranges from equigranular to porphyritic with quartz and feldspar phenocrysts. Quartz-tourmaline nodules and patches are more abundant in the finer white granite than in the coarser, especially in the areas near the red granite. Quartz-tourmaline veins are less abundant in the white granite than in the red. In one area mapped as coarser white granite, multiple intrusions of granite with variations in grain size and sharp contacts were seen. This suggests that the white granite may have been intruded as multiple pulses in the same way as has been suggested for the red granite. The boundary between the finer and coarser white granite appears to be gradational; it was not possible to map this boundary exactly.

PETROGRAPHY

Both the white and red granite types consist dominantly of quartz, K-feldspar, plagioclase and mica. The K-feldspar is generally a fine to coarse perthite and shows considerable cloudy alteration. Plagioclase is also extremely altered with abundant small inclusions of sericite, which is often more abundant in the central parts of crystals. Plagioclase ranges in composition from andesine to pure albite, with oligoclase and albite being most common. The mica is generally brown or reddish brown biotite but in many samples is variably altered to chlorite and to other mica compositions. These other compositions include olive green-brown and green-grey mica. These may be rich in Li and Rb. Probe data (Hajitaheri, 1984) indicates that the biotites are iron rich and close to annite in composition. Accessory minerals include tourmaline, muscovite, apatite, fluorite, cassiterite, topaz, zircon, monazite, sphene, rutile, allanite, magnetite and ilmenite. A small amount of amphibole is present in some red granite samples. Magnetite, sphene and allanite are confined to the red granites. Graphic intergrowths of quartz and K-feldspar are common in both red and white granites. Secondary muscovite, tourmaline, fluorite and topaz are most common in the white granite. Both main granite types appear to have undergone considerable alteration, with the finer white granite being the most altered.

GEOCHEMISTRY

Geochemical data for the Heemskirk Granite is presented in Brooks and Compston (1965), Heier and Brooks (1966), Klominsky (1972) and Hajitaheri (1984). Geochemical plots in this report make use of more modern data, consisting of unpublished data of B. W. Chappell and new data presented here (Table 1).

Plots of various oxides and trace elements against total iron as FeO (FeO*) show that there is considerable overlap in the composition of the red and white granites for most elements (fig. 2). The red granite is generally richer than the white for SiO_2, P_2O_5, Zr, Y and Th at corresponding FeO* values. Both the red and white granites have Rb greater than 250 ppm, suggesting that there has been significant feldspar fractionation. A chondrite-normalised REE plot (fig. 3) shows that both granite types have LREE enrichment relative to HREE and a pronounced negative Eu anomaly. The white granites have lower total REE than the red granite, some markedly so. The Eu anomaly may be the result of plagioclase fractionation or metasomatism. The metasomatic alteration of the granite has probably decreased the initial chemical difference between the white and red granite types.

The mineralogical and chemical composition of the white granite is consistent with it being an S-type granite, whereas the presence of magnetite, allanite and sphene in the red granite suggests that it is an I-type.

Rb/Sr ISOTOPE GEOLOGY

Brooks and Compston (1965) carried out 12 and 14 whole-rock Rb/Sr isotope determinations on the red and white granites respectively. They found that the data for the white granite did not have a good fit to a single isochron, but if three samples from the northern part of the body were considered separately then two isochrons with good fit could be drawn with the same slope but a slightly different initial Sr^{87}/Rb^{87} ratio. This appears to be the main reason for dividing the white granite into series A and B. The area in the north of the body, from where the three series B samples came, does not appear to be different from the rest of the white granite on mapping or petrographic character.

In a later paper Brooks (1966) discussed the scatter of total-rock data points and showed that there was open system behaviour for most samples. There was a loss of radiogenic Sr from K-feldspar and a gain by plagioclase. Biotite either retained radiogenic Sr or leaked a fractional amount (up to 4%). A single sample of white granite from series A, which came from an area far from the granite margins, had remained closed as judged by the fact that the data points for the whole rock, K-feldspar, plagioclase and biotite defined an isochron within the experimental error. This sample therefore gives the best estimate of the initial Sr^{87}/Rb^{87} ratio which is 0.7304 ± 0.0015. The biotite age from this rock is 353.1 ± 4 Ma and is likely to be the best age for the white granite. As the granite body as a whole was clearly rich in hydrothermal fluids, as judged by the texture and mineralogy, and radiogenic Sr was mobile in most samples, it seems probable that the granite gained variable amounts of radiogenic Sr from the Precambrian country rock. This suggestion is supported by a comparison of the isochrons produced by whole-rock data from samples farthest from the granite margins (mostly the coarser white granite) and samples nearer the margins (mostly the finer white granite) (fig. 1). Whole-rock data from the first or interior group define an isochron with an initial Sr^{87}/Rb^{87} ratio of 0.73078 and age of 346.9 Ma, whereas samples from the second or marginal group give an initial Sr^{87}/Rb^{87} ratio of 0.73991 and age of 334.3 Ma. This result is what would be expected if the second marginal group was more contaminated by the more radiogenic, country rock Sr.

None of the red granite samples show closed system behaviour so a reliable estimate of the initial Sr^{87}/Rb^{87} ratio is not possible. The oldest biotite age of 359.3 ± 4 Ma gives the minimum age for the red granite.

MINERALISATION

The mineralisation of the granite was studied by Hajitaheri (1984) using mineralogical, stable isotope and fluid inclusion data. Two types of mineralisation are present in the southern part of the granite; cassiterite-tourmaline-quartz mineralisation in the area near and to the west of Lake Cumberland and polymetallic mineralisation near the southern margin of the granite. The former type was probably produced by magmatic fluid evolved during the emplacement and crystallisation of the white granite. The latter formed largely from circulation of groundwater through the country rocks and the red granite.

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Table 1. Chemical analyses of samples from the Heemskirk Granite.

Specimen No.	H1	H2	H3	H4	H5	H6	H7	H8
Grid ref.	CP535582	CP527578	CP480582	CP458605	CP477603	CP372688	CP405639	CP413632
Attribute	Heemskirk	Heemskirk	Heemskirk	Heemskirk	Heemskirk	Heemskirk	Heemskirk	Heemskirk
	c. red	c. red	f. white	c. white	f. red	c. white	c. white	f. white
SiO_2	73.1	73	74.32	74	74.55	70.51	71.93	75.05
TiO_2	0.28	0.36	0.11	0.07	0.19	0.28	0.34	0.07
Al_2O_3	12.1	12.1	12.76	12.3	12.19	12.65	13.07	13.13
Fe_2O_3	0.35	0.65	0.6	0.31	0.3	0.46	0.37	0.5
FeO	2.48	2.61	1.47	1.41	2.14	1.93	2.55	1.07
MnO	0.05	0.06	0.03	0.04	0.05	0.05	0.06	0.03
MgO	0.45	0.52	0.26	0.17	0.35	0.44	0.57	0.2
CaO	0.61	0.89	0.37	0.35	0.58	0.75	1.02	0.44
Na_2O	3.21	3.1	3.96	3.17	2.91	2.89	2.76	3.32
K_2O	5.23	5.16	4.93	5.11	5.33	4.97	5.13	4.95
P_2O_5	0.07	0.08	0.06	0.04	0.06	0.08	0.11	0.12
H_2O^+	0.61	0.66	0.66	0.58	0.6	2.82	1.05	0.48
H_2O^-	0	0	0	0	0	0	0	0
CO_2	0.15	0.11	0.04	0.1	0.09	0.09	0.1	0.1
Sulphate as SO_3	0.01	0	0.02	0	0	0	0.01	0
Sulphide as SO_3	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.03
Total SO_3	0.03	0.02	0.04	0.01	0.02	0.01	0.02	0.03
LOI	0.49	0.49	0.54	0.53	0.46	2.65	0.87	0.47

Trace elements by XRF

Ba	160	180	25	-23	110	190	260	<23
Rb	380	308	538	492	352	325	349	517
Sr	32	36	7	8	23	35	47	7
Pb	15	29	21	25	26	24	18	20
Th	64	49	24	16	30	26	28	17
U	12	12	21	23	16	23	0	45
Zr	180	196	51	46	110	103	132	38
NB	21	19	22	20	17	13	14	15
Y	48	55	52	47	52	39	45	24
La	74	68	<20	<20	62	29	38	<20
Ce	120	125	36	26	115	71	92	<28
V	21	22	7	<5	14	23	22	8
Cr	11	15	13	<5	7	8	<5	8
Co	<8	<8	<8	<8	<8	<8	<8	<8
Ni	47	47	45	30	47	37	34	32
Cu	38	37	39	29	33	28	26	27
Zn	28	37	19	27	25	23	28	17
Ga	16	17	20	16	17	18	17	19
Nd	77	72	30	41	83	39	50	<20
W	11	14	42	36	24	24	19	17
As	<20	<20	<20	<20	<20	<20	<20	<20
Bi	<5	<5	<5	<5	<5	<5	<5	<5
Mo	7	10	10	6	9	8	9	7
Sn	14	15	48	19	-9	-9	-9	11

REE and other elements by neutron activation

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La	56.5	58.3	11.9	12.7	53.5	28.7	37.1	5.57
Ce	122	123	28.1	28.8	113	65.2	77.2	13.3
Nd	51.5	50.8	18.1	19	50.3	30.2	34	7.75
Sm	10.6	10.2	5.25	5.3	10.7	6.92	8.55	2.25
Eu	0.58	0.77	0.06	0.06	0.37	0.46	0.72	0.04
Tb	1.51	1.49	1.18	1.19	1.59	1.24	1.27	0.49
Ho	2.53	2.44	2.16	2.22	2.5	1.74	1.91	0.87
Yb	6.54	6.3	5.96	6.34	6.93	4.36	4.65	2.84
Lu	1.01	0.88	0.95	1.01	1.04	0.63	0.74	0.47
Hf	6.3	7.2	2.37	2.17	4.41	3.25	4.17	1.54
Sc	4.56	5.14	4.79	4.1	4.8	4.66	5.62	2.97
Th	40.3	37.4	19.9	19.1	34.9	22.2	25.4	11.9
U	7.6	11.1	20.7	15.8	14	13.5	8.29	60.3
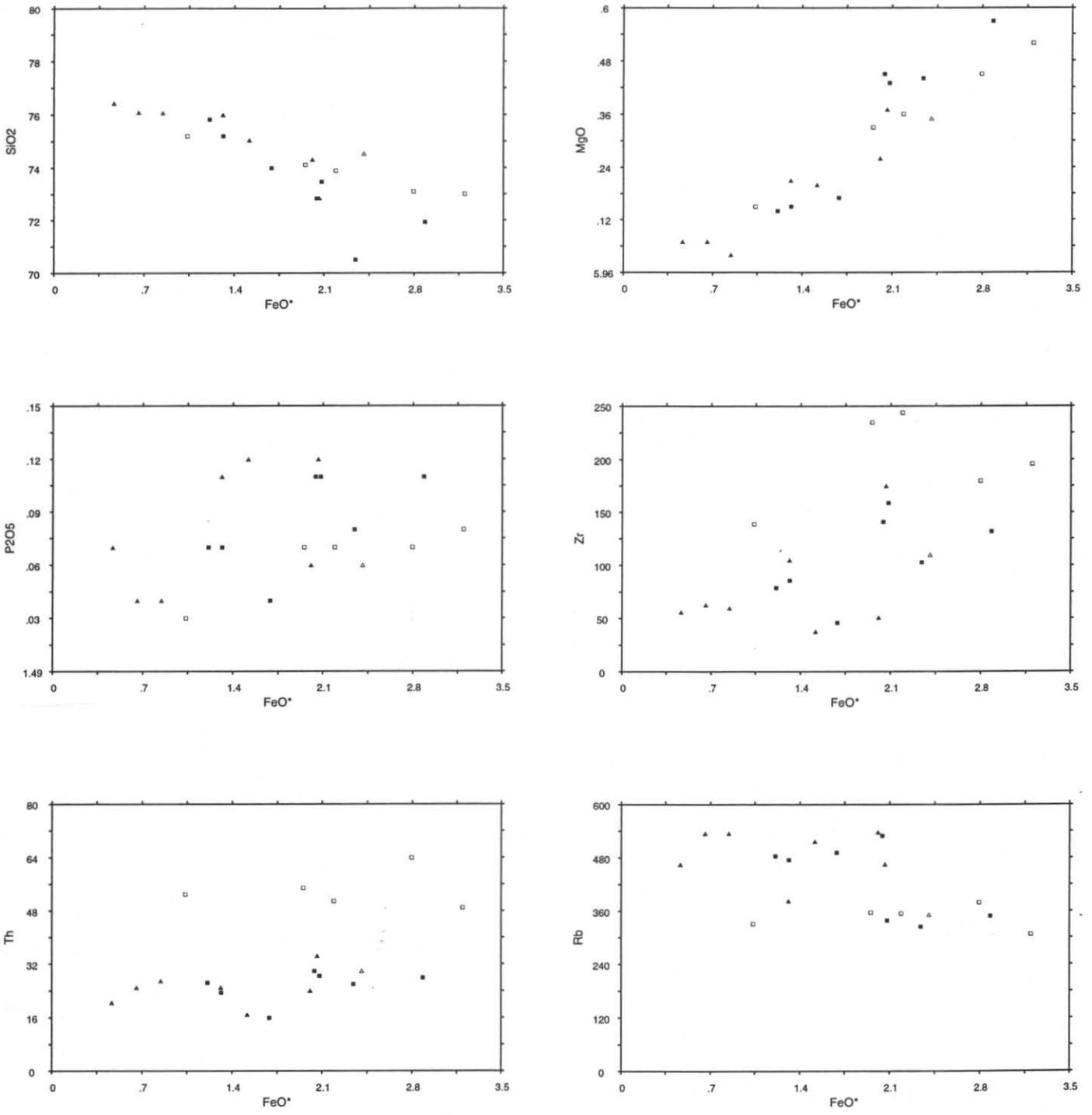
Figure 2

Geochemical plots for samples from the Heemskirk Granite.

Source of data: 8 analyses, this report Table 1; 12 analyses, Chappell (pers. comm.)

coarse-grained red granite — open square
fine-grained red granite — open triangle
coarse-grained white granite — filled square
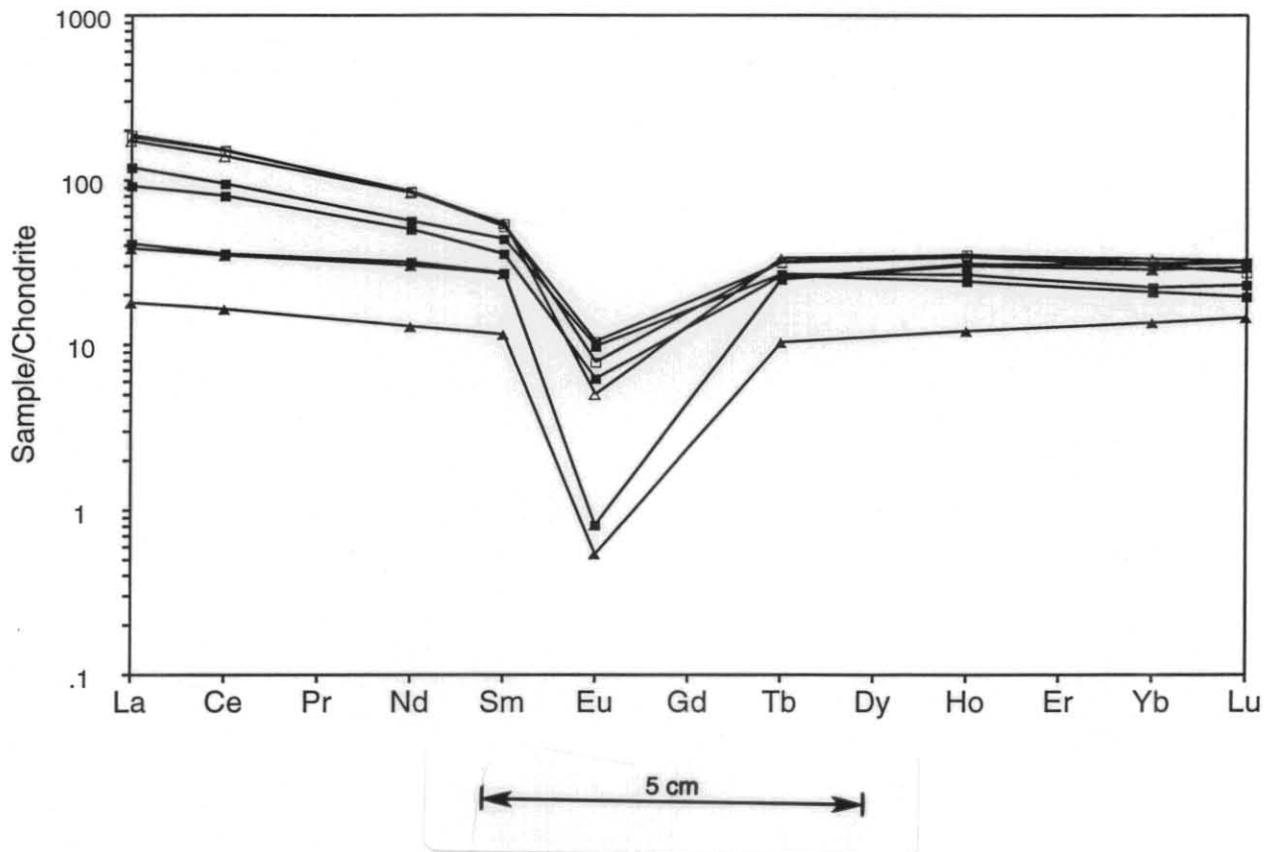fine-grained white granite — filled triangle.

5 cm
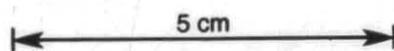
Figure 3

A chondrite normalised REE plot of data from Table 1.

coarse-grained red granite — open square
fine-grained red granite — open triangle
coarse-grained white granite — filled square
fine-grained white granite — filled triangle.