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S- AND I-TYPE GRANITES DURING LATE-STAGE MAGMATISM IN THE BARBERTON MOUNTAIN LAND, SOUTHERN AFRICA

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by

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ABSTRACT

Two distinct groups of granites can be recognized among the late plutons in the Barberton Mountain Land. Discrimination between the two groups is provided by geochemical and mineralogical parameters which are not the result of differences in the magmatic processes, but in the nature of the source material. The high-Ca suite has geochemical parameters indicating its derivation from an igneous source material (I-type) and an accessory mineral assemblage comprising zircon, apatite, allanite and sphene. The low-Ca suite contains a distinctly different accessory mineral assemblage consisting of zircon, apatite, xenotime, zirconosilicates, Ca-Th-phosphates and early monazite and has a chemical signature consistent with its derivation from a metasedimentary precursor (S-type). Intrusion ages for the S-type suite are between 3074 and 2830 Ma and for the I-type granites between 2740 Ma and 2690 Ma. These ages can be correlated with the various stages of evolution of the Limpopo orogenesis.

The existence of S-type plutons as old as 3070 Ma indicates that, at least in the Barberton region, granites had already evolved, by mid-Archaean times, beyond the TTG mode and had assumed many of the characteristics of more modern orogenic granites. Archaean S-type granites may testify, therefore, that plate tectonic processes were in operation already at that time.

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INTRODUCTION

The evolution of the Archaean granite crust surrounding the Barberton greenstone belt occurred episodically from ~3550 Ma to ~2730 Ma ago. Granitoid emplacement can be broadly divided into three episodes (Fig. 1), termed magmatic cycles (Anhaeusser and Robb, 1981). The earliest magmatic cycle comprises pervasively foliated, sodium-rich tonalite/trondhjemite and granodiorite (TTG) and resulted in pre- to syn-kinematic intrusions in low-grade volcanics. Their emplacement ages cluster at ~3445 Ma and ~3225 Ma (Kamo and Davis, 1991). The areally extensive, multi-component, potassium-rich granodioritic to adamellitic batholiths of the second magmatic cycle were passively emplaced into pre-existing tonalite/trondhjemite crust at ~3107 Ma, over a time span of not more than a few million years (Kamo and Davis, 1991). The third magmatic cycle occurred over a period from ~3074 Ma to ~2690 Ma (Kamo and Davis, 1991; A. Kröner, in Trumbull, 1990) and is characterized by the intrusion of discrete, post-tectonic, compositionally heterogeneous, granitoid plutons which cross-cut all other Archaean rock types in the region.

Geochemical models for the origin of Archaean granitoids suggest that the early TTG plutons formed from fractional melts of amphibolite and/or quartz eclogite of basaltic composition at mantle depth (e.g. Robb and Anhaeusser, 1983). The K-rich granodioritic to adamellitic batholiths are presumed to have formed by partial melting of calc-alkaline tonalitic material, which may have been similar to rocks of the first magmatic cycle (Robb and Anhaeusser, 1983). The origin of the third magmatic cycle plutons is less well constrained. They represent a variety of rock types which include tonalites, granodiorites, adamellites and granites. Plutons of granite (*sensu stricto*) composition dominate the third magmatic cycle and these have been divided into two sub-types, namely the Mpageni- and Sicunusa-types (Condie and Hunter, 1976; Robb, 1983a). More recently, Robb and Meyer (1990) distinguished between a high-Ca and a low-Ca granite suite. Genetic models proposed by Condie and Hunter (1976) and Robb (1983a) envisaged that the Mpageni- and Sicunusa-type granites were produced by 70-80% fractional crystallization of a magma which was derived by 20-40% partial melting of the tonalite-trondhjemite parent with differences in the two pluton-types being attributed to varying liquidus assemblages and fO_2 conditions. Trumbull (1990) regarded the low-Ca Sinceni pluton as being derived by 25-35% fractional crystallization of a parent magma which also produced the second magmatic cycle batholiths.

The main subjects of this study are the granite (*sensu stricto*) plutons of the third magmatic cycle. On the basis of accessory mineralogy and geochemical trends it is suggested that both I- and S-type granites can be recognized within the late plutons.

GEOLOGY OF THE GRANITE PLUTONS

A total of 10 granite plutons are recognized in the Archaean terrane of the Barberton region and Swaziland (Fig. 1). Their distribution roughly coincides with two subparallel,

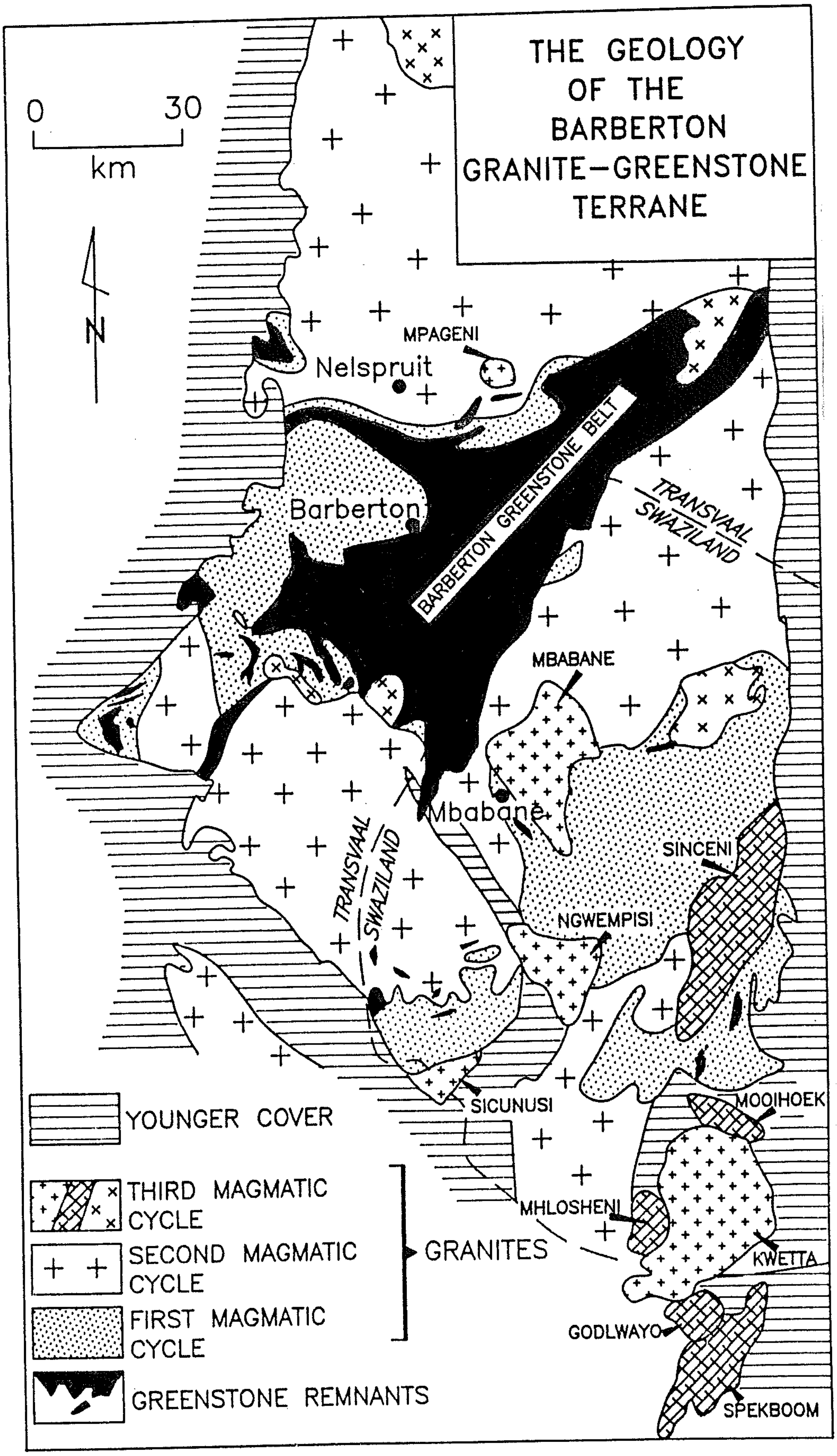

Figure 1: Locality map and generalized geology of the Barberton Mountain Land.

north-south trending, linear arrays. In the west, this trend is defined by the Mpageni, Mbabane, Ngwempisi and Sicunusa plutons, whereas the easterly array comprises the Sinceni, Mooihoek, Mhlosheni, Godlwayo, Spekboom and Kwetta plutons. Compositionally, the plutons occurring in the westerly belt are characterized by high Ca contents, whereas the easterly belt is mainly defined by low-Ca granites (Robb and Meyer, 1990). All of the late granite plutons are unfoliated and are topographically prominent. Attendant hydrothermal alteration and exogenous zones of veining suggest that they generally represent high-level intrusions.

The high-Ca plutons are typically coarse-grained, greyish, hornblende-biotite granites. Quartz, microcline megacrysts, and oligoclase form the dominant rock-forming minerals, while biotite and hornblende are less abundant.

Available chronological data suggest that these granites were emplaced in the time interval from ~2750 to ~2690 Ma. The reported conventional single zircon age for the Mpageni pluton is 2740 ± 15 Ma (Kamo and Davis, 1991) and that for the Mbabane pluton is 2694 ± 4 Ma (Kröner and Layer, 1992). The Ngwempisi pluton intrudes the 2871 ± 30 Ma Usushwana Intrusive Suite (Hegner *et al.*, 1984) and the Rb-Sr whole rock age given by Allsopp *et al.* (1962) is 2819 ± 340 Ma. The Sicunusa pluton also intrudes the Usushwana Intrusive Suite. The available Rb-Sr whole rock age is 2608 ± 123 Ma (Davies, 1971). The reported Rb-Sr whole rock ages for the Kwetta pluton are 2517 ± 522 Ma (Barton *et al.*, 1983) and 2689 ± 52 Ma (Reimold *et al.*, in preparation).

The low-Ca plutons are siliceous, coarse-grained or porphyritic, grey-to-pink rocks. Compositionally, they are meta- to peraluminous granites and consist of alkali feldspar, plagioclase, quartz, biotite and rare muscovite. The rocks are altered in places, with sericitization of feldspars and propylitization of biotite.

The Sinceni pluton shows a progressive increase in fractionation from north to south, with genetically linked Sn-pegmatites occurring close to the southern contact of the pluton (Trumbull, 1990). Age determinations yielded a Rb-Sr whole rock age of 2992 ± 44 Ma (Trumbull, 1990) and a single zircon evaporation age of 3074 ± 4 Ma (A. Kröner, in Trumbull, 1990). The Spekboom and Godlwayo plutons contain numerous rafts and xenoliths of quartzite and pelitic hornfels in their marginal phases (Matthews, 1985). Both granites intrude the basic volcanics of the Pongola Supergroup which has been dated at 3090 ± 90 Ma (Burger and Coertze, 1973) and 2940 ± 22 (Hegner *et al.*, 1984). They are, in turn, intruded by the Kwetta pluton (Matthews, 1985). Rb-Sr whole rock dating of the Godlwayo and Spekboom granites indicates that both plutons are contemporaneous within error limits and that they intruded ca. 2810 Ma ago (Reimold *et al.*, in preparation).

ACCESSORY MINERALS AND MINERAL CHEMISTRY

In the high-Ca plutons accessory minerals are dominated by large, zoned, euhedral grains of zircon, allanite and sphene, the latter reaching up to 1-2 mm in length. Less abundant is apatite, fluorite and uraninite. Magnetite is the main opaque phase in these plutons. Zircon and apatite crystallized early and both minerals are included within biotite.

Allanite is paragenetically later than zircon, but earlier than sphene.

The accessory mineral assemblage in the low-Ca granites is distinctly different from that of the high-Ca granites. Apart from the minor presence of small, compositionally homogeneous, euhedral zircon and apatite, this assemblage is dominated by monazite, xenotime, zirconosilicates and Ca-Th-phosphates. Monazite, zircon and xenotime are often included in biotite and in a few instances in plagioclase. The principal opaque phase is ilmenite and to a lesser extent magnetite.

The chemical composition of some of the above accessory phases was investigated with the electron microprobe. Averaged element concentrations are given in Table 1 and REE patterns are presented in Figure 2. Monazite and allanite are the main hosts for the REE in the late granite plutons. In both minerals the light REE are highly enriched compared to the heavy REE and both minerals show negative Eu anomalies. REE contents in sphene are much lower and the chondrite normalized patterns are flat with a negligible negative Eu anomaly (Fig. 2). Zirconosilicates and Ca-Th-phosphates are less common accessory minerals. They have been described by Cathelineau (1987) from peraluminous granites of the French Massif Central. Both minerals concentrate the heavy REE as well as Y, Th and U. Cathelineau (1987) attributed the origin of these phases to subsolidus alteration of monazite, apatite or zircon.

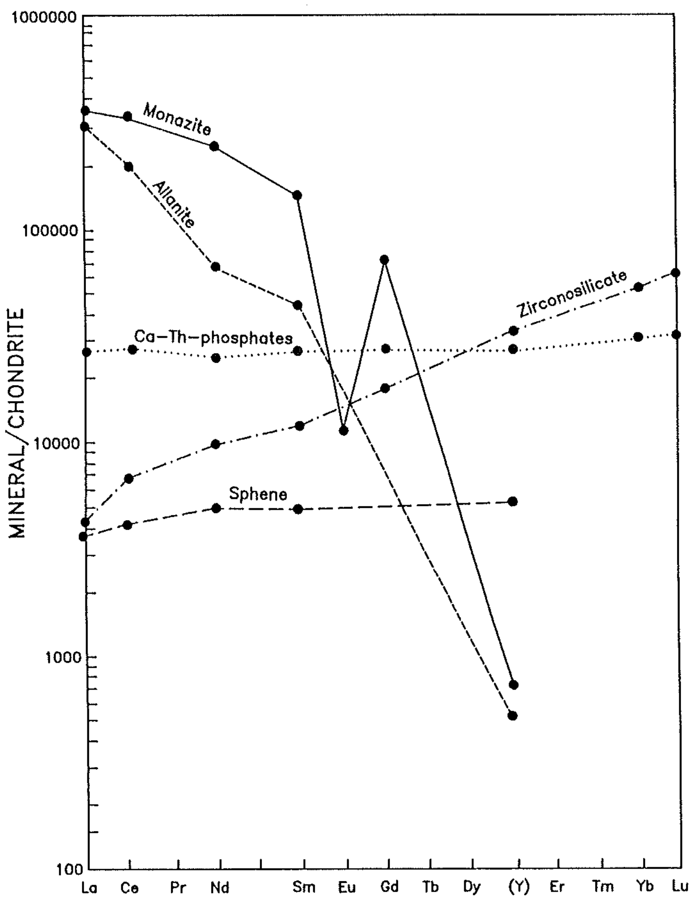

Figure 2: Averaged chondrite-normalized REE distributions in accessory minerals from the high- and low-Ca granites.

Table 1: Mean major and trace element concentrations in accessory minerals from high- and low-Ca granites

	High-Ca Plutons		Low-Ca Plutons		
Mineral	Allanite	Sphene	Monazite	Ca-Th Phosphates	Zircono-silicates
	6	5	4	3	7
SiO_2 (%)	30.4	30.3	0.50	7.39	23.7
TiO_2	1.51	32.4	-	0.10	0.20
Al_2O_3	14.2	2.61	-	0.12	0.84
FeO	8.40	2.19	-	1.88	3.55
MnO	0.76	-	-	-	-
MgO	0.45	-	-	-	-
CaO	12.15	26.9	0.57	9.31	1.57
P_2O_5	0.12	-	30.48	40.5	5.83
F	1.73	-	-	-	-
Cl	0.22	-	-	-	-
Re_2O_3	26.99	1.88	58.37	3.15	3.60
Y_2O_3	0.11	0.61	0.13	4.50	9.33
ZrO_2	-	-	-	0.15	37.2
HfO_2	-	-	-		1.78
ThO_2	-	-	9.56	16.54	2.58
UO_2	-	-	0.10	0.94	0.71
TOTAL	97.04	98.32	99.17	94.52	90.90
La (ppm)	85000	970	95000	6900	1100
Ce	135000	2850	210000	18300	4500
Nd	32000	2700	125000	9500	5100
Sm	7500	820	24000	4300	1900
Eu	-	-	700	-	-
Gd			15000	5400	4000
Yb	-	-	-	5100	8900
Lu	-	-	-	850	1650
Y	770	7300	1050	39000	73500

GEOCHEMISTRY

Major Elements

Fifty-five whole-rock samples from the 10 granite plutons were analyzed for major and trace elements and the data are summarized in Table 2a and b. The composition of the plutons is shown in a normative feldspar diagram (Fig. 3). Samples from both the high-Ca as well as the low-Ca suite plot in the granite field. The two sample populations are, however, separated by the plagioclase-potash feldspar cotectic. This accords with the suggestion by Condie and Hunter (1976) that K-feldspar was the dominant liquidus phase in the low-Ca plutons. In Figure 4 Harker diagrams show that within the high-Ca granites MgO, Fe_2O_3, CaO, TiO_2 and P_2O_5 exhibits good inverse correlations with SiO_2. Extrapolation of these trends would result in an x-axis intersection at ca. 77% SiO_2. This could indicate

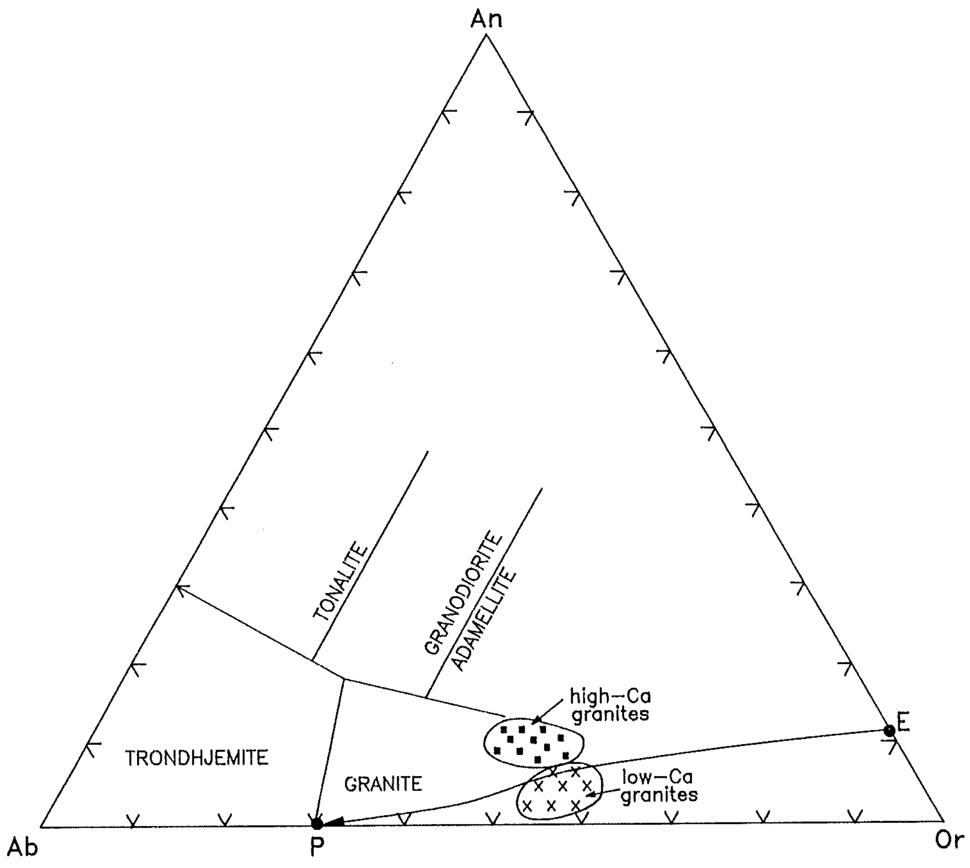

Figure 3: Classification of high- and low-Ca granites in the normative feldspar diagram. EP represents the cotectic line separating plagioclase and K-feldspar fields.

that fractionation of mafic minerals was more important during crystallization of the high-Ca suite. However, similar trends would also result from restite unmixing (e.g. Chappel and White, 1974; Chappel *et al.*, 1987). The low-Ca plutons define an inflection in the above data set, producing almost flat trends. If these shallow regression curves result from restite

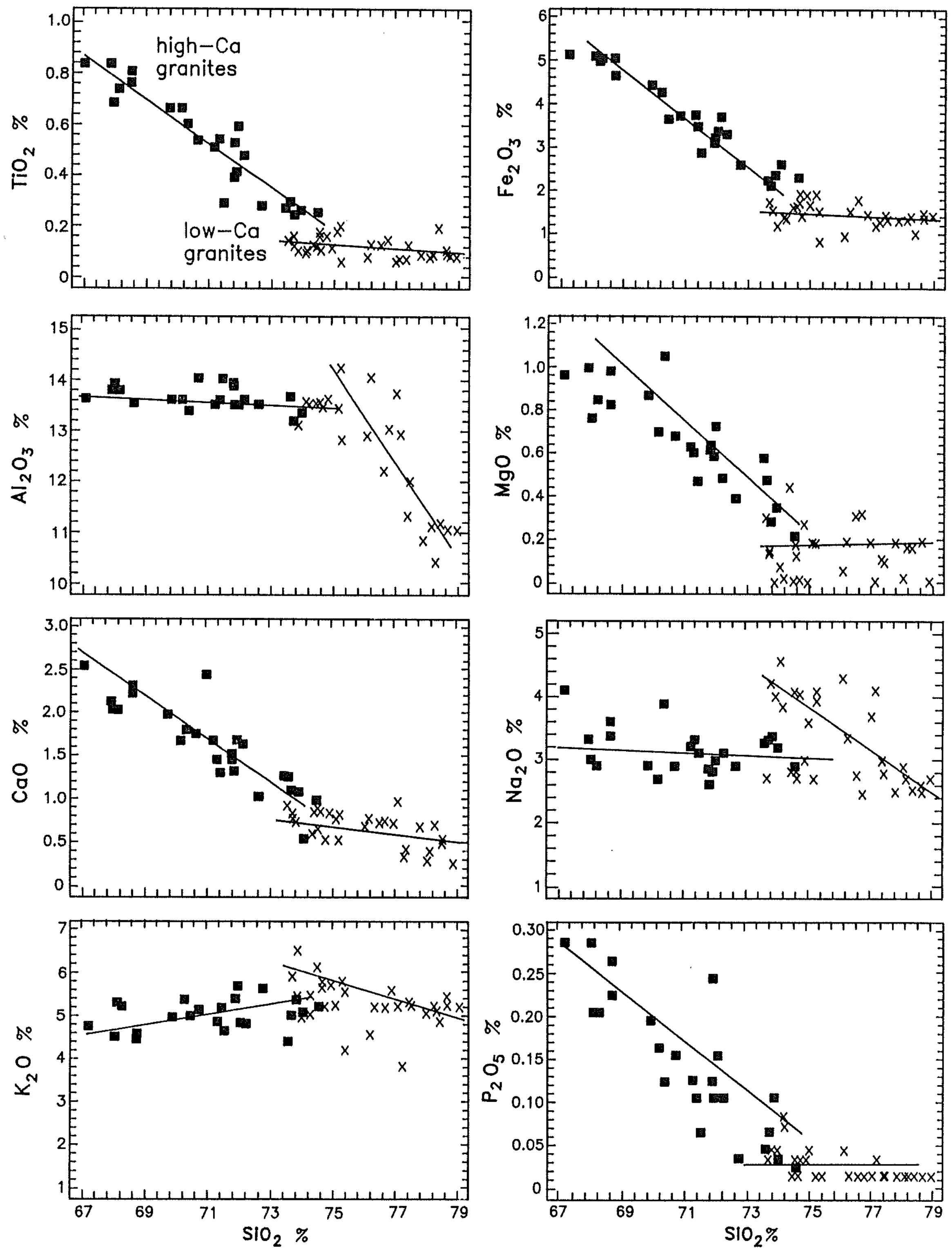

Figure 4: Harker-type major element variation diagrams for high- and low-Ca granites.

Table 2a: Mean major and trace element concentrations in high-Ca granites

Pluton	Mpageni	Mbabane	Ngwempisi	Sicunusa	Kwetta
No	4	5	6	4	5
SiO_2 (%)	72.11	70.00	71.05	72.75	70.31
TiO_2	0.41	0.56	0.53	0.27	0.71
Al_2O_3	13.25	13.85	13.80	13.65	13.70
Fe_2O_3	3.03	4.08	3.64	2.75	3.89
MnO	0.07	0.05	0.05	0.03	0.05
MnO	0.70	0.78	0.67	0.44	0.75
CaO	1.49	1.79	1.65	1.23	2.00
Na_2O	3.41	2.75	3.10	3.15	3.00
K_2O	5.07	5.29	5.06	5.05	4.89
P_2O_5	0.11	0.16	0.13	0.11	0.21
LOI	0.31	0.46	0.29	0.34	0.46
TOTAL	99.96	99.77	99.97	99.87	99.97
Rb (ppm)	171	267	180	92.5	210
Sr	323	248	284	275	263
Ba	1050	1040	1330	430	1125
La	213	197	159	95.4	159
Ce	373	392	318	202	308
Nd	126	162	122	95.0	107
Sm	11.9	17.6	14.4	12.6	16.0
Eu	2.52	2.03	2.16	1.27	2.34
Tb	1.41	1.68	1.48	1.72	2.11
Yb	3.12	5.21	4.66	7.54	6.42
Lu	0.44	0.75	0.67	1.34	0.89
Zr	357	412	375	318	348
Hf	7.41	11.2	9.55	8.20	10.5
Ta	2.40	3.11	2.86	3.45	3.47
Th	32.2	51.2	39.6	48.8	53.0
U	3.77	6.99	5.61	6.89	7.60
Sc	2.77	5.24	5.46	2.32	3.76

Table 2b: Mean major and trace element concentrations in low-Ca granites

Pluton	Mooihoek	Sinceni	Mhlosheni	Spekboom	Godlwayo
No	4	12	5	5	5
SiO_2 (%)	78.10	75.70	78.30	74.00	75.60
TiO_2	0.09	0.14	0.12	0.12	0.08
Al_2O_3	11.50	13.25	11.25	13.50	13.30
Fe_2O_3	1.30	1.55	1.15	1.43	1.16
MnO	0.02	0.02	0.02	0.03	0.03
MgO	0.16	0.24	0.18	0.09	0.01
CaO	0.47	0.81	0.54	0.71	0.85
Na_2O	2.69	2.59	2.62	3.62	3.03
K_2O	5.23	5.56	5.10	5.65	5.24
P_2O_5	0.01	0.01	0.01	0.06	0.04
LOI	0.32	0.31	0.39	0.53	0.51
TOTAL	99.89	100.18	99.68	99.74	99.79
Rb (ppm)	235	335	260	320	370
Sr	40	80	25	55	40
Ba	350	320	235	245	205
La	74.2	79.5	66.1	61.8	44.5
Ce	157	185	150	108	83.0
Nd	74.1	95.0	76.9	42.6	35.5
Sm	16.7	12.6	13.9	7.16	5.70
Eu	1.28	1.05	1.19	0.96	1.02
Tb	2.70	1.52	2.85	1.06	1.61
Yb	8.91	3.23	10.8	3.58	5.61
Lu	1.29	0.44	1.58	0.53	0.84
Zr	220	240	190	190	180
Hf	6.53	5.98	6.19	5.70	5.40
Ta	2.51	2.98	2.42	2.40	2.20
Th	21.4	53.2	22.4	25.4	23.8
U	4.13	12.1	6.29	4.90	4.30
Sc	1.33	1.42	1.10	1.60	1.50

fractionation, then the source, the melt and the restite must contain similar amounts of MgO, Fe_2O_3, CaO, TiO_2, and P_2O_5 (e.g. Chappel *et al.*, 1987). For the high-Ca granites K_2O, Na_2O and Al_2O_3 increases slightly with increasing SiO_2 or stays constant. This could be in response to the early removal of mafic minerals. In contrast, in the low-Ca suite K_2O, Na_2O and Al_2O_3 are inversely correlated with SiO_2, a feature which reflects the source material for these granites (see later).

Trace Elements

In granitic rocks Rb, Sr and Ba reside predominantly in the feldspars and micas. Distinct variations in the abundance of these elements are generally the result of either partial melting or crystal fractionation processes (e.g. Robb, 1983). Rb/Sr and Sr/Ba ratios, however, may also be controlled by the presence or absence of a vapour phase during partial melting of metasedimentary protoliths (Harris & Inger, 1992). The present data reveal that the high-Ca plutons have distinctly higher Sr and Ba but lower Rb than the low-Ca plutons, with Rb/Sr ratios being 4 to 10 times higher in the low-Ca suite. As a first order approximation, the Rb-Sr variation diagram (Fig. 5) suggests that the sub-horizontal trend of the low-Ca granites results from progressive partial melting. In contrast, the steep trend of the high-Ca suite appears to reflect a cumulus assemblage derived by fractional crystallization (e.g. Robb, 1983b).

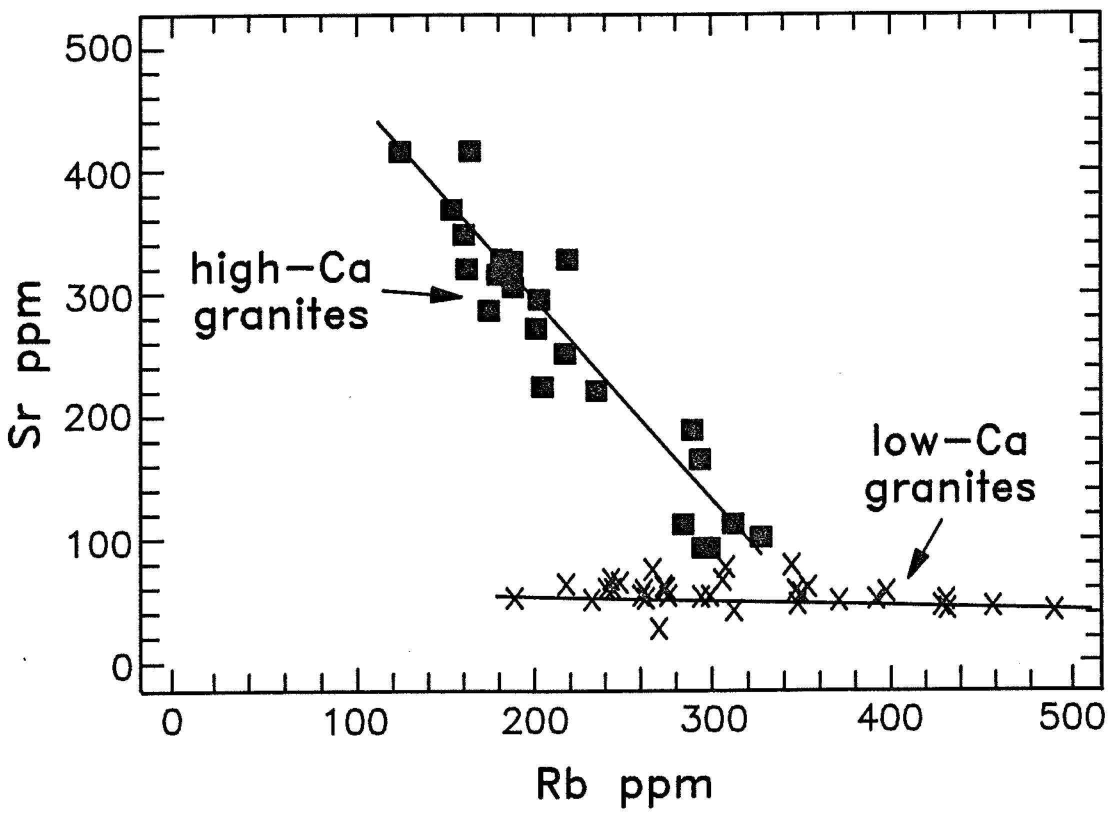

Figure 5: Sr versus Rb diagram for high- and low-Ca granites.

The high-field-strength (HFS) elements, such as REE, Zr, Hf, Ta, Th, U, and Sc are preferentially concentrated in accessory phases. Their abundances in granites are therefore not related to those of the source rock nor are they related to the crystallization of the major liquidus minerals. Average chondrite-normalized REE patterns observed in the high- and low-Ca granites are plotted in Figure 6 a and b. It is obvious from the figure that the high-

(a)

(b)

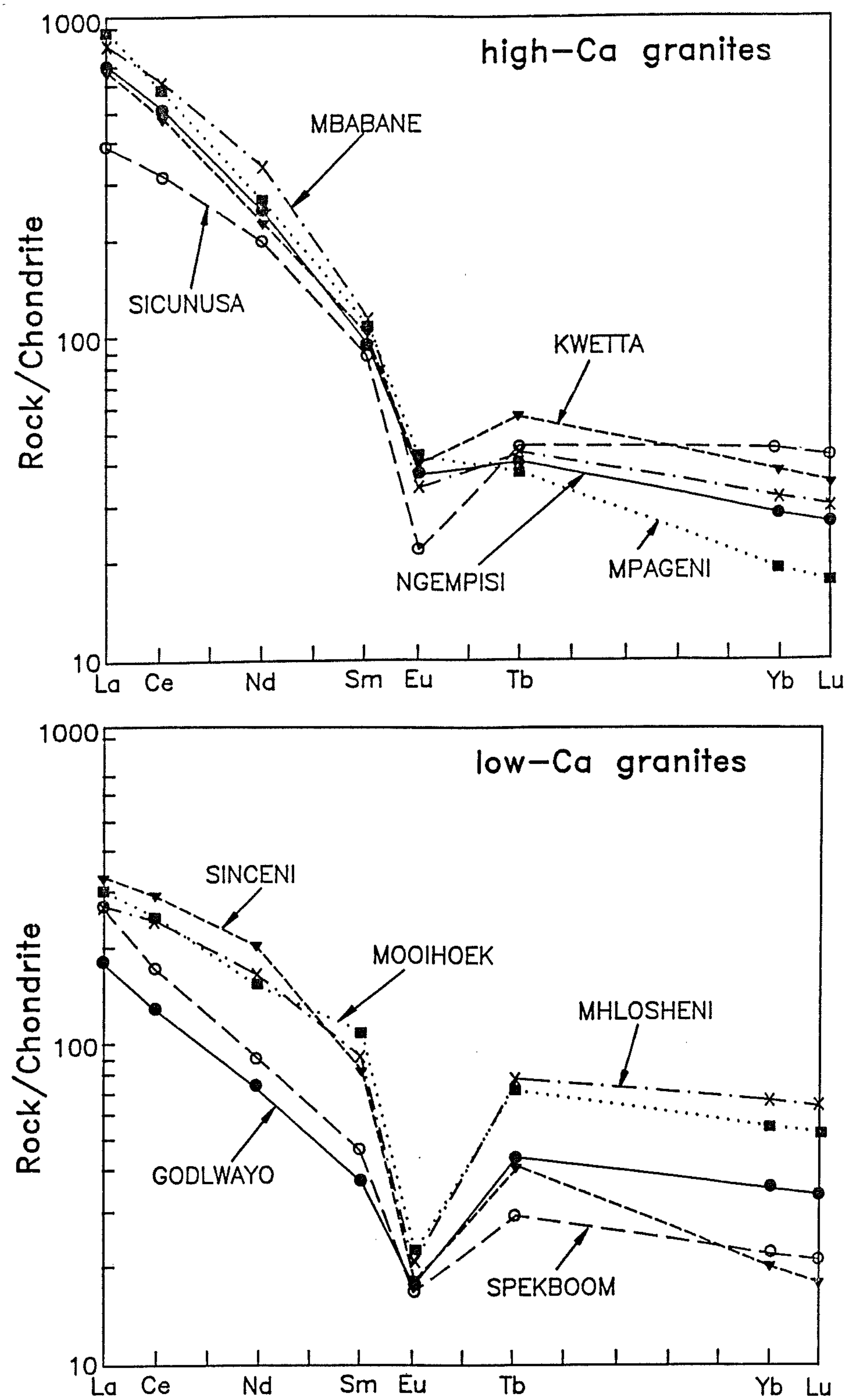

Figure 6: Averaged chondrite-normalized REE distributions in individual high-Ca (a) and low-Ca granites (b).

Ca suite is characterized by high LREE abundances, high LREE/HREE ratios and moderate negative Eu anomalies. The low-Ca suite, in contrast, has lower total REE contents, lower LREE/HREE ratios and in most cases distinctly negative Eu anomalies. Comparison with Figure 2 indicates that the different REE distribution patterns for the two granite suites can be explained by the REE contents of the characteristic accessory minerals in the two granite types. All the other HFS elements, such as Zr, Hf, Ta, Th, Sc and to a lesser extent U are relatively enriched in the high-Ca suite. The higher Zr and Ta concentrations in the high-Ca suite (Fig. 7) can be explained by higher zircon and rutile (and Ta) solubility in more mafic magma compositions (e.g. Watson and Harrison, 1983; Ryerson and Watson, 1987). The concentrations are higher in the high-Ca granites, but U/Th ratios are higher in the low-Ca suite. Robb and Meyer (1990) concluded that these differences are related to elevated Th contents of the high-Ca suite, rather than to U enrichment in the low-Ca granites.

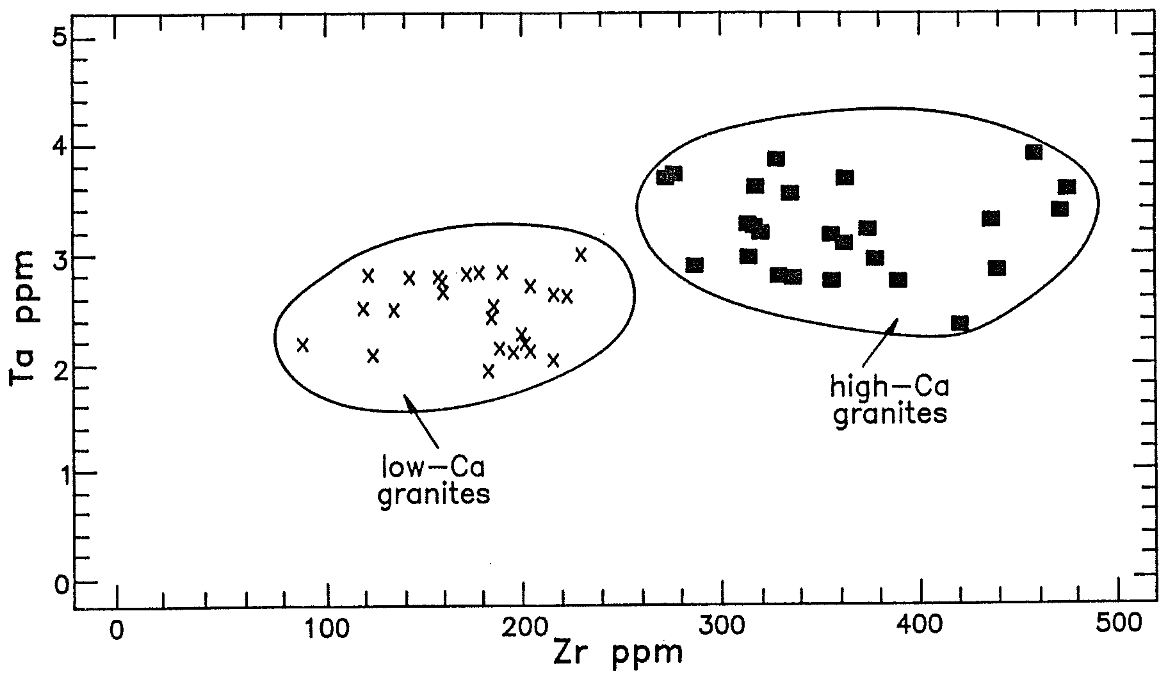

Figure 7: Separation of high- and low-Ca granites on a Ta versus Zr plot.

Isotopes

It is generally accepted that high initial $^{87}Sr/^{86}Sr$ (R_o) and high $^{18}O/^{16}O$ ratios of granites imply a crustal source or severe contamination by continental crust. R_o and $\delta^{18}O$ values for the late granite plutons are summarized in Table 3. Additional R_o values are from the literature. The data suggest that, on average, the low-Ca plutons have higher R_o values and lower $\delta^{18}O$ values than the high-Ca plutons. The high-Ca granites plot near the low-$\delta^{18}O$ end of the 'normal' range established for younger granites. The low-Ca granites have anomalously low $^{18}O/^{16}O$ ratios. Taylor (1977) also reports a similar range of values for the late granite plutons explaining the light oxygen isotope compositions by the probable absence of high $\delta^{18}O$ metasedimentary crust in early Archaean times.

Table 3: Initial $^{87}Sr/^{86}Sr$ and $^{18}O/^{16}O$ ratios for the late granite plutons.

Low-Ca Plutons			High-Ca Plutons		
	R_o	$\delta^{18}O$		R_o	$\delta^{18}O$
Sinceni	0.7116[4]	6.63	Mpageni	0.7065[1]	6.69
Mooihoek	-	5.04	Mbabane	-	7.76
Mhlosheni	0.7880[3]	4.60	Ngwempisi	-	6.69
Spekboom	0.7048[5]	-	Sicunusa	0.7006[2]	7.70
Godlwayo	0.7048[5]	-	Kwetta	0.7065[5]	-

Sources of data: [1] De Gasparis (1967); [2] Davies (1971); [3] Barton et al. (1983); [4] Trumbull (1990); [5] Reimold et al. (in preparation)

DISCUSSION

Petrogenetic modelling in igneous rocks generally assumes that equilibrium was attained between melt and coexisting solid phases at some stage during magma genesis, and that element abundances in the resulting rocks reflect, at least partially, the chemistry of the parent. Clearly, these criteria are not necessarily always met during the formation of granitic magmas. Therefore, geochemical data alone are not sufficient to establish the origin of granites and additional information such as isotopic, mineralogic and geologic data is needed. The available single zircon U-Pb isotope data suggest that the intrusion ages for the low-Ca plutons are >2800 Ma, while the high-Ca granites are significantly younger with ages clustering around 2700 Ma. R_o values and $^{18}O/^{16}O$ ratios are also different for the two granite suites while major elements follow two distinctly different linear trends on Harker-type diagrams. According to the restite unmixing hypothesis (e.g. White and Chappel, 1977) straight line variations can best be explained by progressive separation of residuum and melt. The high-Ca granites show decrease of TiO_2, Fe_2O_3, MgO, CaO, and P_2O_5 with increasing SiO_2, while Al_2O_3 stays constant. In Figure 8 it is shown that these trends could be the result of various degrees of unmixing of a hornblendite restite from a minimum melt. Hornblende compositions are such that a residual hornblendite could have Al_2O_3 contents similar to those of a partial melt and its parent. In contrast, the low-Ca granites display negligible variations in Fe_2O_3, MgO, TiO_2, CaO and P_2O_5 with increasing SiO_2. However, Al_2O_3 decreases dramatically with increasing SiO_2 while K_2O and Na_2O show moderate decreases. Trends like this can be expected from a partial melt derived from a siliceous metagreywacke source with a mineralogy dominated by quartz and minor feldspar and muscovite (Fig. 8). Anatexis of this material would result in a minimum melt composition in Al_2O_3, K_2O, and Na_2O while Fe_2O_3, MgO, TiO_2 and P_2O_5 remain low since there is no contribution of these elements from the parent. The decrease in Al_2O_3 and to a lesser extent K_2O and Na_2O with increasing SiO_2 again can be explained by separation of residuum and melt. The major element trends are, therefore, consistent with an I- and S-type origin for the two suites.

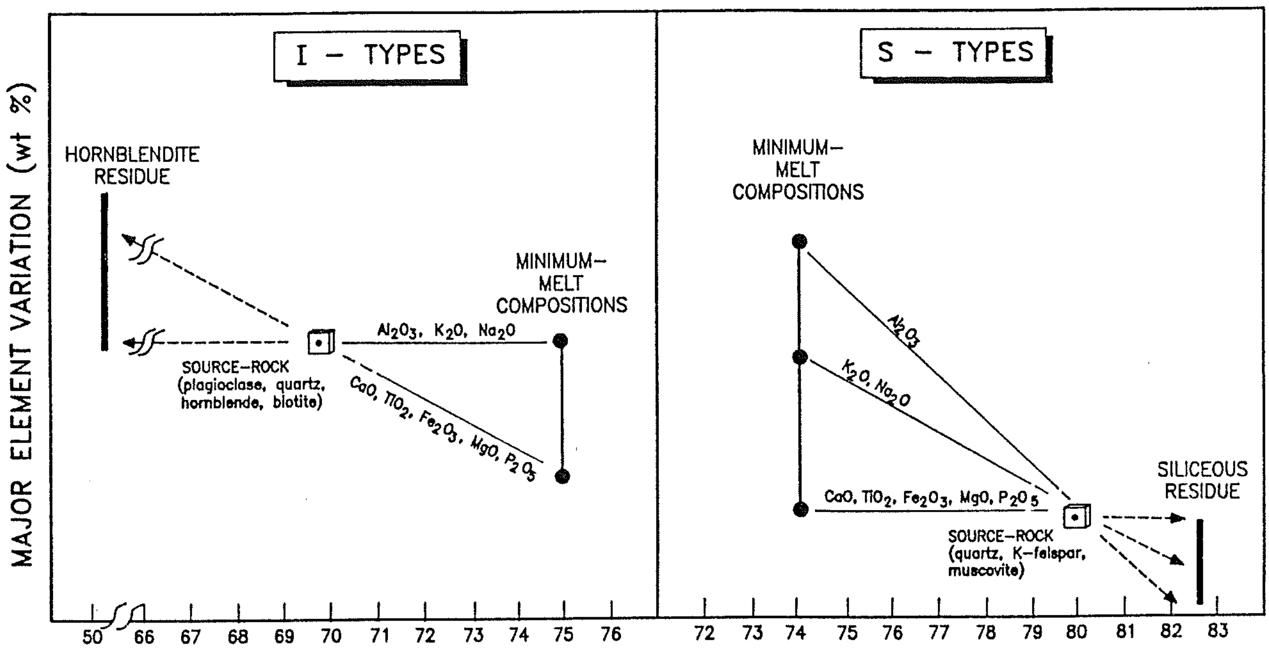

Figure 8: Model major element variation diagram for high-Ca (I-type) and low-Ca (S-type) granites. Compositions along the mixing lines result from the progressive separation of melt and residue. A source rock of dioritic composition is envisaged for the high-Ca granites and a metagreywacke source rock for the low-Ca granites.

It is also apparent that the two granite suites are distinctly different in their accessory mineral assemblages. I-type granitoids typically contain zircon, sphene, allanite and apatite (Cuney and Friedrich, 1987; Sawka and Chappel, 1986) and this is consistent with the accessory mineralogy of the high-Ca suite. The low-Ca suite is characterized by the abundance of monazite which is texturally early and typically included in biotite and plagioclase. Sawka *et al.* (1986) have argued that the low solubility of phosphorus in S-type granite melts inhibits dissolution of monazite during partial melting of the parent sediments and that the mineral is entrained as a restite phase. They further stated that in S-type granites the most abundant occurrence of monazite is within biotite, which is also the main site for REE-rich phosphates in sedimentary rocks. Like monazite, zircon also appears to be a restite phase in the low-Ca plutons. From the major element chemistry, and crystallization conditions of 650-700°C and 5-6 kb (Trumbull, 1990), calculations of the melt composition parameter 'M' (Watson and Harrison, 1983) yielded a value of 1.25. The solubility of zircon in a melt of such a composition should not exceed 100 ppm. However, the mean Zr contents of the low-Ca plutons are in excess of 180 ppm and it must be assumed, therefore, that much of the zircon was entrained as a xenocryst phase in the departing melt fraction.

CONCLUSIONS

The late granite plutons of the Barberton Mountain Land demonstrate significant differences in terms of accessory mineral assemblages, chemical compositions and intrusion ages. This points to the existence of two contrasting granite types previously referred to as high-Ca and low-Ca plutons (Robb and Meyer, 1990). The geochemical and mineralogical signatures of these granites are, however, also consistent with their description as S- and I-type granites, a genetic classification which has implications for the tectonic style and evolution of the region. Most obviously, partial fusion of metasedimentary rocks requires burial of a sedimentary sequence at depths greater than 20 km. A tectonic translation is certainly possible during Himalayan-type continent-continent collision or during prolonged subduction along an Andian-type continental margin. Recent work in the Barberton Mountain Land has seen an increasing tendency to apply plate tectonic processes to the Archaean epoch. Kröner and Layer (1992) have demonstrated that the palaeomagnetic poles for the Barberton region in the period 3100 - 2700 Ma ago underwent major migrations from equatorial to mid-paleolatitudes and back again, with plate velocities ranging from typical present day values to several factors higher in the same period.

De Wit *et al.* (1992), in attempting to reconstruct the accretionary history of the Kaapvaal Craton, emphasized the role that Limpopo orogenesis along the northern flank of the craton has played in crustal evolution between 2900 - 2650 Ma ago. Although chronological constraints are poor, initial northwesterly directed thrusting is thought to have taken place between 2900 - 2700 Ma, followed by later southerly directed crustal shortening and east-west transcurrent shearing at 2700 - 2650 Ma (De Wit *et al.*, 1992). This model is consistent with one previously proposed by Burke *et al.* (1986) who envisaged two periods of compression, an initial Cordilleran-type margin with subduction direction towards the south, followed by a Himalayan-type continent-continent suture formed by collision of the Zimbabwe and Kaapvaal cratons. The contrasting styles of lower and upper Witwatersrand deposits are also thought to reflect these events (Robb *et al.*, 1990, 1991; Stanistreet and McCarthy, 1991). The recognition of S- and I-type granites in the Barberton Mountain Land is supportive of the recent models which recognize plate tectonic analogues in the region. Production of linear arrays of I- and S-type granites suggests scenarios invoking subduction or hot-spot-related granite magma formation from igneous protoliths on the one hand, and anatexis of metasedimentary precursors on the other. Although both the S- and I-type pluton arrays lie close to what is, and probably always has been, the easterly edge of the Kaapvaal plate margin, the existence of peraluminous granites at 3100 Ma and 2880 Ma, and I-type plutons at 2730 Ma on the western side of the craton (Robb *et al.*, 1992), it is still not clear what the disposition of subduction zones and the causative mechanisms for granite magmatism were at these times. The presence of S-type plutons as old as 3070 Ma nevertheless indicates that granites had evolved beyond the TTG mode that typifies so many of the early Archaean shield areas, and had assumed many of the characteristics of more modern orogenic granites by mid-Archaean times, at least in the Barberton region.

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