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GEOCHEMISTRY OF GRANITIC AND ASSOCIATED ROCKS IN THE KAAPVAAL CRATON

by

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ABSTRACT

Major and trace element data of granitic rocks, ranging in age from 3.3 b.y. to 1.95 b.y., are given in thirty tables. The most complete coverage of analytical results is from the acid rocks of the Bushveld Complex (Fourie, 1969). The random nature of the available data from the other granites places some constraints on its interpretation, particularly in determining the mean chemistry.

Granites, dated at 2.3 b.y. and younger, differ from the older granites mainly in respect to their enrichment in Fe relative to Mg and Ti. All granites for which data are available appear to be enriched in Co relative to Mg. K, Rb, and Pb are progressively enriched in the successively younger granites, although the rate of increase in individual granites is not steady. The rate of increase of these cations decreases rapidly after ± 3.0 b.y., which point in time marks the onset of cratonic-type sedimentation in the Kaapvaal craton.

The oldest gneissic terrain has a mean composition that approaches andesite. The composition of the crystalline shield on which cratonic sedimentation and volcanism took place is granodioritic.

Granites that build grossly discordant plutons appear to have higher concentrations of Ba, in particular. Strong fractional crystallization is evident in the Sekukuni and Bobbejaankop granites.

The felsites associated with the Bushveld Complex have been grouped into three types, one of which is of interest in view of the high Zn and Sn values that have been reported.

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INTRODUCTION

The available geochemical data on granitic and associated rocks in the Kaapvaal craton is not extensive, and much of the data is scattered through a number of scientific publications and unpublished theses. It was considered useful to bring together the analytical data in summary form, thereby providing a reference to the sources of information and indicating the areas which require further investigation.

PRESENTATION OF DATA

The general distribution of granitic rocks in the Kaapvaal craton is shown in Figure 1.

The difficulties inherent in attempting to arrive at mean abundances for composite samples need to be emphasized. The present state of our knowledge of the chemistry of most of the rocks discussed here is limited to a few samples collected randomly. In order to obviate the heavy weighting which must result where there is a concentration of samples from particular areas, the analytical data from each area was first meaned, and the derived means used to calculate the mean for a specific granitic mass. In addition to this constraint, there is no data available to indicate the degree of compositional variability in either vertical or lateral senses, the degree of fractionation nor the volumes of individual phases within composite granitic intrusives. Bearing these short-comings in mind, the computed means serve to give a first approximation of the chemical characteristics of granitic rocks within the Kaapvaal craton.

In the tables the number of analyses used to determine the means are given, thus providing a measure of the reliability and significance of the calculated means. It must be emphasized that in some cases one analysis only of a particular element is available so that the reported value indicates a probable order of magnitude rather than a mean for the whole of the granitic mass. The tables should be used with caution in this regard.

Only analytical data that combines both major and trace element determinations has been used in most of the tables, but, for the sake of completeness or comparison, means of analyses reporting only major element chemistry have been listed separately in, for example, the tables dealing with the felsites of the Bushveld Complex.

The terminology applied by the original investigator has been employed, with the exception of the granites belonging to the Bushveld Complex. Following recent proposals (Lenthall, personal communication, 1972) these are subdivided into the Sekukuni granite, which comprises the widespread unmineralized granites, and the Bobbejaankop granite which embraces the Bobbejaankop and Lease granites of Strauss and Truter (1944).

In the last section an attempt is made to define the geochemical characteristics of granitic rocks in relation to their age of emplacement. This requires a subjective approach in view of the inadequate geochronological data in some cases, and results in groupings which may require future modification.

DISCUSSION OF DATA

Study of the tables and diagrams enables inferences to be drawn concerning the geochemical behavior of the elements in the various granites and associated rocks. This section deals with some of the more significant features to which attention should be drawn.

A. ACID ROCKS OF AND ASSOCIATED WITH THE BUSHVELD COMPLEX

The acid rocks of the Bushveld Complex comprise a thick (± 4 000 metres) pile of felsites that are intruded by granites, with which are associated granophyric varieties, granophyres, and porphyries. There is no general agreement as to the time-relationship of the felsites to the basic phase of the Bushveld Complex although von Gruenewaldt (1972) has argued in favour of the felsites, at least in the Tauteshoogte and Bothasberg areas, pre-dating the mafic phase, the intrusion of which being responsible for the generation of certain granophyres. Other granophyres are considered to represent the marginal facies of the Sekukuni granite, the re-constitution of pre-existing sedimentary rocks at the contacts with the intrusive Sekukuni granite or the basic phase of the Bushveld Complex, and the result of the metamorphic imprint of later intrusives, particularly diabase sheets, on the Sekukuni granite. The Sekukuni granite intrudes the felsites, and dykes and larger plugs of granite intrude the basic phase, from which it has been concluded that the Sekukuni granite is the youngest phase. This granite is itself cut by smaller stocks of stanniferous Bobbejaankop granite. In addition to these major intrusives, granite, intrusive into sedimentary rocks correlated with the Waterberg Sequence, has been reported by Glathaar (1954) at Rust de Winter. This granite has been dated by U/Pb methods at ± 1.76 b.y. (Oosthuysen and Burger, 1964).

The so-called leptites that complete the array of acid rocks associated with the Bushveld Complex constitute a group of fine-grained rocks believed to represent the re-constitution of original sedimentary and/or felsitic rocks as a result of the emplacement of the basic phase of the Bushveld Complex.

Geochronological and Sr-isotope studies (Nicolaysen et al, 1958; Davies et al, 1970) provide strong support for the view that the Sekukuni granite post-dates the basic phase and that this granite crystallized from a magma generated by the partial melting of the Archaean crystalline basement. The time relationships of the other members of the acid phase is less firmly established.

The concentration of K in both the Sekukuni and Bobbejaankop granites is relatively uniform and high, with a mean of about 4.1%. However, the Rb content of the Bobbejaankop granite is greater by a factor of 2.4 than in the Sekukuni granite with the result that the K/Rb ratio decreases from 180 in the latter granite to 80 in the Bobbejaankop granite.

Whereas the majority of the Sekukuni granites have K/Rb ratios between 130 and 210, the granite in the area north of Brits and Rustenburg has K/Rb ratios between 310 and 320, although the concentration of K remains at the "normal" level of about 4.1% (Figure 2). Subtle regional variations can be identified within the main field of the Sekukuni granite. In the Zaaiplaats area north of Potgietersrus the K/Rb ratio is uniformly lower than the overall mean. Three of the five analysed samples from the Rooiberg area and samples from Sekhukhuniland, Rust de Winter, east of Groblersdal, and near Argent have values for the K/Rb ratio that are equal to or greater than the mean. The two remaining Rooiberg samples have affinity with the Zaaiplaats Sekukuni granite and the Bobbejaankop granite. Data are insufficient to define the reasons for this variation, additional systematic sampling being necessary to confirm the validity of the apparent regional distribution of the variations. It is clear, however, that the Sekukuni granite displays an increasing enrichment in Rb that is even more marked in the Bobbejaankop granite, suggesting stronger fractionation of the latter.

No data is presently available concerning the concentrations of K and Rb in constituent minerals of the Sekukuni and Bobbejaankop granites which is a necessary further requirement in the study of the geochemical evolution of the Bushveld granites, particularly in the light of studies on the significance of K/Rb ratios (e.g. Erlank, 1968).

The concentrations of K and Rb in the granophyres are less uniform than in the granites, a fact which may reflect their different origins. The granophyre and granite porphyry samples from the Zaaiplaats area plot within the main field of the Sekukuni granite, but with higher K/Rb ratios than the granite from that area. It may be argued, if these rock-types represent a more rapidly chilled phase of the Sekukuni granite, that Rb was preferentially excluded and was concentrated in the residuum that crystallized to form the main mass of the granite in the Zaaiplaats area. Alternatively, it may be concluded that the higher K/Rb ratios are inherited from the overlying felsites which have a mean K/Rb ratio close to those of the granophyre and granite porphyry, and that these rocks represent part of the epicrustal phase of the Bushveld Complex that has been re-crystallized as a result of the emplacement of the Sekukuni granite. As will be shown in the sequel, other trace-element data does not lend support to this alternative.

The granophyres from the Rooiberg area and near Pretoria also plot, in respect to their K and Rb contents, within or close to the main field of the Sekukuni granite but always fall in the upper part of the field. Two samples of granophyre from Rooiberg and the granophyre from the eastern margin of the Sekhukhuniland granite lie in a position intermediate between the main Sekukuni granite and the granite north of Rustenburg and Brits, as does a granite porphyry from near Argent.

The remaining granophyres from the Argent and Loskop Dam areas have distinctly lower contents of K, ranging from 2.5 to 3.5%, and K/Rb ratios in excess of 200. Certain of the felsites overlap into the lower portion of this field.

A quartz porphyry from north of Nylstroom, considered by Coetzee (1970) to be possibly intrusive into the felsites, has an extremely low K/Rb ratio comparable to that found in the Bobbejaankop granite. Such extreme fractionation is not found in the felsites and it is probable that Coetzee's conclusion is correct, although it is not yet possible to relate this intrusive to a particular event.

Glathaar (1956) reported the presence at Rust de Winter of granite and granite porphyry intrusive into sedimentary rocks correlated with the Waterberg Sequence, and which have been dated by U/Pb methods at ± 1.76 b.y. (Oosthuysen and Burger, 1964). The granite lies within the field of the Sekukuni granite in respect to its K and Rb contents but the granite porphyry, which has a K concentration of 5.5% and a K/Rb ratio of 237, lies in a unique position (Figure 2).

The mean content of K in the felsites is somewhat lower than that found in the Sekukuni granite, but the Rb concentration is comparable in both rock-types, with the result that the K/Rb ratio of the felsites falls below that of the granites. However, the felsites display a range of K content from 2.5% to > 5% that is accompanied by a steady decrease in the K/Rb ratio (Figure 1). It should be noted that two felsites from Nylstroom and Zaaiplaats have anomalously low (± 110) K/Rb ratios (Figure 2).

Examination of the available data suggests that three chemically distinct varieties of felsite can be recognized, namely :-

Type I - "normal" major element chemistry with mean concentrations of 3.5% K, 2.87% Na, 1.02% Ca, 172 p.p.m. Rb, 103 p.p.m. Sr, and 178 p.p.m. Zn. This type constitutes 53% of the total number of analyses.

Type II - impoverished with respect to Ca (concentration 0.3%), Sr (55 p.p.m.), and Cs (3.6 p.p.m.), but enriched with respect to Zn (339 p.p.m.). The concentration of K and Rb is similar to that in Type I. This type constitutes 26.5% of the total.

Type III - impoverished with respect to Ca (0.07%), Na (0.07%) and Sr (22 p.p.m.) but enriched with respect to K (4.37%), Rb (339 p.p.m.), and Zn (484 p.p.m.). This type constitutes 20.5% of the total.

The mean value for the felsites given in Table IX, column A, has been calculated on the basis of the above proportions.

In columns G, H, I, and J of Table IX earlier analyses for major elements reveal that a similar grouping can be recognized, with the modification that certain Type I felsites have high total Fe concentrations. The three felsite types are apparently randomly distributed although there is a tendency for the Type I felsites, particularly the Fe-rich variety, to be found at the base of the felsite pile.

Only four leptites have been analysed and, in respect of their K and Rb concentrations, they have affinities with Type I felsites and certain of the granophyres.

The Ba content of all the acid members of the Bushveld Complex is uniformly high with the exception of the Bobbejaankop granite and the quartz porphyry from Nylstroom. The Ba content of the Sekukuni granite ranges from a mean of 1500 p.p.m. in the area north of Rustenburg and Brits to 720 p.p.m. in the Zaaiplaats area, with an overall mean of 963 p.p.m. The Bobbejaankop granite has a low Ba content, averaging 338 p.p.m. The K/Ba ratio increases from 25 to over 130 and is sympathetic with the decrease observed in the K/Rb ratios.

All the granophyres, granite porphyries, felsites, and leptites have high Ba concentrations with K/Ba ratios lying consistently between 25 and 40 with a mean close to 55 (Figure 4).

The Ba/Sr ratios display a considerable scatter (Figure 5), particularly in the felsites. The granite north of Rustenburg and Brits has a Ba/Sr ratio comparable to that of the overall mean for the Sekukuni granite, but the ratio increases in the Zaaiplaats area and reaches a maximum value in the Bobbejaankop granite. Whereas the mean felsite Ba/Sr ratio is comparable to that for the mean Sekukuni granite, the Ba/Sr ratio increases from Type I felsites to Type III felsites. The increase in the ratio is due in the main to an impoverishment in Sr, which differs from the trend observed in the Sekukuni granite where both Ba and Sr are depleted in the Bobbejaankop granite.

Figure 5 illustrates the constancy of the Fe/Mg ratio in the Sekukuni and Bobbejaankop granites. The Fe/Mg ratio in the granite north of Rustenburg, the Zaaiplaats area, and the Bobbejaankop granite is close to 20. The mean felsite and the mean Type III felsite Fe/Mg ratios also lie close to this value, with the Type I felsites having an enhanced value.

There is a well-defined relationship between Fe and Ti in the Sekukuni granite and the felsites (Figure 7) but the Mg/Ti relation is less regular in these two rock types. The Bobbejaankop granite has a broad scatter of both Mg and Fe, reflecting, at least in part, the chlorization which has affected this granite. The close relationship observed in the Sekukuni granite and the felsites suggests that Ti, Mg, and Fe are predominantly present in silicate lattices, with a less important contribution from rutile and sphene. The rate of decrease with fractionation is Mg>Ti>Fe.

The mean concentration of Co in the Sekukuni and Bobbejaankop granites reflects a decrease in Co with increasing fractionation (Table I) both granites having lower contents of Co than the felsites. In detail, however, there is a considerable overlap between the three rock-types (Figure 8). The Bobbejaankop granite displays a similar erratic relationship between Fe and Mg to Co as did Fe and Mg to Ti. The regression line calculated by Carr and Turekian (1961) for Mg/Co is also shown in Figure 8 which suggests that the Sekukuni granites have higher concentrations of Co relative to Mg. A similar enrichment in Co was reported by Kolbe (1966) for the Cape granites. Rooke's (1970) data for African anorogenic acid intrusives also reflects a general, higher Co concentration.

A well-defined relationship is seen in Figure 9 between Fe and Sc for the Sekukuni granite and felsites, but a greater degree of scatter is introduced by the plots of the Sekukuni granite from the Zaaiplaats area and, in particular, the Bobbejaankop granite, the latter having somewhat higher concentrations of Sc as compared to the Sekukuni granite from Argent.

Both Sc and Co are present in higher concentrations in the felsites and granophyres than in the granites, but overlap does occur (Figures 8 and 9).

Examination of the Tables I, IV, VII, and IX indicates that Cu, Ni, and Zn are generally higher in the felsites and certain of the granophyres than in the Sekukuni and Bobbejaankop granites. The Zr concentration in the felsites and Sekukuni granite is similar but is lower in the Bobbejaankop granite, which is, however, enriched with respect to Th, Nb, Hf, Cs, and B. The Pb mean concentration is based on a limited number of determinations. In Table I, two values have been given for Pb in column A. The higher mean value of 53 p.p.m. is obtained if an extreme concentration of 210 p.p.m. (Kaye et al, 1965) is included. It is interesting to note that the mean content of Pb in the Gaborone granite (Table I, column E) is high, while Rooke's (1970) mean for African anorogenic acid intrusives is also significantly higher than the mean for high silica, low calcium granite (Turekian and Wedepohl, 1961) and for average granite (Taylor, 1968).

The mean values of the Sekukuni granite compare closely with those determined by Turekian and Wedepohl (1961) for high silica, low calcium granites (see Table I, columns A and F). Among the major elements iron and manganese are higher in the Sekukuni granite as compared to the high silica, low calcium granites. The Sekukuni granites have lower mean contents of P, Sc, and Sr than Turekian and Wedepohl's mean. The number of determinations is too limited to decide whether the Li content of the Sekukuni granite is lower than Turekian and Wedepohl's mean. B, F, Hf, Rb, Th, Zn, and Zr are all consistently high in the Sekukuni granite, while the high Co content has already been noted. The analytical data on Cr and Ni is not adequate to draw any firm conclusions but, in the light of the high Cr content reported by Rooke (1970) for the Gaborone granite it is possible that these granites may be enriched with respect to Cr. Rooke's (1970) data for Ni from the Gaborone granite, however, indicates that this element is present in low concentrations more comparable to the level that might be expected.

When the Sekukuni granite is compared to Rooke's (1970) mean for African anorogenic acid intrusives (Table I, columns A and H), there are close similarities between the major elements although the Sekukuni granite is distinctly more siliceous. Barium is lower in the African mean, but Ga, Li, and Nb are all significantly higher as compared to the Sekukuni granite.

In Table IX, columns A and L, the mean composition of the Bushveld felsites can be compared to that of African anorogenic acid extrusives (Rooke, 1970). The felsites are more ferruginous and also contain more Mg and Ca, but are impoverished in Na, as compared to Rooke's mean.

The Bushveld felsites and the acid volcanics of uncertain age from near Groblersdal are considerably enriched with respect to Ba as compared to the African average. Rubidium is more abundant in the felsites, and it is possible that they are also richer in Cr, Cu, and Ni. Cs and Zr are both lower in the Bushveld felsites than the mean for African extrusions, and Ga may be similarly impoverished.

B. PALALA AND GABORONE GRANITES

The mean compositions of these granites are listed in columns D and E of Table I. Both these granites were probably emplaced at about 2.3 b.y., and thus pre-date the Sekukuni granite. There is a general similarity between the Palala, Gaborone, and Sekukuni granites, all of which are high silica, low calcium granites. This overall similarity is illustrated in Figures 2 to 5 wherein it can be seen that the plots of the Palala and Gaborone granites fall close to or within the fields of the Sekukuni and Bobbejaankop granite, and their associated granophyres and felsites. In Figure 6, however, an increased Mg content relative to Fe in the Palala and Gaborone granites is apparent and is the reverse of the relation seen in the Sekukuni granite. It is worthy of note that the Sekukuni and Bobbejaankop granites together with the granophyres, granite porphyries, leptites, and felsites have Fe/Mg ratios in excess of 10, whereas the Palala and Gaborone granites, and the older granitic rocks that range in age from 3.3 to 2.6 b.y. have Fe/Mg ratios lower than 10. The acid volcanic rocks of uncertain correlation found near Groblersdal that possibly were extruded within the same time range also have low Fe/Mg ratios. The acid rocks of the Bushveld Complex are clearly enriched with Fe relative to Mg, and relative to Ti as compared to the older granites in the Kaapvaal Craton (Figure 10). In Figure 10, the plot of the Palala granite in the Ti/Fe field shows that this granite is similarly enriched in Ti in respect to Fe as the Sekukuni granite.

In Figure 11, it can be seen that the Palala granite lies close to the regression line determined by Carr and Turekian (1961) for Mg/Co. The Co data for the Gaborone granite has a low content below the detection limit of 10 p.p.m. (Rooke, 1970).

The Gaborone granite differs from the Palala granite in lower concentrations of Ba and Sr, but higher contents of Nb and Rb. Like the Sekukuni granite, the Palala and Gaborone granites have high concentrations of Zr, Cr, Pb, and Cu.

C. THE PRE-2.3 b.y. GRANITIC ROCKS

Geochemical data, particularly relating to the trace-elements, is more fragmentary in the older granite than that pertaining to the Palala, Gaborone, and Sekukuni granites. In the tables only data on which both trace and major elementary chemistry are available have been used.

Table XII lists the data available for the granitic rocks that crop out to form the Johannesburg-Pretoria dome. Rb/Sr age determinations of total rock and separated mineral fractions indicate that the adamellites and granodiorites have an age of ± 3.1 b.y. (Allsopp, 1961). The separated mineral fractions gave widely discordant ages which have been interpreted as the result of the diffusion of radiogenic strontium from mineral to mineral during a period of re-heating at about 2.12 b.y. (Allsopp, 1961).

Anhaeusser (1971) has recognized the following main rock-types:-

1. Mesocratic, hornblende biotite tonalitic gneisses.
2. Leuco-biotite tonalitic gneisses and/or biotite trondhjemites.
3. Homogeneous, medium-coarse grained, pinkish-grey granodiorite.
4. Grey granodiorite suite.
5. Adamellites building characteristic inselberge.

Transitional types between these varieties were also recognized together with minor occurrences of porphyritic granite and felsitic dykes.

In Table XII the geochemical data have been summarized so that column B represents group 1 above. Columns C and D include the leuco-biotite tonalites which have been separated into potassium-rich and potassium-poor groups. In column E, all the analyses of granodiorite in groups 3 and 4 above have been averaged. The adamellites building inselberge are listed in column F.

Partial major and trace element chemistry of rocks from the Johannesburg-Pretoria dome have been determined by Kaye et al (1965) but it is not possible to relate exactly these samples with Anhaeusser's classification. It is probable that Kaye et al's samples were collected from the rock-types listed under columns E and F in Table XII.

The mean values for K and Rb increase sympathetically from the tonalites to the granodiorites and adamellites, as would be expected. The K/Rb ratio is consistently low in all rock-types (see Figures 3 and 12), having mean values between 95 and 129, although Kaye et al's (1965) data gives a higher value.

The mean Ca content from Kaye et al's (1965) data is intermediate between low calcium (0.51% Ca) and high calcium (2.51% Ca) granites (Turekian and Wedepohl, 1961), and the Ba concentration is consistent in also being intermediate between the respective Ba contents calculated by Turekian and Wedepohl (1961). Both Li and Pb appear to be higher than expected in rocks of granodioritic or adamellitic composition.

Table XIII lists data for granitic rocks from the western and northern Transvaal and the north-western Cape Province. Samples from the last-named locality probably represent part of the edge of the Kaapvaal craton that has been affected by the Doringberg lineament. Only partial analytical data is available for the granitic rocks from Ventersdorp, Klerksdorp, Schweizer Renecke, and Marydale.

The Ventersdorp granite (Table XIII, column A) has the highest mean K/Rb ratio so far reported in the Kaapvaal craton (Figure 3), although not as high as ratios in individual samples from the tonalitic diapirs in the Barberton Mountain Land (Figure 12). The K/Ba ratio is close to that reported for the Kaap Valley granite in the eastern Transvaal, and its high Ba concentration is similar to that reported in the Palala, Gaborone, and Sekukuni granites. No age data are available to enable a correlation of this granite to be made, although it is known to pre-date the Ventersdorp Sequence (i.e. >2.3 b.y.).

The Vryburg granite (Table XIII, column B) has not been dated. In respect to its Ca, Na, K, and Ba contents it is similar to the 3.0 b.y. granite from the Eastern Transvaal-Swaziland area, but no correlation is implied in drawing this parallel.

The granites from the Klerksdorp area have been dated at ± 3.0 b.y. and ± 2.6-2.7 b.y. (Allsopp, 1964). The 3.0 b.y. granite has close similarities with the granites of equivalent age from the eastern Transvaal and Swaziland (see Table XIX, column 8). The K/Rb, Ba/Sr, and K/Ba ratios are all similar (Figures 3, 4, and 5), granites from both localities having concentrations of Ba lower than the mean for low calcium granites. Similarly, the 2.6-2.7 b.y. granite from Klerksdorp compares closely with the ± 2.6 b.y. granite in the southeastern Transvaal and Swaziland, particularly in regard to the low concentrations of Ba, Sr, and Li. The eastern Transvaal and Swaziland granites of both ages appear to have higher concentrations of Rb than their time-equivalents in the Klerksdorp area.

The granite cropping out near Schweizer Renecke is dated at ± 2.7 b.y. (Allsopp, 1964). This granite has a similar concentration of K to that found in the Klerksdorp granite of equivalent age but the K/Rb ratio is higher (Figure 12). The Ba content of the Schweizer Renecke granite is greater than in granites of similar ages from Klerksdorp and the southeastern Transvaal, while the concentration of Rb is lower. The Li content, however, is closely comparable to that of the other 2.6-2.7 b.y. granites. The ratio of Rb to Sr approaches unity (Rb/Sr = 1.3) in the Schweizer Renecke granite whereas in the Klerskdorp and southeastern Transvaal granites the Rb/Sr ratio is 6.4 and 6.5 respectively.

The single analysis of the Bandolierskop granite near Pietersburg (Table XIII, column F) reveals that it is enriched in Fe, Mg, Ca, and Na with a high concentration of Ba, Co, and Sc. The K/Rb ratio is high and is similar to that found in the Dalmein-type plutons and Nelspruit migmatites of the eastern Transvaal (Figures 3 and 12). It is enriched in Fe relative to Mg as compared to the Dalmein-type plutons (Figure 10). The Rb/Sr ratio is 0.2 which is similar to that found in the Dalmein granite, but lack of data from this granite precludes the possibility of recognizing any other points of similarity. The Bandolierskop granite has not been dated.

The three analyses of granites from the northwestern Cape Province display a wide range of geochemical characteristics (Table XIII, columns G, H, and I). The granite from near Prieska is a low calcium, slightly potassic rock with a high content of Ba and Co in which the Rb/Sr ratio is 0.4. The two samples from the Marydale area differ from each other in their K/Na ratio and from the Prieska granite in their Rb/Sr ratios of 10.7 and 4.3, and in their very low Ba contents. Granites near Marydale have been dated at ± 2.7 b.y., and in respect to their low Sr concentrates are similar to granites of equivalent age from the western Transvaal, particularly in the case of the analysis listed in column I of Table XIII.

In Tables XV to XX the analytical data from the eastern Transvaal and Swaziland has been summarized.

The trace-element data from the Ancient Gneiss Complex in Swaziland is limited. The tonalitic gneisses have low concentrations of K and Rb, the K/Rb ratio being higher than that reported from the tonalitic gneisses in the Johannesburg-Pretoria dome (Figures 3 and 12). The Rb/Sr ratio is low, lying between 0.34 and 0.46. The highest Sr concentrations are found in the biotite-hornblende gneisses interlayered with the tonalitic gneisses (Table XV, column E). In the remaining rock-types associated with the Ancient Gneiss Complex the Sr concentration ranges between 100 and 300 p.p.m. High contents of Cr and Ni are found in cordierite-cummingtonite gneisses, diopside-plagioclase-quartz granulites, and in a tremolite granulite.

In Table XVII the mean compositions of the diapirs intrusive into the Swaziland Sequence are given, together with the mean compositions of quartz diorite and leucotonalite or trondhjemite which are inferred to be post-Swaziland Sequence in age. There is a paucity of geochemical data from all these rock-types.

Figure 12 illustrates the wide range of K/Rb ratios found in the tonalitic diapirs. The plots of the Swaziland leuco-tonalitic and hornblende tonalite gneisses overlap the field of the tonalitic diapirs. It should be noted that the leuco-tonalitic gneisses from the Johannesburg dome have distinctly lower K/Rb ratios than those from Swaziland and plot below the tonalitic diapir field.

Comparisons have already been drawn between certain of the 3.0 and 2.6 b.y. granites from the eastern Transvaal and Swaziland with those granites of similar age occurring in other parts of the Kaapvaal craton. Granite forming plutons emplaced between 2.9 and 2.6 b.y. are recognized in the eastern Transvaal and Swaziland. On the basis of geochronological data, field relationships, petrology, and chemistry four types of grossly discordant, granitic plutons can be identified as follows:-

		Age
1.	Dalmein-type	± 2.9 b.y.
2.	Kwetta-type	± 2.6 b.y.
3.	Mpageni-type	± 2.6 b.y.
4.	Mooihoek-type	± 2.6 b.y.

The Dalmein-type plutons include the Dalmein, Salisbury Kop, and Mliba plutons. The latter was formerly included as part of the Granodiorite Suite (Hunter, 1968), but recent age data show this pluton to be of a comparable age to the Dalmein and Salisbury Kop plutons (Davies, 1971). No age data are available on the Granodiorite Suite.

Four cross-cutting bodies of slightly porphyritic, coarse-grained granite crop out along the contact between the Swaziland Sequence and the granites in Swaziland. The available analytical data (Davies, 1971) suggests that these granite bodies may be more appropriately correlated with the Dalmein granite. Until age measurements had been obtained from southern Swaziland, the Kwetta granite had been tentatively correlated with the Dalmein-type plutons, but the considerably younger age of the Kwetta granite (Allsopp, personal communication) indicates that it forms part of the suite of ± 2.6 b.y. plutons. The more potassic nature of the Kwetta granite (column E, Table XIX) as compared to the Dalmein, together with mineralogical differences makes the revised classification more acceptable.

The Nelspruit migmatites (column A, Table XIX) lie in a position intermediate between the fields of the tonalitic gneisses and diapirs, and the ± 3.0 b.y. granites as may be expected if the migmatites do, in fact, consist of a complex mix of the two rock-types.

The biotite-microcline, hood-type granite, dated at ± 2.6 b.y., from southern Swaziland and the southeastern Transvaal (column D, Table XIX) has low concentrations of Ba and Sr which was also noted in other granites of similar age from the western Transvaal. The plot of the K/Rb ratios in Figure 12, however, shows the 2.7 b.y. Schweizer Renecke granite to have somewhat higher values for this ratio than the 2.6 b.y. granites.

Of the 2.6 b.y. plutons, only the Mpageni-type has been subjected to trace-element analysis. This granite has higher K/Rb ratios than the 2.6 b.y. hood-type granites (Figure 12), and lower Fe/Mg (Figure 6) and K/Ba (Figure 4) ratios. The Mpageni granite seems to have a lower Co content than the other Kaapvaal granites plotting close to Carr and Turekian's (1961) calculated regression line (Figure 11), but no firm conclusion may be drawn as only one sample has been analysed. The Pb concentration in the Mpageni granite is high and is comparable to that found in the Gaborone, Palala, and Sekukuni granites.

The granites dated at 2.6 b.y. and older tend to plot in fields distinct from the Gaborone, Palala, and Sekukuni granites. In Figure 4 the majority of the older granites have K/Ba ratios greater than 50. The Kaap Valley, Ventersdorp, Prieska, and Pietersburg granites have K/Ba ratios less than 25 while the Palala and Sekukuni granites together with the associated felsites and granophyres lie within an intermediate field. The more fractionated portions of the Sekukuni granite and its final fractionation product, the Bobbejaankop granite, have high values for the K/Ba ratio. Figure 5 illustrates the tendency for the pre-2.6 b.y. granites to have values for the ratio Ba/Sr less than 5 whereas the post-2.6 b.y. granites are relatively enriched in barium with respect to Sr. These latter granites are also enriched in Fe with respect to Mg as compared to the pre-2.6 b.y. granites, although both the Gaborone and Palala granites lie in the older field. Figure 10 illustrates the enrichment in Ti relative to Mg and in Fe relative to Ti in the post-2.6 b.y. granites. The data on the concentration of Co in the older granites is inadequate but there is a suggestion in Figure 11 that these granites are also enriched in Co relative to Mg in a similar degree to that of the post-2.6 b.y. granites. The Fe-Co plot lends further support to the view that the post-2.6 b.y. granites are enriched in Fe.

Figure 12 illustrates the strong concentration of the granites, dated at 3.0 b.y. and younger in respect to their K/Rb ratios and concentration of K. The Dalmein granite is, however, an exception. The oldest rocks namely the tonalitic diapirs and gneisses display a much wider range of values of the ratio K/Rb.

There is a good linear relationship between Sc and Fe in the post-2.6 b.y. granites and associated acid rocks, and the general enrichment in Fe in the younger granites is illustrated in Figure 13.

It is worthy of note that the mean value for the acid volcanics from the Groblersdal area that are of uncertain correlation plots within the field of the older granites in Figures 6, 10, and 13 which suggests that these felsites are distinct from the Rooiberg felsites.

D. THE RARE EARTH ELEMENTS

The abundances of the rare earth elements (REE) reported in the acid rocks related to the Bushveld Complex and in the Palala granite are given in Tables III, VI, VIIB, and XI. Table XXI lists the available data from granites older than ± 2.6 b.y.

The scheme adopted in this paper to compare the concentrations of the REE is that in which the absolute abundances are normalized to the North American shale composite (Haskins et al, 1968).

In Figure 14 the plot of the mean values of the Sekukuni granite is compared with the Bobbejaankop granite, the Sekukuni granite from north of Brits, and the Bushveld norite. The patterns for the light lanthanides in the Sekukuni and Bobbejaankop granites are similar, except that Eu is strongly depleted in the last-named granite. The heavy lanthanides are slightly more abundant in the Bobbejaankop granite than the Sekukuni granite. The granite from Brits is not impoverished with respect to Eu, although in other respects its pattern is similar, but at a lower level of enrichment, to the mean Sekukuni and Bobbejaankop granites. The Argent granophyre pattern is similar to that of the granite from Brits, whereas the Sekukuni granite at Argent has a pattern similar to the mean Sekukuni granite but Eu is depleted to a greater degree. The pattern of the granophyre and granite porphyry from the Zaaiplaats area (Figure 15) is similar to that of the mean Sekukuni granites.

The three felsite types (Figure 14) have very similar patterns in which a slight Eu depletion can be detected. However the felsite from the Rooiberg area displays a much greater degree of relative enrichment in REE, and is more similar to the quartz porphyry from Nylstroom (Figure 14) except that the latter is strongly depleted in Eu.

The granophyres and leptites from the Loskop Dam and Jane Furse areas have patterns (Figure 16) that vary only slightly from linearity. The leptite from the Pretoria (Hebron) area (Figure 16) differs considerably from the other leptites and is more closely similar to the granophyre from that area which also displays a slight Eu depletion. The Rooiberg granophyre pattern (Figure 15) shows enrichment in the lighter REE but no Eu depletion.

In Figures 17 and 18 the patterns of REE abundances in the Palala, Bandolierskop, Vryburg, Prieska, Pongola, Mpageni, and Kaap Valley granites are given, the enrichment or depletion in the different rare earths being apparent. The REE pattern of North American Precambrian granite composite (Haskin et al, 1968) is compared in Figure 18 with the mean for the Kaapvaal granites and the Sekukuni granite. It will be seen that the North American and Kaapvaal granites are similar in regard to the light lanthanides, but the heavy lanthanides are depleted relative to the shale composite in the granites of the Kaapvaal craton. The enrichment in rare earths in the Sekukuni granite is clear.

The interpretation of the significance of these patterns is a complex question, still fraught with many uncertainties. The average patterns of REE in continental basalts and intermediate to acid plutonic and volcanic rocks commonly display a close similarity to the shale composite, except for the depletion in Eu. The shale pattern may have developed as a result of extraction of continental material from the mantle or as a result of a cycle of sedimentation, metamorphism, partial melting, and further exposure to weathering (Goles, 1968). The former hypothesis would require that the light lanthanides should show a relative increase with decreasing time. The alternative supposes that the oldest rocks on continents might be expected to have REE patterns like those of recent rocks, if the mechanism of extraction of continental material has remained generally unchanged (Goles, 1968). At the present time this view is receiving the most support. The REE patterns of granites from the Kaapvaal craton do not reveal any steady increase in the relative enrichment of REE with decreasing time.

There is no direct connection between the absolute REE abundances in the Kaapvaal granitic and acid volcanic rocks and their acidity, nor is there a direct link between the degree of Eu depletion and acidity, except in a very general way. The following tabulation demonstrates this point:-

1.	Sekukuni granite north of Brits	72.7% SiO_2	No Eu depletion
2.	Sekukuni granite	75.0% SiO_2	Eu depletion
3.	Bobbejaankop	75.7% SiO_2	Major Eu depletion
4.	Felsites	71.9% SiO_2	No or slight Eu depletion
5.	Leptite (Loskop Dam)	68.9% SiO_2	No Eu depletion
6.	Felsite Rooiberg	70.8% SiO_2	Slight Eu depletion

The depletion in Eu is conveniently measured by reference to the Eu/Gd ratio, but Gd has not been determined for the Kaapvaal granites. In Figure 19, Fourie's (1969) measure of the ratio of the absolute Eu content to the calculated Eu content has been plotted against Rb, Cs, Sr, and Ba. The Sekukuni and Bobbejaankop granites display a wide spread of values for this ratio, which decreases (i.e. Eu depletion increases) as Ba and Sr decrease, and as Rb and Cs increase. The low K/Rb and Ba/Rb ratios in the Bobbejaankop granite are consistent with those expected during fractional crystallization. The parallel behavior of Eu with Ba and Sr suggests that it is probably present as Eu^{2+}, intermediate in size between Ba^{2+} and Sr^{2+}, Eu preferentially entering the K sites with the divalent Ba and Sr. The first crystallization products would be expected to have higher K/Rb and K/Cs ratios, and lower K/Sr, K/Ba, and K/Eu ratios than the melt. The residual liquid from which the Bobbejaankop granite crystallized would then be enriched in Rb and Cs, and depleted in Ba, Sr, and Eu.

Strong Eu depletion is apparent in the quartz porphyry from Nylstroom wherein low K/Rb and K/Ba ratios suggest that it crystallized from a residual melt. The plots of the two analysed samples of Nylstroom quartz porphyry are shown on Figure 19, in which it can be seen that Ba, Rb, and Cs fall close to or within the Sekukuni-Bobbejaankop granite field. Sr, however, appears to be enriched in the quartz porphyry as compared to the Sekukuni and Bobbejaankop granites. The data is not sufficient to propose that the Eu depletion in the quartz porphyry followed from a similar process as has been suggested for the Bobbejaankop and Sekukuni granites.

The ratios of the absolute La and Ce concentrations in various Kaapvaal granites, granophyres and felsites to the average content of La and Ce of chondrites are plotted against the total REE concentration in Figure 20. There is a close linear relationship between the ratios (i.e. the degree of relative enrichment) and the total REE content of the various rock-types. The strong enrichment in the lighter lanthanides in the felsite from Rooiberg (No. 18 in Figure 20) as compared to the felsite mean (No. 13 in Figure 20) is remarkable. No evidence for extreme fractionation is apparent from the available data.

The correlation between large REE content and enrichment in light lanthanides observed in the Kaapvaal granitic rocks is difficult to interpret on the basis of fractional crystallization, but could possibly be explained if the REE were transported as complexed ions (Mineyev, 1963). There is a progressive increase in the relative abundances of the heavy REE from the Sekukuni granite to the Bobbejaankop granite (see Figure 14), the latter being rich in volatiles, particularly F. The Palala granite, which is strongly enriched in the lighter lanthanides, is not, however, enriched in the heavy REE (see Figure 17), although its F content is comparable to that in the Sekukuni granite (Table I, columns A and D).

COMPOSITIONAL VARIATIONS ACCORDING TO TECTONIC SETTING AND AGE

Tables XXII to XXX provide first approximations of the geochemical characteristics of the acid plutonic rocks, arranged according to their tectonic setting and age. The data from which means have been calculated are indicated in each table. The problems inherent in attempting to determine geochemical variations during the evolution of the granitic rocks building the Kaapvaal craton are readily apparent. The difficulty of not knowing the true volume nor the degree of compositional variation of individual granitic intrusives, together with random sampling that tends to place greater emphasis on those granites that have been studied in more detail combine to introduce errors for which no adequate correction can be made at present. The value for the concentration of trace elements is, in some cases, based on a single analysis and cannot, therefore, be regarded as a mean. In consulting the tables, reference should be made to the number of analyses that are available. This information is given as footnotes in Tables I to XXI.

In Table XXII the mean values of essentially tonalitic rocks that are commonly foliated are given in columns A to F, from which it can be seen that there is a considerable degree of variation in the major element chemistry. These rocks have, in addition, enhanced concentrations of Al, Mg, Ca, and Na. The trace element chemistry is inadequate but the strong predominance of Sr over Rb is apparent. The mean composition of these rock-types (Table XXVIII, column A) compares closely with the mean for high calcium, low silica granites (Table XXVIII, column G) with the exception that Na is higher, and K lower in the Kaapvaal mean.

The granites emplaced at ± 3.0 b.y. and ± 2.6 b.y. have similar chemical characteristics, the younger granites being slightly enriched in K, Mg, Li, and Rb but impoverished with respect to Na and Sr as compared to the ± 3.0 b.y. granites. These granites are similar in major element geochemistry to the low calcium, high silica granite mean (Table XXVIII, columns B and I), but apparently have lower concentrations of Ba, Li, Sc, and Zr, and higher contents of Co, Pb, Rb, and Zn than the world-wide average.

Granites that are typically coarse-grained, often porphyritic, and build grossly discordant plutons are listed in Table XXIV. They have been grouped into six types, based on their age relationships and chemistry. These granites carry higher concentrations, in general, of Fe, Ti, Mn, Ca, and K than the granites listed in Table XXIII, columns G and H, but both Fe and Ca are present in variable amounts. With the exception of the Dalmein-type plutons, which are also the oldest plutons, K is more abundant than Na. The Rb content of the Dalmein-type plutons is low and is greatly exceeded by Sr. The Mooihoek-type plutons are highly siliceous with low concentrations of Al, Mg, Ca, and P.

The high content of Ba in the granites building plutons is readily apparent. Both Pb and Zr attain higher concentrations in the plutons. In column G of Table XXIV two values for the mean content of Pb in the Sekukuni granite are given. Kaye et al (1965) report a high value of 210 p.p.m. from one of their samples, which if excluded from the calculation of the mean results in the Sekukuni granite having an average Pb content of 22 p.p.m. In view of the fact that high Pb concentrations are reported from other plutons, it is possible that the higher mean of 53 p.p.m. for the Sekukuni granite may be valid. Rooke's (1970) mean Pb content in African acid rocks (column E, Table XXVIII) is 32 p.p.m. which is significantly higher than Turekian and Wedepohl's (1961) world-wide mean, although it is close to Taylor's (1968) mean for average granite. The contents of Nb, Rb, and Zn are high in the Dalmein-, Palala-, and Sekukuni-type plutons, whereas the Mpageni-type plutons appear to be impoverished in Zn, Co, Hf, and Zr. The Palala-type plutons are enriched with respect to Cr, Cu, Ga, and V, as compared to the other granites, but the concentration of V in the Palala-type granite is below that calculated for high silica, low calcium granites (Turekian and Wedepohl, 1961).

The chemistry of the various granitic events in the Kaapvaal craton is summarized in Table XXVI. In column B of this table a provisional estimation of the bulk composition of the ancient gneissic terrain that consists of interlayers of grey tonalitic gneiss and amphibolite is given. The result listed in column 5 in the following tabulation* indicates that the gneiss terrain has a composition closely similar to various estimates of the composition of the continental crust, except with respect to the significantly lower K and higher Mg contents. The major element composition bears a general resemblance to that of andesite (Taylor, 1966).

The salient features of the changing chemistry with time are illustrated in Figures 21, 22, and 23. The increase in Rb content in the Kaapvaal granitic rocks is accompanied by a sympathetic decrease in Sr, but the increase and decrease is not steady (Figure 21). In general terms there is a rapid increase in Rb content up to ± 3.0 b.y. after which the curve flattens out rapidly with granitic rocks younger than ± 2.5 b.y. having Rb contents of between 200 and 300 p.p.m. Similarly the general rate of Sr impoverishment is rapid to ± 2.6 b.y. after which time the Sr content becomes more stable at between 70 and 90 p.p.m.

In Figure 22 the ratio K/Na is plotted against time and this shows a generalized curve that has a shape similar to that for Rb. Again the increase in the K/Na ratio is not steady but fluctuates about the general curve.

* see following page

	1	2	3	4	5
SiO_2%	60.18	63.1	59.4	60.3	60.0
TiO_2%	1.06	0.8	1.2	1.0	0.6
Al_2O_3%	15.61	15.2	15.6	15.6	15.7
Σ Fe as FeO%	6.71	6.0	7.1	7.2	6.8
MgO	3.56	3.1	4.2	3.9	5.7
CaO	5.17	4.1	6.6	5.8	6.1
Na_2O	3.91	3.4	3.1	3.2	3.2
K_2O	3.19	3.0	2.3	2.5	1.2
Σ	99.39	98.7	99.5	98.8	99.3

1. Clarke and Washington (1924) : average of 5159 igneous rocks.
2. Vinogradov (1962) : two parts of felsic and one part basic rock (quoted from Taylor, 1967).
3. Poldervaart (1955).
4. Taylor (1967).
5. Kaapvaal gneiss composite.

Figure 12 illustrates the tendency for granites dated at 3.0 b.y. and younger to lie in a more compact field with K values ranging from 3.0 to 4.5 per cent and K/Rb ratios between 90 and 250. The older granitic rocks lie to the left of this field with K/Rb ratios ranging up to >600.

In Figure 23 the mean concentrations in the different ages of granitic rocks of the major elements, and Ba, Pb, Li, and Zr are shown. The granites building discordant plutons are distinguished from the remaining granites. It can be seen that:-

(i) Al, Na, and K for both tectonic groups of granite lie on a single curve.

(ii) Mg and Ca appear to be somewhat enriched in the pluton-building granites.

(iii) Ba concentration appears to increase steadily with decreasing time, although the 2.9 b.y. plutons are possibly strongly enriched.

(iv) The curve showing the increase in Pb is sympathetic to the curve for K.

(v) Li, as might be expected of an element largely related to the volatiles, has an erratic distribution.

(vi) The Zr concentration shows a crude linear relationship with time.

This data must be treated with circumspection due to the random nature of the sampling. The remaining trace elements have not been plotted because this data is very incomplete for the different age groupings.

The significant feature of the Rb and K/Na curves (Figures 21 and 22) is that addition of both Rb, Pb, and K decreases after ± 3.0 b.y. This point in time marks in the Kaapvaal craton the onset of cratonic type sedimentation (i.e. the deposition of the Pongola Sequence). No data for Th concentration prior to 3.0 b.y. is available, but Table XXVI indicates that there is a general, but fluctuating, increase in Th with decreasing time after 3.0 b.y. The rate of migration of the sialic constituents and heat-producing cations decreased after 3.0 b.y. by which time the Kaapvaal craton achieved stability and strength, the underlying mantle being depleted of its head-producing cations. There is no reason to suppose that the rate of migration of these cations was or indeed should be constant around the Earth, so that the onset of cratonic conditions in other parts of the Earth could be earlier or later than in the Kaapvaal craton, depending on the time taken to deplete the underlying mantle in K, Pb, U, and Th. A first approximation of the composition of the crystalline crust on which cratonic-type sedimentation occurred can be obtained from the data in columns B, C, D, and E in Table XXVI, and is compared with estimates made by Eades et al (1966) and Poldervaart (1955) in the following tabulation:-

	Kaapvaal	Eades et al (1966)	Poldervaart (1955)
SiO_2	67.0	65.8	66.4
TiO_2	0.4	0.49	0.6
Al_2O_3	15.2	16.4	15.5
Σ Fe as FeO	3.7	4.3	4.4
MgO	2.4	2.3	2.0
CaO	3.4	3.4	3.8
Na_2O	4.1	4.1	3.5
K_2O	2.5	2.9	3.3
Σ	98.7	99.69	99.5

Attention has already been drawn to the fact that the Palala- and Sekukuni-type plutons are enriched in Fe with respect to Mg. There seems to be a trend towards an increase Pb concentration in the granitic rocks with decreasing time.

The mean composition of the granitic rocks in the Kaapvaal craton is given in column D, Table XXVIII which shows a close resemblance in major element chemistry to Taylor's (1968) average granite. The minor elements, Co, Nb, Pb, Rb, and Zr are all enriched in the Kaapvaal granite mean as compared to Taylor's (1968) average granite. Sc is apparently impoverished in the Kaapvaal composite as compared to average granite. The Kaapvaal granite mean is intermediate in respect to the major elements between Turekian and Wedepohl's (1961) high and low calcium granites. Bearing in mind the intermediate character of the Kaapvaal granite composite between the high and low calcium granites, the minor elements Co, Nb, Pb, Rb, Th, Zn, and Zr are present in higher concentrations than in either of Turekian and Wedepohl's groups. Rooke's (1970) data for African acid intrusives similarly reflects enhanced values for Co, Nb, Rb, and Zr. It would appear that the higher values for these minor elements is characteristic of African rocks as a whole and is not unique to the Kaapvaal craton.

The mean composition of the Kaapvaal granite composite bears a close resemblance in respect to major elements to Rooke's (1970) average for African acid rocks, with the Kaapvaal mean Ca concentration being slightly higher. The African mean has higher values for Nb and Zr but a lower value for Sr than the Kaapvaal composite.

The relative enrichment in Rb and Ba in the Kaapvaal granite composite is reflected in the low K/Rb and K/Ba ratios, and higher Rb/Sr ratio as compared to Taylor's data.

The REE data is presented in Table XXX and Figure 18. The lighter lanthanides in the Kaapvaal composite are similar to those for the North American Precambrian granite composite and the granite with >70% SiO_2 (Haskin et al, 1968), but the Kaapvaal composite is impoverished in the heavier rare earths.

CONCLUSIONS

1. The Sekukuni and Bobbejaankop granites have a major element chemistry similar to that of the associated felsites, but wide differences in trace element composition exist between the Bobbejaankop granite and the felsites. Rb, Cs, Nb, and Th are enriched, and Ba, Sr, Zn, and Eu depleted in the Bobbejaankop granite as compared with the felsites. The trace element data from the Bobbejaankop granite is consistent with that to be expected if this granite results from fractional crystallization.

2. The Sekukuni granite trace element chemistry lies intermediate between the felsites and the Bobbejaankop granite. Enrichment in Rb, Cs, Nb, and Th, and depletion of Ba, Sr, and Eu is found in the Sekukuni granites. A regional distribution of granites having enhanced or depleted contents of these elements is suggested but the sampling points are too randomly distributed to confirm this suggestion. The least fractionated granites are found north of Brits and Rustenburg. The trace element data is indicative of a derivation of the Sekukuni granite by fractional crystallization which however did not proceed to the same degree as in the Bobbejaankop granite.

3. The felsites are unfractionated. Although two analysed samples have lower K/Rb ratios, the contents of other trace elements do not change in a manner to be expected in fractional crystallization. In the felsites the K/Rb ratio decreases slightly as the concentration of K increases. In the Sekukuni and Bobbejaankop granites the K/Rb ratio decreases and the K content remains nearly constant.

4. Three, chemically distinct felsite-types can be distinguished, and they appear to have an entirely random, regional distribution. The essential differences between the types can be summarized:-

	Type I	Type II	Type III
Ca%	1.02	0.3	0.07
Na%	2.87	1.92	0.07
K%	3.5	3.61	4.37
Rb	172	182	339
Sr	103	55	22
Zn	178	339	484

The highest Zn concentration reported in a type III felsite is 1671 p.p.m. (Fourie, 1969). In view of the important association of volcanism and mineralization in orogenic settings, the validity of this three-fold division needs to be tested and any economic potential assessed. Fourie (1969) also reports a tin content of 59 p.p.m. in a felsite which has been classed here as type III.

5. The trace element chemistry of the granophyres is variable, bearing resemblances to the granites and the felsites. This is not unexpected as it has been proposed that granophyres having different origins are present in the Bushveld Complex.

6. It is suggested provisionally that the felsites may also represent the products of the partial melting of the Archaean basement, that was explosively extruded. The continued presence of a heat source at depth led to more complete melting, at which stage fractional crystallization began to operate, giving rise to the Sekukuni and Bobbejaankop granites. This provisional model would be in keeping with the geochemical data.

7. The Palala and Gaborone granites bear a close geochemical resemblance to the Sekukuni granite.

8. The Sekukuni, Palala, and Gaborone granites are enriched in Fe relative to Mg and Ti, as compared to the older granites (i.e. >2.6 b.y.) in the Kaapvaal craton.

9. Granites dated at ± 3.0 b.y. and 2.6 to 2.7 b.y. that are known in the eastern Transvaal and Swaziland to form hoods over the older gneiss basement appear to have low Ba contents. This is more marked in the 2.6 to 2.7 b.y. group of granites which also have low concentrations of Li and Sr. A similar feature is noted in granites of an equivalent age from the Klerksdorp area of the western Transvaal.

10. Granites that form discordant plutons which have been dated at 2.9 to 2.6 b.y. have moderate to high concentrations of Ba and, in the Mpageni-type plutons, of Th.

11. All the granitic rocks in the Kaapvaal craton younger than 3.0 b.y. are enriched in Co relative to Mg. No data are available for granitic rocks older than 3.0 b.y. The concentration of Pb appears to increase in the younger granites, attaining a maximum of 58 p.p.m. in the Gaborone granite.

12. The rate of migration of the large heat-producing cations decreases rapidly after 3.0 b.y. at which point in time cratonic conditions, marked by the deposition of the Pongola Sequence, existed in the Kaapvaal craton.

13. The crystalline crust in the Kaapvaal craton prior to 3.3 b.y. has a mean composition, in respect to the major elements, that is similar to andesite. The Kaapvaal 3.0 b.y. crystalline shield on which cratonic sedimentation took place is granodioritic in composition.

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TABLE I

MEAN COMPOSITIONS OF SEKUKUNI, BOBBEJAANKOP, PALALA, AND GABORONE GRANITES

	A	B	C	D	E	F	G	H
Si%	35.25 (1,4)	35.49	35.58	35.04	34.24	34.7	33.3	33.98
Ti%	0.13 (1,4)	0.11	0.03	0.12	0.22	0.12	0.24	0.16
Al%	6.45 (1,4)	6.19	6.66	6.25	6.63	7.2	7.78	6.62
ΣFe%	2.42 (1,4)	2.29	1.87	2.50	2.81	1.42	2.52	2.52
Mn	635 (1,4)	404	349	570	420	390	400	590
Mg%	0.14 (1,4)	0.11	0.11	0.32	0.25	0.16	0.33	0.16
Ca%	0.72 (1,3,4)	0.43	0.78	0.95	0.88	0.51	1.43	0.61
Na%	2.39 (1,3,4)	2.09	2.57	1.89	2.53	2.58	2.63	3.16
K%	4.09 (1,3,4)	4.09	4.03	3.70	4.33	4.2	3.47	4.15
B%	0.007 (5)	0.007 (5)	0.012 (5)	-	-	0.001	0.001	-
F%	0.12 (6,7)	0.19 (6)	0.63 (6)	0.13 (9)	0.20 (10)	0.085	-	0.21
P	131 (1,4)	101	70	700	600	600	700	400
CO_2%	0.18 (6,7)	0.09 (6)	0.45 (6)	-	-	-	-	-
Ba	963 (1,3,4)	721	338	1111	550 (10,11)	840	600	420
Be	-	-	-	-	8 (11)	3	-	9
Co	2.1 (4)	1.4	1.1	2.2	<10 (11)	1	2	<10-15
Cr	17 (1)	-	-	-	29 (11)	4.1	10	<10-30
Cs	3.5 (1,4)	2.7	6.3	1.4	4.6 (10)	4	5	-
Cu	7.6 (1)	-	-	-	19 (11)	10	10	<5-18
Ga	19 (1)	-	17.6 (2)	-	33 (11)	17	20	38
Hf	6.1 (4)	6	8.6	5.8	-	3.9	4	-
Li	20 (1,3)	-	-	-	39 (10,11)	40	30	66
Mo	-	-	3 (2)	-	3 (11)	1.3	2	<3-6
Nb	22 (4)	23	48	20	47 (11)	21	20	100
Ni	22 (1)	-	-	-	<10 (11)	4.5	4	<10-12
Pb	22/53 (1,3)	-	-	-	58 (11)	19	30	42
Rb	215 (1,3,4)	290	523	277	350 (10,11)	170	145	255
Sc	2.2 (1,4)	1.1	1.3 (2,4)	3.1	<10 (11)	7	6	<10-10
Sn	3 (4)	19	23	6	-	3	3	-
Sr	66 (1,3,4)	19	6	141	65 (11)	100	285	71
Th	23.8 (4)	22.5	49.5	20.9	-	17	17	-
Tl	1.1 (3)	-	-	-	-	2.3	1.0	-
V	3 (1)	-	-	-	20 (11)	44	40	<3-16
Zn	84 (4)	103	62	48	-	39	40	-
Zr	354 (1,4)	347	260	331	570 (11)	175	180	460

A. Sekukuni granite (1. Liebenberg, 1961 - 3 analyses; 2. Edge and Ahrens, 1962 - 1 analysis; 3. Kaye et al, 1965 - 4 analyses; 4. Fourie, 1969 - 14 analyses of which 7 are from the Zaaiplaats area; 5. Wasserstein, 1951 - 3 analyses of Sekukuni granite from Zaaiplaats area; 6. Strauss, 1954 - 4 analyses of Sekukuni granite from Zaaiplaats area; 7 Visser, 1954 - 4 analyses for F and 2 analyses for CO_2).

B. Sekukuni granite, Zaaiplaats area (Fourie, 1969 - 7 analyses; 5. Wasserstein, 1951 - 3 analyses; 6. Strauss, 1954 - 4 analyses).

C. Bobbejaankop granite, Zaaiplaats area (Fourie, 1969 - 7 analyses; 2. Edge and Ahrens, 1962 - 1 analysis; 4. Fourie, 1969 - 17 analyses; 5. Wasserstein, 1951 - 2 analyses; 6. Strauss, 1954 - 2 analyses).

D. Palala granite (major elements - Visser, 1953, 1 analysis and Fourie, 1969, 1 analysis; 9. Visser, 1953 - 1 analysis; trace elements, Fourie, 1969, 1 analysis).

E. Gaborone granite (major elements - Wright, 1961 - 5 analyses, except for Fe, 18 determinations, Na and K, 19 determinations; Rooke, 1970 - 7 analyses; trace elements, 10. Wright, 1961 - 9 analyses; 11. Rooke, 1970 - 7 analyses).

F. High silica, low calcium granite (Turekian and Wedepohl, 1961).

G. Average granite (Taylor, 1968).

H. Mean of African anorogenic acid intrusives (Rooke, 1970 - 45 analyses used to compile means of major elements; 52 analyses for Ba, Cr, Ga, Li, Mo, Nb, Ni, Pb, Sr, V, and Zr; 51 analyses for Be and Co; 48 analyses for Rb; 45 analyses for P; 43 analyses for Mn; 31 analyses for Cu; 29 analyses for Sc, and 17 analyses for F).

TABLE II

RATIOS OF ELEMENTS IN THE SEKUKUNI, BOBBEJAANKOP, PALALA, AND GABORONE GRANITES

	A	B	C	D	E	F	G	H
K/Rb	180	143	80	134	124	247	240	162
K/Cs	11,700	18,000	7,420(2) 6,400	26,500	9,410	10,500	6,940	-
K/Tl	37,200	-	-	-	-	18,000	34,700	-
Rb/Tl	195	-	-	-	-	74	145	-
K/Ba	41.4	58	131	33.3	78.7	50	58	100
Ba/Rb	4.5	2.5	0.67	4	1.57	5	4.1	1.6
Ba/Sr	14.6	40	56	8	8.4	8.4	2.1	6
Ca/Sr	110	194	1,800	67.3	135	51	50.2	86
K/Na	1.79	1.95	1.57	1.96	1.71	1.62	1.32	1.31
Th/U	-	-	-	-	-	5.7	3.5	-
$Th/Kx10^4$	5.8	5.4	12.3	5.7	-	4	4.7	-
$U/Kx10^4$	-	-	-	-	-	0.7	1.4	-
Fe/Mg	17.3	22.3	16.5	7.8	11.2	8.9	7.6	15.8
Mg/Ti	1.07	1.06	3.8	2.67	1.14	1.33	1.4	1
Fe/Mn	38	61	50.5	44	67	36.7	63	42.7
Mg/V	467	-	-	-	125	36.4	82.5	-
Mg/Cr	82	-	-	-	86	390	330	53
Mg/Co	667	800	1,000	1,450	-	1,600	1,650	-
Fe/Co	11,500	16,360	11,370	10,400	-	14,200	12,600	-
Mg/Ni	64	-	-	-	-	355	825	-
Fe/Ni	1,100	-	-	-	-	3,155	6,300	-
Ni/Co	10.5	-	-	-	-	2	2	-
Mg/Li	70	-	-	-	64	40	110	24
$Ga/Alx10^4$	2.9	-	2.6	-	4.9	2.6	2.6	5.7
Zr/Hf	58	58	32	57	-	45	45	-

For key to rock-types see Table I

TABLE III

RARE EARTH ELEMENT CONTENTS OF THE SEKUKUNI, BOBBEJAANKOP, PALALA, AND GABORONE GRANITES

	A	B	C	D	E	F	G	H	I
La	91 (1,3)	83	92 (2,3)	121	125	50	55	55	49
Ce	125 (3)	139	153 (2,3)	207	–	100	92	57	97
Nd	–	–	65 (2)	–	–	46	37	33	42
Sm	13.7 (3)	14.6	14.4 (3)	12.6	–	8.3	10	7.1	7.2
Eu	1.8 (3)	1.8	0.3 (3)	2.2	–	1.10	1.6	1.1	1.25
Dy	6.3 (3)	6.5	8.2 (3)	3.7	–	–	7.2	–	–
Yb	3 (3)	2.4	4.1 (3)	2.0	–	4.8	4.0	4.0	3.5
Lu	0.7 (3)	0.6	0.9 (3)	0.2	–	0.78	1.2	–	0.52
Y	–	–	21 (2)	–	96	42	40	40	31
ΣREE	251.5	247.9	338.9	348.7	–	212.98	208	167.2	201.5

A. Sekukuni granite (1. Liebenberg, 1961 - 3 analyses; 3. Fourie, 1969 - 14 analyses of which 7 are from the Zaaiplaats area)

B. Sekukuni granite. Zaaiplaats area only. (Fourie, 1969 - 7 analyses).

C. Bobbejaankop granite (2. Edge and Ahrens, 1962 - 1 analysis; 3. Fourie, 1969 - 17 analyses).

D. Palala granite (Fourie, 1969 - 1 analysis)

E. Gaborone granite (Rooke, 1970 - 7 analyses)

F. Granite composite (>70% SiO_2). (Haskin et al, 1968).

G. High silica, low calcium granite. (Turekian and Wedepohl, 1961).

H. Average granite. (Taylor, 1968).

I. Western North American Precambrian granites. (Haskin et al, 1968).

TABLE IV

MEAN COMPOSITIONS OF GRANOPHYRES, GRANOPHYRIC GRANITE PORPHYRIES AND QUARTZ PORPHYRIES FROM THE BUSHVELD COMPLEX

	A	B	C	D	E	F	G	H	I
Si%	35.49	34.36	34.92	33.04	34.72	35.25	34.07	35.27 (1,2)	36.16
Ti%	0.14	0.18	0.16	0.38	0.11	0.15	0.23	0.15 (1,2)	0.09
Al%	6.61	6.34	6.53	6.54	6.43	6.41	6.16	6.08 (1,2)	6.41
ΣFe%	2.34	3.54	2.63	4.13	2.72	2.70	4.03	2.87 (1,2)	2.29
Mn	603	391	304	899	5397	850	850	552 (1,2)	247
Mg%	0.13	0.19	0.08	0.33	0.15	0.09	0.18	0.06 (1,2)	0.22
Ca%	0.26	1.00	0.55	1.58	0.24	0.19	0.90	0.77 (1,2)	0.21
Na%	2.31	1.91	3.03	3.06	1.54	2.08	2.36	2.41 (1,2)	1.21
K%	4.09	4.17	3.99	2.71	5.54	4.17	3.64	3.96 (1,2)	3.56
P	155	250	90	575	90	80	180	247 (1,2)	110
Ba	1098	1169	1137	836	1108	1300	2500	1334 (1,2)	541
Co	2.7	4.9	1.5	7.2	6.7	-	-	2.2 (1)	1.2
Cr	-	-	-	-	-	11	19	12 (2)	-
Cs	1.3	2.6	5.2	1.8	5.6	2	1.5	2.1 (1,2)	6.9
Cu	-	-	-	-	-	12	86	9 (2)	-
Ga	-	-	-	-	-	19	17	15 (2)	-
Hf	6	4.9	7.5	5.0	8.9	-	-	6 (1)	5.8
Li	-	-	-	-	-	2	9	20 (2)	-
Nb	21.5	19	23	21	33	-	-	16 (1)	36.5
Ni	-	-	-	-	-	21	30	15 (2)	-
Pb	-	-	-	-	-	28	17	20 (2)	-
Rb	230	188	219	108	234	270	155	182 (1,2)	578
Sc	1.35	5.7	1.8	8.1	1.3	-	5	2.7 (1)	2.1
Sn	15	7	9	3.2	3	-	-	-	11.5
Sr	100	55	43	207	18	47	140	85 (1,2)	38
Th	20.3	17.1	18.9	10.8	71	-	-	7.7 (1)	101.8
V	-	-	-	-	-	-	3	7 (2)	-
Zn	156	53	61	100	27	-	-	123 (1)	46
Zr	421	359	449	383	401	400	500	353 (1,2)	221

A. Mean of granophyre and granite porphyry, Zaaiplaats area (Fourie, 1969 - 2 analyses).

B. Granophyre, Rooiberg (Fourie, 1969 - 3 analyses).

C. Granophyre, near Pretoria (Fourie, 1969 - 2 analyses).

D. Granophyre, Bronkhorstspruit-Argent (Fourie, 1969 - 10 analyses).

E. Granophyric granite porphyry, Rest de Winter (Fourie, 1969 - 1 analysis).

F. Granophyre, Sekukuniland (Liebenberg, 1961 - 1 analysis).

G. Granophyre, Olifants River, Groblersdal (Liebenberg, 1961 - 1 analysis).

H. Mean of two analyses of granophyre, Jane Furse (1. Fourie, 1969 - 1 analysis; 2. Liebenberg, 1961 - 1 analysis).

I. Quartz porphyry, Nylstroom (Fourie, 1969 - 2 analyses; Coetzee, 1970 - 1 analysis, major elements).

TABLE V

RATIOS OF ELEMENTS IN GRANOPHYRES, GRANOPHYRIC GRANITE PORPHYRY AND QUARTZ PORPHYRY FROM THE BUSHVELD COMPLEX

	A	B	C	D	E	F	G	H	I
K/Rb	178	222	182	251	237	154	235	218	62
K/Cs	31,460	16,000	7,673	15,000	9,900	20,850	24,260	18,000	5,200
K/Ba	37	35.6	34	32.4	50	32	14.6	30	66
Ba/Rb	4.8	6.2	5.2	7.7	4.7	4.8	16	7.3	0.93
Ba/Sr	11	21	26.4	4	61.6	27.7	18	15.6	14
Ca/Sr	26	182	128	76.3	116	40.4	64	90.6	55
K/Na	1.77	2.18	1.32	0.88	3.6	2	1.54	1.64	2.53
Fe/Mg	18	18.6	33	12.5	18	30	22.4	48	10.4
Mg/Ti	0.9	1.05	0.5	0.9	1.4	0.6	0.8	0.4	2.4
Fe/Mn	39	90.5	86.4	46	5	32	50	52	92
Mg/V	-	-	-	-	-	-	600	85.9	-
Mg/Cr	-	-	-	-	-	82	94	50	-
Mg/Co	481	387	533	486	225	-	-	272	1,800
Fe/Co	8,700	7,224	17,555	5,736	4,060	-	-	13,000	19,000
Mg/Ni	-	-	-	-	-	43	60	40	-
Fe/Ni	-	-	-	-	-	1,300	1,340	1,913	-
Ni/Co	-	-	-	-	-	-	-	7	-
Mg/Li	-	-	-	-	-	450	200	30	-
$Ga/Al \times 10^4$	-	-	-	-	-	3	2.7	2.4	-
Zr/Hf	70	73	60	76.6	45	-	-	59	38
$Th/K \times 10^4$	5	4.1	4.7	4	12.8	-	-	1.9	28.6

For key to rock-types see Table IV.

TABLE VI

RARE EARTH ELEMENT CONTENTS OF GRANOPHYRES, GRANOPHYRIC GRANITE PORPHYRY AND QUARTZ PORPHYRY FROM THE BUSHVELD COMPLEX

	A	B	C	D	E	F	G	H	I
La	70	69	73	56	145	220	51	46	139
Ce	117	112	125	84	308	-	-	79	247
Sm	12.8	9.9	13	11	22.2	-	-	7.3	21
Cu	1.8	2.1	2	2.8	0.24	-	-	1.8	0.15
Dy	6.9	5	7.6	4.0	9	-	-	3.1	7
Yb	3.45	2.6	2.2	1.7	3.6	-	-	1.5	2.9
La	0.71	0.5	0.51	0.42	0.8	-	-	0.4	0.6
ΣREE	212.66	201.1	223.31	159.92	488.84	-	-	139.1	417.15

For key to rock-types see Table IV

TABLE VII

MEAN COMPOSITIONS OF LEPTITES AND GRANOPHYRE FROM THE BUSHVELD COMPLEX

A. Major and Trace Elements

	A	B	C	D
Si%	32.38	32.90	34.61	34.12
Ti%	0.31	0.28	0.17	0.23
Al%	6.57	6.63	6.59	6.66
ΣFe%	5.38	4.90	3.11	4.09
Mn	858	929	652	1196
Mg%	0.29	0.26	0.14	0.17
Ca%	1.79	1.43	1.14	1.11
Na%	2.85	2.25	2.84	2.62
K%	3.09	3.44	3.68	3.82
P	600	500	220	260
Ba	835	913	960	1006
Co	11.8	7.8	4	3.4
Cs	2.1	1.9	2.9	2.7
Hf	4.0	4.85	4.9	6.2
Nb	19.5	17	19	18
Rb	143	149	134	155
Sc	11.2	10.7	6.3	7.3
Sn	3.5	5.5	-	-
Sr	141.5	121	107	89
Th	8.7	15	5.8	16.9
Zn	89	104	78	131
Zr	303	350	322	400

B. Rare Earth Elements

	A	B	C	D
La	40	46	45	54
Ce	80	96	70	103
Sm	4.85	7.65	5.9	9.8
Eu	1.85	1.95	2.0	1.3
Dy	4.5	4.15	2.3	5.0
Yb	2.05	2.35	1.9	1.9
Lu	0.49	0.56	0.52	0.63
ΣREE	133.74	158.66	127.62	175.63

A. Mean composition of leptites east of Loskop Dam (Fourie, 1969 - 2 analyses).

B. Mean composition of granophyres associated with A (Fourie, 1969 - 2 analyses).

C. Leptite, Drogehoek, near Jane Furse (Fourie, 1969 - 1 analysis).

D. Leptite, Hebron, near Pretoria (Fourie, 1969 - 1 analysis).

TABLE VIII

RATIOS OF ELEMENTS IN LEPTITES AND GRANOPHYRES FROM THE BUSHVELD COMPLEX

	A	B	C	D
K/Rb	217	235	275	246
K/Cs	14,700	18,000	12,700	13,400
K/Ba	37	37.7	38	38
Ba/Rb	5.8	6	7	6.5
Ba/Sr	5.9	7.5	9	11.3
Ca/Sr	126	118	106.5	124.7
K/Na	1.08	1.53	1.29	1.46
Fe/Mg	18.9	18.8	22.2	23.5
Mg/Ti	0.9	0.9	0.8	0.7
Fe/Mn	62.7	50	44	34
Mg/Co	245	333	350	500
Fe/Co	4,474	6,300	7,775	12,000
Zr/Hf	76	72	65.7	64.5
$Th/K \times 10^4$	2.8	3	1.6	4.4

For key to rock-types see Table VII

TABLE IX

MEAN COMPOSITIONS OF FELSITES FROM THE BUSHVELD COMPLEX

	A	B	C	D	E	F	G	H	I	J	K	L
Si%	33.74	34.32	33.77	34.42	34.77	33.56	34.15	32.21	34.16	35.82	35.13	33.10
Ti%	0.24	0.21	0.22	0.21	0.20	0.25	0.18	0.36	0.32	0.11	0.26	0.18
Al%	6.32	6.43	6.31	6.39	6.60	6.05	6.03	6.21	6.29	6.56	6.21	6.72
ΣFe%	4.19	4.58	4.80	4.34	4.61	3.79	3.46	6.02	3.80	2.54	2.12	3.14
Mn	1078	1145	1187	1015	1232	1780	660	1000	850	900	431	980
Mg%	0.21	0.21	0.14	0.25	0.23	0.26	0.26	0.27	0.08	0.27	0.25	0.16
Ca%	1.10	0.46	1.02	0.29	0.07	2.87	1.33	2.24	0.30	0.30	0.61	0.69
Na%	1.98	1.62	2.87	1.92	0.07	1.91	2.12	3.13	2.82	0.29	1.69	3.56
K%	3.83	3.94	3.49	3.61	4.71	3.51	3.55	4.49	4.04	3.74	4.99	3.75
P	320	230	250	250	200	240	520	720	250	100	350	300
F%	-	-	-	-	-	-	0.105	-	-	0.045	-	0.14
Ba	1170	1145	1055	1144	1236	1300	-	-	-	-	1100	590
Co	3.9	3.9	3.9	3.5	4.3	-	-	-	-	-	-	<3- 7
Cr	17	-	-	-	-	+7	-	-	-	-	23	<10
Cs	5.4	5.9	7.6	3.6	6.6	4	-	-	-	-	18	9
Cu	27	-	-	-	-	27	-	-	-	-	9	18
Ga	18	-	-	-	-	18	-	-	-	-	13	35
Hf	6.1	6.1	6.8	5.8	5.7	-	-	-	-	-	-	-
Li	19.6	-	-	-	-	19.6	-	-	-	-	10	20
Nb	18	18	19	18	17	-	-	-	-	-	-	17.5
Ni	37	-	-	-	-	37	-	-	-	-	23	<10-22
Rb	217	231	172	182	339	203	-	-	-	-	279	120
Sc	6.9	6.9	7.8	7	6	7	-	-	-	-	5	<10-15
Sr	88	60	103	55	22	107	-	-	-	-	57	69
Pb	18	-	-	-	-	18	-	-	-	-	27	<5-27
Th	16.0	16.6	15	18	16.7	-	-	-	-	-	-	-
V	-	-	-	-	-	-	-	-	-	-	8	<3-12
Zn	283	334	178	339	484	-	-	-	-	-	-	-
Zr	373	381	374	386	382	350	-	-	-	-	455	610

A. Mean composition of felsites in columns C to J, representing average felsite of Bushveld Complex.

B. Mean composition of felsites in columns C to E (Fourie, 1969 - 10 analyses).

C. Mean composition of type I felsites (Fourie, 1969 - 2 analyses).

D. Mean composition of type II felsties (Fourie, 1969 - 3 analyses).

E. Mean composition of type III felsites (Fourie, 1969 - 5 analyses).

F. Felsite (Liebenberg, 1961 - 1 analysis).

G. Mean composition of type IA felsites (Visser, 1964 - 7 analyses).

H. Mean composition of type IB felsites (Visser, 1964 - 2 analyses; von Gruenewaldt, 1968 - 2 analyses; Groeneveld, 1968 - 3 analyses; Coetzee, 1970 - 1 analysis).

I. Mean composition of type II felsites (Visser, 1964 - 6 analyses).

J. Mean composition of type III felsites (Visser, 1964 - 1 analysis; Coetzee, 1970 - 1 analysis).

K. Mean composition of felsites of uncertain correlation cropping out near Groblersdal (Liebenberg, 1961 - 2 analyses).

L. Mean composition of African anorogenic acid extrusives (Rooke, 1970 - 25 analyses).

TABLE X

RATIOS OF ELEMENTS IN FELSITES FROM THE BUSHVELD COMPLEX

	A	B	C	D	E	F	G	H	I	J	K	L
K/Rb	176	170	209	202.5	142	172	-	-	-	-	-	310
K/Cs	7,100	6,700	4,600	9,300	7,140	8,875	-	-	-	-	9,880	-
K/Ba	33	34.4	34	31.4	38.5	27.3	-	-	-	-	44.9	63.5
Ba/Rb	5.4	5.0	6.2	6.5	3.7	6.4	-	-	-	-	3.9	5
Ba/Sr	13.3	19	10.2	20.9	87.8	7.6	-	-	-	-	19.4	8.5
Ca/Sr	125	77	99	53	32	157	-	-	-	-	115	100
K/Na	1.93	2.43	1.2	1.88	69	1.84	1.67	1.43	1.43	12.9	3.01	1.05
Th/K$\times10^4$	4.2	4.2	4.15	5	4	-	-	-	-	-	-	-
Fe/Mg	20	21.1	33.7	17.8	19.4	14.5	-	-	-	-	8.5	19
Mg/Ti	0.9	1.0	0.67	1.2	1.2	1.04	1.4	0.75	0.25	2.45	0.96	0.9
Fe/Mn	39	40	40.4	44.6	116	21.3	52.4	60	44.7	28.2	49	21.6
Ga/Al$\times10^4$	2.8	-	-	-	-	2.7	-	-	-	-	2.1	5.2
Mg/Li	107	-	-	-	-	132	-	-	-	-	250	80
Zr/Hf	61	62	55	68	67	-	-	-	-	-	-	-
Mg/Co	590	540	564	600	465	-	-	-	-	-	-	-
Fe/Co	10,700	12,000	12,300	12,400	10,700	-	-	-	-	-	-	-
Mg/V	-	-	-	-	-	-	-	-	-	-	312	-
Mg/Cr	130	-	-	-	-	150	-	-	-	-	104	-
Mg/Ni	59	-	-	-	-	70	-	-	-	-	104	-
Fe/Ni	1,130	-	-	-	-	1,024	-	-	-	-	920	-
Ni/Co	9.5	-	-	-	-	9.5	-	-	-	-	-	-

For key to rock-types see Table IX

TABLE XI

RARE EARTH ELEMENT CONTENTS OF FELSITES FROM BUSHVELD COMPLEX

	A	B	C	D	E	F
La	57	55	55	62.5	180	56
Ce	104	90	105	113	361	91
Pr	-	-	-	-	-	12.2
Nd	-	-	-	-	-	46
Sm	11.7	10.5	10.7	13.9	37.5	8.5
Eu	1.8	1.8	1.7	1.9	7.3	1.39
Gd	-	-	-	-	-	7.3
Tb	-	-	-	-	-	1.09
Dy	5.03	5.3	4.6	4.5	11	-
Hσ	-	-	-	-	-	1.66
Er	-	-	-	-	-	4.6
Tm	-	-	-	-	-	0.72
Yb	2.7	2.6	2.8	2.6	3.8	4.6
Lu	0.7	0.7	0.73	0.69	0.8	0.72
Y	-	-	-	-	-	44
ΣREE	182.93	165.9	180.53	199.09	601.4	287

A. Mean composition of columns B to D.

B. Mean composition of type I felsites (column C, Table IX) (Fourie, 1969 - 2 analyses).

C. Mean composition of type II felsites (column D, Table IX) (Fourie, 1969 - 3 analyses).

D. Mean composition of type III felsites (column E, Table IX, but excluding felsite from Rooiberg area) (Fourie, 1969 - 4 analyses).

E. Felsite, Rooiberg area (Fourie, 1969 - 1 analysis).

F. Rhyolite composite (Haskin et al, 1968).

TABLE XII

MEAN COMPOSITIONS OF GRANITIC ROCKS OF THE JOHANNESBURG-PRETORIA DOME

A. Major and Trace Element Contents

	A	B	C	D	E	F
Si%	-	29.56	31.76	34.20	34.18	33.83
Ti%	-	0.31	0.22	0.17	0.16	0.22
Al%	-	8.41	8.72	7.74	7.52	7.52
ΣFe%	-	3.65	2.16	1.51	1.28	1.67
Mn	-	800	250	380	380	425
Mg%	-	2.09	0.78	0.31	0.29	0.27
Ca%	1.13	3.98	2.57	1.51	1.06	1.19
Na%	3.18	2.76	3.73	3.26	3.14	3.14
K%	3.34	1.30	1.20	2.80	3.35	3.38
P	-	1,200	440	310	350	480
Ba	621	-	-	-	-	-
Li	42.6	-	-	-	-	-
Rb	209	136	112	216	308	317
Sr	198	845	658	458	224	274
Pb	25	-	-	-	-	-
Tl	1.2	-	-	-	-	-
Zr	150 (1)	-	-	-	-	-

B. Ratios of Elements

	A	B	C	D	E	F
K/Rb	160	95.5	107	129	109	107
K/Tl	31,500	-	-	-	-	-
Rb/Tl	197	-	-	-	-	-
K/Ba	54	-	-	-	-	-
Ba/Rb	3	-	-	-	-	-
Ba/Sr	3.1	-	-	-	-	-
Ca/Sr	57	47	39	49.5	47.3	43.4
K/Na	1.05	0.47	0.32	0.86	1.07	1.06
Mg/Ti	-	6.7	3.5	1.8	1.8	1.2
Fe/Mg	-	1.7	2.8	4.9	4.4	5.7

A. Mean of five analyses of granitic rocks (Kaye et al, 1965).
B. Hornblende-biotite tonalite (Anhaeusser, 1971 - 2 analyses).
C. Potassium-poor leucotonalite (Anhaeusser, 1971 - 4 analyses).
D. Potassium-rich leucotonalite (Anhaeusser, 1971 - 2 analyses).
E. Granodiorites and adamellites (Anhaeusser, 1971 - 9 analyses).
F. Adamellites building castle koppies (Anhaeusser, 1971 - 4 analyses).

(1) Schutte (1963) - 1 analysis.

TABLE XIII

MEAN COMPOSITIONS OF GRANITIC ROCKS FROM VENTERSDORP, VRYBURG, KLERKSDORP, SCHWEIZER RENECKE, PIETERSBURG, PRIESKA, AND MARYDALE

	A	B	C	D	E	F	G	H	I	J
Si%	-	35.00	-	-	-	31.18	33.49	-	-	-
Ti%	-	0.12	-	-	-	0.44	0.22	-	-	-
Al%	-	7.26	-	-	-	6.69	7.24	-	-	-
ΣFe%	-	1.36	-	-	-	3.10	2.13	-	-	-
Mn	-	120	-	-	-	640	451	-	-	-
Mg%	-	0.25	-	-	-	0.60	0.31	-	-	-
Ca%	1.57	0.69	0.56	0.70	0.52	1.82	0.89	0.39	0.06	0.23
Na%	3.66	3.12	2.60	2.81	2.73	3.29	2.92	4.34	2.63	3.48
K%	2.47	3.15	3.81	4.02	4.19	3.28	3.97	1.47	3.53	2.50
P	-	310	-	-	-	300	570	-	-	-
Ba	1042	524	450	300	747	1357	1459	95	200	147
Co	-	4.1	-	-	-	17.9	7.4	-	-	-
Cs	-	4.9	-	-	-	5.2	3.8	-	-	-
Hf	-	3.1	-	-	-	4.8	5.3	-	-	-
Li	38	-	39	15	16.5	-	-	31	12	21.5
Nb	-	22	-	-	-	18	58	-	-	-
Rb	64	236	245	308	198	118	164	145	245	195
Sc	-	3.1	-	-	-	7.3	4.4	-	-	-
Sn	-	2	-	-	-	3	1	-	-	-
Sr	686	169	86	48	146	365	401	13	57	35
Pb	20	-	27	25	32	-	-	21	9.1	15
Th	-	14.4	-	-	-	5.1	15.4	-	-	-
Tl	0.80	-	1.3	1.8	1.3	-	-	0.87	1.3	1.08
Zn	-	48	-	-	-	63	32	-	-	-
Zr	-	127	-	-	-	294	308	-	-	-

A. Ventersdorp area (Kaye et al., 1965 - 2 analyses).

B. Vryburg area (Fourie, 1969 - 1 analysis).

C. Klerksdorp area, dated at ± 3.0 b.y. (Kaye et al., 1965 - 1 analysis).

D. Klerksdorp area, dated at ± 2.6 - 2.7 b.y. (Kaye et al., 1965 - 2 analyses).

E. Schweizer Renecke area, dated at ± 2.7 b.y. (Kaye et al., 1965 - 4 analyses).

F. Pietersburg, Bandolierskop granite (Fourie, 1969 - 1 analysis).

G. Prieska area (Fourie, 1969 - 1 analysis).

H. Marydale (Kaye et al., 1965 - 1 analysis).

I. Marydale (Kaye et al., 1965 - 1 analysis).

J. Mean of H and I.

TABLE XIV

RATIOS OF ELEMENTS IN GRANITIC ROCKS FROM VENTERSDORP, VRYBURG, KLERKSDORP, SCHWEIZER RENECKE, PIETERSBURG, PRIESKA, AND MARYDALE

	A	B	C	D	E	F	G	H	I	J
K/Rb	386	133.5	151	130	211.6	278	242	100	144	128
K/Cs	-	6,400	-	-	-	6,300	10,400	-	-	-
K/Ba	24	60	84	134	56	24	27	154	176	170
K/Tl	31,000	-	29,300	22,300	32,000	-	-	17,000	27,000	23,000
Rb/Tl	80	-	190	170	152	-	-	167	190	180
Ba/Rb	16.3	2.2	1.8	0.97	3.8	11.5	8.8	0.66	0.8	0.75
Ba/Sr	1.5	3.1	5.2	6.2	5.1	3.7	3.6	7	3.5	4.2
Ca/Sr	22.9	40.8	65	145	35.6	50	23	290	11	66
K/Na	0.67	1.01	1.47	1.43	1.53	1.00	1.36	0.34	1.35	0.72
$Th/K \times 10^4$	-	4.6	-	-	-	1.55	3.8	-	-	-
Fe/Mg	-	5.4	-	-	-	5	7	-	-	-
Mg/Ti	-	2	-	-	-	1.4	1.4	-	-	-
Fe/Mn	-	113	-	-	-	48	47	-	-	-
Mg/Co	-	610	-	-	-	341	419	-	-	-
Fe/Co	-	3,320	-	-	-	1,732	2,900	-	-	-
Zr/Hf	-	41	-	-	-	61.25	58	-	-	-
FeO/FeO+MgO	-	0.8	-	-	-	0.8	0.84	-	-	-

FeO = Total Fe as FeO

For key to rock-types see Table XIII.

TABLE XV

MEAN COMPOSITIONS OF GRANITIC AND ASSOCIATED ROCKS FROM THE EASTERN TRANSVAAL AND SWAZILAND

A. Ancient Gneiss Complex

	A	B	C	D	E	F	G	H	I	J
Si%	33.81	30.75	36.10	36.73	31.65	27.83	34.73	25.47	25.67	24.03
Ti%	0.18	0.25	0.09	0.16	0.34	0.31	0.14	0.45	0.29	0.10
Al%	7.84	8.07	6.43	5.51	7.73	6.75	3.74	6.69	8.53	3.14
ΣFe%	1.72	3.29	1.40	3.48	3.11	7.65	2.03	8.45	4.85	6.45
Mn	150	600	150	300	700	1500	2700	1500	2000	1200
Mg%	0.55	1.92	0.26	1.40	1.32	9.01	2.42	3.57	1.41	12.17
Ca%	2.31	3.33	0.31	Tr	3.36	1.74	5.50	6.14	9.90	6.85
Na%	3.40	3.01	2.97	0.40	2.83	0.31	1.61	2.59	2.81	0.77
K%	1.67	1.95	2.94	1.73	1.09	0.24	0.44	0.53	0.31	0.16
P	520	570	130	130	610	480	130	3000	300	-
Ba	-	-	700	400	500	<100	200	100	100	<100
Cr	-	-	<10	<10	50	1200	2900	300	500	3100
Ni	-	-	<30	<30	40	200	600	100	200	1500
Rb	91 (1)	79 (1)	-	-	-	-	-	-	-	-
Sr	199 (1)	235 (1)	150	200	1500	100	200	300	200	100

A. Leucotonalitic gneiss (Hunter, 1968 - 6 analyses of major elements; 1. Davies, 1971 - 6 analyses for Na, K, Rb, and Sr; Viljoen and Viljoen, 1969 - 2 analyses for Na and K).

B. Hornblende tonalite gneiss (Hunter, 1968 - 2 analyses of major elements; 1. Davies, 1971 - 3 analyses for Na, K, Sr, and Rb).

C. Quartzofeldspathic gneiss (Hunter, 1968 - 2 analyses).

D. Quartz-biotite-garnet gneiss (Hunter, 1968 - 1 analysis).

E. Biotite-hornblende gneiss (Hunter, 1968 - 1 analysis).

F. Cordierite-cummingtonite gneiss (Hunter, 1968 - 1 analysis).

G. Quartz-diopside-plagioclase granulite (Hunter, 1968 - 1 analysis).

H. Amphibolite (Hunter, 1968 - 1 analysis).

I. Diopside-plagioclase granulite (Hunter, 1968 - 1 analysis).

J. Tremolite rock interlayered with I (Hunter, 1968 - 1 analysis).

TABLE XVI

RATIOS OF ELEMENTS IN ROCKS OF THE ANCIENT GNEISS COMPLEX

	A	B	C	D	E	F	G	H	I	J
K/Rb	193	247	-	-	-	-	-	-	-	-
K/Ba	-	-	42	43	22	-	22	53	31	-
Ba/Sr	-	-	4.67	2	0.33	-	1	0.33	0.5	-
Ca/Sr	116	142	20.7	-	22.4	174	275	205	495	685
Fe/Mg	3.1	1.7	5.4	2.5	2.3	0.85	0.84	2.2	3.4	0.53
Fe/Ti	9.5	13	15.5	21.8	9.1	2.5	14.5	18.8	16.7	64.5
K/Na	0.49	0.4	0.9	4.3	0.38	0.77	0.27	0.2	0.11	0.2
Fe/Mn	113	55	93	116	44.4	45	7.5	56.3	24.25	54
FeO/FeO+MgO	0.7	0.68	0.8	0.65	0.64	0.38	0.39	0.64	0.72	0.28
CaO/Al_2O_3	0.21	0.3	0.03	-	0.3	0.19	1.1	0.68	0.87	1.63
Fe_2O_3/FeO	0.3	0.3	1.67	0.15	0.24	0.06	0.13	0.10	0.24	0.51
Fe/Ni	-	-	-	-	777.5	382.5	33.6	845	242.5	43
Mg/Ni	-	-	-	-	330	450	40.3	357	70.5	81

FeO = Total Fe as FeO

For key to rock-types see Table XV.

TABLE XVII

MEAN COMPOSITIONS OF GRANITIC AND ASSOCIATED ROCKS FROM THE EASTERN TRANSVAAL AND SWAZILAND

B. Post-Swaziland Sequence Diapiric and Other Intrusives

	A	B	C	D
Si%	33.35	30.47	26.42	31.80
Ti%	0.11	0.29	0.46	0.29
Al%	7.76	8.03	10.46	8.44
ΣFe%	1.36	3.16	4.51	2.48
Mn	380	300	800	380
Mg%	0.47	1.56	1.51	0.77
Ca%	1.67	3.08	3.83	2.54
Na%	3.98	3.69	3.89	3.40
K%	1.67	1.04	2.29	1.84
P	260	800	1450	750
Ba	-	422 (3)	-	-
Ga	-	10 (2)	-	-
Li	-	23 (3)	-	-
Mo	-	0.97 (2)	-	-
Rb	52 (1)	44 (1,2,3)	-	-
Sc	-	1.8 (2)	-	-
Sn	-	1.5 (2)	-	-
Sr	498 (1)	530 (1,3)	-	-
Pb	-	9.7 (3)	-	-
Tl	-	0.59 (3)	-	-
Zr	-	100 (4)	-	-

A. Leucotonalitic diapirs (Viljoen and Viljoen, 1969 - 3 analyses except for Na and K eleven determinations, Rb and Sr nine determinations).

B. Kaap Valley granite (1. Viljoen and Viljoen, 1969 - 4 analyses, except for Na and K seven determinations and Rb and Sr, one determination; 2. Edge and Ahrens, 1962 - 1 analysis; 3. Kaye et al., 1965 - 1 analysis; 4. Schutte, 1963 - 1 analysis).

C. Quartz diorite, Swaziland (Hunter, 1968 - 2 analyses).

D. Leucotonalite, Swaziland (Hunter, 1968 - 6 analyses).

TABLE XVIII

RATIOS OF ELEMENTS IN POST-SWAZILAND SEQUENCE DIAPIRS AND OTHER INTRUSIVES

	A	B	C	D
K/Rb	320	240	-	-
K/Tl	-	17,600	-	-
K/Ba	-	24	-	-
K/Cs	-	7,420 (1)	-	-
Ba/Rb	-	9.6	-	-
Ba/Sr	-	0.8	-	-
Ca/Sr	33.5	58	-	-
Mg/Li	-	678	-	-
Fe/Mg	2.89	2	2.98	3.2
Fe/Ti	12.4	11	9.9	8.5
K/Na	0.42	0.28	0.74	0.54
FeO/FeO+MgO	0.68	0.61	0.6	0.71

(1) Edge and Ahrens (1962), FeO = Total Fe as Feo

For key to rock-types see Table XVII.

TABLE XIX

MEAN COMPOSITIONS OF GRANITIC AND ASSOCIATED ROCKS FROM THE EASTERN TRANSVAAL AND SWAZILAND

C. Nelspruit Migmatites, Homogeneous Hood Granites, and Plutons

	A	B	C	D	E	F	G
Si%	31.84	34.23	33.29	34.38	32.46	34.36	36.81
Ti%	0.15	0.14	0.22	0.15	0.38	0.15	0.11
Al%	7.48	7.81	7.77	7.26	7.47	7.17	5.95
ΣFe%	1.68	1.66	1.84	1.90	3.05	1.73	1.29
Mn	230	620	385	485	1900	380	460
Mg%	0.36	0.41	0.55	0.17	0.56	0.36	0.18
Ca%	1.82	0.90	1.29	0.68	1.41	1.22	0.40
Na%	3.24	2.92	3.40	2.05	2.32	2.48	1.88
K%	2.83	3.73	3.00	4.38	4.03	4.29	4.02
F%	-	-	-	0.02	-	-	0.04
P	400	1200	610	350	880	400	40
Ba	500 (1)	500 (1)	-	257 (1,4)	-	604 (1,4)	-
Co	-	-	-	4 (4)	-	0.93(4)	-
Cs	-	-	-	28.7 (4)	-	4.2 (4)	-
Hf	-	-	-	3.5 (4)	-	2.4 (4)	-
Li	41 (1)	44 (1)	-	15 (1)	-	44 (1)	-
Nb	-	-	-	23 (4)	-	20 (4)	-
Pb	20 (1)	41 (1)	-	49 (1)	-	52 (1)	-
Rb	108 (1,2)	226 (1,2,5)	109 (2,5)	380 (1,4)	-	295 (1,2,4,5)	-
Sc	-	-	-	2.5 (4)	-	2 (4)	-
Sn	-	-	-	31 (4)	-	4 (4)	-
Sr	287 (1,2)	122 (1,2,5)	488 (2,5)	59 (1,4)	-	132 (1,2,4,5)	-
Th	-	-	-	20.7 (4)	-	31 (4)	-
Tl	0.9 (1)	1.4 (1)	-	1.7 (1)	-	1.5 (1)	-
Zn	-	-	-	62 (4)	-	19 (4)	-
Zr	215 (3)	-	120 (3)	130 (4,6)	-	161 (4)	-

A. Nelspruit migmatites (Viljoen and Viljoen, 1969 - 3 analyses except for Na and K, ten determinations; trace elements 1. Kaye et al., (1965) - 2 analyses; 2. Viljoen and Viljoen (1969) - 5 analyses; 3. Schutte (1963) - 1 analysis).

B. Homogeneous hood granite ± 3.0 b.y. (Major elements - Hunter, 1968, - 5 analyses; Viljoen and Viljoen, 1969 - 1 analysis except for Na and K, 5 determinations; Kaye et al., 1965, - 3 determinations of Ca, Na, and K : trace elements - 1. Kaye et al., 1965, - 3 determinations; 2. Viljoen and Viljoen, 1969 - 2 determinations).

C. Dalmain-type pluton ± 2.9 b.y. (Major elements - Hunter, 1968 - 1 analysis; Viljoen and Viljoen, 1969 - 3 analyses, except for Na and K, 12 determinations : trace elements - 2. Viljoen and Viljoen, 1969 - 9 determinations; 3. Schutte, 1963 - 1 determination; 5. Davies, 1971 - 6 determinations for Na, K, Rb and Sr).

D. Homogeneous hood granite ± 2.6 b.y. (Major elements - Hunter, 1968 - 2 analyses; Fourie, 1969 - 1 analysis; Kaye et al., 1965 - 1 determination of Ca, Na, and K : trace elements - 1. Kaye et al., 1965 - 1 analysis; 4. Fourie, 1969 - 1 analysis; 5. Davies, 1971 - 3 analyses of Na, K, Rb and Sr; 6. Hunter, 1968 - 1 analysis).

E. Kwetta-type pluton ± 2.6 b.y. (Hunter, 1968 - 1 analysis; Visser, 1964 - 1 analysis).

F. Mpageni-type pluton ± 2.6 b.y. (Major elements - Hunter, 1968 - 2 analyses; Fourie, 1969 - 1 analysis; Viljoen and Viljoen, 1969 - 1 analysis except for Na and K, 4 determinations; Kaye et al., 1965 - 1 determination of Ca, Na, and K; Davies, 1971 - 3 analyses for Na and K : trace elements - 1. Kaye et al., 1965 - 1 analysis; 2. Viljoen and Viljoen, 1969 - 1 analysis; 4. Fourie, 1969 - 1 analysis; 5. Davies, 1971 - 3 analyses for Na, K, Rb, and Sr).

G. Mooihoek-type pluton ± 2.6 b.y. (Hunter, 1968 - 2 analyses; Visser, 1964 - 1 analysis).

TABLE XX

RATIOS OF ELEMENTS IN NELSPRUIT MIGMATITES, HOMOGENEOUS HOOD GRANITES AND PLUTONS

	A	B	C	D	E	F	G
K/Rb	262	165	266	115	-	145	-
K/Cs	-	-	-	1,500	-	12,200	-
K/Tl	31,000	28,000	-	26,000	-	28,000	-
Rb/Tl	120	161	-	223	-	197	-
K/Ba	56.6	74	-	170	-	70	-
Ba/Rb	4.6	2.21	-	0.83	-	2.13	-
Ba/Sr	1.74	4	-	4.3	-	4.5	-
Ca/Sr	61	73	26.4	115	-	92.4	-
K/Na	0.87	1.27	0.89	2.08	1.74	1.73	2.13
Th/Kx10^4	-	-	-	4.7	-	7.2	-
Fe/Mg	4.67	4.05	3.34	11.18	5.44	4.8	7.2
Mg/Ti	2.4	2.9	2.5	1.13	1.44	2.4	1.6
Fe/Mn	73	26	48	40	16	45.5	28
Mg/Co	-	-	-	425	-	1,610	-
Fe/Co	-	-	-	4,250	-	17,500	-
Mg/Li	90	90	-	113	-	82	-
Zr/Hf	-	-	-	30	-	67	-
FeO/FeO+MgO	0.77	0.76	0.72	0.89	0.81	0.82	0.84

FeO = Total Fe as FeO

For key to rock-types see Table XIX.

TABLE XXI

RARE EARTH ELEMENT CONTENT OF GRANITES IN KAAPVAAL CRATON

	A		B	C	D	E	F	G	H
	(i)	(ii)							
La	62	15	72	62	64	22	41	121	91
Ce	450	30	100	96	78	37	96	207	125
Nd	-	101	-	-	-	-	-	-	-
Sm	-	2.7	4.7	10.9	11.9	6.7	5.1	12.6	13.7
Eu	-	0.8	0.68	2.3	2.0	0.27	0.69	2.2	1.8
Tb	-	0.41	-	-	-	-	-	-	-
Dy	-	-	0.08	6.5	1.7	3.9	1.6	3.7	6.3
Yb	-	1.2	2.2	3.0	1.1	2.1	1.0	2.0	3
Lu	-	0.21	0.5	0.41	0.53	0.98	0.29	0.20	0.7
Y	34	-	-	-	-	-	-	-	-
ΣREE	-	50.32	180.16	181.11	159.23	72.95	145.68	348.7	251.5

A. (i) Kaap Valley granite (Edge and Ahrens, 1962).
(ii) Kaap Valley granite (Goles, 1968).
B. Granite, Vryburg (Fourie, 1969).
C. Bandoliersdop granite, Pietersburg (Fourie, 1969).
D. Granite, Prieska (Fourie, 1969).
E. Homogeneous hood granite, Pongola River, ± 2.6 b.y. (?) (Fourie, 1969).
F. Mpageni-type pluton, ± 2.6 b.y., Nelspruit (Fourie, 1969).
G. Palala granite (Fourie, 1969).
H. Sekukuni granite composite (Fourie, 1969, and Liebenberg, 1961).

TABLE XXII

MEAN COMPOSITIONS OF TONALITIC GNEISSES, DIAPIRS, QUARTZ DIORITE-TONALITE-ADAMELLITE, AND GRANITIC INTRUSIVES IN THE KAAPVAAL CRATON

	A	B	C	D	E	F	G	H
Si%	32.78	33.35	30.47	27.99	31.80	34.00	34.61	34.38
Ti%	0.20	0.11	0.29	0.38	0.29	0.19	0.13	0.15
Al%	8.28	7.76	8.03	9.43	8.44	7.52	7.50	7.26
ΣFe%	1.94	1.36	3.16	3.40	2.48	1.82	1.51	1.90
Mn	200	380	300	800	400	400	360	485
Mg%	0.66	0.47	1.56	1.80	0.77	0.28	0.33	0.17
Ca%	2.44	1.67	3.08	3.90	2.54	1.13	0.55	0.63
Na%	3.55	3.98	3.69	3.33	3.40	3.15	2.73	2.53
K%	1.43	1.67	1.04	1.79	1.84	3.37	3.65	4.19
P	480	260	800	1325	750	400	750	350
Ba	-	-	422	-	-	621	490	435
Co	-	-	-	-	-	-	4	4
Cs	-	-	-	-	-	-	5	-
Ga	-	-	10	-	-	-	-	-
Hf	-	-	-	-	-	-	3	3.5
Li	-	-	23	-	-	42.6	40	15
Mo	-	-	0.97	-	-	-	-	-
Nb	-	-	-	-	-	-	22	23
Pb	-	-	9.7	-	-	25	34	42
Rb	102	52	44	136	-	295	259	292
Sc	-	-	1.8	-	-	-	3	2.5
Sn	-	-	1.5	-	-	-	2	31
Sr	433	498	534	845	-	233	129	88
Th	-	-	-	-	-	-	14	20
Tl	-	-	0.59	-	-	1.2	1.4	1.6
Zn	-	-	-	-	-	-	48	62
Zr	-	-	100	-	-	150	130	130

A. Leucotonalitic gneisses - mean of column C, Table XII and column A, Table XV.

B. Leucotonalitic diapirs - column A, Table XVII.

C. Mesocratic tonalitic diapir - column B, Table XVII (Kaap Valley granite).

D. Quartz diorite - mean of column B, Table XII and column C, Table XVII.

E. Tonalite - column D, Table XVII.

F. Granodiorite and adamellite - columns E and F, Table XII (3.1 b.y.).

G. Granite - columns B and C, Table XIII and column B, Table XIX (3.0 b.y.).

H. Granite - columns D and E, Table XIII and column D, Table XIX (2.6 b.y.).

TABLE XXIII

RATIOS OF ELEMENTS IN TONALITIC GNEISSES, DIAPIRS, QUARTZ DIORITE-TONALITE-ADAMELLITE, AND GRANITIC INTRUSIVES IN THE KAAPVAAL CRATON

	A	B	C	D	E	F	G	H
K/Rb	140	320	-	132	-	114	141	143
K/Tl	-	-	17,600	-	-	28,000	26,000	26,000
Rb/Tl	-	-	74.5	-	-	245	185	182
K/Ba	-	-	24	-	-	54	74.5	95
Ba/Rb	-	-	9.6	-	-	2.1	1.5	1.5
Ba/Sr	-	-	0.8	-	-	2.7	3.8	4.0
Ca/Sr	56	33.5	58	46	-	48.5	42.8	71.6
K/Na	0.40	0.42	0.28	0.54	0.54	1.07	1.34	1.65
Fe/Mg	3	2.9	2	2	3.2	6.5	4.6	4.6
Mg/Ti	3.3	4.3	5.3	4.7	2.6	1.4	2.6	1.1
Zr/Hf	-	-	-	-	-	-	42	30
Mg/Li	-	-	670	-	-	66	82	113
FeO/FeO+MgO	0.7	0.68	0.61	0.6	0.71	0.83	0.78	0.89

FeO = Total Fe as FeO

For key to rock-types see Table XXII.

TABLE XXIV

MEAN COMPOSITIONS OF GRANITE PLUTONS IN THE KAAPVAAL CRATON

	A	B	C	D	E	F	G
Si%	32.65	32.46	34.36	36.81	35.54	34.64	35.25
Ti%	0.29	0.38	0.15	0.11	0.21	0.17	0.13
Al%	7.32	7.47	7.17	5.95	6.86	6.44	6.45
ΣFe%	2.36	3.05	1.73	1.29	2.02	2.65	2.42
Mn	490	1900	380	460	910	500	635
Mg%	0.48	0.56	0.36	0.18	0.37	0.28	0.14
Ca%	1.33	1.41	1.22	0.40	1.01	0.91	0.72
Na%	3.10	2.32	2.48	1.88	2.23	2.21	2.39
K%	3.40	4.03	4.29	4.02	4.11	4.01	4.09
P	490	880	400	40	440	650	131
Ba	1400	-	604	-	-	830	963
Co	12.5	-	0.9	-	-	<10	2.1
Cr	-	-	-	-	-	29	17
Cs	4.5	-	4.2	-	-	3.0	3.5
Cu	-	-	-	-	-	19	7.6
Ga	-	-	-	-	-	33	19
Hf	5	-	2.4	-	-	5.8	6.1
Li	-	-	44	-	-	39	20
Nb	38	-	20	-	-	33	22
Pb	-	-	52	-	-	58	22/53
Rb	130	-	295	-	-	313	215
Sc	5.8	-	2	-	-	<10	2.2
Sn	2	-	4	-	-	6	3
Sr	424	-	132	-	-	103	66
Th	10	-	31	-	-	21	24
Tl	-	-	1.5	-	-	-	1.1
V	-	-	-	-	-	20	3
Zn	47	-	19	-	-	48	84
Zr	240	-	161	-	-	450	354

A. Dalmein-type pluton, mean of columns F and G, Table XIII, and column C, Table XIX.

B. Kwetta-type pluton, column E, Table XIX.

C. Mpageni-type pluton, column F, Table XIX.

D. Mooihoek-type pluton, column G, Table XIX.

E. Mean composition of 2.6 b.y. plutons in columns B, C, and D of this table.

F. Palala-type pluton, mean of columns D and E, Table I.

G. Sekukuni-type pluton, column A, Table I.

TABLE XXV

RATIOS OF ELEMENTS IN GRANITE PLUTONS IN THE KAAPVAAL CRATON

	A	B	C	D	F	G
K/Rb	263	-	145	-	128	180
K/Cs	7,500	-	10,200	-	13,360	11,700
K/Ba	24	-	70	-	48	41.4
Ba/Rb	10.9	-	2.1	-	2.65	4.5
Ba/Sr	3.3	-	4.5	-	8	16.6
Ca/Sr	31	-	92.4	-	88	110
K/Na	1.1	1.74	1.73	2.13	1.81	1.79
Fe/Mg	4.9	5.4	4.8	7.2	9	17.3
Mg/Li	-	-	82	-	72	70
Zr/Hf	48	-	67	-	75	58
FeO/FeO+MgO	0.79	0.81	0.82	0.84	0.88	0.93

FeO = Total Fe as FeO

For key to rock-types see Table XXIV.

TABLE XXVI

MEAN COMPOSITIONS OF GRANITIC EVENTS IN THE KAAPVAAL CRATON

	A	B	C	D	E	F	G	H	I	J	K
Si%	32.78	28.21	31.91	31.26	34.61	32.65	34.38	35.54	34.64	35.25	33.65
Ti%	0.20	0.34	0.20	0.29	0.13	0.29	0.15	0.21	0.17	0.13	0.20
Al%	8.28	8.32	7.89	8.46	7.50	7.32	7.26	6.86	6.44	6.45	7.38
ΣFe%	1.94	5.31	2.26	2.57	1.51	2.36	1.90	2.02	2.65	2.42	2.18
Mn	200	-	340	500	360	490	485	910	500	635	500
Mg%	0.66	3.44	1.01	0.95	0.33	0.48	0.17	0.37	0.28	0.14	0.49
Ca%	2.44	4.32	2.37	2.52	0.55	1.33	0.63	1.01	0.91	0.72	1.39
Na%	3.56	2.36	3.83	3.29	2.73	3.10	2.53	2.23	2.21	2.39	2.87
K%	1.43	0.96	1.35	2.33	3.65	3.40	4.19	4.11	4.01	4.09	3.17
P	480	-	530	825	750	490	350	440	650	130	500
Ba	-	-	400	600	490	1400	435	600	830	960	685
Co	-	-	-	-	4	12.5	4	0.9	<10	2.1	4.7
Cs	-	-	-	-	5	4.5	-	4.2	3	3.5	4.6
Hf	-	-	-	-	3	5	3.5	2.4	5.8	6.1	4.3
Li	-	-	23	42	40	-	15	44	39	20	32
Nb	-	-	-	-	22	38	23	20	33	22	29
Pb	-	-	10	25	34	-	42	52	58	53	39
Rb	102	-	48	210	259	130	292	295	313	215	207
Sc	-	-	1.8	-	3	5.8	2.5	2	<10	2.2	2.9
Sr	433	-	518	539	129	424	88	132	103	66	270
Th	-	-	-	-	14	10	20	31	21	24	20
Tl	-	-	0.59	-	1.4	-	1.6	1.5	-	1.1	1.2
Zn	-	-	-	-	48	47	62	19	48	84	51
Zr	-	-	100	150	130	240	130	161	450	354	214

A. 3.35 b.y. granitic event (column A, Table XXII).

B. Mean composition of 3.4 b.y. terrain (mean of column A, Table XXII, column B, Table XV and amphibolite H1247 [Hunter, 1968]).

C. 3.31 b.y. granitic event (mean of columns B and C, Table XXII).

D. 3.1 b.y. granitic event (mean of columns D, E, and F, Table XXII).

E. 3.0 b.y. granitic event (column G, Table XXII).

F. 2.9 b.y. granitic event (column A, Table XXIV).

G. 2.6-2.7 b.y. granitic event (hood type) (column H, Table XXII).

H. 2.6 granitic event (plutons) (column E, Table XXIV).

I. 2.3 granitic event (column F, Table XXIV).

J. 2.0 granitic event (column A, Table I).

K. Mean composition of granitic rocks in previous columns (excluding column B).

TABLE XXVII

RATIOS OF ELEMENTS IN GRANITIC ROCKS OF THE KAAPVAAL CRATON

	A	C	D	E	F	G	H	I	J	K
K/Rb	140	281	111	141	263	143	140	128	180	153
K/Cs	-	-	-	7,300	7,550	-	9,800	13,360	11,700	6,900
K/Ba	-	34	39	71.5	24	95	68.5	48	41.4	46
Ba/Rb	-	8	3	1.5	10.9	1.5	2	2.65	4.5	3.3
Ba/Sr	-	0.77	1.1	3.8	3.3	4	4.5	8	16.6	2.5
Ca/Sr	56	45	46.7	42.8	31	71.6	76.5	88	110	51
K/Na	0.40	0.35	0.71	1.34	1.1	1.65	1.84	1.81	1.79	1.1
Fe/Mg	3	2.2	2.7	4.6	4.9	4.6	5.4	9	17.3	4.4
Mg/Ti	3.3	5	3	2.6	1.6	1.1	1.8	1.53	1.1	2.4
Mg/Li	-	440	226	82	-	113	84	72	70	153
Zr/Hf	-	-	-	42	48	30	67	75	58	50
FeO/FeO+MgO	0.7	0.64	0.67	0.78	0.79	0.89	0.88	0.88	0.93	0.77

FeO = Total Fe as FeO.

For key to rock-types see Table XXVI.

TABLE XXVIII

MEAN COMPOSITIONS OF GRANITIC ROCKS IN THE KAAPVAAL CRATON, ACCORDING TO THEIR TECTONIC SETTING

	A	B	C	D	E	F	G	H	I
Si%	31.73	34.5	34.36	33.65	33.48	31.3	31.4	33.3	34.7
Ti%	0.24	0.14	0.20	0.20	0.19	0.34	0.34	0.23	0.12
Al%	8.24	7.38	6.80	7.38	7.06	8.31	8.20	7.78	7.2
ΣFe%	2.36	1.70	2.25	2.18	2.42	2.94	2.96	2.52	1.42
Mn	410	420	727	500	540	600	540	400	390
Mg%	0.92	0.25	0.33	0.49	0.32	0.95	0.94	0.33	0.16
Ca%	2.48	0.59	0.99	1.39	0.91	2.54	2.53	1.43	0.51
Na%	3.53	2.63	2.40	2.87	3.07	2.85	2.84	2.63	2.58
K%	1.83	3.92	3.97	3.17	3.95	2.55	2.52	3.47	4.20
P	670	550	430	500	500	920	920	700	600
Ba	510	460	950	685	650	500	420	600	840
Co	-	4	5	4.7	<10-21	10	7	2	1
Cs	-	5	4	4.6	-	4	2	5	4
Hf	-	3	5	4.3	-	3	2.3	4	3.9
Li	32	27	34	32	29	25	24	30	40
Nb	-	22	26	29	91	20	20	20	21
Pb	17	38	54	39	32	15	15	30	19
Rb	117	275	238	207	195	110	110	145	170
Sc	1.8	2.5	3.1	2.9	<10-18	14	14	6	7
Sr	550	108	181	272	170	440	440	285	100
Th	-	17	21.5	20	-	10	8.5	17	17
Tl	1.0	1.5	1.3	1.2	-	0.9	0.72	1	2.3
Zn	-	55	50	51	-	-	60	-	39
Zr	125	120	300	214	390	140	140	180	175

A. Mean composition of tonalitic gneisses, diapirs, and differentiated suites (columns A to F, Table XXII).

B. Mean composition of granites (columns G and H, Table XXII).

C. Mean composition of plutons (columns A to D, F, and F, Table XXIV).

D. Mean composition, Kaapvaal granitic rocks (column K, Table XXVI).

E. Mean composition of African acid rocks (Rooke, 1970).

F. Mean composition, granodiorite (Taylor, 1968).

G. Mean composition, high calcium granite (Turekian and Wedepohl, 1961).

H. Mean composition, granite (Taylor, 1968).

I. Mean composition, low calcium granite (Turekian and Wedepohl, 1961).

TABLE XXIX

RATIOS OF ELEMENTS IN GRANITIC ROCKS OF THE KAAPVAAL CRATON ACCORDING TO THEIR TECTONIC SETTING

	A	B	C	D	E	F	G	H	I
K/Rb	156	150	175	153	200	230	230	240	247
K/Cs	-	7,540	9,700	6,900	-	6,380	12,600	6,940	10,500
K/Ba	35	85	42	46	61	51	60	58	50
Ba/Rb	4.4	1.8	3	3.3	3.3	4.5	3.8	4.1	5
Ba/Sr	0.9	4.3	5.2	2.5	3.8	1.14	0.95	2.1	8.4
Ca/Sr	45	55	53	51	53.5	57.7	57	50.4	51
Rb/Sr	0.21	2.5	1.3	0.79	1.14	0.25	0.25	0.51	1.7
K/Na	0.5	1.4	1.74	1.1	1.28	0.9	0.9	1.32	1.62
Fe/Mg	2.6	6.8	6.8	4.4	7.56	3.1	3.15	7.6	8.9
Mg/Ti	4	1.8	1.6	2.4	1.6	2.8	2.8	1.4	1.33
Mg/Li	280	92	97	153	82	380	390	110	40
Zr/Hf	-	40	62.5	50	-	47	60	45	45

For key to rock-types see Table XXVIII.

TABLE XXX

MEAN RARE EARTH ELEMENT CONTENT OF KAAPVAAL GRANITES AND ACID EXTRUSIVES

	A	B	C	D	E	F	G	H
La	61	63	57	142	50	43	49	56
Ce	96	103	104	277	100	83	97	91
Sm	8.5	9	11.7	21.6	8.3	8.5	7.2	8.5
Eu	1.22	2.1	1.8	0.2	1.1	2.0	1.25	1.39
Dy	2.97	5.3	5.03	8	-	-	-	-
Yb	1.95	2.3	2.7	3.3	4.8	3.25	3.5	4.6
Lu	0.48	0.51	0.7	0.7	0.78	0.54	0.52	0.72
ΣREE	173.12	185.21	182.93	452.8	164.98	150.29	158.47	162.21

A. Kaapvaal granite composite (Table XXI, columns A(ii) to H).

B. Granophyres in Bushveld Complex (Table VI, columns A to D and column H).

C. Felsites, Bushveld Complex (Table XI, column A).

D. Granophyric granite porphyry and quartz porphyry (Table VI, columns E and I).

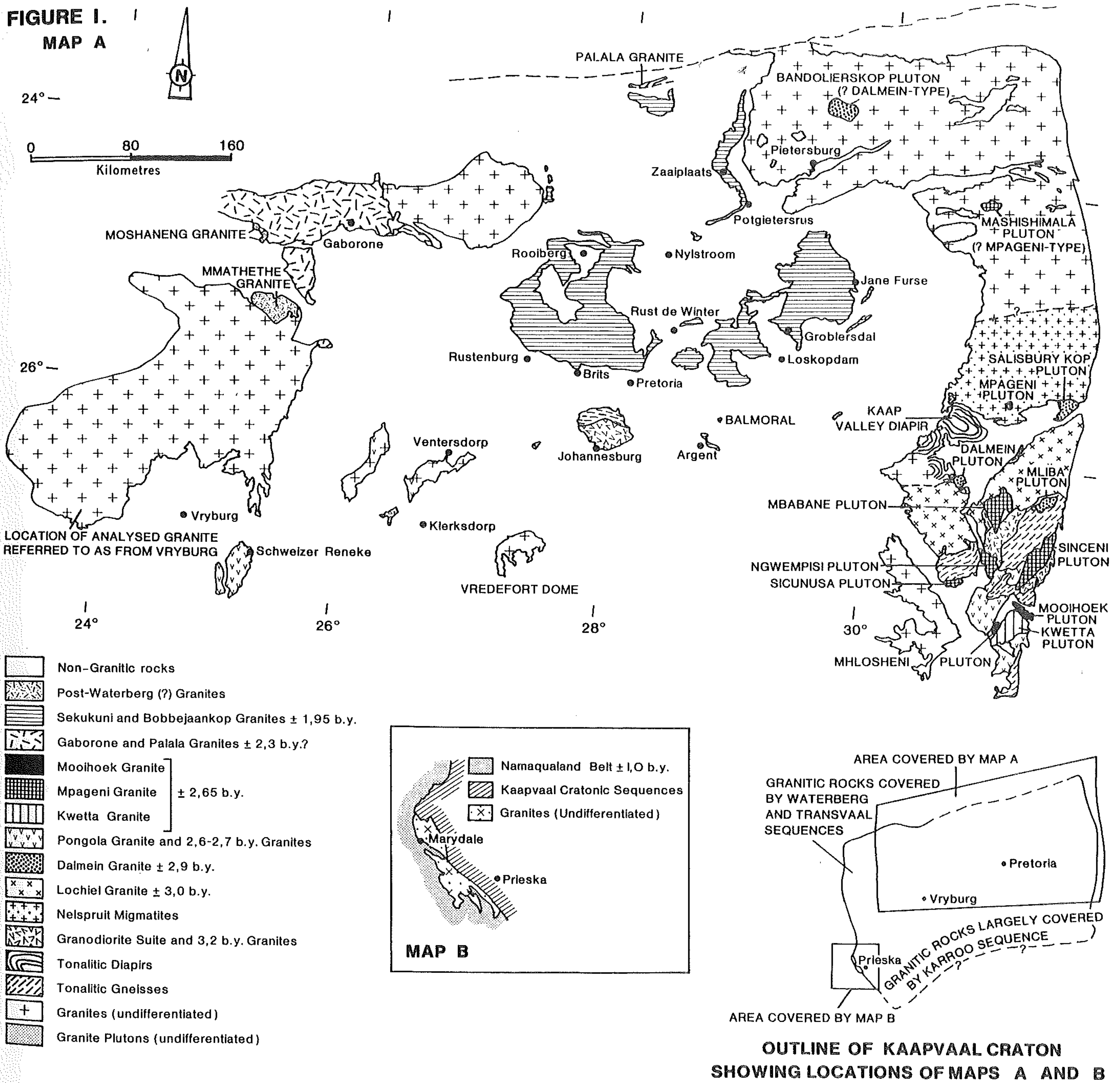
E. Granite >70% SiO_2 (Haskin et al., 1968).

F. Granite 60-70% SiO_2 (Haskin et al., 1968).

G. North American Precambrian granites (Haskin et al., 1968).

H. Rhyolites (Haskin et al., 1968).

FIGURE I.


MAP A
N
24°
26°
28°
30°
0
80
160
Kilometres
PALALA GRANITE
BANDOLIERSKOP PLUTON
(? DALMEIN-TYPE)
Pietersburg
Zaaiplaats
Potgietersrus
MOSHANENG GRANITE
Gaborone
MMATHETHE GRANITE
Rooiberg
Nylstroom
Jane Furse
MASHISHIMALA PLUTON
(? MPAGENI-TYPE)
Rust de Winter
Groblersdal
Loskopdam
Rustenburg
Brits
Pretoria
SALISBURY KOP PLUTON
MPAGENI PLUTON
KAAP VALLEY DIAPIR
BALMORAL
Ventersdorp
Johannesburg
Argent
DALMEIN PLUTON
MLIBA PLUTON
MBABANE PLUTON
Vryburg
Klerksdorp
LOCATION OF ANALYSED GRANITE REFERRED TO AS FROM VRYBURG
Schweizer Reneke
VREDEFORT DOME
NGWEMPISI PLUTON
SICUNUSA PLUTON
SINCENI PLUTON
MOOIHOEK PLUTON
KWETTA PLUTON
MHLOSHENI PLUTON
Non-Granitic rocks
Post-Waterberg (?) Granites
Sekukuni and Bobbejaankop Granites ± 1,95 b.y.
Gaborone and Palala Granites ± 2,3 b.y.?
Mooihoek Granite
Mpageni Granite
Kwetta Granite
± 2,65 b.y.
Pongola Granite and 2,6-2,7 b.y. Granites
Dalmein Granite ± 2,9 b.y.
Lochiel Granite ± 3,0 b.y.
Nelspruit Migmatites
Granodiorite Suite and 3,2 b.y. Granites
Tonalitic Diapirs
Tonalitic Gneisses
Granites (undifferentiated)
Granite Plutons (undifferentiated)
Namaqualand Belt ± I,O b.y.
Kaapvaal Cratonic Sequences
Granites (Undifferentiated)
Marydale
Prieska
MAP B
AREA COVERED BY MAP A
GRANITIC ROCKS COVERED BY WATERBERG AND TRANSVAAL SEQUENCES
Pretoria
Vryburg
Prieska
GRANITIC ROCKS LARGELY COVERED BY KARROO SEQUENCE
AREA COVERED BY MAP B
OUTLINE OF KAAPVAAL CRATON SHOWING LOCATIONS OF MAPS A AND B

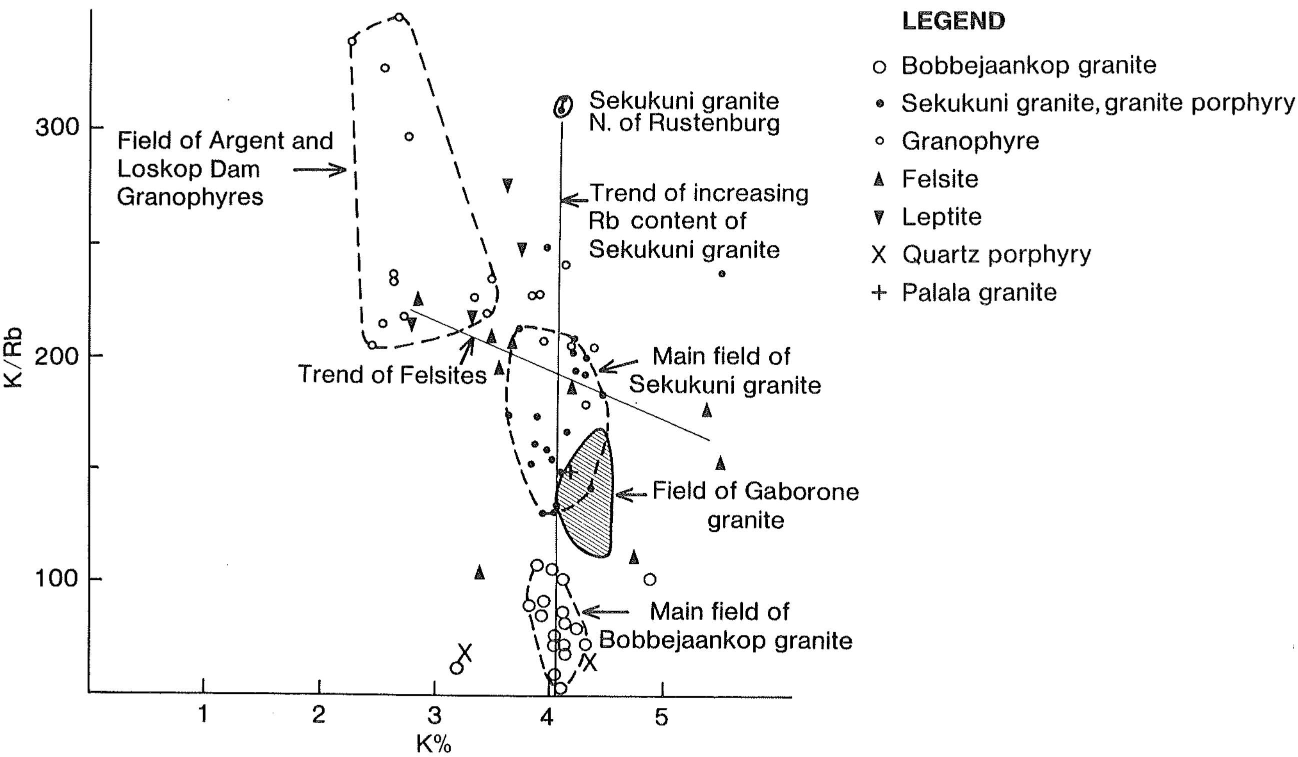


Figure 2. Abundance of K plotted against K/Rb for the Sekukuni, Bobbejaankop, Palala, and Gaborone granites, and various acid rocks associated with the Bushveld Complex. Field of Gaborone granite from Wright's (1961) data.

● 1. Sekukuni granite
2. Sekukuni granite (Zaaiplaats)
3. Bobbejaankop granite
4. Palala granite
5. Gaborone granite
6. Sekukuni granite (Rustenburg)
7. Sekukuni granite (Brits)
8. Sekukuni granite (Argent)

X 1. Mean Felsite
2. Type i Felsite
3. Type ii Felsite
4. Type iii Felsite
5. Felsite (Liebenberg, 1961)
6. Felsite (Groblersdal)
7. Felsite (Rooiberg)
8. Felsite (Rust-de-Winter)

○ 1. Mesocratic tonalite (Johannesburg)
2. Leuco-tonalite (Johannesburg)
3. K-rich leuco-tonalite (Johannesburg)
4. Adamellite (Johannesburg)
5. "Castle Kop" Adamellite (Johannesburg)
6. Granite (Ventersdorp)
7. Granite (Vryburg)
8. Granite 3,0 b.y. (Klerksdorp)
9. Granite 2,7 b.y. (Klerksdorp)
10. Granite (Schweizer Renecke) 2,7 b.y.
11. Granite (Pietesburg)
12. Granite (Prieska)
13. Kaap Valley granite ± 3, 3 b.y.
14. Tonalitic diapir (Barberton)
15. Nelspruit migmatites
16. Lochiel granite ± 3, 0 b.y.
17. Dalmein granite ± 2, 9 b.y.
18. Pongola granite ± 2, 6 b.y.
19. Mpageni granite ± 2, 6 b. y.
20. Tonalitic gneiss (Swaziland) ± 3, 3 b. y.
21. Mesocratic tonalitic gneiss (Swaziland)
22. Marydale
23. Marydale

▲ 1. Granophyre (Zaaiplaats)
2. Granophyre (Rooiberg)
3. Granophyre (Pretoria)
4. Granophyre (Argent)
5. Granite porphyry (Rust-de-Winter)
6. Granophyre (Sekhukhuniland)
7. Granophyre (Olifants River)
8. Granophyre (Jane Furse)
9. Quartz porphyry (Nylstroom)
10. Granophyre (Loskop Dam)

+ 1. Leptite (Loskop Dam)
2. Leptite (Jane Furse)
3. Leptite (Pretoria)

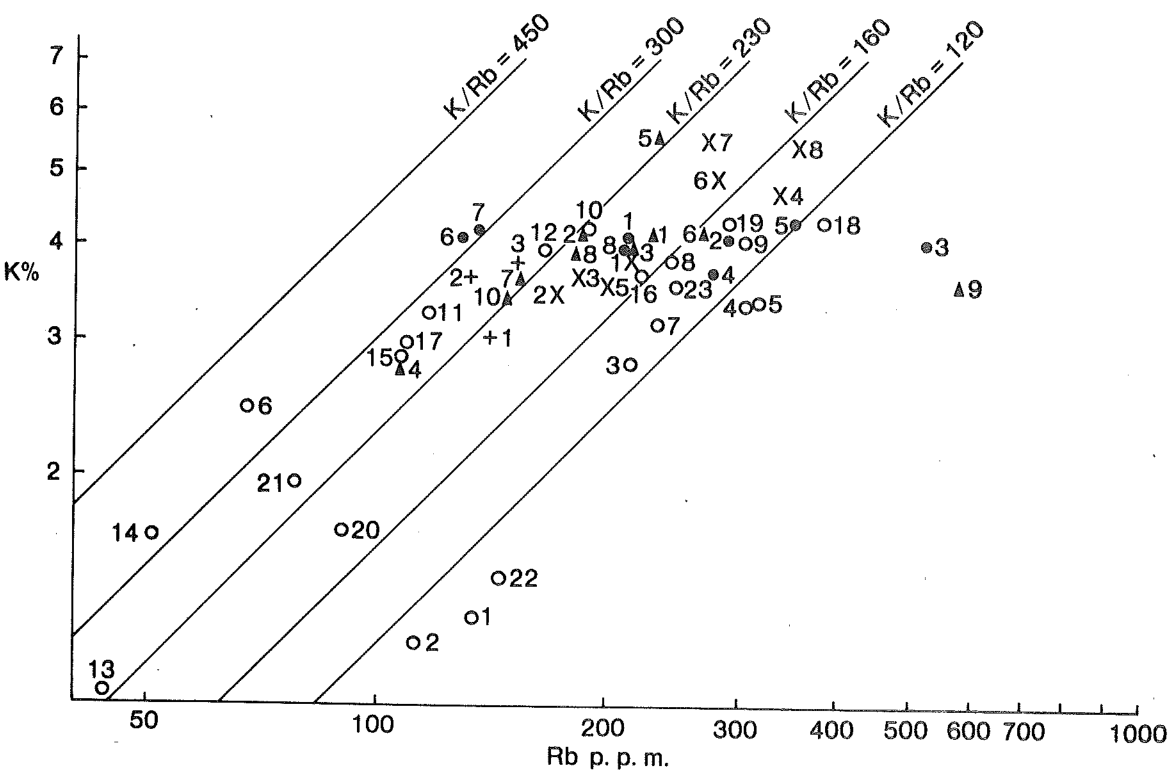


Figure 3. Abundances of K plotted against Rb for granitic and associated acid rocks in the Kaapvaal craton. Note: the names Lochiel and Pongola granites are the suggested names for the homogeneous, hood-type, biotite-microcline granites emplaced at ±3, 0 b. y. and ±2, 6 b. y. respectively in the Eastern Transvaal and Swaziland.

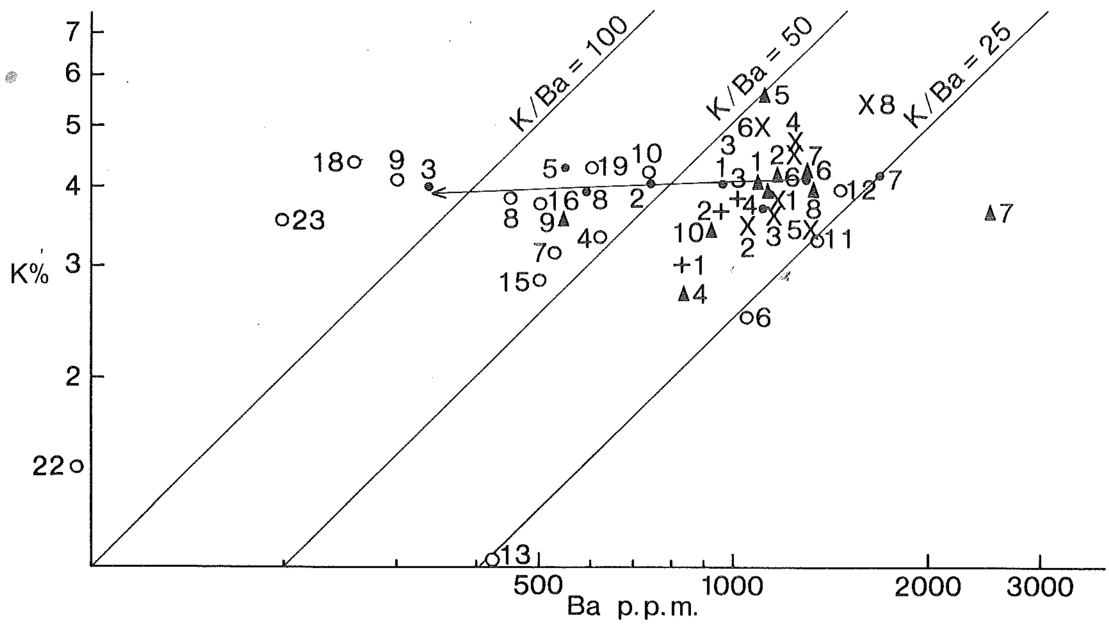


Figure 4. Abundances of K plotted against Ba for granitic and associated acid rocks in the Kaapvaal craton. For key to legend see Figure 3.

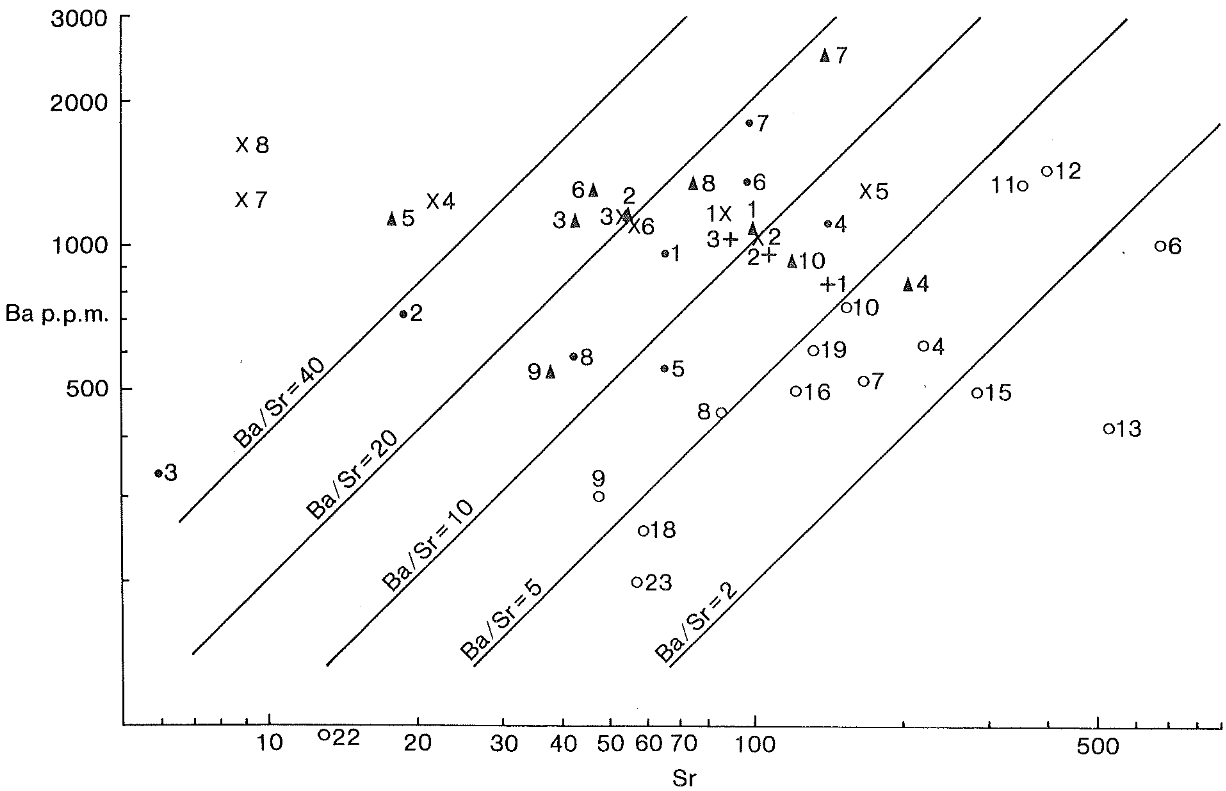


Figure 5. Abundances of Ba plotted against Sr for granitic rocks and associated acid rocks in the Kaapvaal craton. For key to legend see Figure 3.

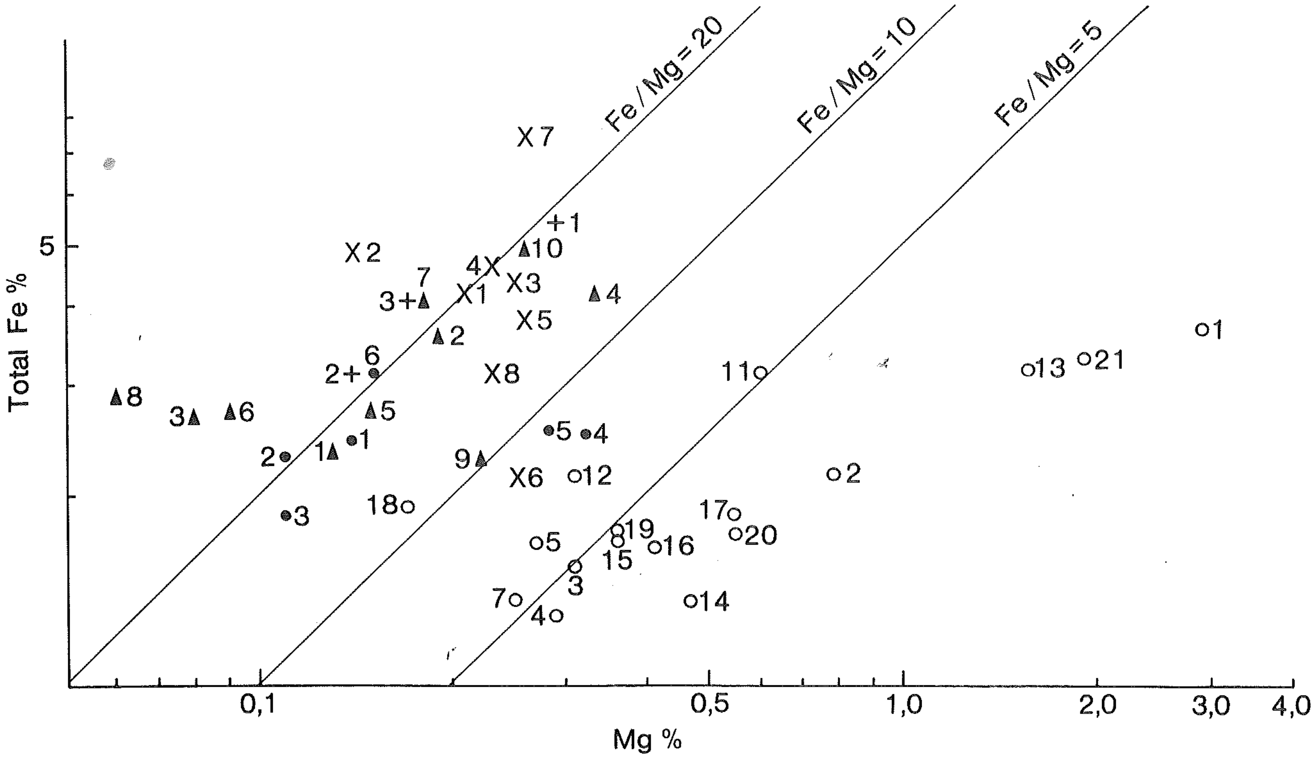


Figure 6. Abundances of total Fe plotted against Mg for granitic and associated acid rocks in the Kaapvaal craton. For key to legend see Figure 3.

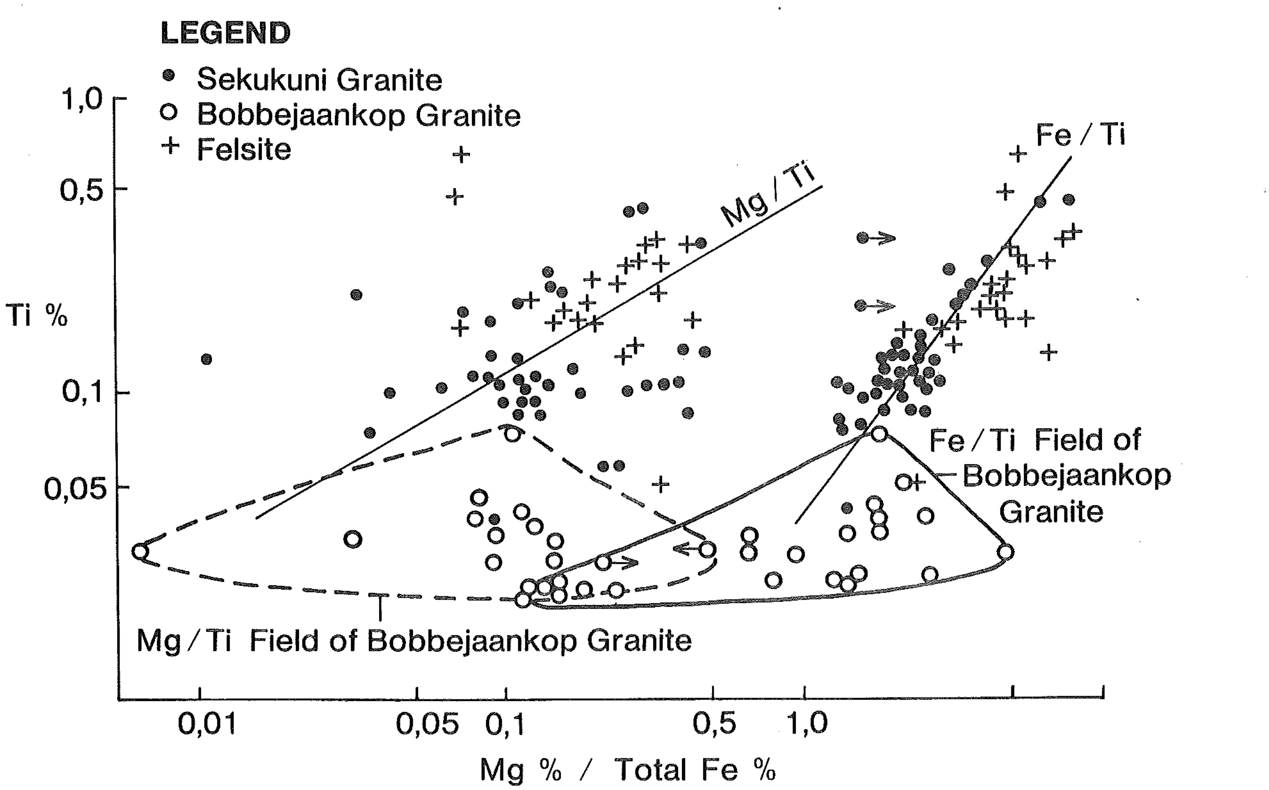


Figure 7. Abundances of Ti plotted against Mg and total Fe for the felsites of the Bushveld Complex and the Sekukuni and Bobbejaankop granites.

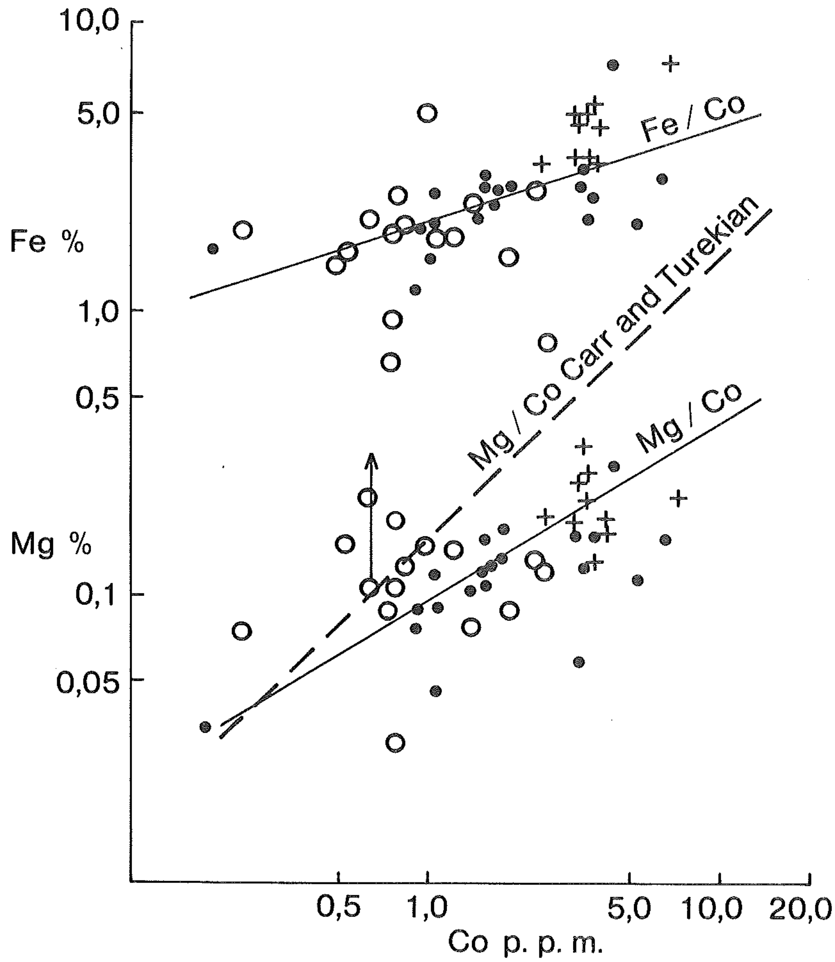


Figure 8. Abundances of total Fe and Mg plotted against Co for the felsites of the Bushveld Complex and the Sekukuni and Bobbejaankop granites.

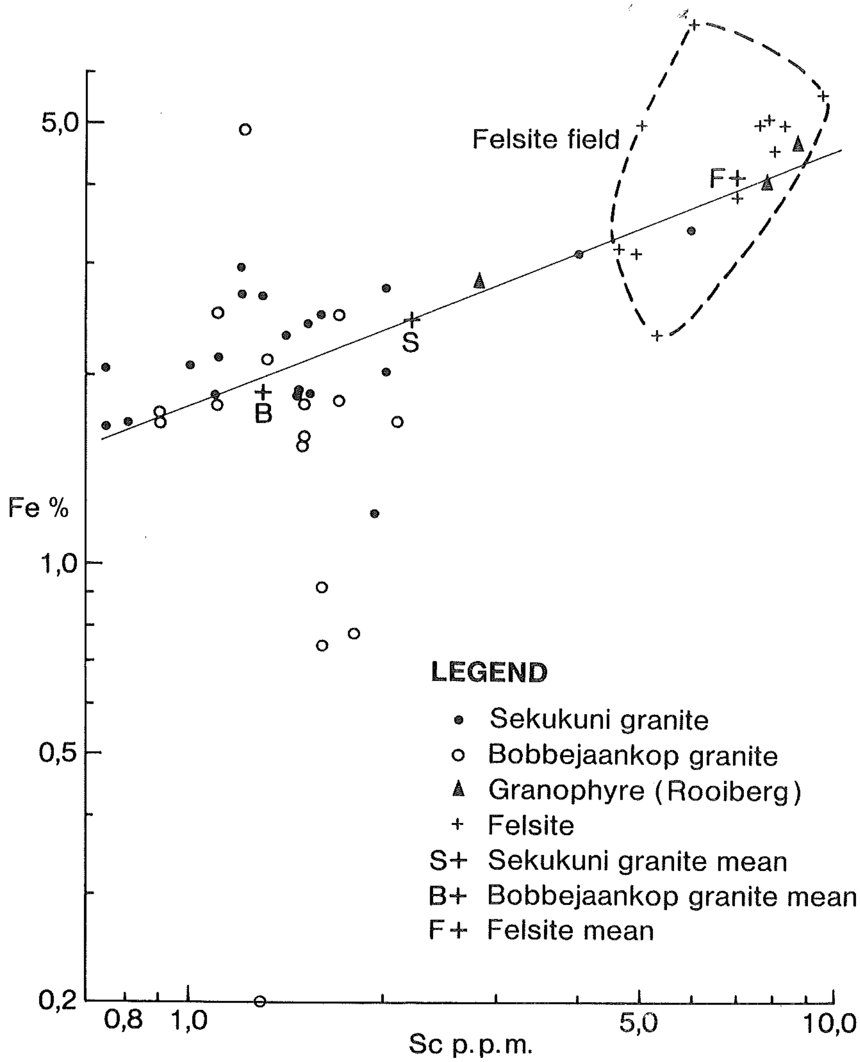


Figure 9. Abundances of total Fe plotted against Sc for the felsites of the Bushveld Complex and the Sekukuni and Bobbejaankop granites.

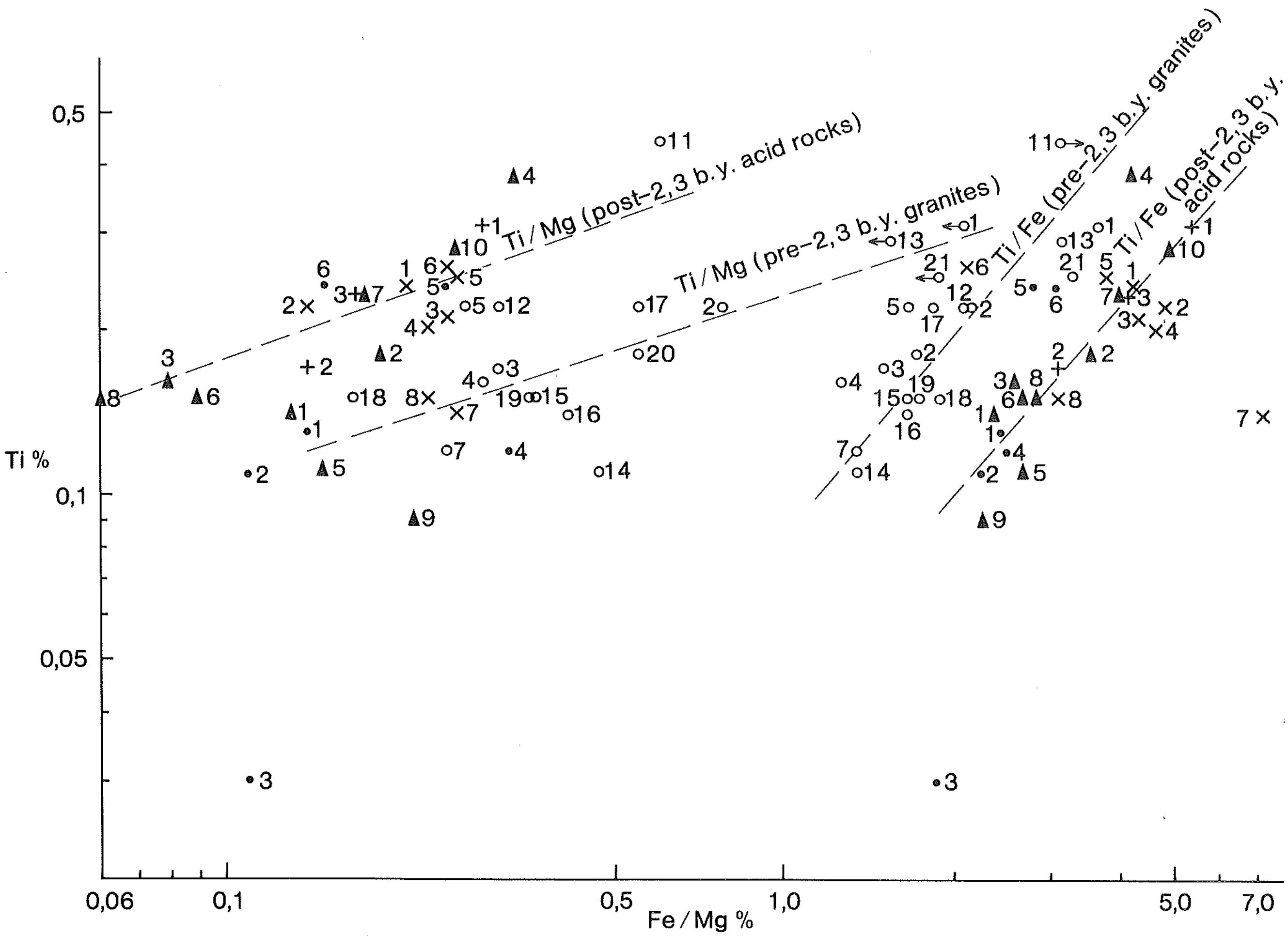


Figure 10. Abundances of Ti plotted against Mg and total Fe for granitic and associated volcanic rocks in the Kaapvaal craton. For key to legend see Figure 3.

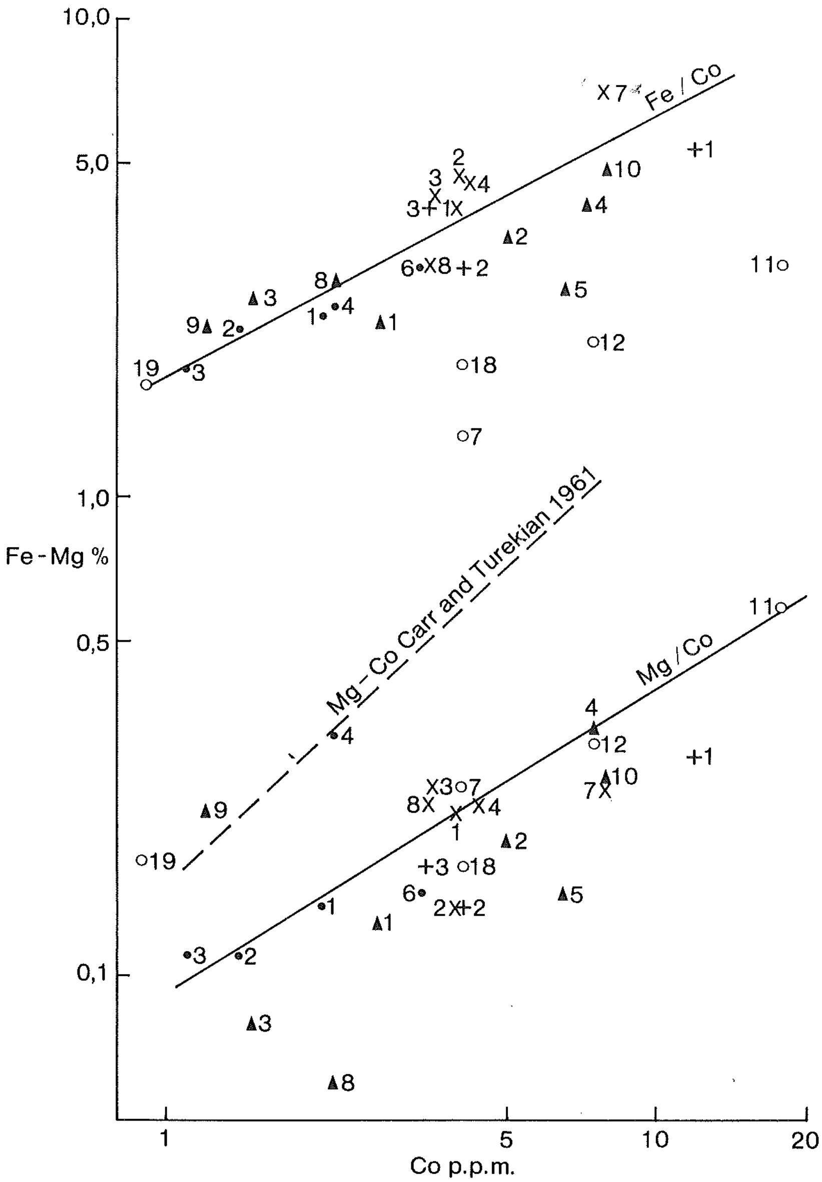


Figure 11. Abundances of total Fe and Mg plotted against Co for granitic and associated volcanic rocks in the Kaapvaal craton. For key to legend see Figure 3.

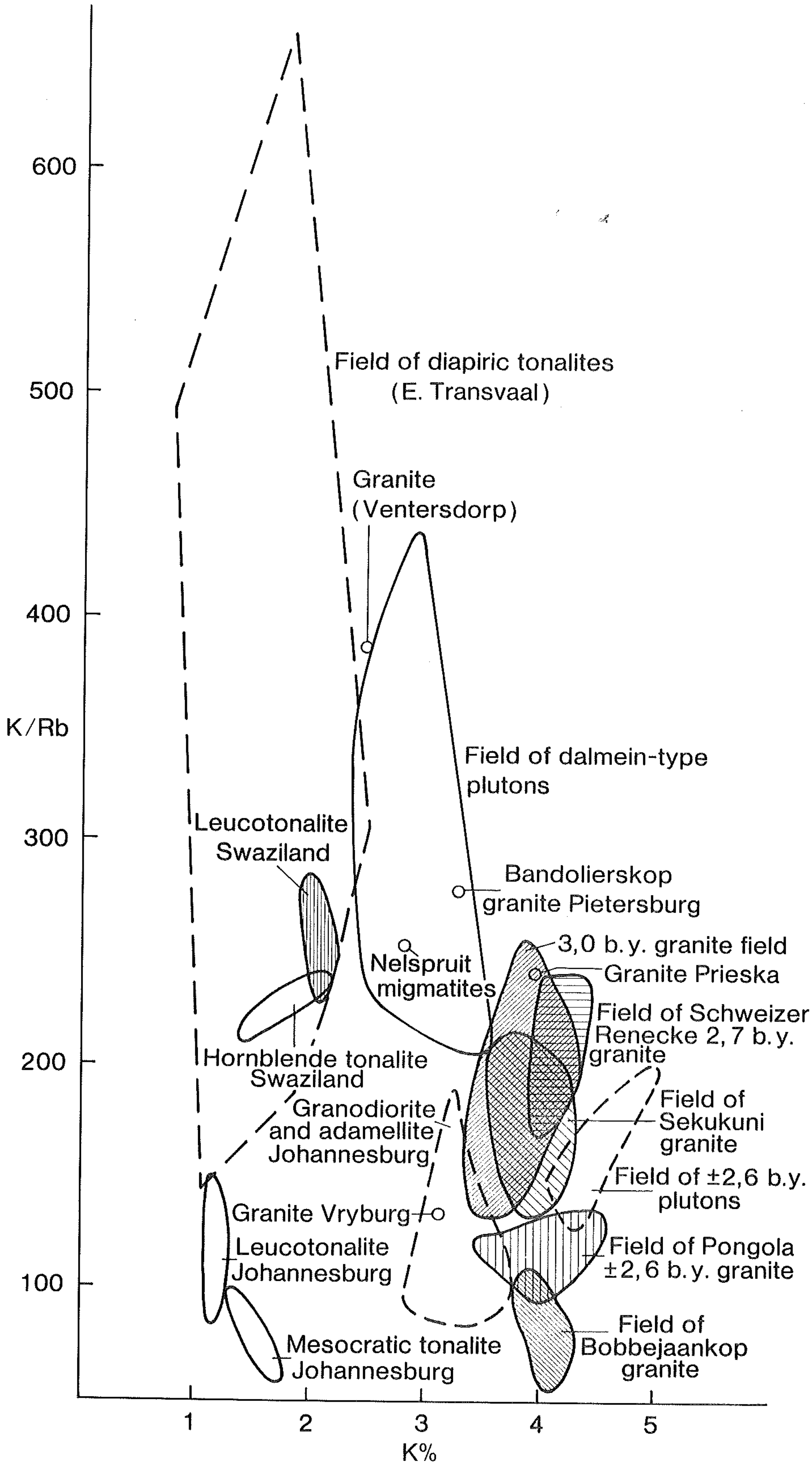


Figure 12. Abundance of K plotted against K/Rb for granitic rocks in the Kaapvaal craton.

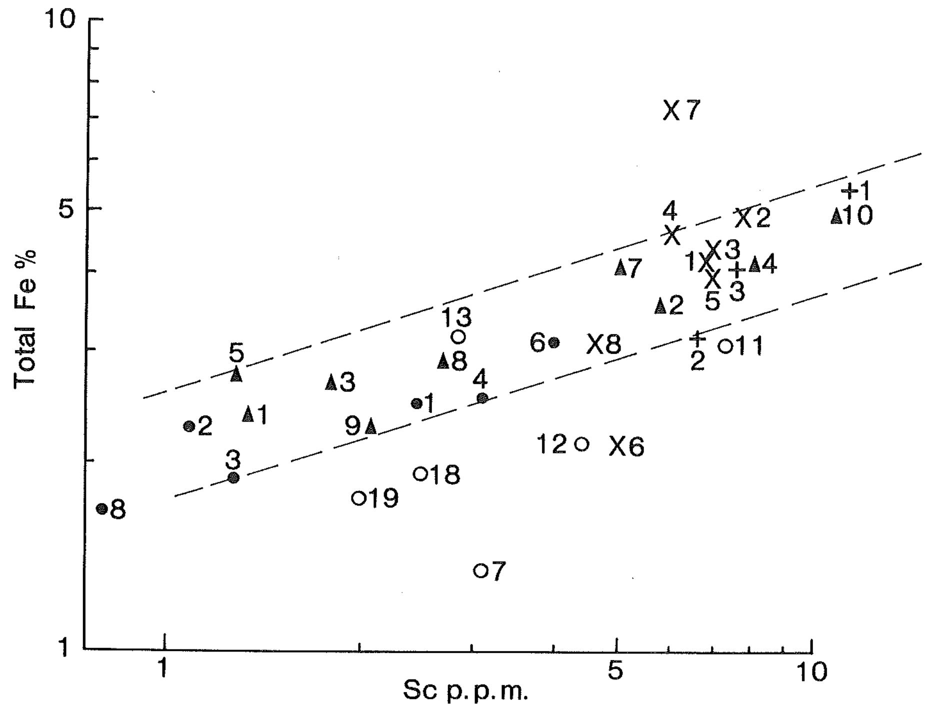


Figure 13. Abundances of total Fe plotted against Sc for granitic and associated rocks in the Kaapvaal craton. For key to legend see Figure 3.

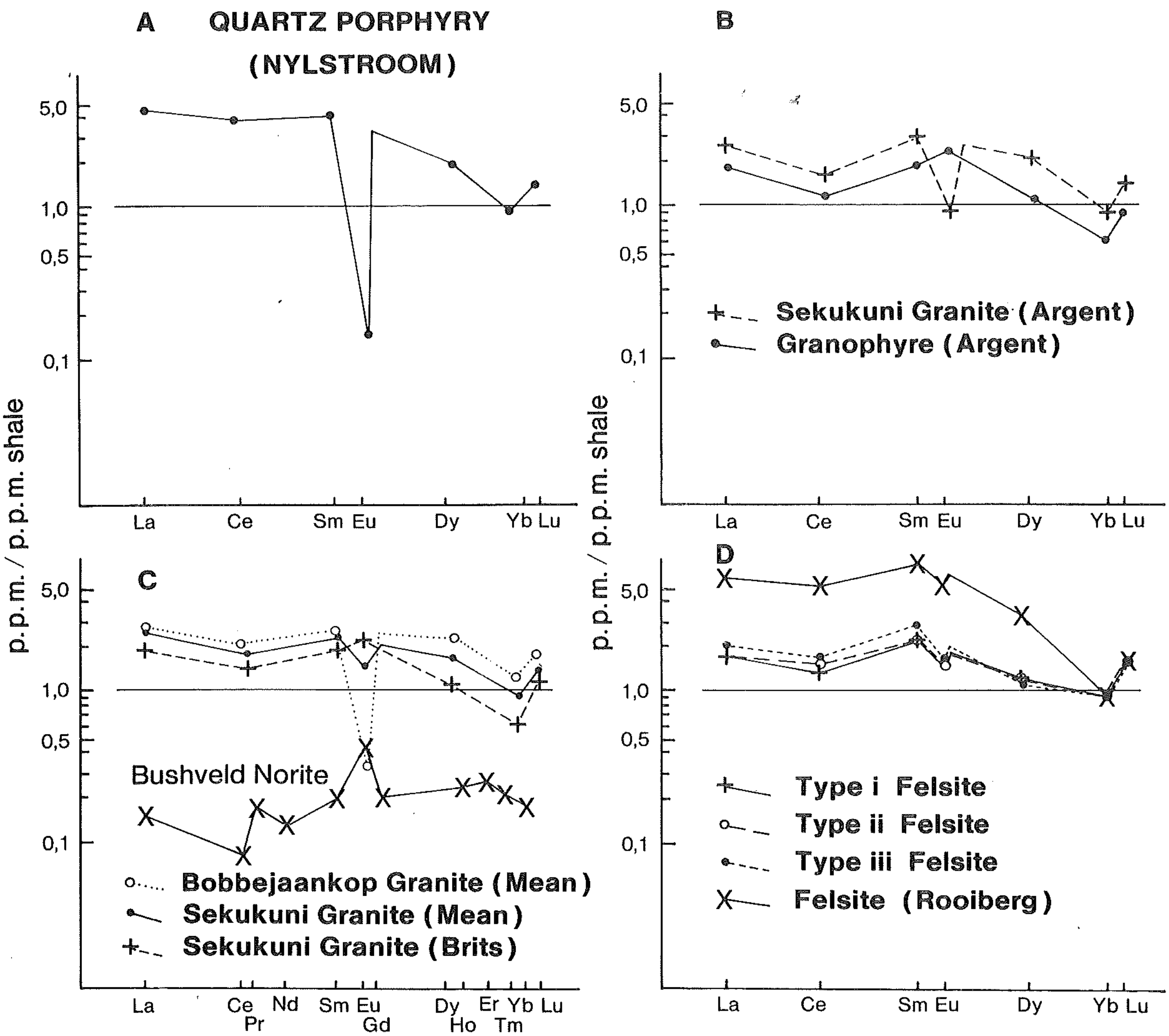


Figure 14. Rare earth abundance patterns of acid rocks of Bushveld Complex ratioed element by element to the North American shale abundances (Haskin et al, 1968). Data for Bushveld norite from Haskin et al (1966).

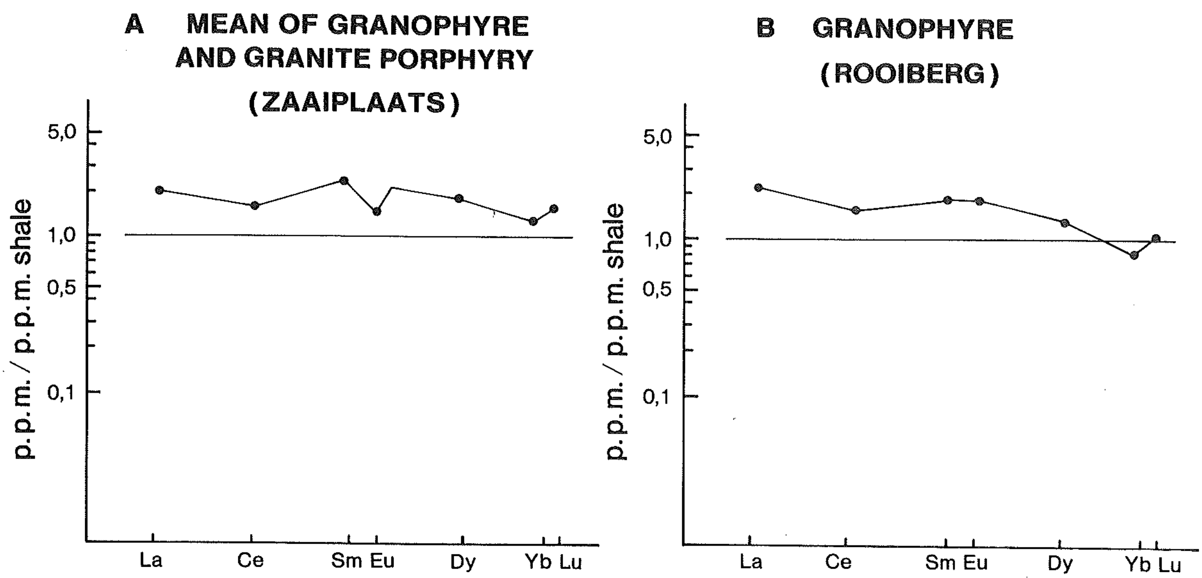


Figure 15. Rare earth abundance patterns of granophyre and granite porphyry ratioed element by element to the North American shale abundances (Haskin et al, 1968).

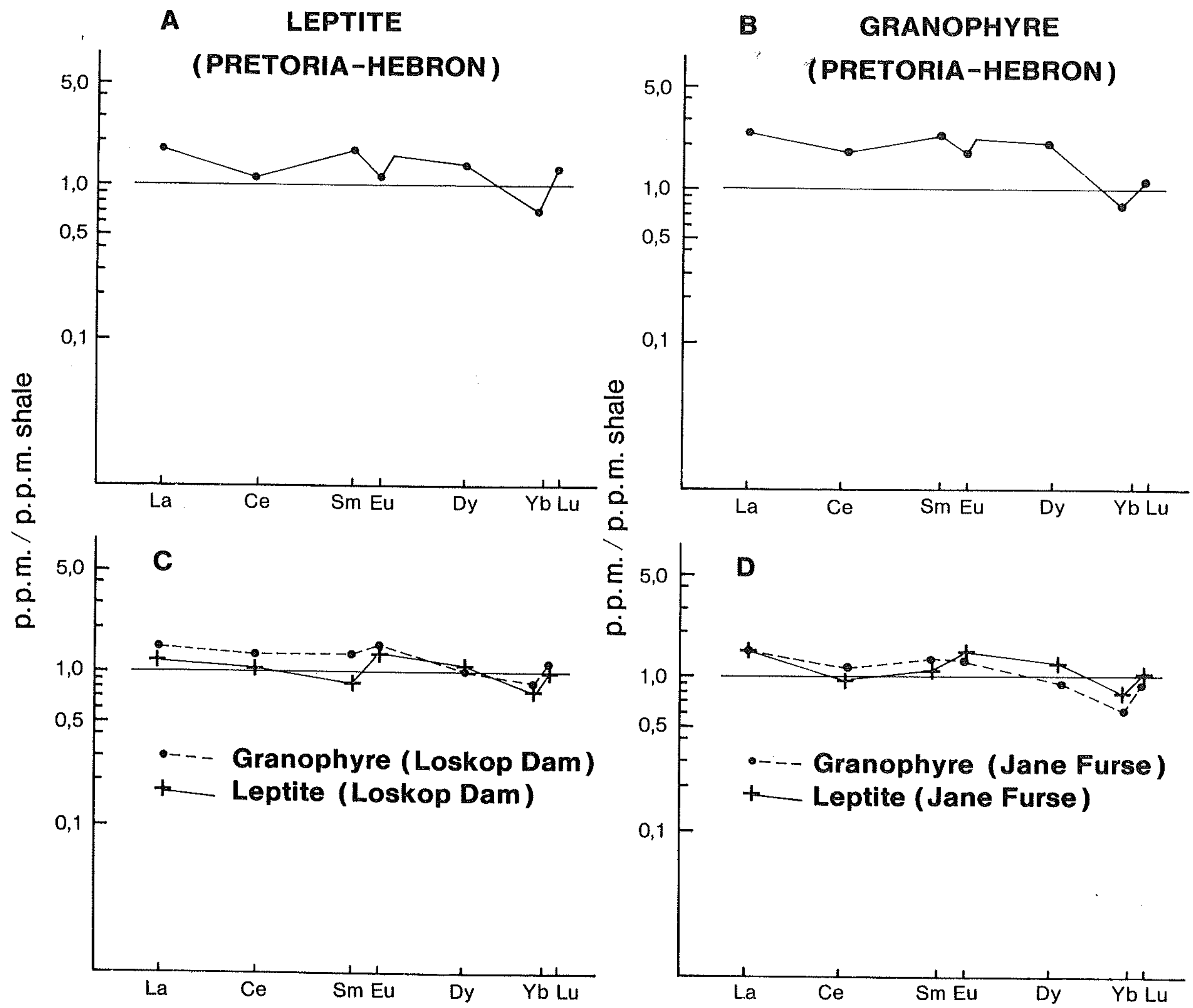


Figure 16. Rare earth element abundances of leptites and associated granophyres ratioed element by element to the North American shale abundances (Haskin et al, 1968)

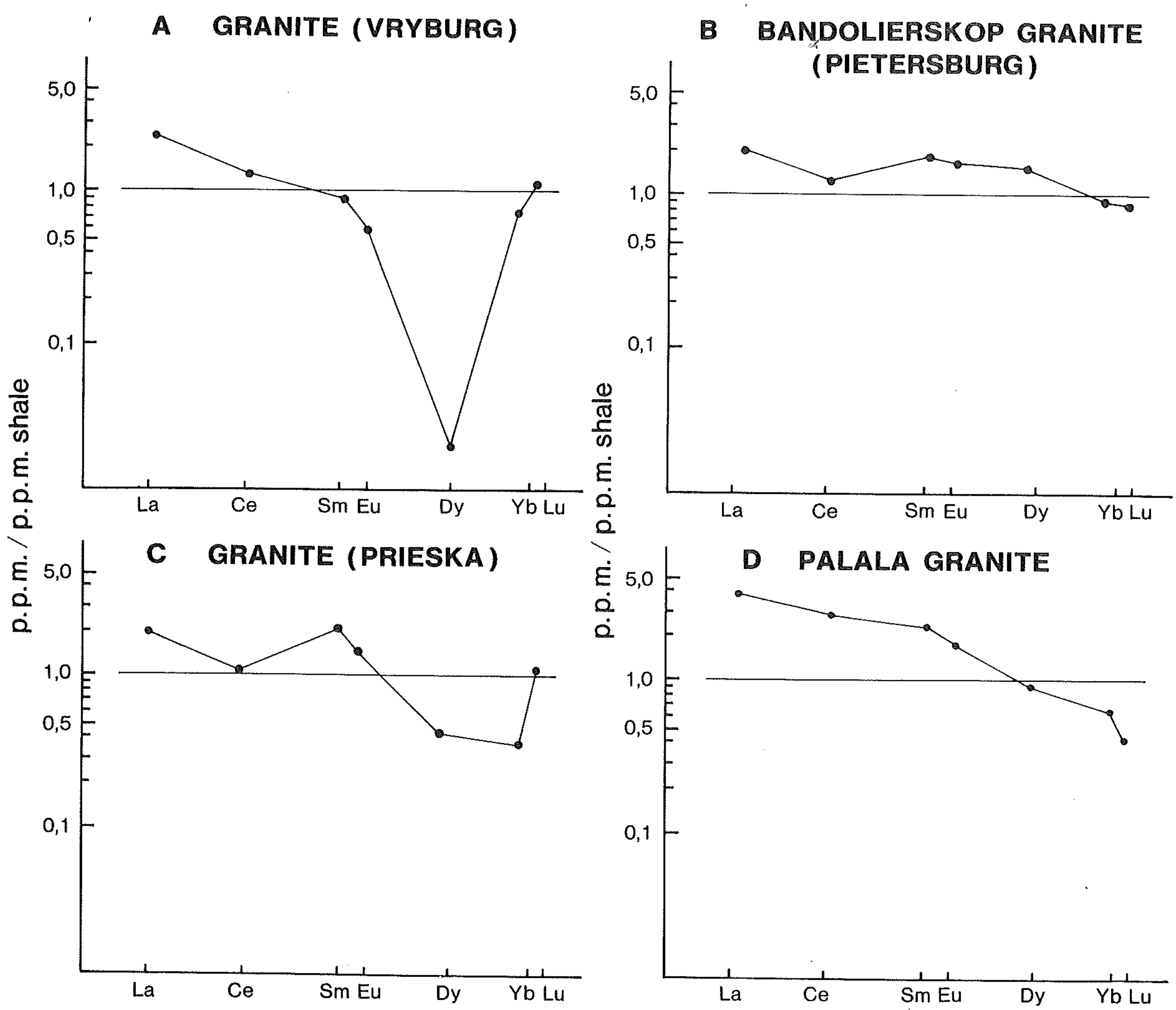


Figure 17. Rare earth element abundances of Palala granite and granites from Vryburg, Prieska, and Pietersburg ratioed element by element to the North American shale abundances (Haskin et al, 1968)

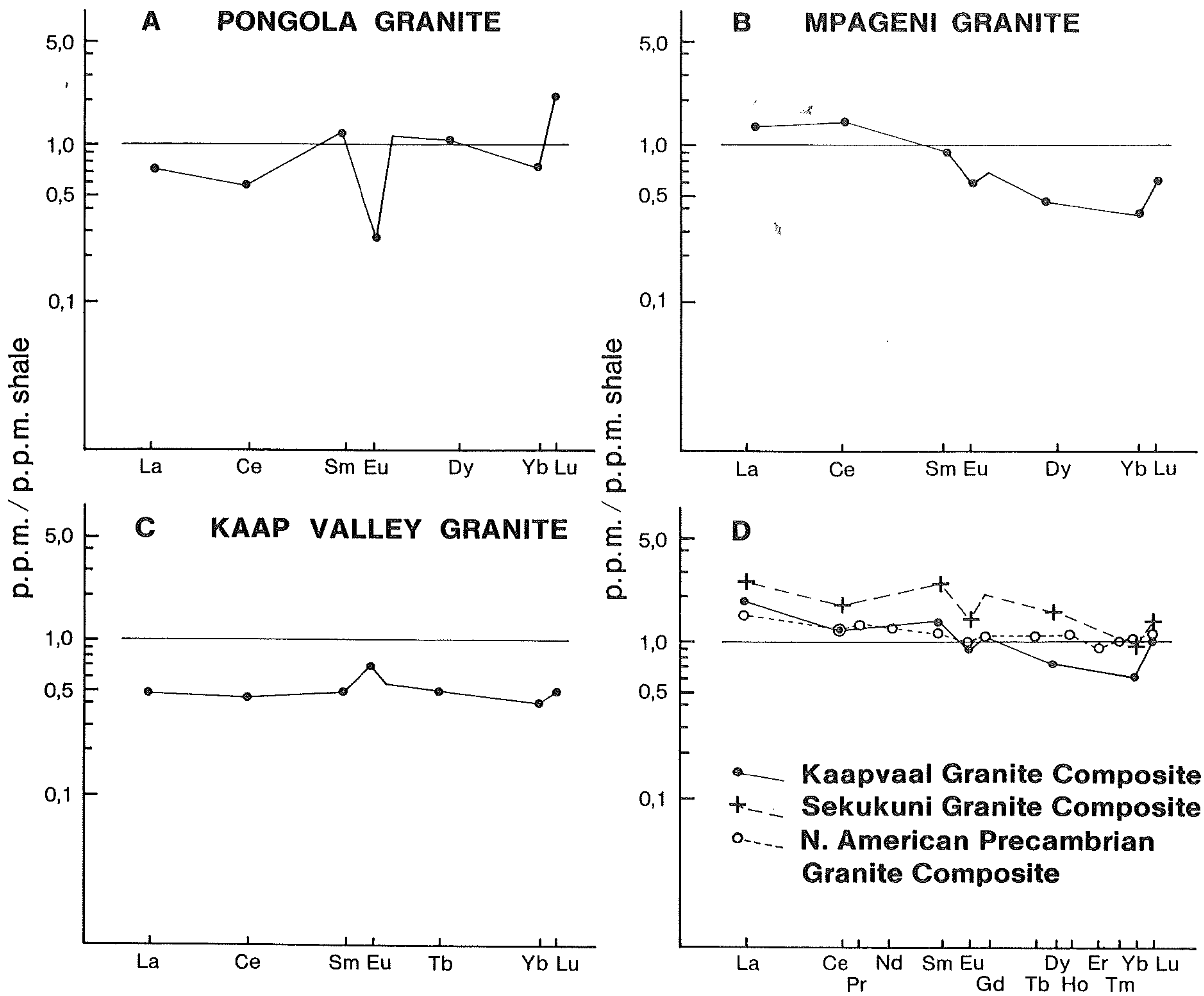


Figure 18. Rare earth element abundances of the Pongola, Mpageni, and Kaap Valley granites ratioed element by element to the North American shale abundances (Haskin et al, 1968). In D the pattern of the Kaapvaal granite composite is compared with the North American granite composite (Haskin et al, 1968).

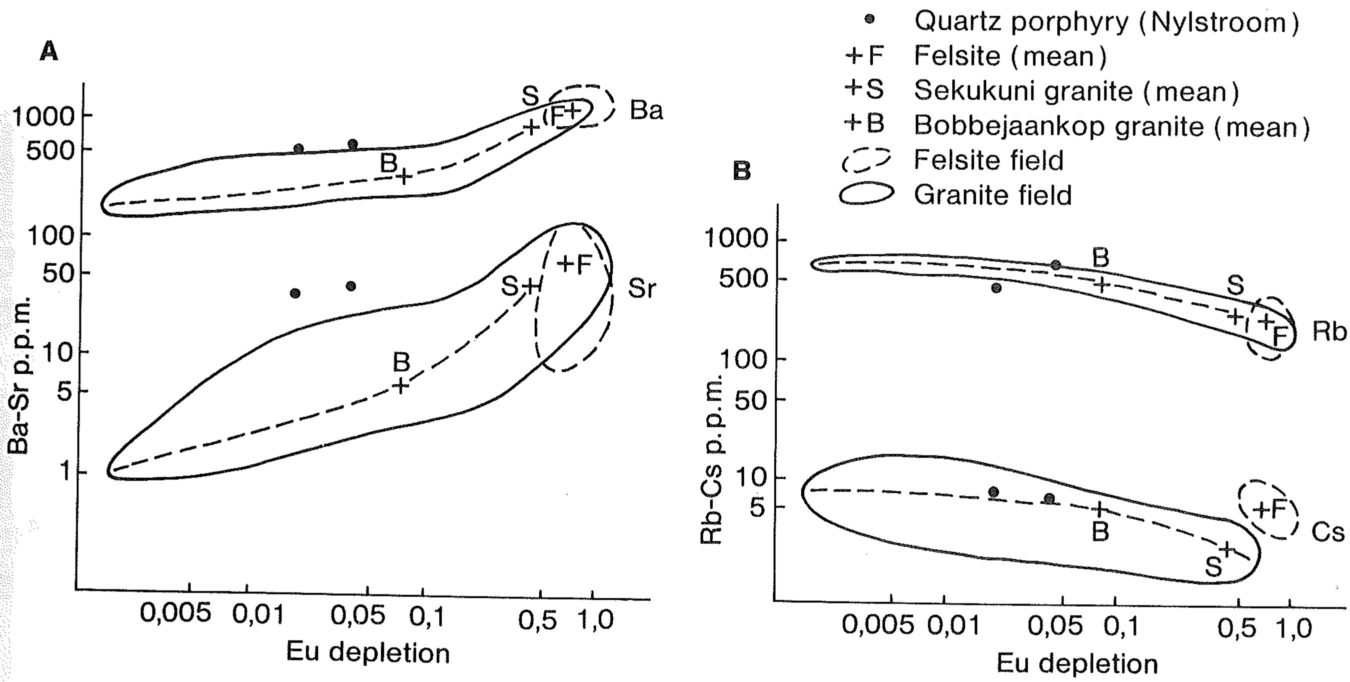
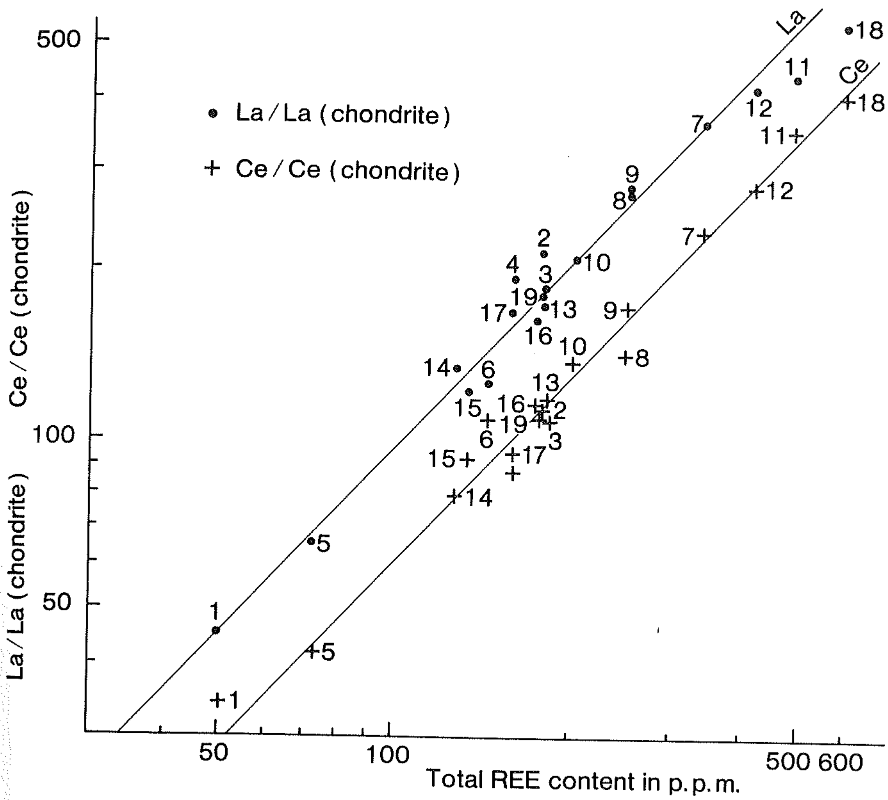


Figure 19. Abundances of Ba and Sr (A) and Rb and Cs (B) plotted against Fourie's (1969) ratio of Eu depletion for acid rocks of the Bushveld Complex.



1. Kaap Valley granite
2. Granite (Vryburg)
3. Granite (Pietersburg)
4. Granite (Prieska)
5. Pongola granite
6. Mpageni granite
7. Palala granite
8. Sekukuni granite (mean)
9. Bobbejaankop granite (mean)
10. Granophyre (Rooiberg)
11. Granite porphyry (Rust de Winter)
12. Quartz porphyry (Nylstroom)
13. Felsite (mean)
14. Leptite (Jane Furse)
15. Leptite (Loskop Dam)
16. Leptite (Pretoria-Hebron)
17. Granophyre (Argent)
18. Felsite (Rooiberg)
19. Sekukuni granite (north of Brits)

Figure 20. Abundances of La and Ce ratioed to the La and Ce abundances of chondrite (Haskin et al, 1968) plotted against the total rare earth element content of the rock.

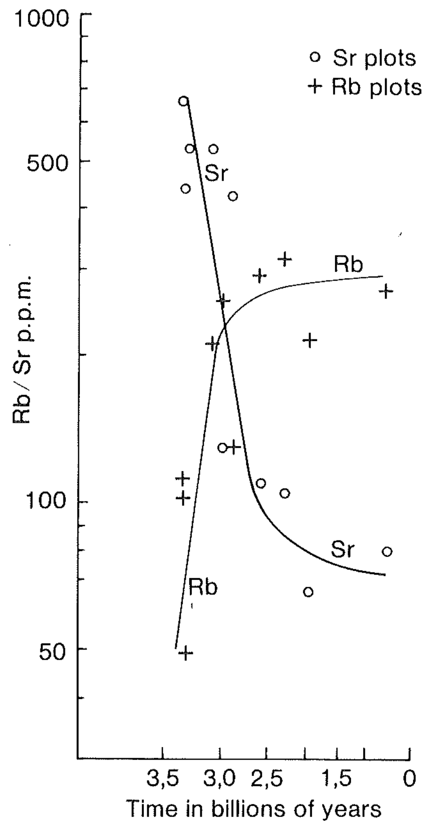


Figure 21. Abundances of Rb and Sr in various granitic rocks from the Kaapvaal craton plotted against the age of the granite. Data for the O, 6 b. y. (i. e. Cape) granite from Kolbe (1966)

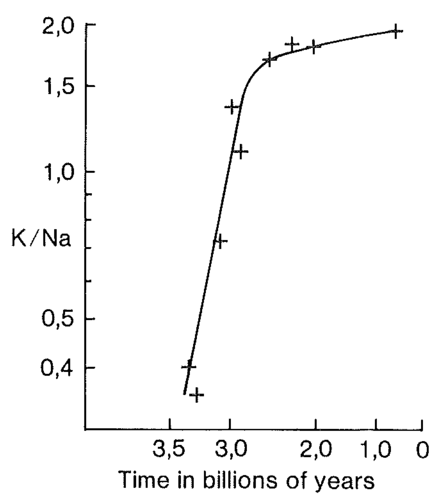


Figure 22. The ratio K/Na in various granitic rocks from the Kaapvaal craton plotted against the age of the granite. Data for the O, 6 b. y. (i. e. Cape) granite from Kolbe (1966)

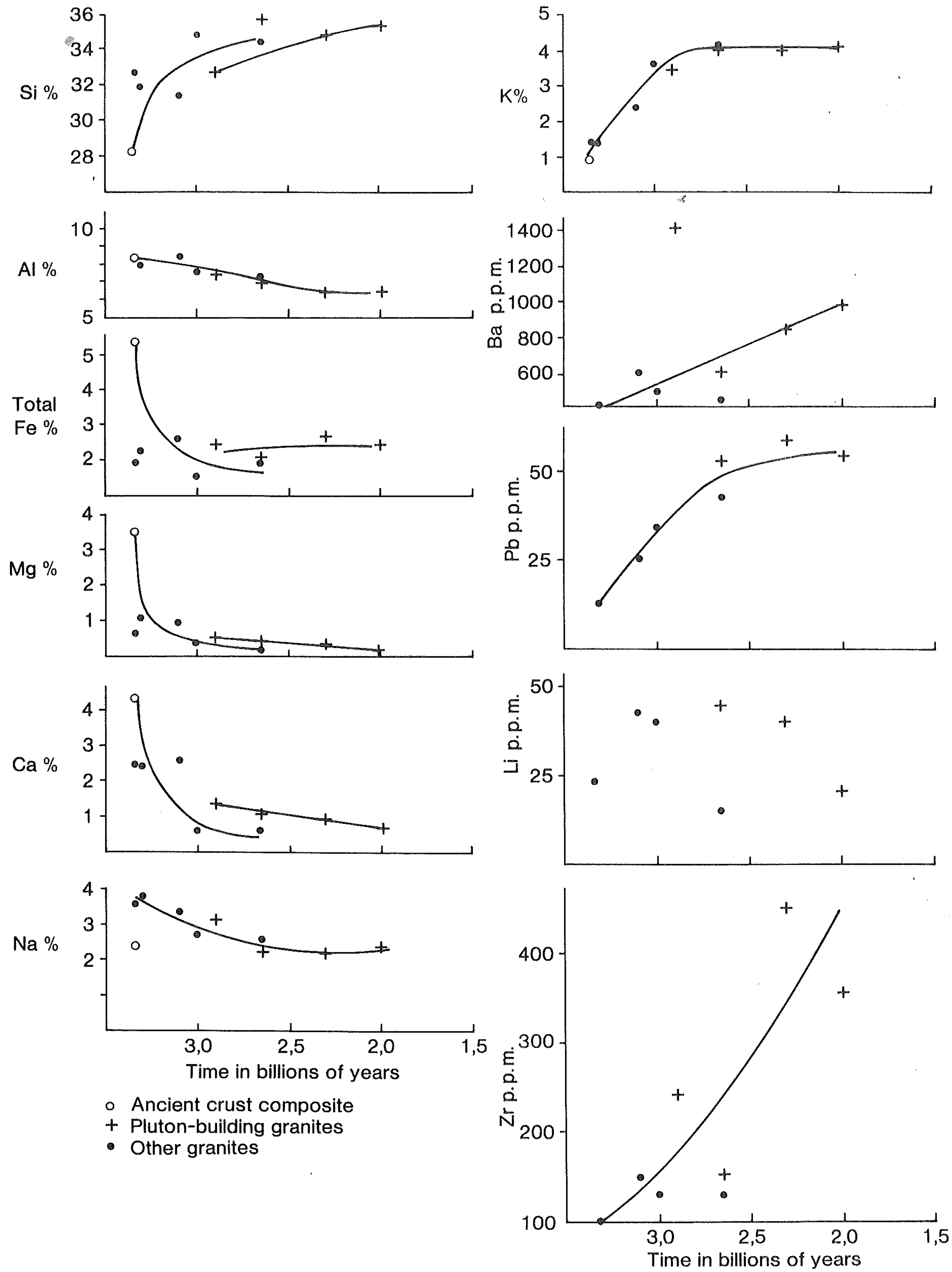


Figure 23. Mean abundances of major and trace elements of granites from the Kaapvaal craton plotted against their age.