ECONOMIC GEOLOGY RESEARCH UNIT

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Johannesburg

THE DISTRIBUTION OF GRANITOPHILE ELEMENTS IN ARCHAEAN GRANITES OF THE EASTERN TRANSVAAL, AND THEIR BEARING ON GEOMORPHOLOGICAL AND GEOLOGICAL FEATURES OF THE AREA

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ABSTRACT

Recent geochemical studies in the Archaean granitic terrane between Nelspruit and Bushbuckridge have provided the controls necessary for establishing the relationships that exist between granite composition and topography in the area. The rate of weathering of granites is shown to be partially dependent on their composition in that granitic rocks of high K_2O/Na_2O ratios are generally more resistant than those with lower K_2O/Na_2O ratios. Porosity is also shown to be an important feature in the weatherability of granitic rocks.

The distribution of granitophile elements in the Nelspruit Porphyritic Granite are also illustrated in trend surface maps which are thought to reflect the geological processes related to the mode of formation of this granite. The concentric or semi-concentric distribution of certain granitophile elements provides semi-quantitative evidence for the progressive fractional crystallization of mineral phases from the margins of the body, inwards.

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CONTENTS

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I. INTRODUCTION

The eastern Transvaal lowveld, although generally flat and low-lying, is, in certain areas, characterized by considerable variation in topography, the reasons for which are both geologic and geomorphic in nature. The Barberton Mountain Land, for example, owes its relief to a combination of diverse lithology and structure whereas the adjacent, low-lying Kaap Valley Tonalite owes its lack of relief to its mineralogical constituents, the latter being relatively out of equilibrium with the lithosphere and atmosphere.

Notwithstanding topographic variation between totally different rock types, it is also apparent that considerable topographic variation exists between the various Archaean granite types that occur in the region. If the granites that underlie the White River or the Lochiel areas are compared with either the Kaap Valley Tonalite, or the area east of Bushbuckridge, it is evident that granite composition plays an important role in the rate of weathering of this Archaean terrain. Even on a localized scale topographic variations may be striking, for example when comparing the very prominent Boesmanskop Syenite pluton with the surrounding trondhjemitic gneiss and migmatitic terrane [*1] in the area east of Badplaas (Figure 1).

This paper illustrates the fact that, on a regional scale in the eastern Transvaal, a relationship exists between the chemical composition of a granite and its rate of weathering, the latter being gauged by the topographic expression underlying a particular granite type. This relationship has been tested in the area between Nelspruit and Bushbuckridge, in the eastern Transvaal, where mapping and systematic geochemical sampling have provided the necessary control. These data have made it possible to produce contour maps and profiles across granites of differing composition, thereby providing evidence of a relationship between granite composition and topography.

In addition to the contour maps of the study region a trend surface analysis of the area was also attempted. The exercise resulted in a smoothed contour surface which points to a concentric or semiconcentric distribution of certain granitophile elements in the Nelspruit Porphyritic Granite. The latter is a large body of potassic granite, possessing batholithic dimensions, which has undergone a crystallization sequence that was initiated along its margins and progressed inwards towards its core. The trend surfaces described in this paper support the suggestion of fractional crystallization within this granite, an idea originally conceived on the basis of evidence from trace element modelling (McCarthy and Robb, 1978).

Thus a knowledge of the distribution of granitophile elements in the granites of the region is shown to be informative in two disciplines; firstly, in applying constraints to petrogenetic models applicable to particular granite types and secondly, in providing an explanation for differential weathering in Archaean basement rocks. As the latter point forms the dominant theme of this paper it is dealt with first.

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*1 The spelling of terrain/terrane is often the cause of some confusion in the geological literature. Two independent definitions indicate that "Terrain" refers to topography and has a geographical connotation whereas "terrane" refers to a rock formation and has a geological connotation :

(i) "TERRAIN 2. A tract of ground considered with regard to its natural features, configuration etc. ......

3. Geol. (usually spelt terrane) A name for a connected series, group, or system of rocks or formations; a stratigraphical subdivision". (Oxford English Dictionary, 1933).

(ii) "TERRAIN The tract or region of ground immediately under observation".

"TERRANE A formation or group of formations; the area or surface over which a particular rock or group of rocks is prevalent". (Glossary of Geology and Related Sciences, 1962).

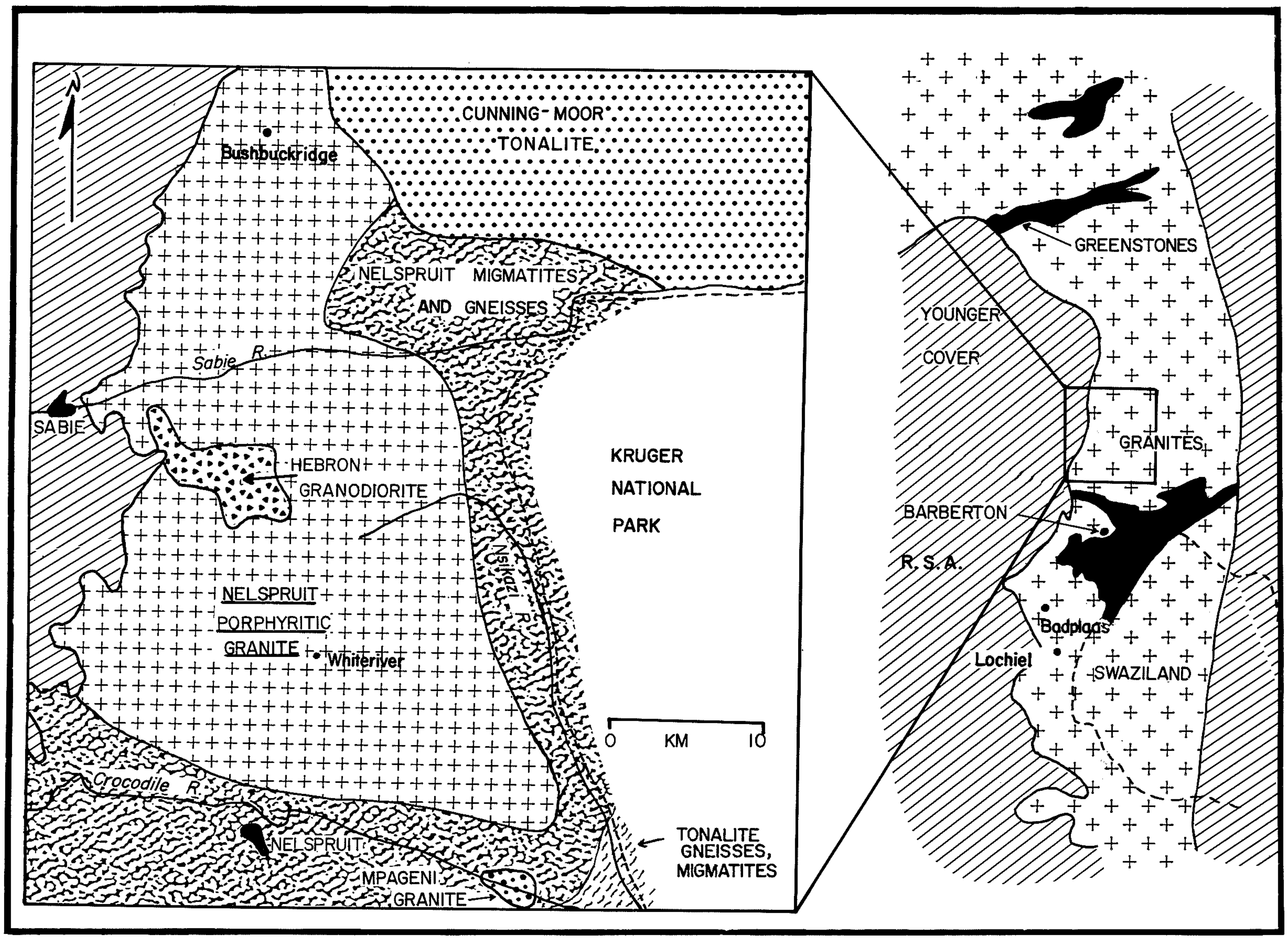

Figure 1 : *A schematic locality map of the Archaean granitic terrane between Nelspruit and Bushbuckridge, eastern Transvaal (after Robb, 1978).*

II. THE RELATIONSHIP BETWEEN GRANITE COMPOSITION AND TOPOGRAPHY IN THE STUDY AREA

A. Geological Description of the Area

The Archaean granitic terrane in the area between Nelspruit and Bushbuckridge, covering an area of some 2 500 km^2, has recently been mapped and extensively sampled for geochemical purposes (Robb, 1978). In this area six distinct granite types have been identified (Figure 1). These are, in order of decreasing age :

(i) The Tonalitic Gneisses and Migmatites which occur in the southernmost portion of the study area, in the immediate vicinity of greenstone remnants. They are sodic in composition but have commonly been altered due to the effects of shearing and mylonitization.

(ii) The Nelspruit Migmatite and Gneiss Terrane occupies the lower-lying areas in the south and west of the study area and represents a complex suite of migmatites and gneisses, generally potassic in character.

(iii) The Nelspruit Porphyritic Granite, which is a massive, potassic, granite of batholithic dimensions underlying the major portion of the study area. It is characterized by the almost ubiquitous presence of microcline phenocrysts.

(iv) The Hebron Granodiorite, which is a small pluton-like body intruded into the Nelspruit Poprhyritic Granite to the north-northwest of White River.

(v) The Cunning Moor Tonalite which underlies the flat and low-lying tract of country in the northeastern corner of the study area.

(vi) The Mpageni Granite Pluton, which is a small stock-like body truncating the regional fabric of the Nelspruit Migmatite and Gneiss Terrane to the east of Nelspruit.

Of the six varieties the Nelspruit Porphyritic Granite and the Nelspruit Migmatite and Gneiss Terrane (which are considered to be cogenetic, Robb, 1978) together with the Cunning Moor Tonalite, comprise approximately 95 per cent of the study area. The former two units comprise an essentially potassic suite of rocks (average $K_2O/Na_2O \simeq 1$, Robb, 1978), whereas the latter unit is sodic in composition with average $K_2O/Na_2O < 0,5$. In the study area a number of samples were collected and analysed for K_2O, Na_2O, Rb, Sr and Ba (see Appendix). These five granitophile elements are considered to be most definitive in terms of identifying the compositional character of a granite. These data were used in the construction of the contour maps, cross-sections and polynomial trend surfaces discussed below. The details regarding sample density and distribution, analytical techniques, and contouring procedure are provided in the appendix.

B. Previous Work Regarding the Weathering of Granites

Little, if any, work has been carried out regarding the relationship between rate of weathering and granite type in the eastern Transvaal. This geomorphological control factor has, however, been noted and Viljoen and Viljoen (1969) stated that "A remarkable correlation exists in the Barberton region between rock type and topography". By comparison, in other parts of the world a considerable amount of literature has accumulated on granites and their relationship to rates of weathering.

A host of factors are likely to influence the rate of weathering of a particular granite type and these include grain size and shape, mineralogical constituents, mobility of elements and the porosity and permeability of the rock in question. Although it may be possible for any one of these factors to predominate over others, under natural conditions the rate of weathering is likely to be influenced by a combination of all the influencing parameters. As far as grain size and texture are concerned contradictory reports are available regarding their role with respect to the rate of weathering. In parts of Australia it was found that coarse-textured granites were more susceptible to weathering than fine-textured varieties (Twidale, 1962), whereas theoretical considerations suggest that larger minerals are more difficult to weather than smaller ones (Ollier, 1969). In southern Africa it was found that tors developed in the Archaean granitic terrane around Pietersburg were concentrated in zones of porphyritic granite rather than in the surrounding granite-gneiss (Brook, 1970). These contradictory relationships illustrate clearly that the grain size and texture factors are not decisive in terms of rate of weathering.

Insofar as the mobility of elements in the granite system is concerned there is consensus that certain elements are considerably more mobile in the weathering environment than others. Anderson and Hawkes (1958), studying the composition of stream waters and adjacent rock types, deduced a well-defined order of mobility as follows : Mg>Ca>Na>K>Si>Al. Similar studies on granites from Oklahoma and Georgia have shown that Ca and Na are mobilized early in the weathering process whereas K, Rb and Th are mobilized only in the intermediate and final stages of weathering (Harriss and Adams, 1966). Coupled with the mobility of elements is the question of mineral stabilities in the weathering environment. Harriss and Adams (1966) stated that in granites the sequence plagioclase felspar-biotite-potassium felspar-quartz is a reflection of increasing mineral stability. Similarly, studies in the Far East, have shown that the breakdown of minerals in the granite system occurs in the order biotite-plagioclase felspar-orthoclase (Ruxton and Berry, 1957). They also support Twidale (1962) who stated that coarse textured granites are more susceptible to weathering than fine textured varieties.

It is clear that the mobility of elements and the stability of mineral phases in granites play an important role in the rate of weathering of this rock type. It is also apparent that mafic minerals and plagioclase felspar are more unstable in the weathering environment than are K-felspar and quartz, and subsequently Mg, Na and Ca are more mobile than K, Al, Rb and Th. Although grain size and texture play an important role it is evident, from discrepancies in the literature, that this factor may only play a subsidiary role in the processes which affect rates of weathering. The following section considers the points mentioned above in relation to the area studied between Nelspruit and Bushbuckridge in the eastern Transvaal.

C. The Distribution of K_2O, Na_2O, Rb, Sr, and Ba in the Study Area

Figure 2 is a simplified contour map of the area between Nelspruit and Bushbuckridge. This map is computer drawn from the altitudes of more than two hundred sample locality points (see Appendix). The area is characterized by two topographic regimes; the first, covering most of the region, is underlain by high-lying, undulating terrain with considerable variation in relief whereas the second, occupying the northeastern quadrant, is flat and low-lying. These two regimes are clearly demarcated by the configuration of topographic contours (Figure 2). An examination of the geological map (Figure 1) shows that the low-lying surface coincides with the area shown to be underlain by the Cunning Moor Tonalite whereas the high-lying, undulating surface is underlain mainly by the Nelspruit Porphyritic Granite. It is evident that differences in surface morphology in the study region are a function principally of granite type rather than any of the other features mentioned previously. This relationship is not uncommon and a well-documented case occurs in the Laramie Range of southeast Wyoming. Here the Sherman Erosion Surface, a flat, peneplained landscape is exclusively underlain by the Trail Creek Granite whereas the adjacent, hilly "parkland tor topography" is underlain by the Cap Rock Quartz Monzonite (Eggler et al., 1969). Although the parameters for differential weathering in this case are not the same as those suggested for this particular study, the concept, as applicable to granitic terranes, is a well-established one.

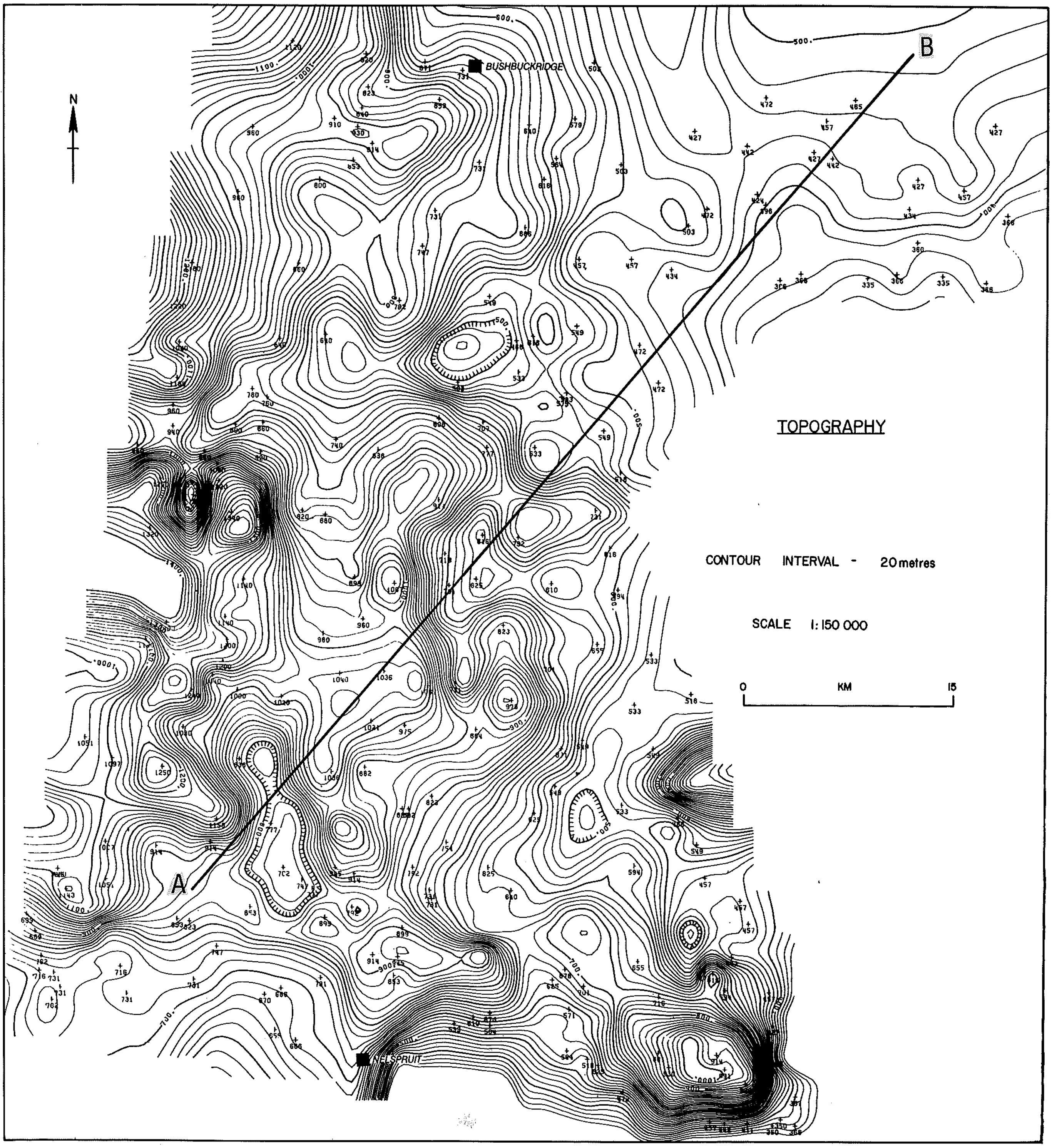

Figure 2 : *Simplified contour map of the topography between Nelspruit and Bushbuckridge, eastern Transvaal.*

It is suggested that in the area between Nelspruit and Bushbuckridge the difference in chemical composition of granite types is the principal cause of differential weathering amongst the Archaean granites of the region. An examination of Figure 3a-f reveals that a good correlation exists between topographic expression and the distribution of certain granitophile elements along the random section line A-B, shown in Figure 2. Figure 3a shows the topographic cross-section along A-B, where high-lying undulating terrain in the vicinity of White River gradually gives way to flat and low-lying terrain to the east of Bushbuckridge. The K_2O distribution in the granites along the section A-B indicates high, but variable, K_2O contents characterizing the high-lying areas, whereas lower and less variable K_2O contents characterize the flat erosion surface in the northeast of the study area (Figure 3b). In order to illustrate that this relationship is not fortuitous along a suitably chosen section, a three-dimensional representation of the K_2O surface in the study area is shown in Figure 4. This surface (computer drawn, see Appendix) shows that the overall distribution of potash in the region coincides with the regional topographic surface (Figure 2). This positive correlation between topography and K_2O substantiates the suggestion that potash granites are considerably more resistant to weathering and erosion than their sodic counterparts. Although, in many cases, it may be argued that the sodic granites (tonalites) are in fact older than the adamellites and granites (*sensu stricto*) in the area, in the case of the Cunning Moor Tonalite, recent geochronological work has shown it to be considerably younger than the higher-lying, more resistant, Nelspruit Porphyritic Granite (E. Barton, personal communication, 1978; Robb, 1978).

Another element whose distribution exhibits a direct correlation with topography is rubidium. On average rubidium is three times more abundant in the Nelspruit Porphyritic Granite than it is in the Cunning Moor Tonalite (Figure 3c). Although Rb and topography show a close correlation it is unlikely that the abundance of this trace element actually has any effect on the rate of weathering but rather acts as a tracer for the amount of K-felspar present in the rock. Rb is known to have a much higher distribution coefficient into K-felspar than into plagioclase and this, in all likelihood, explains the pattern observed in Figure 3c. In the same way the distribution of Ba is likewise affected (Figure 3d). This diagram shows large variations of Ba within the Nelspruit Porphyritic Granite where a number of factors may have influenced the partitioning of this element in the granite (McCarthy and Robb, 1978). By contrast there is a smooth Ba distribution pattern in the Cunning Moor Tonalite because the main mineralogical constituents of this rock were less suitable as a host to this element.

Although not nearly as convincing as K_2O, the distribution of Na_2O (Figure 3e) exhibits a recognizably inverse relationship with the topography. The Nelspruit Porphyritic Granite generally has lower soda contents than the Cunning Moor Tonalite which exhibits a higher and more uniform distribution. The distribution of strontium, in contrast with the elements discussed previously bears little or no relation to the topography in the area. Although variations in the Sr content are more marked in the Nelspruit Porphyritic Granite than in the Cunning Moor Tonalite, the relative abundances in each are indistinguishable. This is also a reflection of the distribution coefficient of Sr into the granite-forming minerals, as this element is approximately equally partitioned into both K-felspar and plagioclase (Arth and Hanson, 1975).

It is clear that the rates of weathering exhibited in the granitic terrane between Nelspruit and Bushbuckridge are a function of their major element chemistry, particularly K_2O and Na_2O. The distribution of trace elements is considered to be a broad reflection of the mineralogy of the granite and does not directly influence the rate of weathering. Thus the mineralogy of the granites in this area plays a fundamental role in their rate of weathering and this provides confirmatory evidence for the relative stabilities of granite-forming minerals. Undoubtedly plagioclase flespar is less stable under surface conditions than K-felspar, this fact being independent of the minor climatic variations encountered in the study area (e.g. the Nelspruit Porphyritic Granite, adjacent to the Transvaal Drakensberg Escarpment, is in a higher rainfall region than the low-lying, less resistant Cunning Moor Tonalite (Robb, 1977).

D. Factors Affecting the Rate of Weathering of the Hebron Granodiorite

During the course of mapping, a prominent, stock-like granodioritic body was encountered some 15 km north-northwest of White River (Figure 1). This body, known as the Hebron Granodiorite, has an average K_2O/Na_2O ratio of 0,75 and is known to intrude the more potassic Nelspruit Porphyritic Granite (Robb, 1977). The area underlain by the Hebron Granodiorite coincides with the highest point in the study area (Figure 2). Thus the Hebron Granodiorite forms a geomorphologically resistant buttress, a feature not compatible with its K_2O/Na_2O ratio which, in terms of the previous discussion, indicates that it should be more prone to weathering than the Nelspruit Porphyritic Granite. Clearly, chemical compositions and mineral stabilities are not the only factors which affect the rate of weathering in the granites of this area. The Hebron Granodiorite is a medium-to-fine-grained equigranular rock, this texture suggesting that it may be less permeable and have a lower porosity than the coarser-grained, porphyritic granite which it intrudes. As porosity is likely to have an important influence in determining rates of weathering, a simple experiment was devised to test the porosity of the Hebron Granodiorite relative to the Nelspruit Porphyritic Granite and the Cunning Moor Tonalite. Six samples (two from each granite type), which showed no signs of fracturing, alteration or any other features affecting the imperviousness of the rock, were carefully selected. From each sample a 50 x 50 x 10 mm slab was cut. These were thoroughly dried in a furnace at 200°C for 12 hours and then weighed. The slabs were then immersed in water for a period of one week and then re-weighed. All the slabs weighed more after immersion than before indicating that water had been absorbed into the pore-spaces in the rocks. The percentage increase in mass of the slabs is considered to be a reflection of the relative porosity of each of the three granite types being examined (Table 1). The results show that the Hebron

PROFILES ACROSS A RANDOM SECTION IN THE NELSPRUIT-BUSHBUCKRIDGE AREA

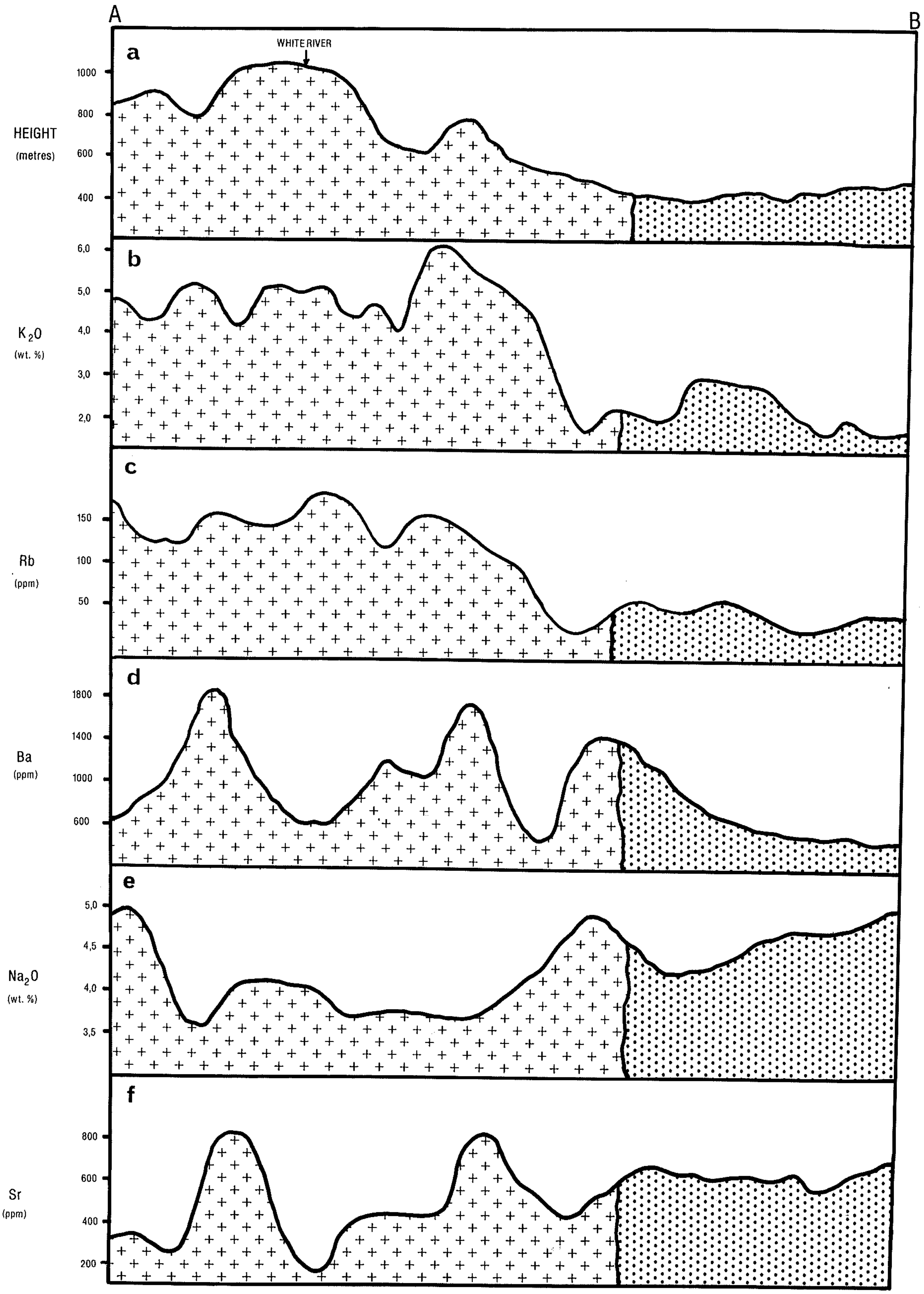

Figure 3 : A sequence of profiles along the section A-B shown in Figure 2. Crosses (+) represent the terrain underlain by the Nelspruit Porphyritic Granite, stippling that underlain by the Cunning Moor Tonalite.

3-D K_2O DISTRIBUTION

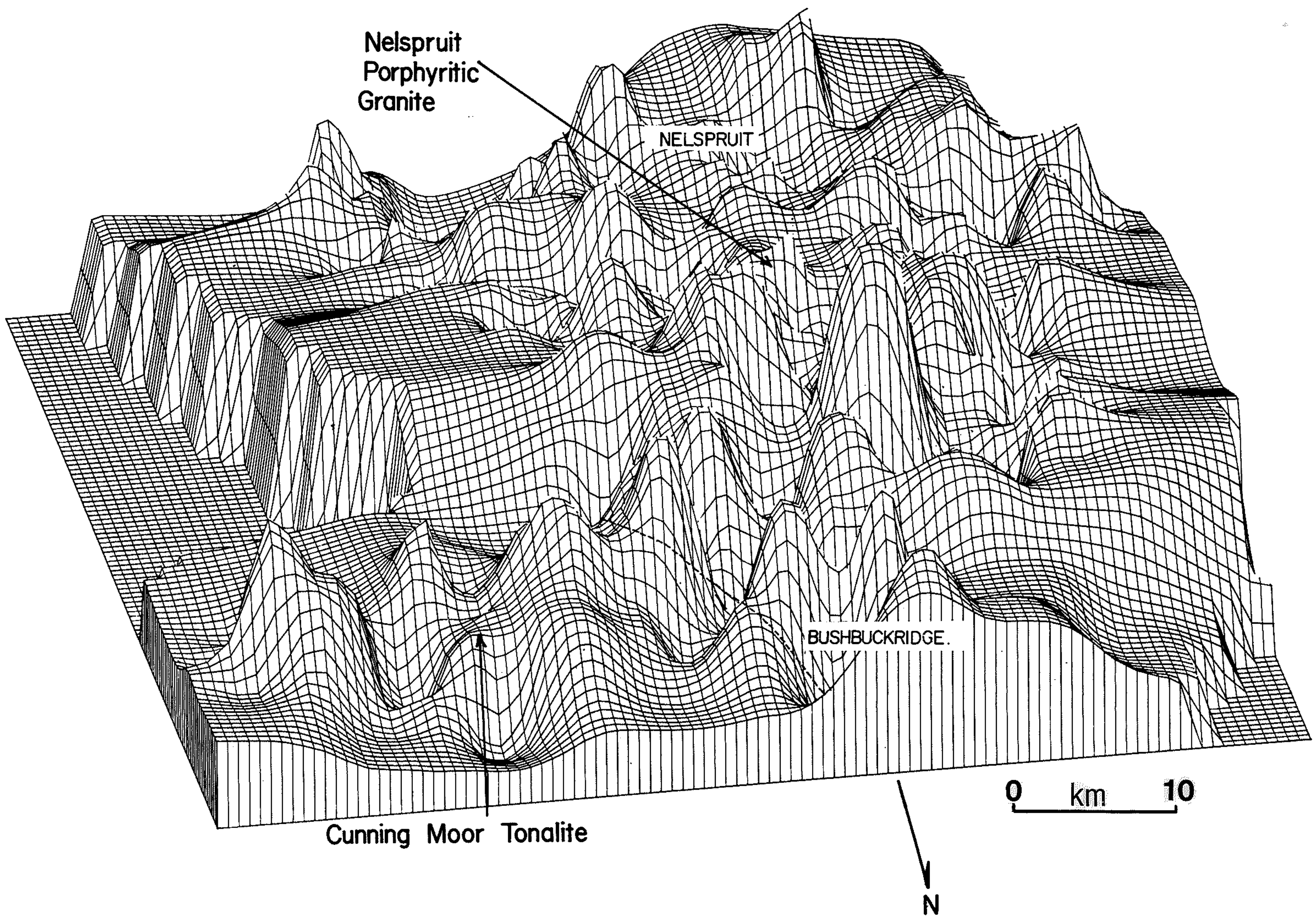

Figure 4 : *A computer-drawn three dimensional surface of the potash distribution in the study area. The area is viewed from a vantage point east of north at a elevation of 25° from the horizontal. The high, irregularly distributed values of K_2O are seen to coincide with the area underlain by the Nelspruit Porphyritic Granite whereas lower, more regular values of potash coincide with the Cunning Moor Tonalite.*

Granodiorite is, by virtue of its texture, considerably less porous than the Nelspruit Porphyritic Granite. It is suggested that, in this case, porosity overrides chemical composition and mineral stability as a factor in influencing the rates of weathering, and therefore the latter can be considered to play a dominant role in weathering and denudation only if porosity is an independent variable. Table I also shows that the Cunning Moor Tonalite is considerably less porous than the Nelspruit Porphyritic Granite. Thus the fact that the former weathers more easily is undoubtedly related to its mineralogy and composition.

E. A Note Concerning Erosion Cycles

In a discussion such as that above, caution should be exercised when trying to relate erosion surfaces to granite composition because of the possibility that such surfaces may be the result of primary erosion cycles. The eastern Transvaal lowveld (below the Transvaal Drakensberg Escarpment) is known to have been formed by the multi-stage Quaternary Erosion Cycle (King, 1967). The marked step between the high-lying Nelspruit Porphyritic Granite and the low-lying Cunning Moor Tonalite may be prematurely interpreted as representing the nick-point between two periods of incision of the Quaternary Cycle (Figure 3a). However, this is considered unlikely because, (i) the overall drainage pattern on both surfaces is similar, i.e. dendritic, (ii) no nick-points occur on any of the rivers that traverse the area between the two granite types and (iii) the step between the two granite types is enhanced by a very prominent dyke and sill swarm (Robb, 1977), so that the actual step between the high and low-lying granitic terrane is not as pronounced as that indicated in Figure 3a.

TABLE I

ESTIMATES OF THE RELATIVE POROSITIES OF THE HEBRON GRANODIORITE, NELSPRUIT PORPHYRITIC GRANITE AND CUNNING MOOR TONALITE

Rock Type	Dry Mass (g)	Mass After Immersion (g)	Mass Gain (g)	Porosity* (%)
Cunning Moor Tonalite	93,266	93,510	0,244	0,706
Nelspruit Porphyritic Granite	102,561	103,475	0,914	2,406
Hebron Granodiorite	110,000	110,237	0,237	0,582

(Values reflected in the Table comprise the average of two samples of each rock type measured)

Note :

* (a) Porosity is the percentage of pore space in the rock.

(b) Assuming that granite has a density of 2,70 g/cm³ (Weast, 1975) and water has a density of 1,0 g/cm³, then the porosity is calculated as follows :

$$\text{Porosity} = \frac{2{,}70 \text{ (Mass Gain)}}{\text{(Dry Mass)}} \times 100$$

(c) The values of porosity presented in Table I will only be a true value if all the pore spaces were filled with water after immersion. As this condition may not have been fulfilled the value presented above may, at best, only reflect the relative porosities of each of the three granite types.

No detailed geomorphological analysis of this area has yet been undertaken and, until such time as this is done the possibility that Quaternary incision may have contributed to the surfaces being discussed cannot be discounted.

III. THE RELATIONSHIP BETWEEN CHEMICAL TREND SURFACE MAPS AND THE MODE OF CRYSTALLIZATION OF THE NELSPRUIT PORPHYRITIC GRANITE

In addition to presenting the data as contour maps and sections, the information discussed previously may also be analysed in terms of trend surfaces. Polynomial trend surface analysis is a contouring technique which assesses only the regional trend of data distribution by fitting a polynomial regression curve to the data. The effect is to eliminate localized fluctuations and produce a simplified contour surface which reflects only broad regional trends. This technique is commonly used in granitic terranes and is considered useful in assisting petrogenetic interpretations of such rock types (Parslow, 1971; Taylor, 1976).

The Nelspruit Porphyritic Granite which underlies the larger part of the study area (Figure 1), exhibits a systematic distribution of granitophile elements which is likely to be related to its petrogenetic history. A detailed study has recently shown that the Nelspruit Porphyritic Granite underwent a mode of crystallization akin to fractional crystallization in mafic magmas (McCarthy and Robb, 1978). This mode of crystallization has affected the distribution of both major and trace elements within this granite. The suggestion was made that the granite cooled very slowly, probably from its margins inwards. As in all magmatic bodies certain mineral phases crystallize before others, and in this particular granite plagioclase appears to have crystallized before K-felspar (McCarthy and Robb, 1978). It was suggested, therefore, that plagioclase (together with quartz and minor biotite) crystallized in the marginal areas of the Nelspruit Porphyritic Granite whereas plagioclase + K-felspar (together with quartz and minor biotite) crystallized only towards the centre of the body (Figure 5). This step-wise crystallization sequence would be likely to have a significant effect on the concentrations of major and particularly trace elements occurring within the body, an effect which may be recognized on trend surface maps. Trace elements such as Rb, Sr and Ba should be particularly sensitive to this mode of crystallization as they tend to obey strict partitioning laws between the various granite-forming minerals.

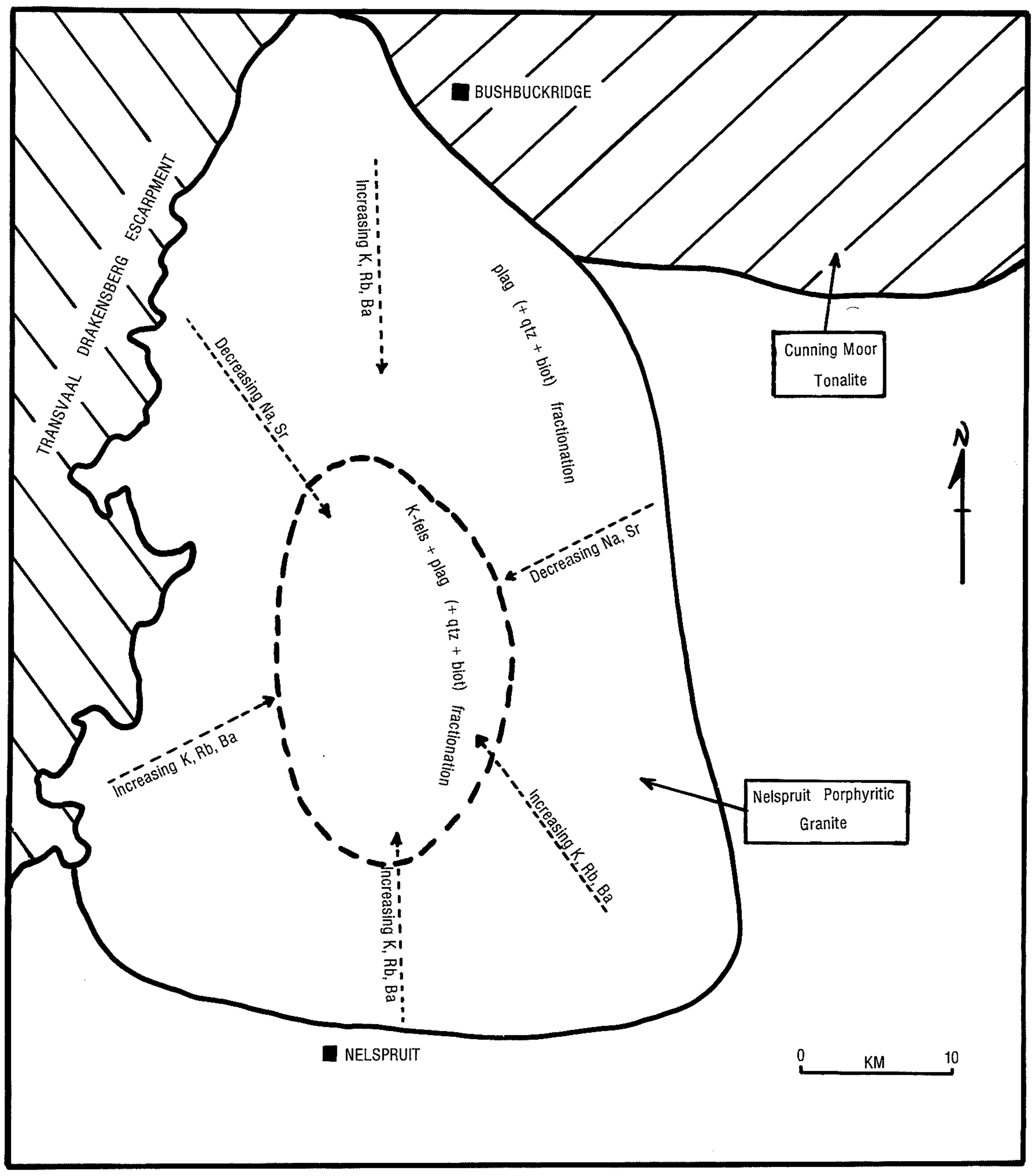

Figure 5 : *A schematic diagram illustrating the suggested mode of crystallization of the Nelspruit Porphyritic Granite and the regional trends expected of certain granitophile elements.*

An examination of the trend surface maps (Figures 6, 7 and 8) shows that the broad regional trends indicated by certain of the granitophile elements confirm the suggested mode of crystallization of the Nelspruit Porphyritic Granite. The third degree polynomial trend surface of K_2O (Figure 6) illustrates a broad concentric distribution of potash over the porphyritic granite body, with the highest concentrations occurring towards the centre of the batholithic mass. Such a distribution would be compatible with the suggestion that K-felspar appeared in the liquidus at an advanced stage of crystallization. The contour lines of the trend surface also differentiate between the area underlain by the Nelspruit Porphyritic Granite and that underlain by the Cunning Moor Tonalite (Figure 6).

Similar distribution patterns are shown in Figures 7 and 8 where Rb and Ba, respectively, exhibit broad regional concentric or semi-concentric trends with increases in concentration towards the central portions of the Nelspruit Porphyritic Granite. Such a distribution is to be expected as both Rb and Ba are more strongly partitioned into K-felspar than into plagioclase. It is interesting to record that Na_2O and Sr did not exhibit the same definitive concentric trend surface distributions. In the case of Sr this is because this element is partitioned equally strongly into both plagioclase and K-felspar, whereas with Na_2O the effect is likely to be due to the fact that plagioclase was crystallizing uniformly throughout the body.

The trend surface analysis attempted here has proved informative in providing additional confirmation of a crystallization model which was originally deduced on the basis of other evidence. Such broad regional trends in geochemical data may therefore prove to be useful in helping to understand the genesis of other magmatic bodies where either fractional crystallization or the consecutive crystallization of mineral phases has taken place.

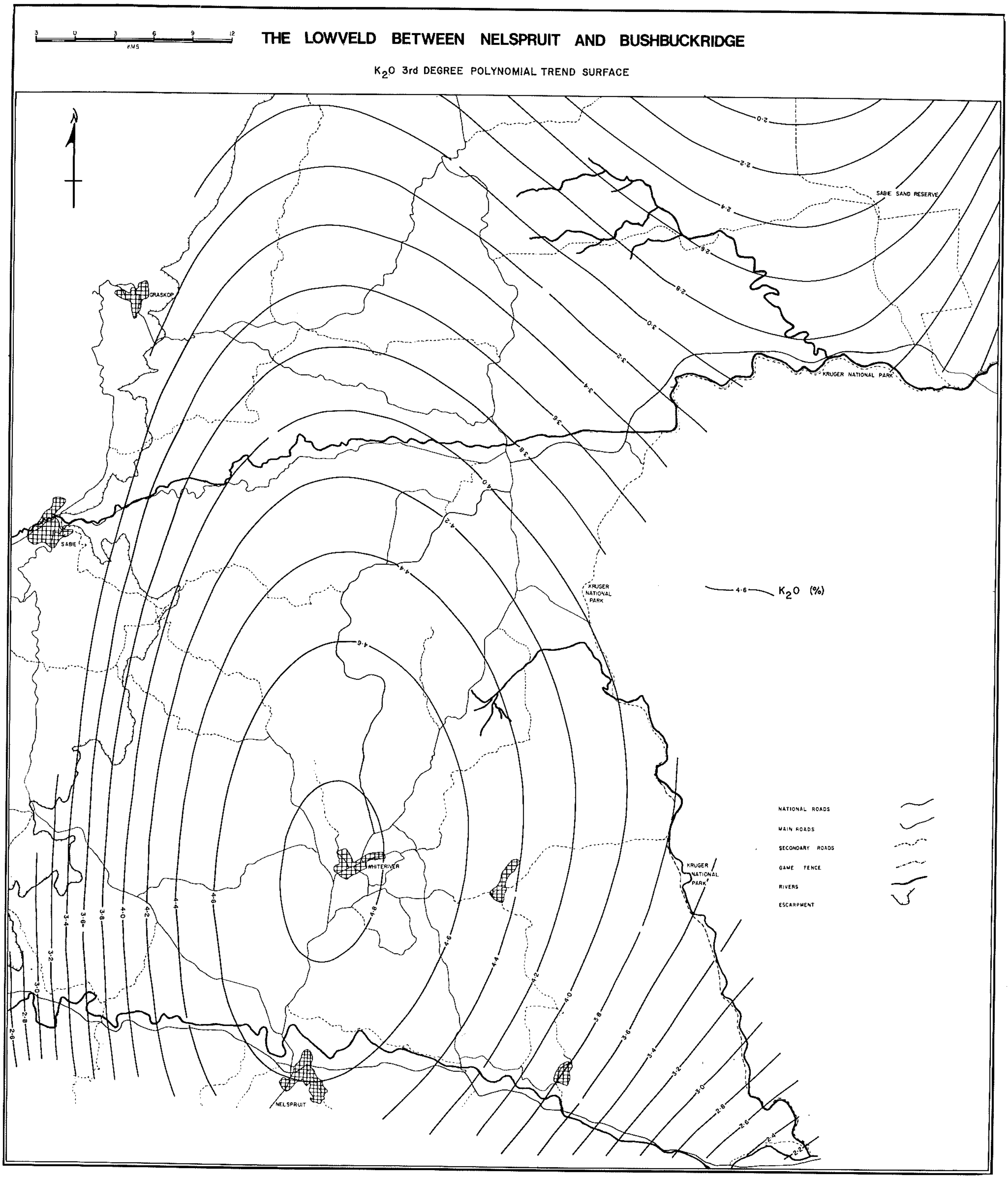

Figure 6 : *Third degree polynomial trend surface of the potash distribution in the study area.*

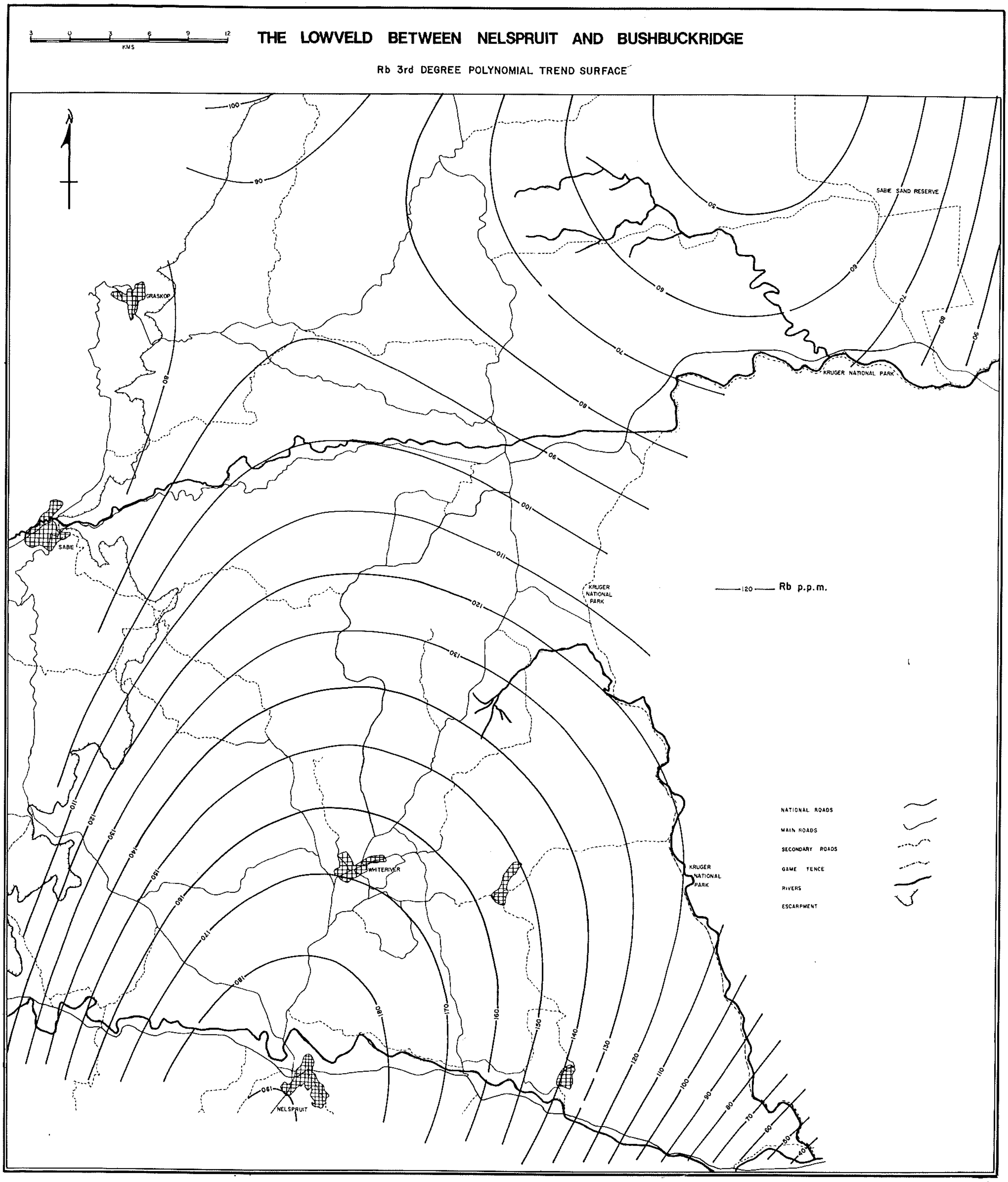

Figure 7 : *Third degree polynomial trend surface of the rubidium distribution in the study area.*

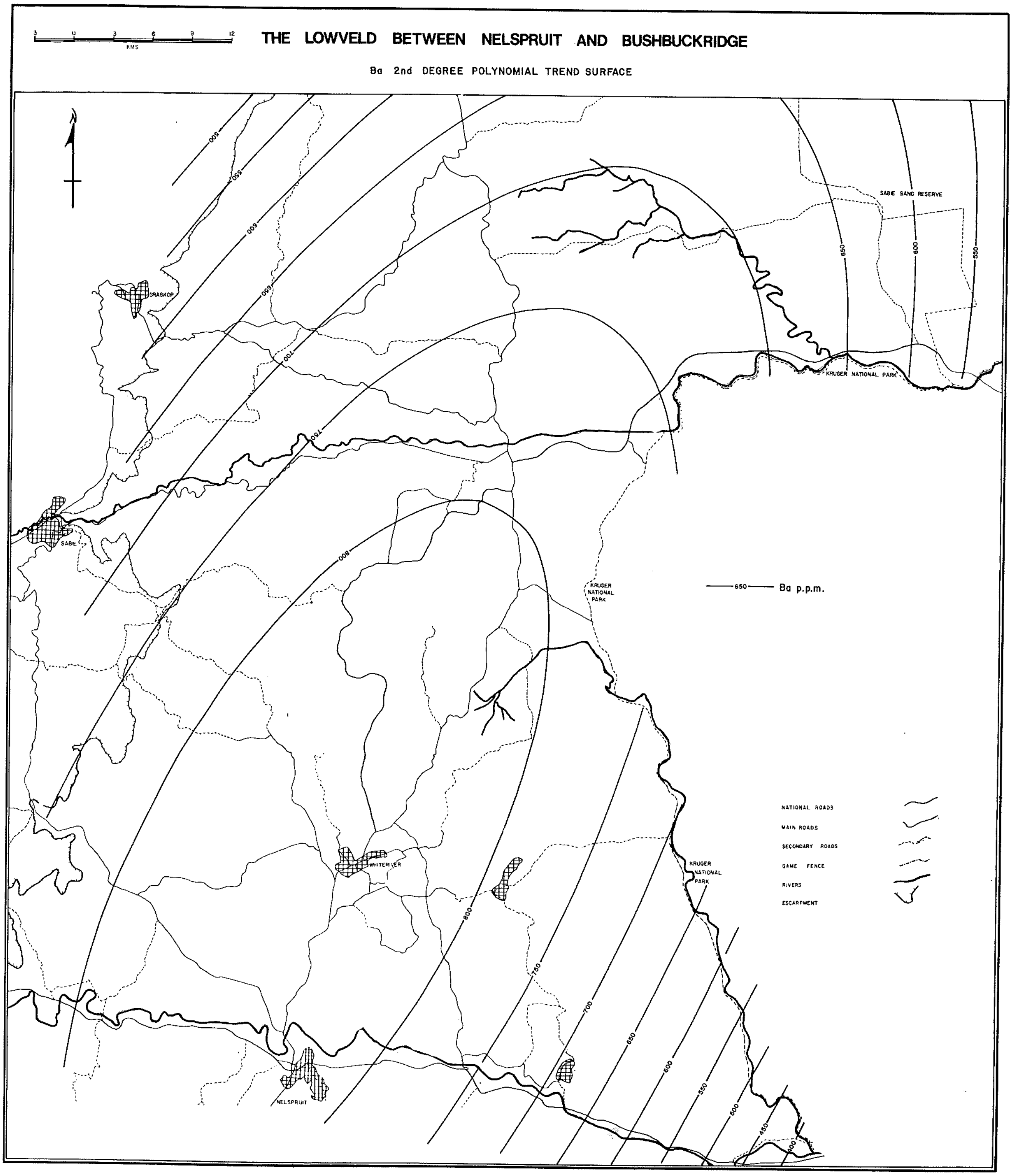

Figure 8 : *Second degree polynomial trend surface of the barium distribution in the study area.*

IV. SUMMARY AND CONCLUSIONS

(i) Considerable variations in topography exist in the granitic terrane of the eastern Transvaal lowveld and these can be partially explained by the geology of the area. Potash-rich granites (*sensu stricto*) and adamellites are generally more resistant to weathering, and therefore have a greater expression of relief, than soda-rich granodiorites, tonalites and trondhjemites. This fact may also be partially responsible for topographic variations in the basement rocks that are still covered by supracrustal sequences in the Kaapvaal Craton.

(ii) A specific study of key granitophile elements in the area between Nelspruit and Bushbuckridge shows that the potassic Nelspruit Porphyritic Granite is considerably more resistant to weathering than the younger Cunning Moor Tonalite. The relationship between topography and major element chemistry is also reflected in the distribution of certain trace elements which partition themselves between the granite-forming minerals. Granites enriched in Rb and Ba are therefore more resistant to weathering than those relatively depleted in these elements. The mechanism determining the rates of weathering, however, is not the presence, or lack, of constituent elements, but the relative stabilities, under lithospheric conditions, of the dominant granite-forming minerals. This mechanism may also account for the fact that sea water is some thirty times enriched in sodium ions than it is in potassium ions (Mason, 1966).

(iii) An exception to the general rule relating topographic expression to chemical composition is provided in the study area by the Hebron Granodiorite. The fine-grained equigranular texture of this body has, it is suggested, an important effect on its relative porosity compared with the surrounding coarser-grained Nelspruit Porphyritic Granite. Thus the role played by chemical composition and mineralogy is, in this example, superceded by texture and porosity in influencing the rate of weathering of the Hebron Granodiorite. Although chemical composition plays an important part, it is obvious that a number of related parameters affect the final results of denudation in granitic terranes.

(iv) The results of the trend surface analysis in the study area have provided additional confirmation of the mode and sequence of crystallization within the Nelspruit Porphyritic Granite. Although the limitations of trend surface analysis should always be recognized, particularly regarding the interpretations derived from these surfaces, this technique nevertheless provides a useful subsidiary tool in evaluating the genesis of magmatic bodies such as is provided in this study. Where fractional crystallization or the consecutive crystallization of mineral phases within an igneous body has taken place, broad regional trend surfaces are bound to reflect the sequence and mode of crystallization. Such a tool may also prove to be useful in determining the location of incompatible element accumulations, the latter possibly being related to the development of syngenetic ore deposits within igneous rocks.

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APPENDIX

A. Sampling and Analytical Techniques

A total of approximately 230 samples of granite was collected in the study area. Seventy of these underwent full major and trace element analysis. The remaining 160 were partially analysed for K_2O, Na_2O, Rb, Sr and Ba. The details of sample localities and distribution, as well as a full account of analytical techniques will be found in the author's M.Sc. dissertation (Robb, 1977).

B. Contouring Techniques

The contour maps produced in this paper (Figure 2) as well as others used to produce the cross-sections presented here (Figure 3) were all drawn by the CALCOMP plotter on the University of the Witwatersrand's IBM 370 computer. The software that was used in processing the data was the standard "General Purpose Contouring Programme" (GPCP).

The three dimensional plot of the potash distribution in the area was done by the same method. The trend surfaces (Figures 6, 7 and 8) were also drawn using an option of the GPCP which calculates polynomial regression coefficients and plots the resultant surfaces for a specified order of polynomial expression. Complete presentations of all the contour and trend surface maps will be found in the author's M.Sc. dissertation (Robb, 1977).

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