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**THE SEQUENTIAL ERUPTION AND TECTONIC
HISTORY OF THE KLIPRIVIERSBERG GROUP
AS ILLUSTRATED BY THE DISTRIBUTION
OF GEOCHEMICAL UNITS**

P.L. LINTON, T.S. McCARTHY and C.A. BROWN

INFORMATION CIRCULAR No. 271

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by

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ABSTRACT

Samples of Klipriviersberg Group lavas were collected from ten localities both within and outside the Witwatersrand Basin. By classifying the samples into their geochemical units it is possible to map the areal distribution of individual units and thus to analyse the sequential eruption of the Klipriviersberg Group. Initially, volcanism was limited to the north-eastern portion of the Witwatersrand Basin and to the Koster area. After a retraction in the area initially covered by the volcanics, a progressive spread of volcanism with time is apparent. The volume of liquid erupted increases substantially with time. The distribution of geochemical units can be correlated with pre-existing fault systems, which controlled the extent of volcanism. Faults outside the Witwatersrand Basin, in particular the Thabazimbi-Murchison Line, also exercised control over Klipriviersberg Group volcanism. Units 1 to 6 were erupted in a NE-SW directed compressive regional stress field. In the case of Units 2 to 6 this resulted in the trapping of liquid in crustal or sub-crustal magma chambers, and consequently in the fractionated compositions erupted. Stress release due to crustal failure caused temporary collapses of the regional stress field and permitted extension normal to the principal stress direction, during which eruption of lava occurred. Changes in dyke directions across the Witwatersrand Basin indicate that extensional movement occurred in a rotational sense. Total collapse of the stress field occurred at the beginning of Unit 7, which allowed the passage of primitive liquids to the surface. The intimate relationship between the Klipriviersberg Group and the Central Rand Group in the Witwatersrand Basin suggests that the Klipriviersberg Group is a reliable stratigraphic guide for exploration for Witwatersrand sub-basins.

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INTRODUCTION

The work of Palmer et al. (1986), Bowen et al. (1986) and Myers et al. (1990a) has shown that a definite geochemical stratigraphy exists within the Klipriviersberg Group. Myers et al. (1990a) were able to identify eight units on the basis of chemistry, and indicated that a further two units may be locally present at the top of the Klipriviersberg Group. Importantly, chemical changes within the lava sequence are distinct, and are correlatable on a regional basis (Myers et al., 1990a). Therefore the distribution of geochemical units can be mapped (Myers et al., 1990a, Figure 16).

The breaks between geochemical units probably represent time surfaces, and thus the distribution of successive units allows the sequential evolution of the entire sequence to be studied. The Klipriviersberg Group occupies an important stratigraphic position as it lies between the compressional Witwatersrand basining event (Burke et al., 1986; Winter, 1987; Myers et al., 1990b) and the extensional Platberg Group rifting event (Buck, 1980; Burke et al., 1985; Meintjes et al., 1989). Thus a study of the evolution of the Klipriviersberg Group will document the transition of the stress field on the Kaapvaal Craton from compression to extension.

In this paper we present the results of data for Klipriviersberg Group samples collected subsequent to the work of Myers et al. (1990a). This data provides more complete coverage of the western portion of the Witwatersrand Basin in particular, and also extends to areas to the north of the Witwatersrand Basin. The data allow for more precise constraints to be placed on the distribution of geochemical units, and thus for a more complete analysis of the eruption of the Klipriviersberg Group. In addition, data for areas beyond the confines of the presently defined Witwatersrand Basin may highlight areas of exploration potential as the pre-Klipriviersberg surface locally contains important placers.

METHODOLOGY

The samples collected come from a number of different localities (Figure 1). Samples from the Virginia, Hennenman, Edenville, Vredefort, Ventersdorp, Koster, Bezuidenhout Valley, Kelvin, Krugersdorp and Broederstroom areas were collected by the authors. Analyses of samples from the Derdepoort area were taken from Martin (1990).

Samples were collected from both surface outcrop and borehole core. In all cases a representative sample was taken, and care was exercised to avoid obviously discoloured, altered, veined or amygdaloidal material. When necessity demanded that veined or amygdaloidal material be sampled, all foreign material was removed from the sample prior to crushing.

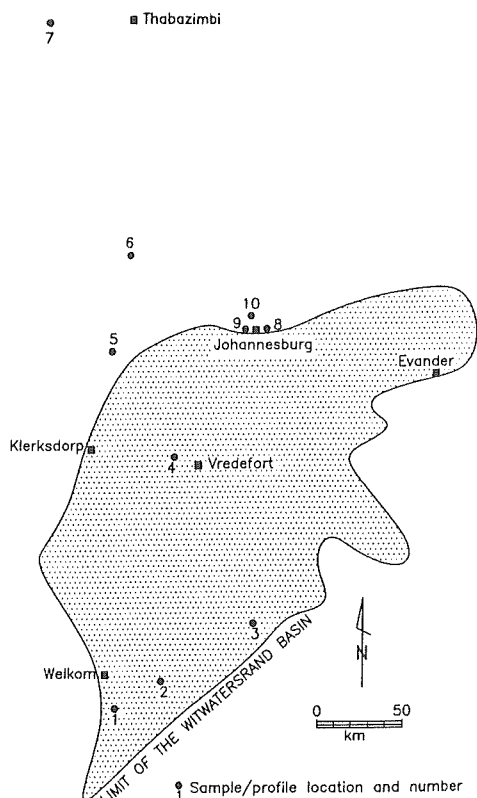


Figure 1: Map showing the positions of the localities sampled. 1 - Virginia, 2 - Hennenman, 3 - Edenville, 4 - Vredefort, 5 - Ventersdorp, 6 - Koster, 7 - Derdepoort, 8 - Bezuidenhout Valley, 9 - Krugersdorp, 10 - Broederstroom.

Sample preparation and analysis was undertaken at the Geology Department, University of the Witwatersrand. Samples were analysed by X-ray fluorescence spectroscopy on a Phillips PW1400 spectrometer. Major and minor elements were analysed from homogenised fusion disks using the method of Norrish and Hutton (1969), and trace elements were analysed from undiluted powder briquettes. The spectrometer was calibrated using a set of twenty-eight international standards.

Since the samples were analysed over a period of approximately three years, the between-run accuracy of the spectrometer was examined by running a set of internal standards with each batch of samples. The average errors for the elements used in this study (TiO_2 , Zr, Y, V and Cr) are low, and range between 2.7 and 7.3% across the working range of sample concentrations. The errors are in all cases smaller than the between unit differences in concentration.

The approach followed has been to construct stratigraphic profiles after the method of Myers et al. (1990a) for those areas where sufficiently long, and stratigraphically controlled intersections are available. In areas where no stratigraphic control is available the data were classified using the techniques of Bowen et al. (1986) and Linton and McCarthy (1993) in order to establish if the samples come from the Klipriviersberg Group, and if so, which geochemical unit they belong to.

RESULTS

The general geology and results of each area are discussed individually. Complete descriptions of the geochemical stratigraphy of the Klipriviersberg Group and the discriminant function analysis technique used are not given here, and the reader is referred to Myers et al. (1990a) and Linton and McCarthy (1993) respectively for details.

Virginia

Borehole JR5 from just to the north of Virginia was sampled. The borehole contains a thickness of almost 950m of Klipriviersberg Group. The lavas rest conformably on conglomerates of the Central Rand Group and are overlain by black shales of the Karoo Supergroup. From the stratigraphic profile it is evident that only Units 6 and 7 are present (Figure 2).

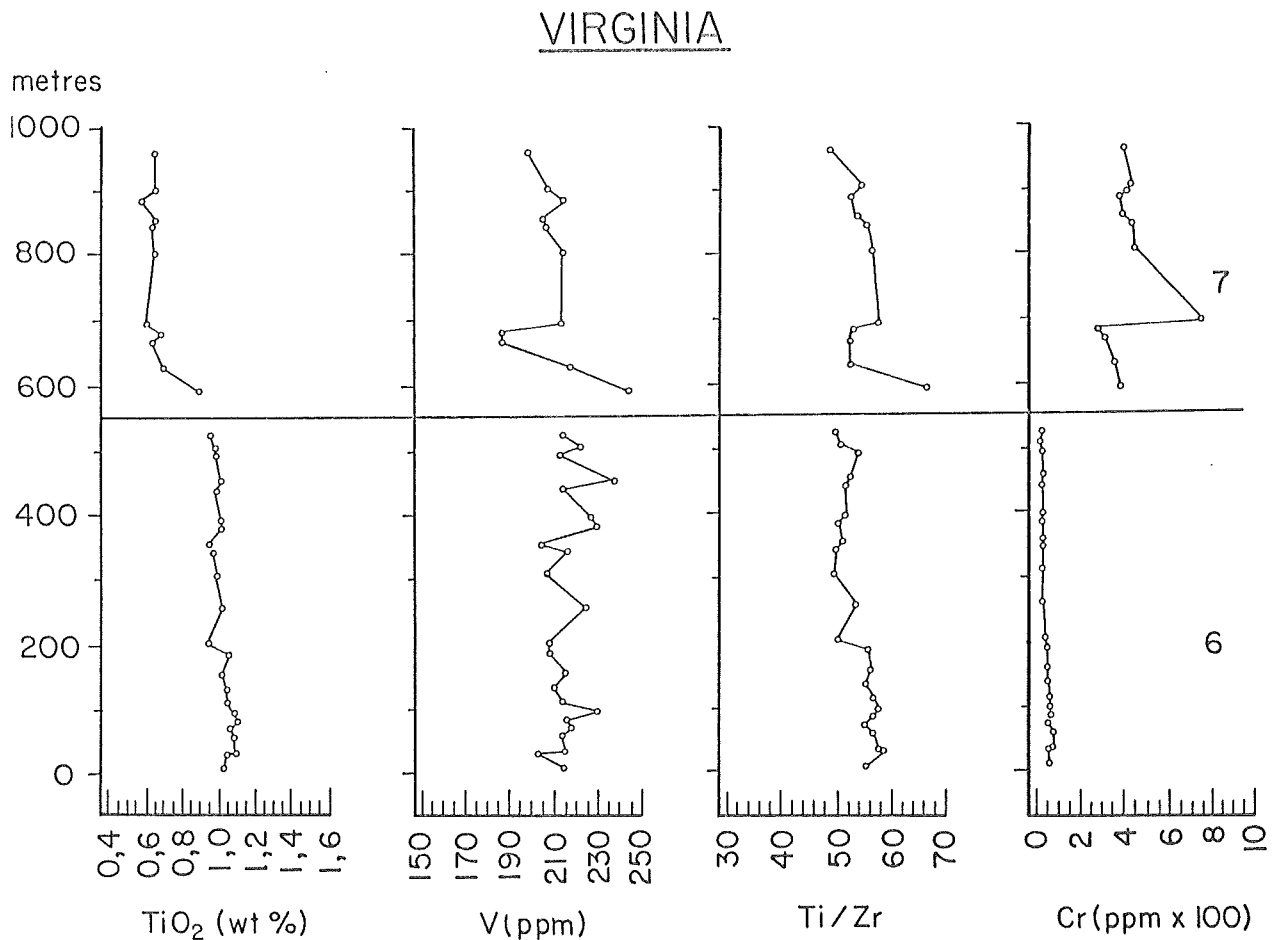


Figure 2: Plot of TiO_2 , V, Ti/Zr and Cr against stratigraphic height for the Virginia profile.

Hennenman

Borehole HZP1, in which the Klipriviersberg Group is approximately 1500m thick, was sampled. The lavas lie conformably on Central Rand Group conglomerates and are

overlain by Karoo Supergroup shales. On the stratigraphic profile (Figure 3), Units 5, 6, 7, and 8 can be identified. Of interest is the basal sample, which although having incompatible element chemistry consistent with the Unit 5 sample above, is enriched in compatible elements. Similar samples occur in the Ventersdorp and Koster profiles and have been reported from the Bothaville area (Linton et al., 1990).

HENNENMAN

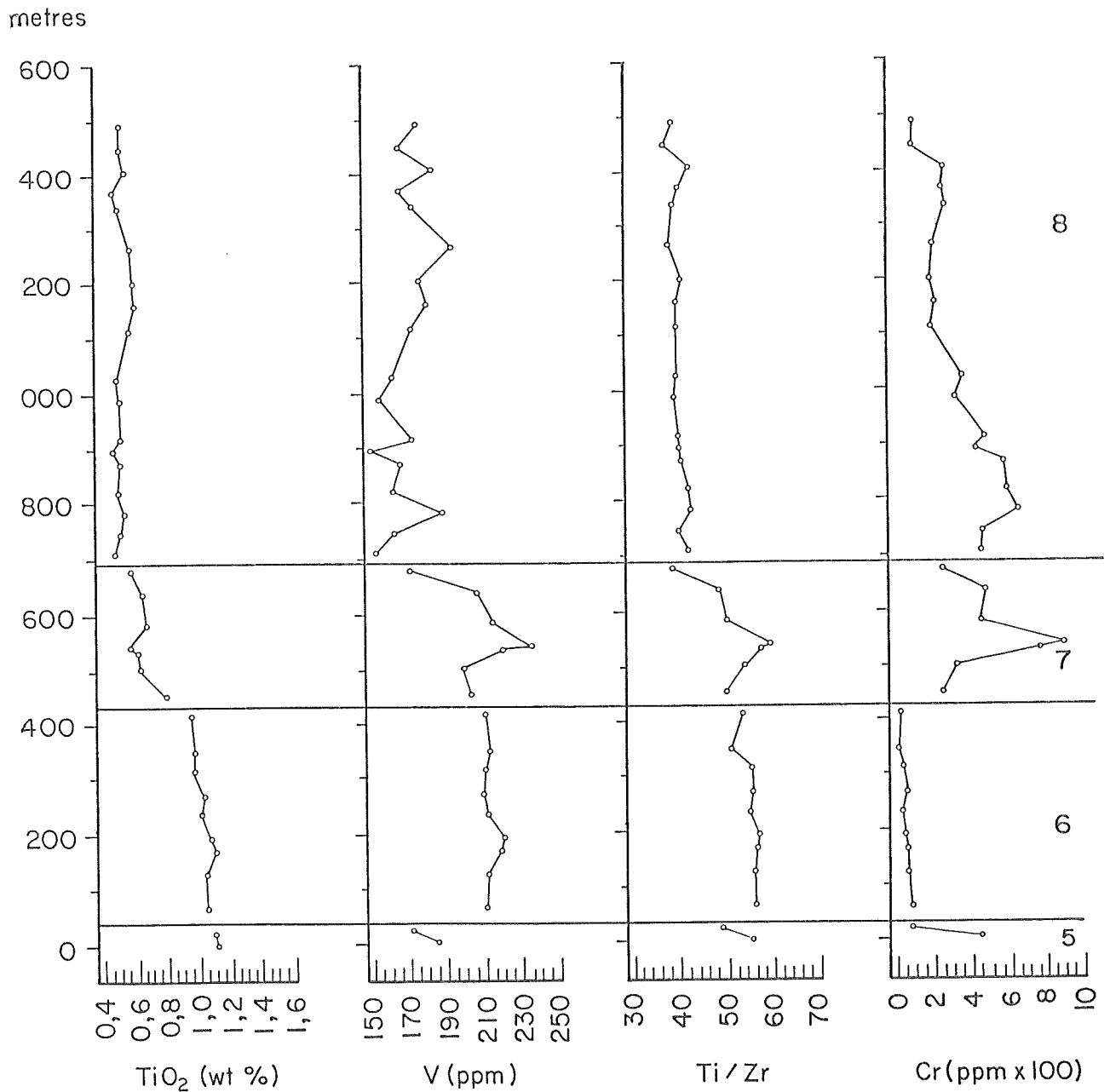


Figure 3: Plot of TiO_2 , V, Ti/Zr and Cr against stratigraphic height for the Hennenman profile.

Edenville

Samples were taken from borehole EUZ1 which was drilled to the west of Edenville. The Klipriviersberg Group is approximately 1150m thick in EUZ1. The lavas rest unconformably on quartzites of the West Rand Group and are overlain by quartz porphyries of the Makwassie Formation. On the stratigraphic profile, Units 5, 6 and 7 can be identified (Figure 4).

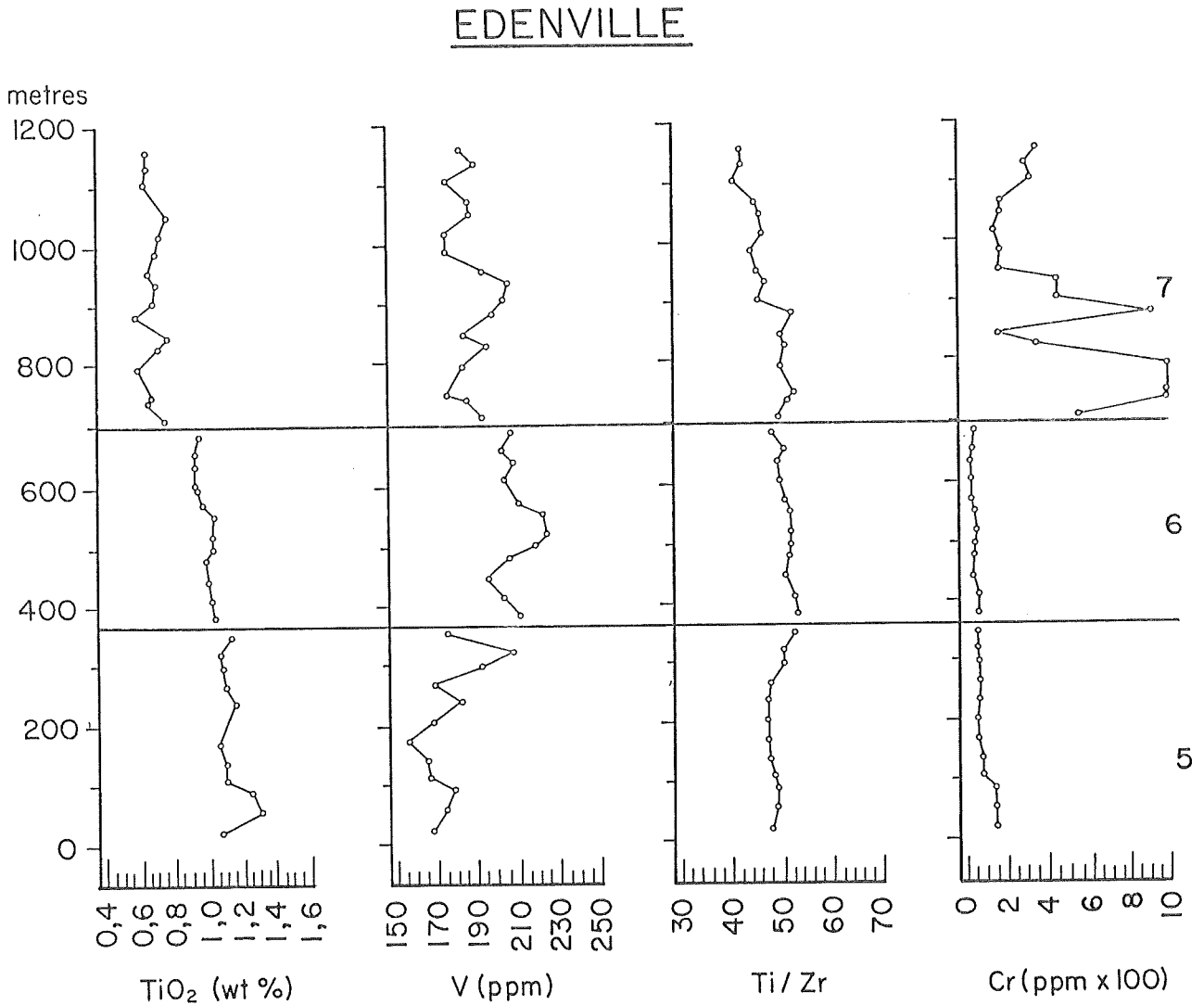


Figure 4: Plot of TiO₂, V, Ti/Zr and Cr against stratigraphic height for the Edenville profile.

Vredefort

A surface profile from the western rim of the collar rocks to the Vredefort Dome was sampled. The Klipriviersberg Group in this area is approximately 1500m thick. The relationship between the lavas and the underlying Central Rand Group strata cannot be determined due to lack of outcrop near the base of the Klipriviersberg Group. The lavas are overlain by the Black Reef Formation. On the stratigraphic profile (Figure 5), Units 5, 6 and

8 can be identified. Unit 7 appears to be absent from this profile, as is the case in the Bothaville area (Linton et al., 1990).

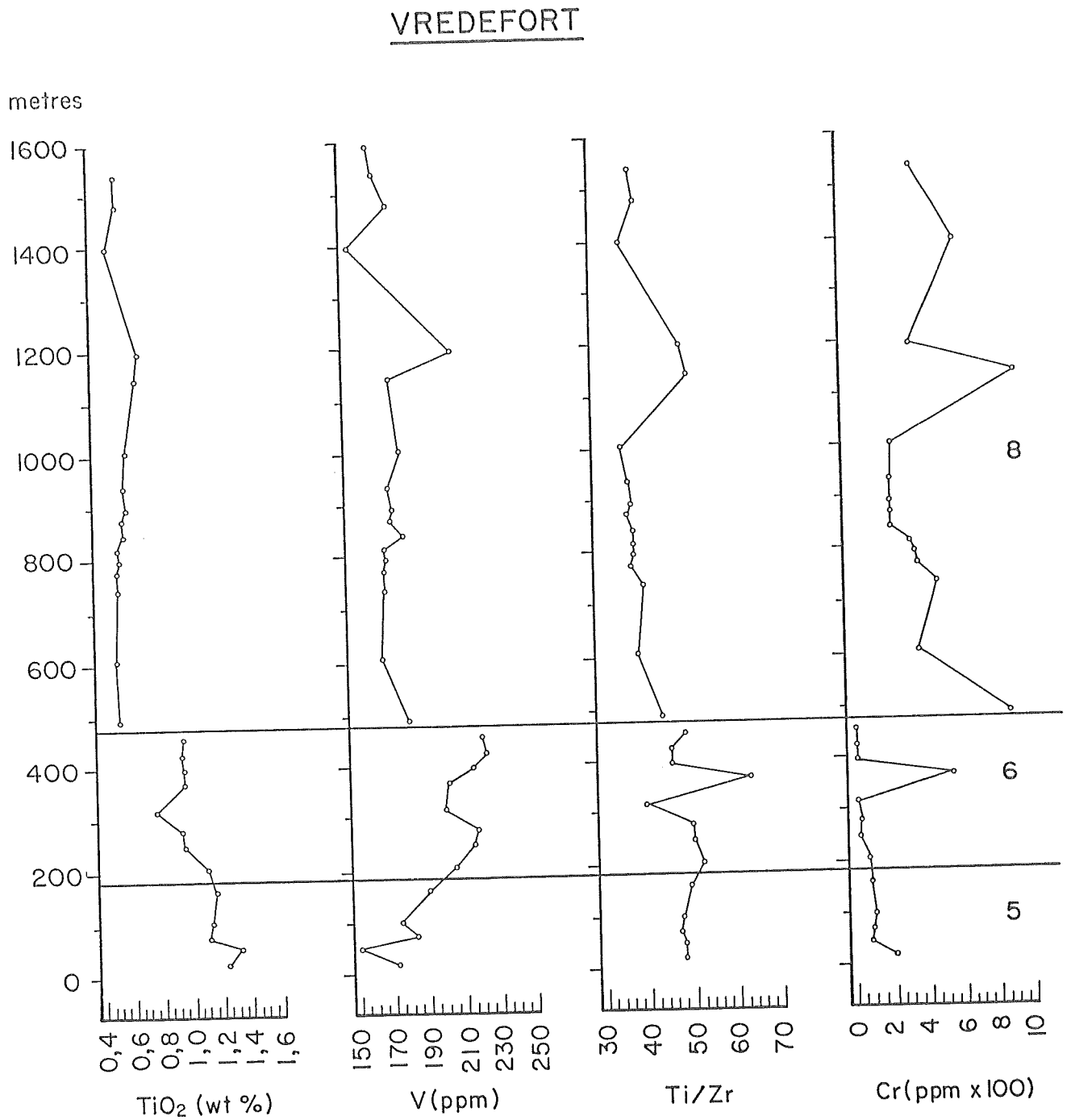


Figure 5: Plot of TiO₂, V, Ti/Zr and Cr against stratigraphic height for the Vredefort profile.

Ventersdorp

Borehole 714 from the Ventersdorp area was sampled. The borehole contains 420m of Klipriviersberg Group lava. The lavas unconformably overlie West Rand Group sediments, and they are overlain by sediments of the Platberg Group. On the stratigraphic profile (Figure 6), Units 5, 6 and 7 can be identified. Unit 5 in this profile shows compatible element enrichment.

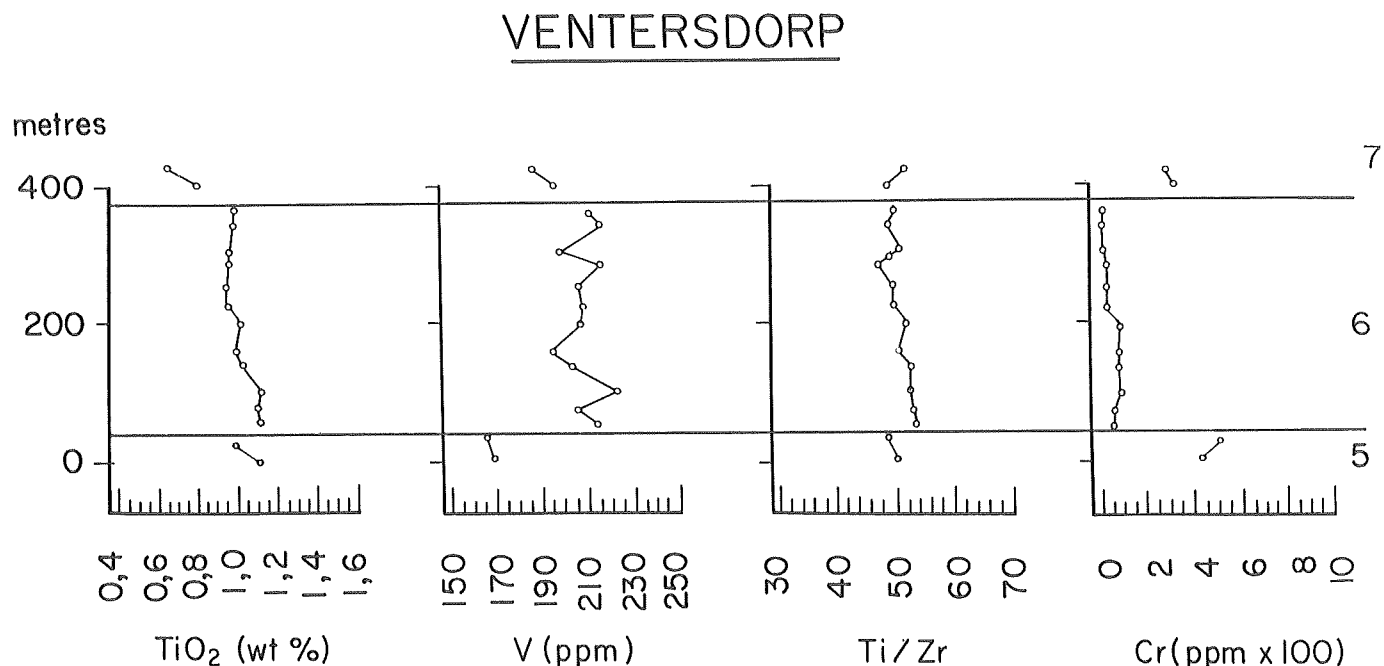


Figure 6: Plot of TiO₂, V, Ti/Zr and Cr against stratigraphic height for the Ventersdorp profile.

Koster

Samples were taken from borehole GV1, which was drilled to the south-west of Koster. The borehole contains almost 900m of Klipriviersberg Group. The lavas unconformably overlie West Rand Group sediments, and are overlain by Platberg Group sediments. On the stratigraphic profile Units 1, 5, 6, 7 and 8 can be identified (Figure 7). Unit 5 again displays a compatible element enriched chemistry.

Derdepoort

The results for this area were taken from Martin (1990). In this area, basic volcanics outcrop in two east-west trending belts, viz. the Derdepoort and Tshwene-Tshwene belts (Tyler, 1979). The Derdepoort belt lies slightly to the north of the Tshwene-Tshwene belt. Samples in the Derdepoort belt were collected from the lavas of the Waterval Formation, which overlie quartzites and conglomerates of the Hampton Formation, and are in turn overlain by acid volcanics of the Witfonteinrand Formation. On the basis of their stratigraphic position and their chemistry these were felt by Tyler (1979) and Martin (1990) to be Klipriviersberg Group correlates. This is confirmed by the discriminant function plot (Figure 8), on which samples belonging to Units 4 and 5 can be identified. Due to lack of outcrop,

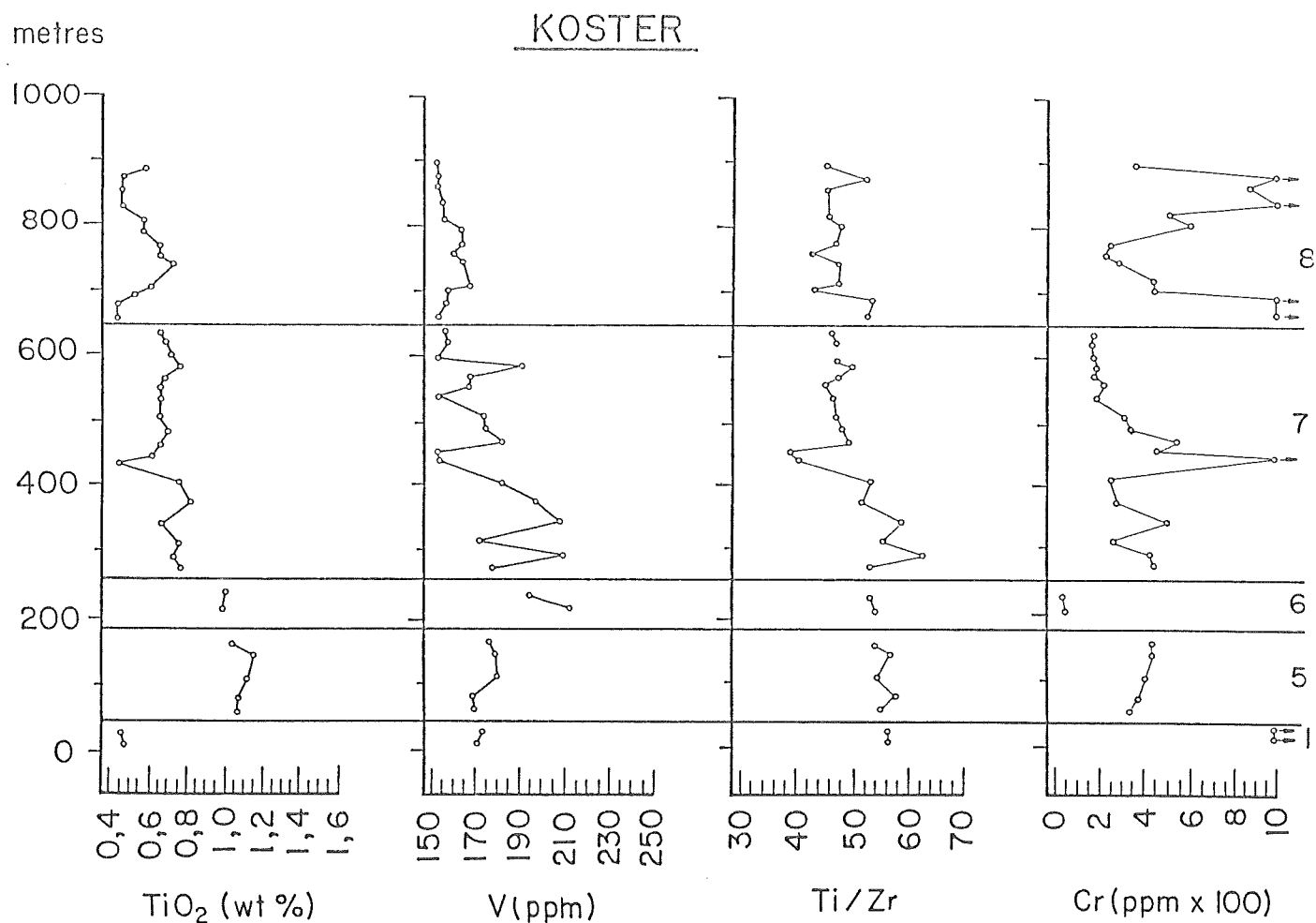


Figure 7: Plot of TiO₂, V, Ti/Zr and Cr against stratigraphic height for the Koster profile.

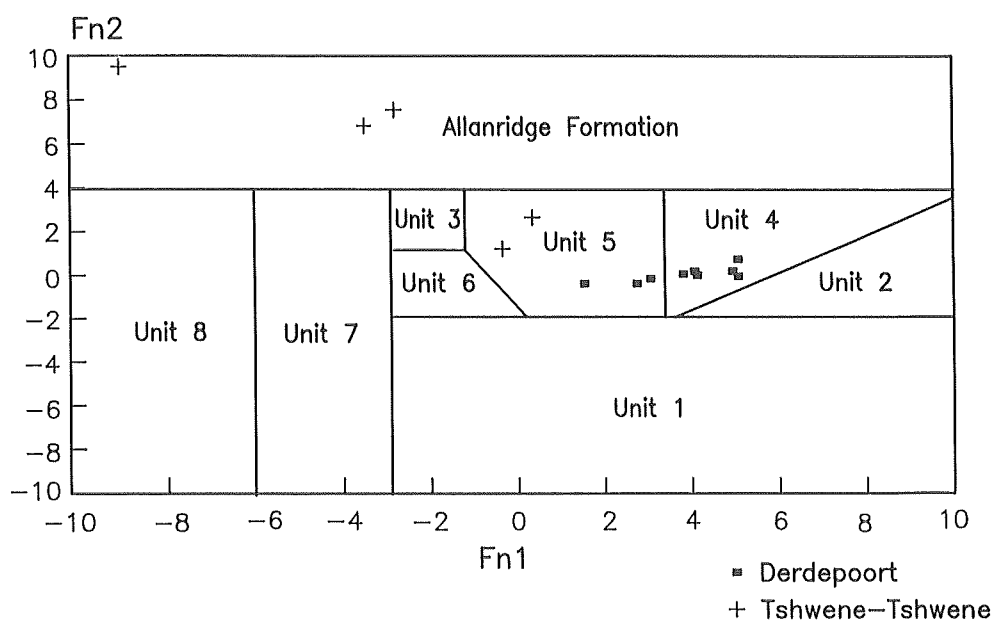


Figure 8: Plot of discriminant function 1 vs. discriminant function 2 for samples from the Derdepoort area.

the stratigraphic positions of the samples collected from the Tshwene-Tshwene belt could not be constrained. On the basis of major element analyses, Tyler (1979) correlated these lavas with the Klipriviersberg Group. The discriminant function plot (Figure 8) reveals that two of these samples belong to Unit 5 of the Klipriviersberg Group, while the other samples belong to the Allanridge Formation.

Bezuidenhout Valley

Samples in the Bezuidenhout Valley area were taken from discontinuous outcrop areas. The generally poor outcrop made it difficult to constrain the stratigraphic position of the samples. The geology of the Ventersdorp Supergroup in the Bezuidenhout Valley area has been described by McCarthy et al. (1990b). In a borehole drilled in the Croydon area, ultramafic lavas of the Westonaria Formation (which is equivalent to Unit 1 (Myers et al., 1990a)) were encountered underlying homogeneous and porphyritic basaltic lavas. The ultramafic lavas are not preserved in outcrop, which consists only of the homogeneous and porphyritic lavas. The Klipriviersberg Group is overlain by sediments of the Platberg Group, and McCarthy et al. (1990b) estimated its thickness to be approximately 650m. The discriminant function plot for the area (Figure 9) reveals that Units 4, 5 and 7 are present in outcrop, and as discussed earlier, probable Unit 1 was encountered in borehole core, although the lava was not sampled.

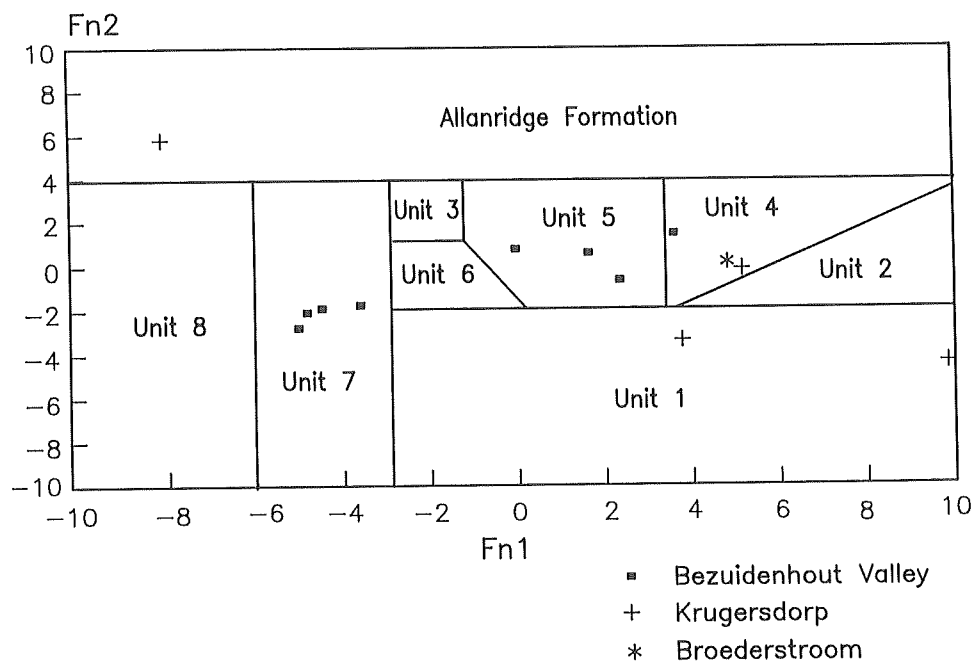


Figure 9: Plot of discriminant function 1 vs. discriminant function 2 for samples from the Bezuidenhout Valley, Krugersdorp and Broederstroom areas.

Krugersdorp

A number of samples were collected from a small Ventersdorp Supergroup inlier just to the north of Krugersdorp located by Mr. David Grant. The Ventersdorp Supergroup rocks comprise lavas, tuffs, and sediments. They are underlain by quartzites of the West Rand

Group, and overlain by the Black Reef Formation. The stratigraphy and structure of the inlier is complex and is yet to be established, and the stratigraphic positions of the samples could thus not be determined. The discriminant function plot (Figure 9) suggests that only three of the four lava samples collected belong to the Klipriviersberg Group, and that one sample belongs to the Allanridge Formation. The Klipriviersberg Group samples belong to Units 1 and 4. One sample that plots in the Unit 1 field has similar chemistry to the Unit 4 sample, and thus appears to have been misclassified by the discriminant function analysis. The definite Unit 1 sample displays a highly modified chemistry, as it is enriched in TiO_2 , total iron, Y and Zr relative to Unit 1 in other areas, while retaining typically high MgO, Cr and Ni concentrations. The sample contains appreciable amounts of quartz and quartzite grains set in a volcanic matrix, and is directly comparable in that respect to the lithic tuff of Wyatt (1976). However, the modified chemistry can only be explained by assimilation of material rich in iron and incompatible elements, and which has sufficiently high MgO, Cr and Ni concentrations not to dilute these significantly in the lava. The most likely contaminants are West Rand Group shales, which have the correct chemistry to fulfil these criteria (Fuller et al., 1981; Wronkiewicz and Condie, 1987).

Broederstroom

A single sample of Klipriviersberg Group lava was collected from an inlier on the northern margin of the Johannesburg Dome (Roering, 1984). The sample plots in the Unit 4 field on the discriminant function plot (Figure 9).

DISCUSSION

The addition of the data reported here to that collected by Myers et al. (1990a) allows for an updated map showing the distribution of the Klipriviersberg Group to be drawn (Figure 10). Within the boundaries of the presently defined Witwatersrand Basin, the only modification to the map of Myers et al. (1990a) is in the distribution of Unit 5, which is not controlled in an east-west sense, but rather in a north-south sense. The presence of Unit 5, albeit thin, in the Hennenman profile, and its absence from the Welkom and Virginia profiles, allows for its distribution to be accurately constrained.

Units 1 and 4 are encountered just to the north of the Witwatersrand Basin margin. The presence of Unit 1 in the Koster area, and Unit 4 in the Derdepoort area suggests that their distributions may be fairly widespread to the north of the Witwatersrand Basin. Units 2 and 3 are not encountered outside the Witwatersrand Basin. Units 5, 6, 7 and 8 are absent from one or more areas, but this is more likely a function of preservation than non-eruption. The exception is the absence of Unit 7 in Vredefort, which is probably due either to faulting or non-eruption since Unit 8 occurs in the profile.

In general, the distribution of units can be tightly constrained within the Witwatersrand Basin, but data for areas to the north is sparse and interpretation is largely speculative. It is impossible to determine, for example, whether Unit 4 is continuous between the Witwatersrand Basin and Derdepoort, or whether its occurrence in Derdepoort is in the form of a localised outlier. The same applies for Units 1, 5, 6, 7 and 8 which all occur to the north of the Witwatersrand Basin.

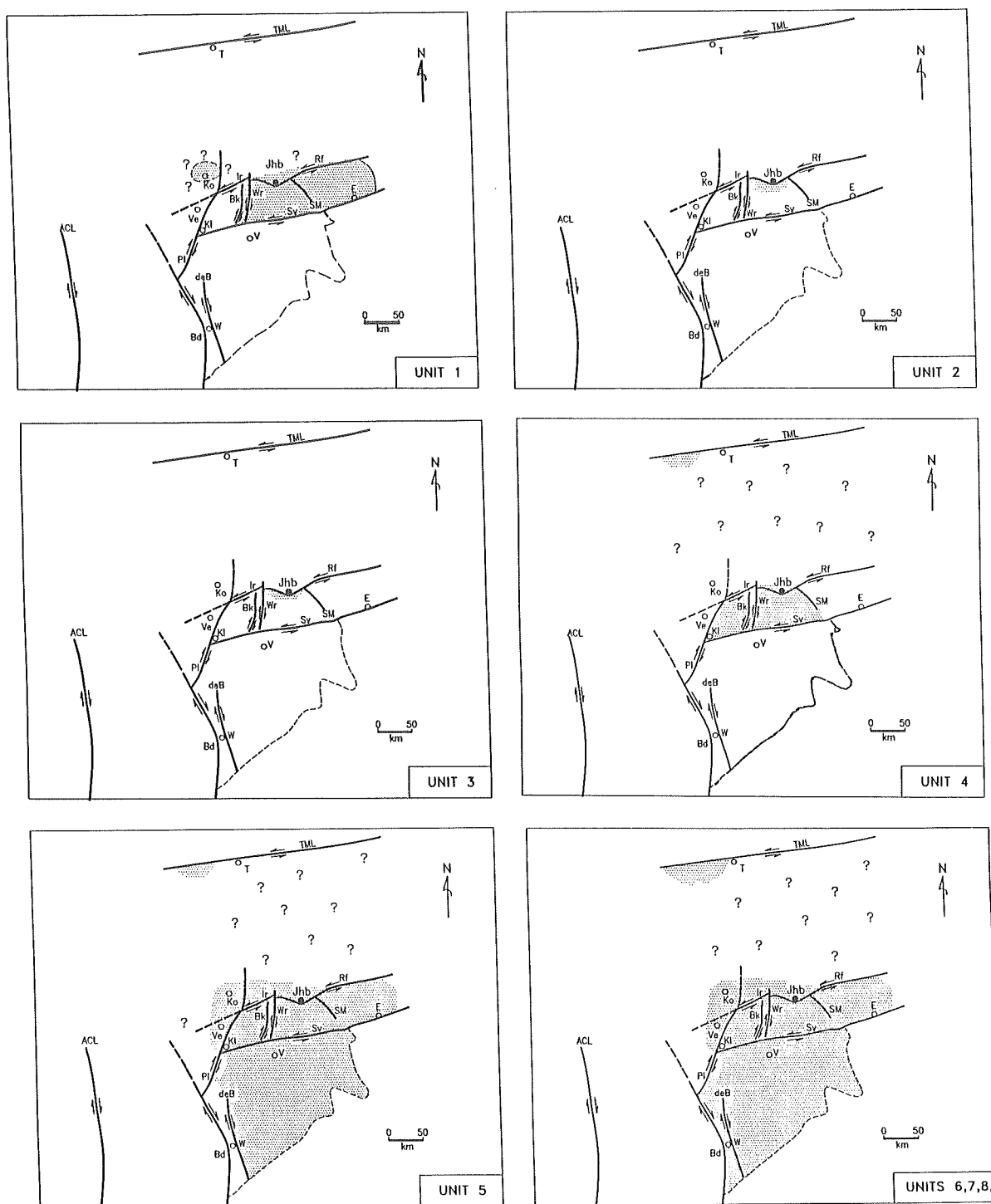


Figure 10: The distribution of geochemical units. The thin dashed line represents the limit of the Witwatersrand Basin. Solid lines represent the positions of major faults (after Myers et al., 1990b, and Stanistreet and McCarthy, 1991) and dashed lines the possible extensions of these faults. ACL - Amalia-Colesburg Line, BD - Border Fault, Bk - Bank Fault, deB - de Bron Fault, Ir - Ireton Fault, Pl - Platberg Fault, Rf - Rietfontein Fault, Sb - Sugarbush Fault, SM - Springs Monocline, TML - Thabazimbi-Murchison Line, WR - West Rand Fault. Cities and towns: E - Evander, Jhb - Johannesburg, Kl - Klerksdorp, Ko - Koster, T - Thabazimbi, Ve - Ventersdorp, Vr - Vredefort, W - Welkom. The hatched area represents the known extent of geochemical units, and the question marks the possible extent of geochemical units.

It is possible to calculate the volume of lava erupted in each unit (Table 1). Volumes have been calculated for both the known extent and the possible extent of the individual geochemical units as shown on Figure 10. From Table 1, it can be seen that the volume of melt erupted declines from Unit 1 to Unit 3, before increasing steadily. The average thickness of units increases with time, from less than 100m in Units 1, 2 and 3 to almost 500m in Unit 8. Due to erosion, the thickness of Unit 8 is poorly constrained, and the average may be considerably greater than 490m. A minimum of 72 000km³ of lava was erupted, and possibly as much as 238 000km³.

Table 1. Minimum and possible maximum volumes of liquid erupted in each geochemical unit

Unit	Min. area (km ²)	Max. area (km ²)	Ave. thickness (m)	Min. volume (km ³)	Max. volume (km ³)
1	13100	21000	50	655	1050
2	600	600	90	54	54
3	600	600	50	30	30
4	13500	26500	190	2565	5035
5	46000	109500	160	7360	17520
6	48000	167500	370	17760	61795
7	48000	167500	420	20160	70350
8	48000	167500	490	23520	82075
Total				72104	237909

The distribution of the geochemical units, and the volume of liquid erupted, decreases from Unit 1 to Unit 3. Units 2 and 3 are confined almost totally to the Central Rand, as opposed to Unit 1, which is relatively widespread. The distribution of Unit 4 reflects a large increase in the areal extent of volcanism, as it covers approximately twenty-five times the area of Unit 3. A further large increase occurs in Unit 5, which covers more than three times the area of Unit 4. A further small increase occurs in Unit 6, by which time the full extent of Klipriviersberg Group volcanism appears to have been reached.

Myers et al. (1990b) have showed that deposition of the Central Rand Group was controlled by compressive block faulting. Faults acted as oblique-slip, reverse structures, and defined at least eighteen fault-bounded blocks. The fault-bounded blocks moved independently, but responded simultaneously to the regional stress field. It appears that this crustal architecture was also responsible for controlling the extent of volcanism within the Witwatersrand Basin. The limits of distribution of several geochemical units coincides closely with the positions of major fault systems that were active in Central Rand Group times (Figure 10), such as the Rietfontein, Ireton, Sugarbush, West Rand/Bank, Springs, Border and Platberg faults. The distribution of Unit 5 suggests that the de Bron fault may have

become active in Klipriviersberg Group times as suggested by Myers et al. (1990b), and was not necessarily initiated during Platberg Group extension.

The distribution of the Klipriviersberg Group to the north of the Witwatersrand Basin may also have been controlled by fault systems. The Derdepoort samples were taken in close proximity to the Thabazimbi-Murchison Line (TML), which had a pre-Ventersdorp history (Martin, 1990). The TML thus appears to have influenced the distribution of Units 4 and 5, and possibly the later units. The absence of Unit 4 from the Ventersdorp profile can be related to control by the Platberg fault, and its absence from the Koster profile may possibly be related to a northerly extension of this structure (Figure 10).

The Klipriviersberg Group displays an intimate relationship with the Central Rand Group within the Witwatersrand Basin. The lavas have a conformable relationship with the underlying sediments, indicating that the transition between sedimentation and volcanism was extremely rapid. McCarthy et al. (1990b) and Myers et al. (1990b) suggested that the eruption of the lavas destroyed the depositional systems and terminated sedimentation. The Klipriviersberg Group thins onto the northern margin of the Witwatersrand Basin (Stanistreet et al., 1986; McCarthy et al., 1990b; Charlesworth and McCarthy, 1990), which appears to have changed only marginally during eruption of the Klipriviersberg Group. This implies that the NE-SW directed compression that controlled sedimentation persisted during volcanism.

Dyke orientations in the northern part of the Witwatersrand Basin suggest that the NE-SW directed compressive stress field persisted up to the end of Unit 6 (McCarthy et al., 1990a). A change in dyke orientation in Unit 7 documents a change to an extensional stress field, which is accompanied by a radical change in the nature of the eruptives. The chemistries of Units 2 to 6 are highly evolved, indicating that liquids had long residence times in crustal or sub-crustal magma chambers prior to eruption. In contrast, Units 7 and 8 contain highly primitive compositions with up to 18% MgO and 3000ppm Cr, and may include direct mantle melts. The change to extensional conditions thus allowed the rapid passage of liquids to the surface with little or no fractionation occurring.

Clendenin et al. (1988) pointed out that volcanic conduits are closed and the "plumbing" system of a lava sequence will become sealed under compression. They felt that extension began with the advent of volcanism, and that in order to allow the eruption of the komatiitic liquids (McIver et al., 1982) of the Westonia Formation (equivalent to Unit 1), large degrees of extension must have occurred. This is a salient point, but is at odds with the dyke evidence. The preferred mechanism is one where the stress field is dominantly compressive, but during periods of stress release, lateral extension can occur normal to the regional stress field and permit the eruption of lava.

The abrupt breaks between units suggest that eruption, and thus stress release, occurred episodically after which the compressive stress field was re-established. An initial and apparently very rapid stress release occurred during which Unit 1 was erupted. Thereafter, conditions in the crust forced accumulation of magma at depth, allowing highly evolved magma compositions to develop. Units 2 to 6 each have a highly restricted compositional range, and in order to preserve the homogeneity of the units, eruption must have occurred extremely rapidly. It is likely, therefore, that each unit was erupted during a relatively short-

lived event.

The distribution of geochemical units indicates that stress release occurred on a progressively wider scale, and allowed larger and larger areas to be covered by lava. Unit 1 displays komatiitic affinities and occurs on a reasonably wide scale. Thus, as suggested by Clendenin et al. (1988), the first extension event must have been intense in order to produce widespread komatiitic volcanism. When the regional stress field was re-established, compression was dominant and the stress release events which produced Units 2 and 3 were minor. As volcanism progressed, stress release and the extent of eruption spread progressively to an increasing number of fault-bounded blocks. The degree of stress release must also have increased, as the volumes of lava erupted became progressively larger.

Klipriviersberg Group dykes provide some indication of the changing stress field during the progressive extension of volcanism, at least as far as the area within the Witwatersrand Basin is concerned. Dykes in the Central Rand and Carletonville Goldfields strike NE-SW; in the Klerksdorp Goldfield the strike is predominantly NW-SE; while in the Welkom Goldfield the strike is predominantly E-W (McCarthy et al., 1990a). These directions define the maximum and minimum principal stress directions at the time of emplacement. Coeval with this change in direction was an extension of the area of volcanic activity, initially towards Klerksdorp in the west, and later towards Welkom in the south (Figure 10). These relationships imply that the initial phase of eruption was the result of eastward extension of crustal blocks between the Rietfontein and Sugarbush faults. Later, this was accompanied by north-easterly extension in the Klerksdorp area, and still later by northerly extension in the Welkom area. The overall extensional movement is one of progressive failure in a rotational sense (Figure 11).

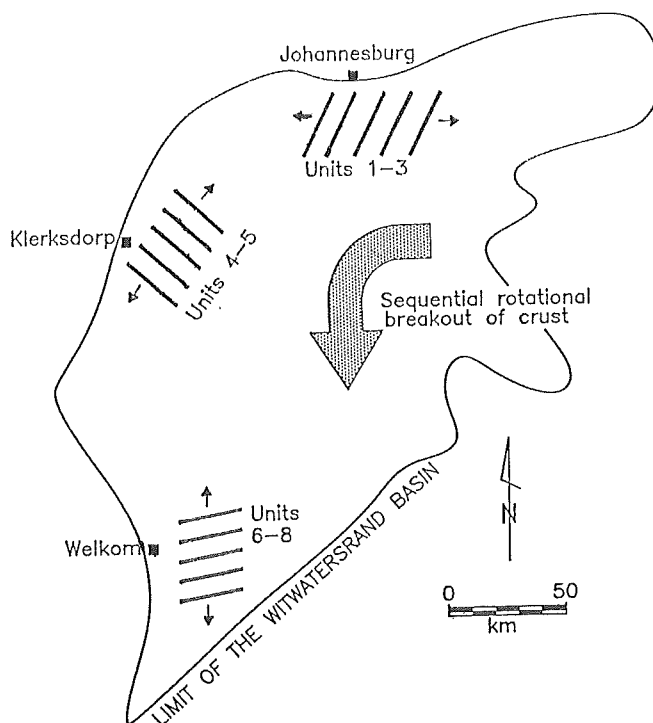


Figure 11: The orientations and ages of Klipriviersberg Group dykes in the Central Rand, Klerksdorp and Welkom Goldfields (after McCarthy et al., 1990a) showing the sequential rotational breakout of crust.

The progressive change in chemistry of the volcanics after Unit 6 suggests that the final phase of break-up was particularly rapid, and moreover accelerated with time. The close association between high level crustal structures, the progressive spread of volcanism and magma chemistry indicates that events within the crust exerted a pronounced control on the mantle processes attending magma generation, ponding and eruption. Indeed, the association is so close that it appears that magma generation during Klipriviersberg Group times was a response to crustal events, perhaps with mantle melting being orchestrated by adiabatic decompression induced by crustal failure.

The early units are restricted to the north-eastern portion of the Witwatersrand Basin, which suggests that the volcanic centre was located in this area. Regional variations in the chemistry of Units 7 and 8 indicate that the volcanic centre was located towards the western margin of the Witwatersrand Basin at this time, as more primitive compositions were erupted there than in areas to the east, probably due to differentiation during transport in dykes (Myers et al., 1990a). The shift of the volcanic centre to the west is coeval with the change in the stress field, and thus may herald the onset of Platberg Group rifting. The cessation of Klipriviersberg Group volcanism, and the onset of Platberg Group sedimentation and acid volcanism can be related to the opening of the Lichtenburg trough, which occurred due to south-easterly escape of crust (McCarthy et al., 1990a; Stanistreet and McCarthy, 1991). The entire succession from Witwatersrand Supergroup to Platberg Group can thus be thought of as progressive failure of the crust during a single compressive event, possibly due to a collision between the Kaapvaal and Zimbabwe cratons (Burke et al., 1985; Stanistreet and McCarthy, 1991).

The presence of the Klipriviersberg Group just to the north of the Rietfontein Fault in the Krugersdorp, Bezuidenhout Valley and Broederstroom areas may be related to relaxation on this fault during extension, and the resultant slight overstepping of the structure by the lavas. In these areas, the Klipriviersberg Group often overlies West Rand Group sediments. A similar feature is observed in the Edenville and Ventersdorp profiles, which both lie close to the margin of the Witwatersrand Basin, and in both of which the Klipriviersberg Group is found overlying the West Rand Group.

Myers et al. (1990b) pointed out that the presently defined Witwatersrand Basin is a structural basin, and is thus confined within marginal faults. However, the original depository appears to have been much greater in extent, and there is a strong possibility that structural sub-basins similar to the Evander Basin may be preserved elsewhere on the Kaapvaal Craton. The Klipriviersberg Group samples lying far from the known limits of the Witwatersrand Basin (eg. Koster, Derdepoort) should be seen in this context. The Klipriviersberg Group provides a reliable stratigraphic guide during exploration for such sub-basins, as the marginal faults of the sub-basins would also have exerted control on the lavas. As the Klipriviersberg Group pre-dates the three major erosional events that have affected the Kaapvaal Craton, namely the pre-Platberg, pre-Black Reef and pre-Karoo unconformities, where Klipriviersberg Group lava is intersected, the probability of encountering Central Rand Group sediments or VCR is thus high.

The correlation of the upper Hampton Formation with the Central Rand Group (Martin, 1990) indicates that the TML may have been a marginal structure to a Witwatersrand sub-

basin. The possibility thus exists that further sub-basins may be developed south of the TML. The Rietfontein-Ireton and Border structures form a conjugate strike-slip set along the margins of the Witwatersrand Basin, and the TML and the Amalia-Colesburg Line appear to form a similar conjugate set (Stanistreet and McCarthy, 1991). The possibility thus also exists that Witwatersrand sub-basins may exist to the east of the Amalia Line. The presence of Klipriviersberg Group in these areas (Derdepoort, and the south-western Transvaal and northern Cape as suggested by Van der Westhuizen et al., 1991) is thus highly prospective.

CONCLUSIONS

An analysis of the distribution of the geochemical units within the Klipriviersberg Group highlights the close relationship between the lavas and the Central Rand Group. The Klipriviersberg Group was initially erupted in the same NE-SW directed compressive regional stress field that controlled Central Rand Group sedimentation, and consequently the compressive block faults active in the Central Rand Group remained active in Klipriviersberg Group times. These fault systems imposed limitations on the extent of volcanism. The close relationship between crustal structures and volcanism suggests that crustal failure may have initiated mantle melting. Volcanism occurred during brief periods of stress release when the compressive regional stress field collapsed, and permitted extension normal to the principal stress direction. There is a progressive increase in the extent of volcanism both areally and volumetrically, which indicates that stress release occurred on a progressively larger scale and more rapidly in the later stages. Stress release can be related to the sequential rotational breakout of crust. Total collapse of the regional stress field occurred prior to Unit 7, which allowed highly primitive liquids to be erupted. The cessation of volcanism occurred when the Lichtenburg trough opened, possibly due to south-easterly tectonic escape of crust (McCarthy et al., 1990a; Stanistreet and McCarthy, 1991). The succession from the Witwatersrand Supergroup to the Platberg Group can be viewed as progressive crustal failure during a single compressive event. The close relationship between the Central Rand Group and Klipriviersberg Group is important for exploration. The control exercised by Witwatersrand Basin marginal faults on the extent of volcanism implies that where the Klipriviersberg Group is found, the probability of encountering Central Rand Group strata or the VCR is high.

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