3

Local Geology of the Study Area

3.1. Geological Characteristics of the Lebowa Granite Suite in the Rooiberg District of the Western Bushveld Complex

The area of detailed study is denoted by the box in Figure 3.1, and is located principally in the granites of the western Bushveld Complex.

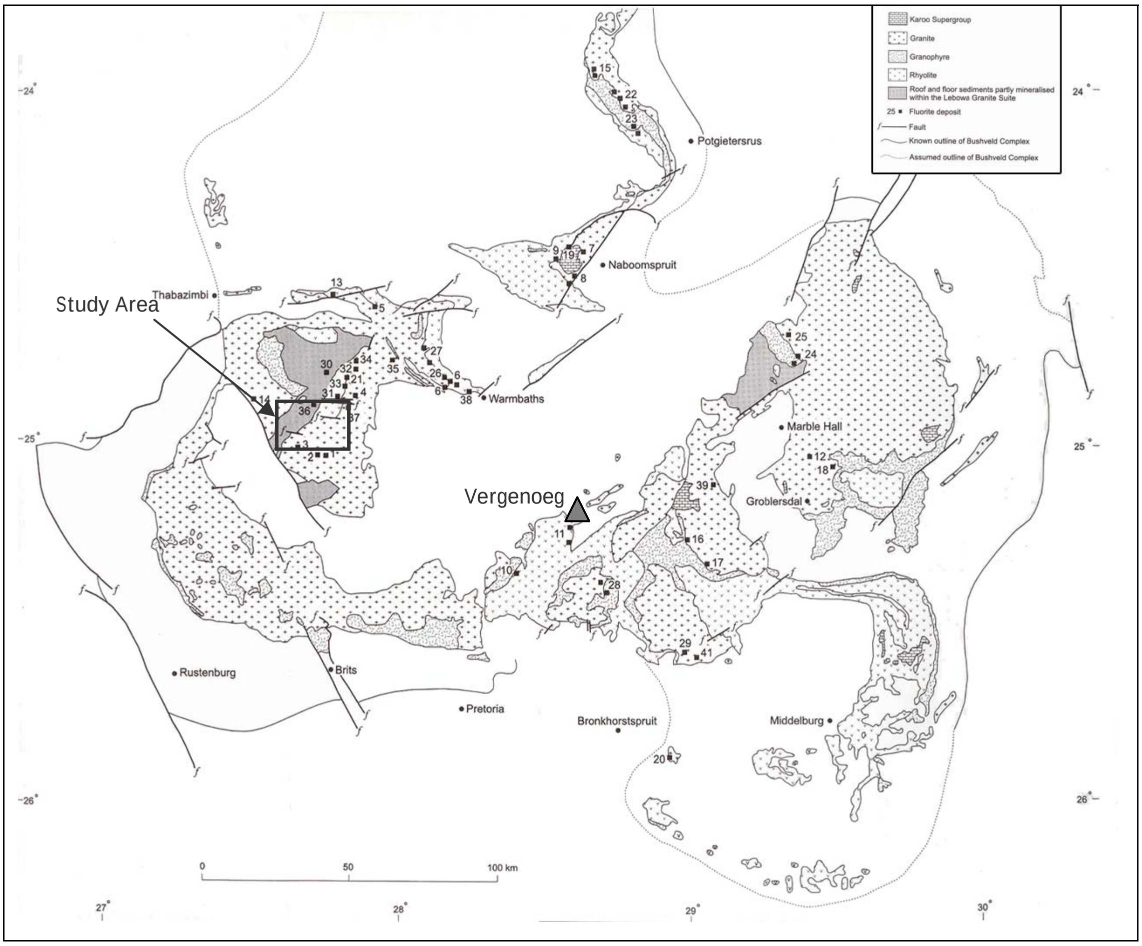


Figure 3.1. Inferred limit of the Bushveld Complex showing the west, east, north and south lobes. The granites of the Lebowa Granite Suite (LGS) are indicated with crosses. Vergenoeg Fe-F mine is located in the near geographic centre of the Complex. The detailed study area is indicated by the black frame to the left of the picture (after Crocker *et al.*, 2001).

The western lobe of the Lebowa Granite Suite, west of the town of Warmbaths, consists primarily of coarse-grained, deuterically-altered Nebo granites of the Bushveld Complex with subordinate Klipkloof-type and Bobbejaankop-type granites, granophyres, and Rooiberg Group rhyolites. Two large fragments of Transvaal Supergroup sediments are located around the towns of Rooiberg and Assen, the Rooiberg and Crocodile River fragments respectively. The granite lithologies become more highly differentiated toward the north and west, with the core of the massive Bushveld laccolith exposed in the central regions of the lobe. The mafic rocks of the Rustenburg Layered Suite rim the Lebowa Granite Suite and outcrop to the west.

The geology of the area around the town of Rooiberg is depicted in Figure 3.2. The Rooiberg fragment, which consists of Transvaal Supergroup sediments, is positioned in the centre of the map and is surrounded on all sides by lithologies of the Lebowa Granite Suite and the Rooiberg Group. Fluorite occurrences, as identified by Crocker *et* al. (1988), are denoted by the black dots. They occur both in the granites but also more significantly at the contacts with the Rooiberg rhyolites and Transvaal sediments. In the proximity of the detailed study area, denoted by the black frame, an upward stratigraphic trend is suggested from southwest to northeast, beginning with Nebo granite towards the centre of the Complex, through to more differentiated granite varieties such as Klipkloof and Bobbejaankop type granites, into the roof-rock lithologies, of the Rooiberg Group and the Transvaal Supergroup.

The granites of the study area are considered to represent a single pluton, variably dissected by structure and later dykes, which may generate the appearance of multiple plutons at surface. Crocker *et al*. (1988) identified Paalkraal- and Kenkelbos-type granites[*] in the vicinity, but insufficient evidence exists for these distinct lithologies, and any textural or colour variation observed has been attributed to differentiation and its relative position to the roof rocks.

[*] These varieties of Nebo granite have not been recognised by SACS (1980).

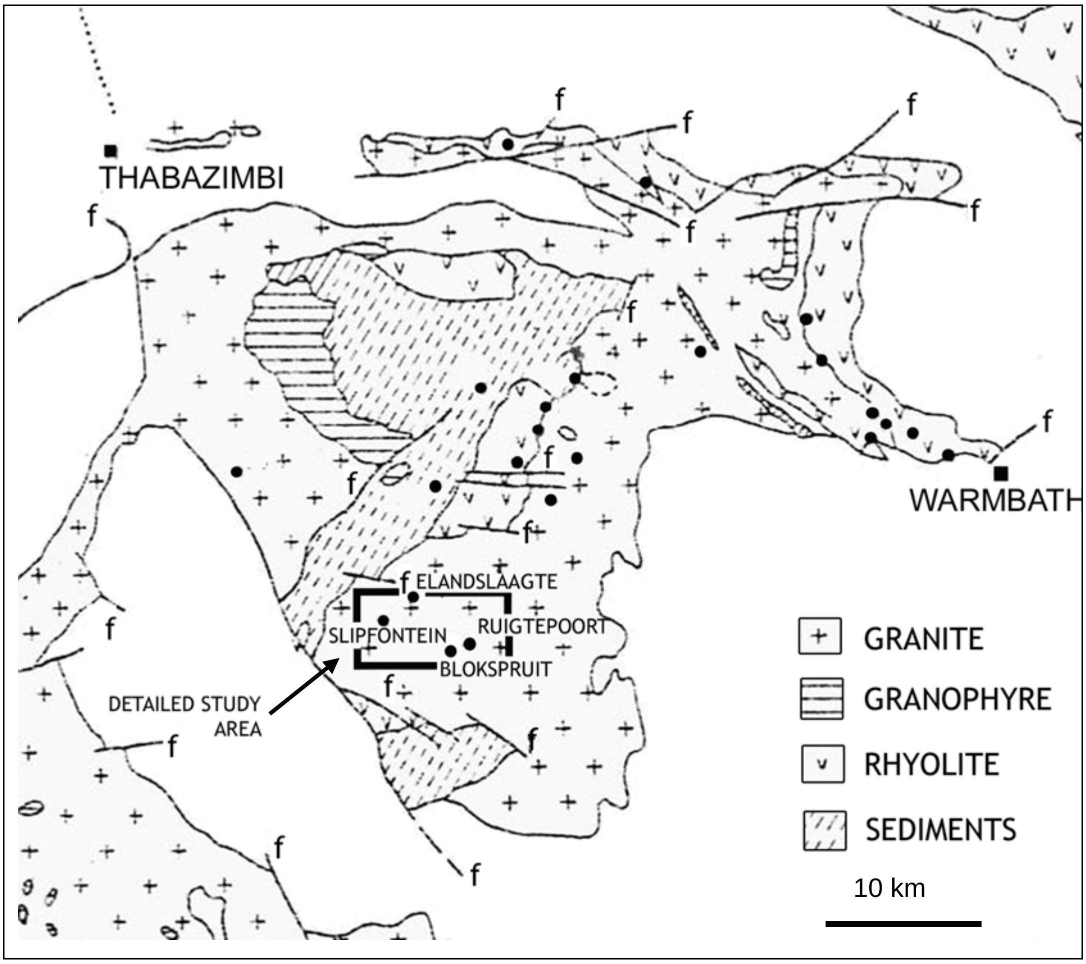


Figure 3.2. Geological sketch map of the area near Rooiberg. The detailed study area of this report is marked by the black frame, including the mineral occurrences at Ruigtepoort, Blokspruit, Slipfontein and Elandslaagte. Fluorite occurrences, as identified by Crocker *et* al. (1988), are denoted by black dots.

Detailed mapping was undertaken of the contiguous farms Ruigtepoort 162JQ, Blokspruit 157JQ, Slipfontein 551KQ, Elandslaagte 154JQ, Doornfontein 155JQ and Paalkraal 556KQ (Figure 3.3). These farms were previously studied and mapped by Crocker (1976) and Crocker *et al*. (1988, 2001) towards an inventory of fluorite occurrences of South Africa. It was necessary to re-evaluate these farms in the context of IOCG deposits and their associated alteration and mineralisation.

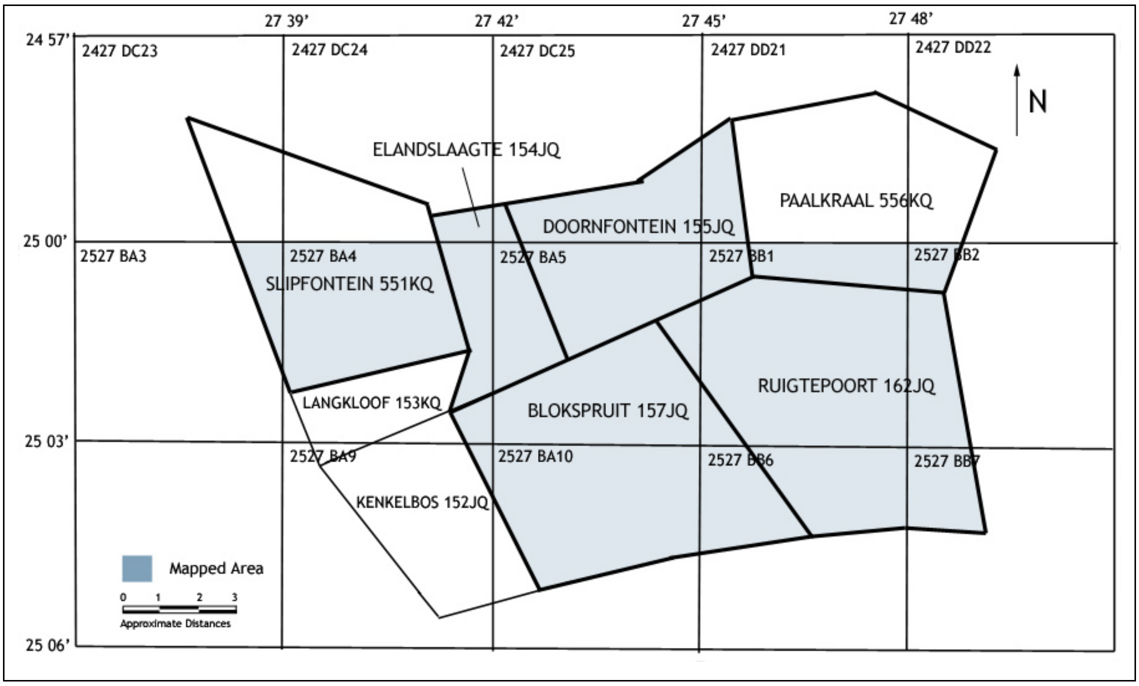


Figure 3.3. Farm boundaries and the area mapped in this study.

Detailed Geology of the Study Area

A 1:10 000 scale interpreted, geological outcrop map was produced for the farms shown in Figure 3.3 and resized to be included in this text (Figure 3.4).

The area comprises predominantly of red Nebo granites, with occasional Bobbejaankop-type granites and Klipkloof aplitic dykes. Grey Nebo granite and porphyritic varieties are found in the northeast portion of the map, but are of limited distribution.

The Nebo granites are shown in pink on the map with delineated outcrops marked in darker pink. Outcrop of the Nebo granites is better in the southern portion of the map with low hills developed. The relief of the central and northern portions of the map is much more gradual and outcrop tends to be poor and sparse. Outcrop geometry tends to be controlled by joints and larger bounding structures such as faults and dykes. The most prominent jointing direction is 120°, and the principal faulting orientation is 150°, which reflects the orientation of prominent regional structures, namely the Rustenburg Fault and the Crocodile River Fault.

Klipkloof aplites are shown in orange with actual outcrops in dark orange. These dykes and sills tend to be thin and sinuous following prevailing structural orientations. A prominent arcuate dyke is depicted on the map in the southern portion of the map on the farms Blokspruit and Ruigtepoort. It is steeply dipping in the west (*c.* 80° to the north) to shallow dipping in the east (*c.* 20° to the north-northwest) and chilled against the Nebo granite. There are numerous barren pegmatitic pods, approximately 0.5-20 m in diameter, associated with it in its central portions, occurring within it and discontinuously on its upper and lower contacts. As the dyke goes westerly and northerly, it becomes co-linear with massive iron oxide mineralisation distributed north-south. According to Crocker *et al*. (2001), apart from the stratigraphic position and lack of metasomatic alteration, the dyke resembles the Lease Granite with its pegmatite, found in the Zaaiplaats area.

Minor lithologies include outcrops of granophyres of the Rashoop Granophyre Suite (yellow on map) and rhyolites and agglomerates of the Rooiberg group (green on map). These lithologies have been used to delineate high-level zones in the granite stratigraphy, however, they have limited distribution, and the lack of credible outcrop or sub-outcrop makes their delineation difficult. Contact relations with the Nebo granites cannot be determined with much certainty. Towards the north of the area, close to outcrops of Rooiberg agglomerates, the surrounding granites begin to adopt a granophyric texture, which is interpreted as contact pseudogranophyre. Pseudogranophyre is recognised elsewhere in the Bushveld as having been derived from recrystallised Rooiberg rhyolites, which also coarsen towards the underlying granite contact.

Xenoliths of Transvaal Supergroup sediments, of principally orthoquartzitic derivation, are found on each of the farms but tend to be of limited extent. Crocker *et al*. (2001) described these xenoliths as “silicic leptite and hybrid,

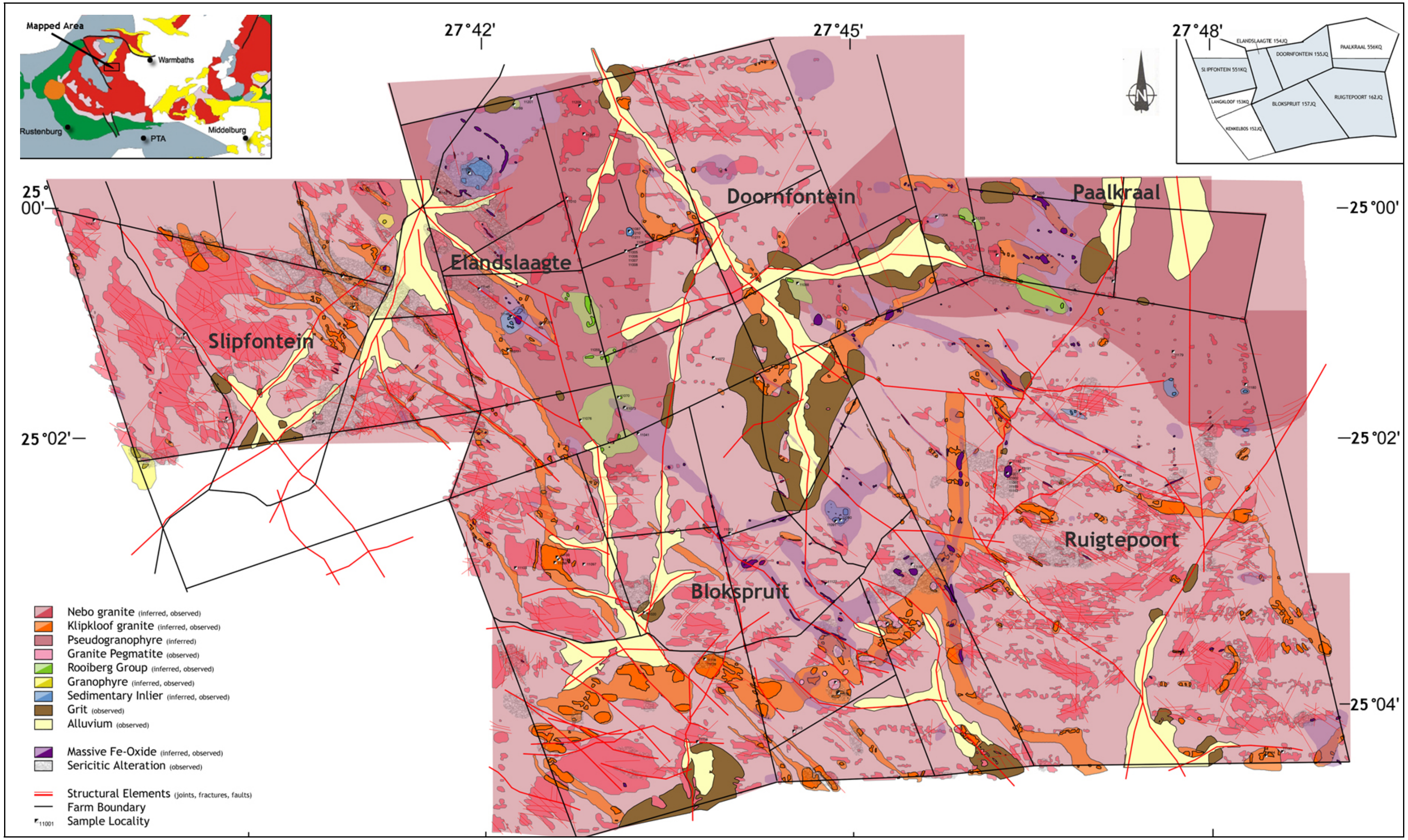


Figure 3.4. Geological outcrop map with interpretation of the farms near Ruigtepoort.

metasomatised granophyre”. These xenoliths are consistently and pervasively mineralised by oxidising fluids, and are often flushed with iron oxides and Rare Earth phosphates. The wall-rock granite is commonly pervasively chloritised.

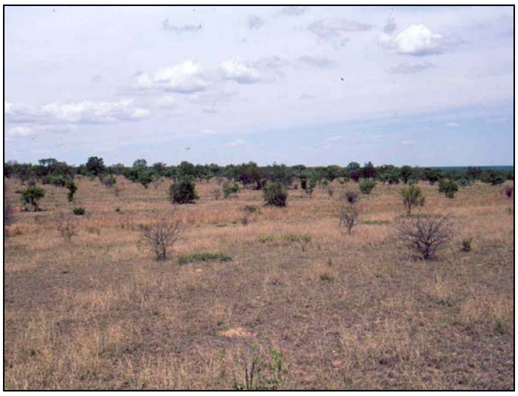
Modern unlithified alluvium marks the position of ephemeral drainage structures (shown in light yellow). Karoo-aged grits (Hancox, pers. comm.), shown in dark brown, are developed along and near present day drainage structures suggesting that these features have been present and utilised for a long time.

Field Descriptions of Main Rock Types

Nebo Granite

The Nebo granites are by far the most abundant lithology in the area of interest, and they form low, undulating topography. Typically these granites weather to flat plains, as observed in the north-eastern portions of the area, but where late-fractionate, Klipkloof aplites or granophyres are present this may be affected and more outcrop and hills may be developed. The presence of the large aplitic dyke/sill across the southern portion of the area and the granophyres in the far western portion may account, in part, for the increased outcrop in the vicinity and the low, rocky hills, as depicted on the outcrop map (Figure 3.4). The geomorphological differences may be observed in Plates 3.1 (a) - (c).

The Nebo granite is a hypersolvus, coarse-grained, equigranular rock, and is typically grey, pink or pinkish-red in colour (Plates 3.1 (d) and 3.1 (e)). The granite is composed principally of quartz, perthite, interstitial biotite and/or hornblende and some minor oxides, with hornblende occurring more abundantly at the base of the granite sheet and biotite in the more fractionated portions. It is commonly porphyritic with K-feldspar phenocrysts up to 10 mm in size and quartz phenocrysts up to 3 mm in size (Plate 3.1 (f)), which weather prominently.


a


b


c


d


e


f

Plate 3.1. a) Flat, outcrop-poor weathered surface of Bushveld granites in the north, central and eastern portions of the area. b) Low hills and outcrops, often wooded, of the southern and western portions of the area. Fracture related depressions and drainage features tend to be more prominent. c) Rounded-boulder granite outcrop of the southern portion of the area, usually well-vegetated. d) Typical dull-pink perthitic Nebo granite from Blokspruit 157JQ; Sample #ID 11120. e) Grey hornblende-rich Nebo granite representing least differentiated material. Sharp contact with aplitic (Klipkloof) phase. From Paalkraal 556KQ. f) Porphyritic variety Nebo granite from Ruigtepoort 162JQ; Sample #ID 11141.

The different varieties of granite weather distinctly, in particular, the Bobbejaankop variety is distinguishable by its characteristic quartz chains (Plates 3.2 (a)-(b).

The colouration of the granites intensifies and reddens towards the top of the 2.5 km thick granite sheet, as the Fe^{2+}/ Fe^{3+} ratio decreases in the upper, more fractionated portions (Plate 3.2 (c)) (Bailie, 1997). Changes in the mineralogy are characterised by an increase in K-feldspar/perthite over plagioclase, and ascendant proportions of biotite as the principal femic mineral over hornblende. The upper Nebo rocks are further characterised by the formation of linked chains and clusters of quartz. Signs of hydrothermal alteration are common, and in the vicinity of Zaaiplaats Tin Mine, in the northern Bushveld, the degree of hydrothermal alteration is particularly intense. This hydrothermal fluid is likely a late discrete phase linked to the culmination of magmatic crystallisation of the Bushveld granite, which was concentrated and trapped beneath an impervious roof, or escaped to produce alteration and mineralisation elsewhere. These granites are locally known as *Bobbejaankop* and the deep reddish colour, quartz chains, hydrothermal alteration and biotite-bearing mineralogy are indicative of their highly fractionated nature and proximity to the roof of the granite sheet (Plate 3.2 (d)).

The fine-grained microgranite or aplite, which is commonly found in the uppermost parts of the sheet, is generally known as the *Klipkloof* granite and is mineralogically and chemically identical to the Nebo granite (Plate 3.2 (e)). It also occurs as sills, dykes and veins throughout the entire thickness of the granite sheet, and like the Nebo granite, it is grey at the base and reddish at the top.

In general, the Nebo granite grades from grey, hornblende-rich, plagioclase-bearing granites at its base, upwards to red biotite-rich, K-feldspar-dominated granites with increased quartz abundance. The fractionation trends in the Nebo granite are stated previously in Table 2.2.

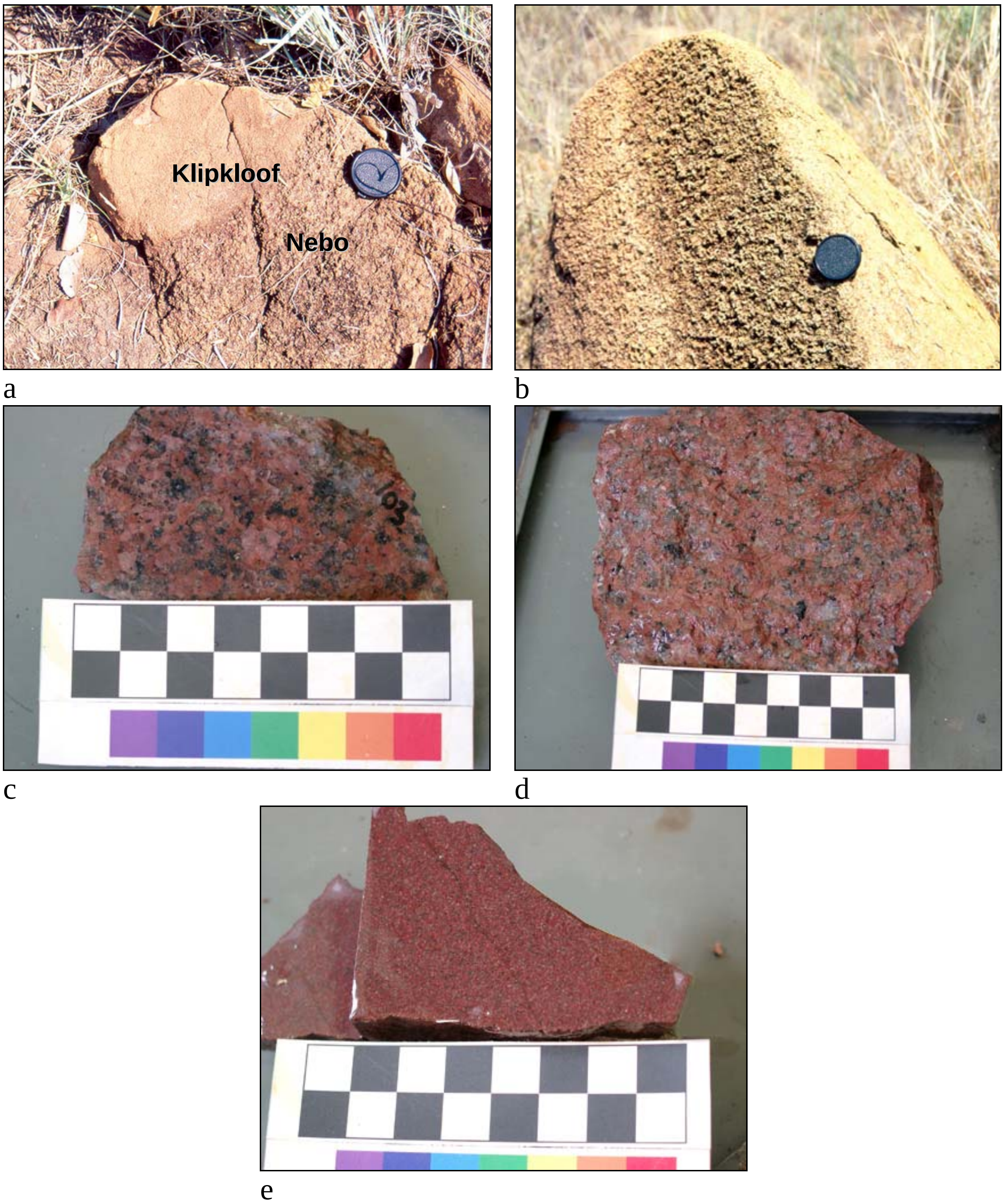


Plate 3.2. a) Weathered surface of Nebo and Klipkloof granites. Coarse quartz grains in the Nebo granite weather prominently forming a rough, pitted surface; by contrast, the Klipkloof is smooth and even. b) Outcrop of Bobbejaankop granite with characteristic quartz chains weathering prominently. c) Red Nebo granite common throughout the area. The mafic phase is dominantly biotite, which is commonly chloritised. From Bloksspruit 157JQ; Sample #ID 11103. d) Bobbejaankop variety Nebo granite from type-locality in the eastern Bushveld e) Klipkloof variety Nebo granite from Ruigtepoort 162JQ.

Rashoop Granophyres

The granophyre is an extremely uniform, fine- to medium-grained rock that varies in colour from purplish red when fine textured to reddish brown when coarser textured (Bailie, 1997). It weathers to brownish-orange or reddish brown colours and forms rounded to oblate boulders, which may superficially appear coarse-grained, but on closer inspection comprise a much finer-grained granophyric intergrowth of quartz and feldspar. It commonly has a pitted weathered surface due to the preferential weathering of the dark interstitial clots and blebs of hornblende or chloritised hornblende (Gain & Twist, 1995). The granophyre is distinguished from the Nebo granite by the ubiquitous granophyric intergrowths and the absence of visible free quartz. The granophyre tends to coarsen towards the underlying granite contact.

Rooiberg Rhyolites, Agglomerates and Pseudogranophyres

The rhyolites are commonly massive, although classic volcanic textures may occur, including flow-banding in the lavas, welding textures in the ash-flows (fiamme), amygdales, gas cavities and spherulites (Gain & Twist, 1995). A range of volcanic breccias has been recognised, including agglomerates, flow-top breccias, hyaloclastites, tuffs, and lapilli tuffs (Bailie, 1997; Gain & Twist, 1995).

The massive rhyolite is a fine- to very fine-grained brick-red rock with a splintery fracture, being porphyritic in places and typically weathers to small angular fragments. The groundmass, consisting of plagioclase feldspar, lesser K-feldspar and quartz, has generally a size of 0.06 mm or less; whereas phenocrysts of plagioclase, often highly sericitised, may vary in size from 1 to 2.5 mm (Bailie, 1997). Minor phases include anhedral magnetite and hematite, and hornblende or biotite, which has been extensively chloritised.

The rhyolite may exhibit a spherulitic texture, composed of radiating laths, and may be indicative of rapid quenching (Plates 3.3 (a)-(b)) (Bailie, 1997; Gain & Twist, 1995).

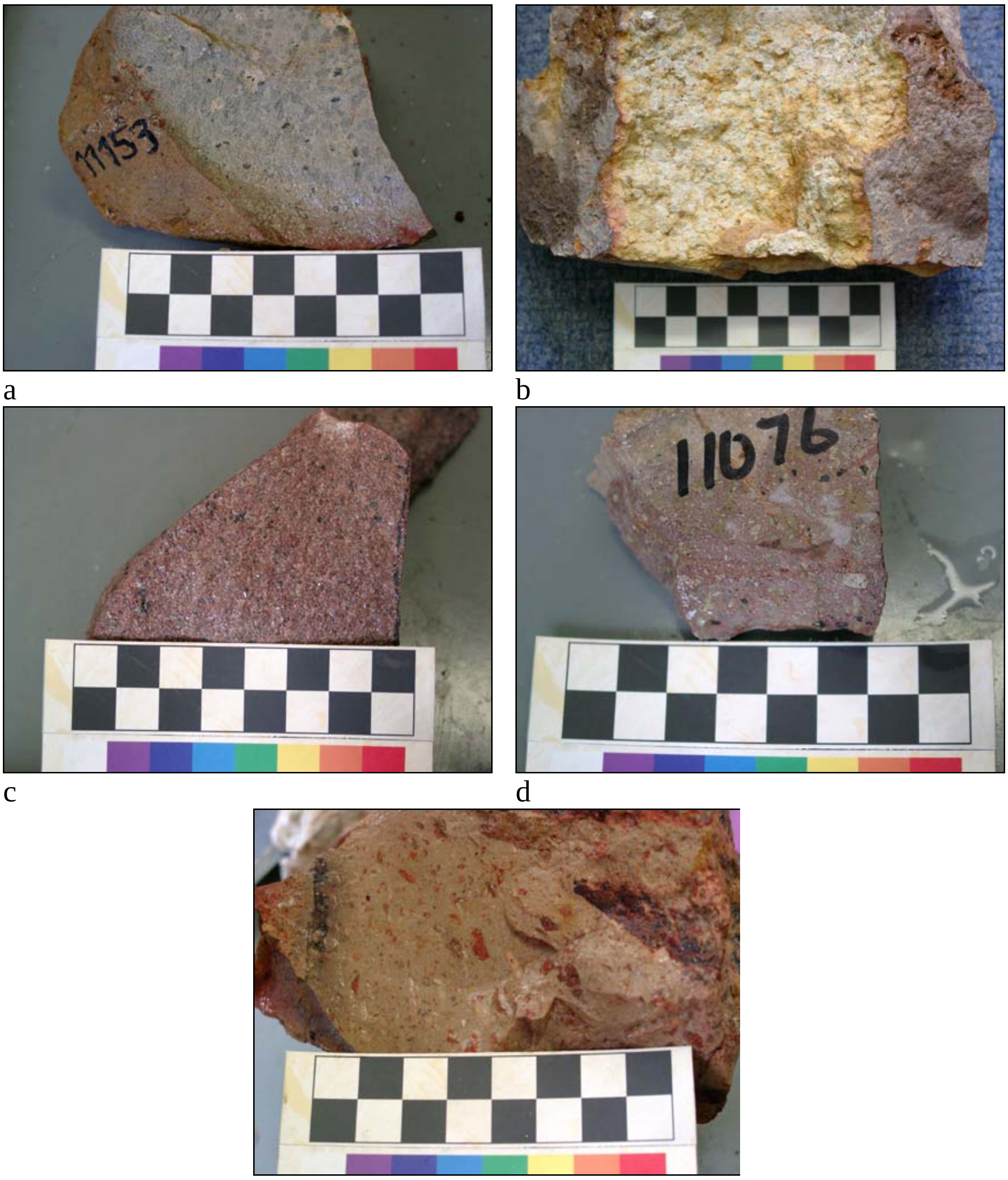
Pseudo-granophyric texturing has been noted whereby fine-grained granitic texture is observed with areas of granophyric intergrowth (Plate 3.3 (c)). This has been interpreted as magmatic recrystallisation of the overlying rhyolites by the granites, rather than direct crystallisation from a magma (Bailie, 1997). This feature is particularly common in the north of the study area towards the roof of the granites.

The agglomerate unit is commonly dark brown in colour, although green and cream-coloured varieties have been observed locally. It consists of sub-rounded to angular rhyolite and quartzitic fragments ranging in size from 10 cm to 1 cm or less, set in a fine-grained rhyolitic matrix (Plates 3.3 (d)-(e)).

Quartzite xenoliths, Leptites and other Sedimentary Lithologies

Commonly, roof-rock sediments have been identified to be spatially associated with Rooiberg lithologies. It is presumed that these blocks were incorporated from the roof during eruption of the Rooiberg and entrained in the magma, undergoing extensive metamorphism. They may range from blocks of clean, white quartzitic material; to laminated Fe-rich sediments and massive, quartzo-feldspathic leptites (Plates 3.4 (a)-(c)). Quartzite xenoliths found elsewhere in the Bushveld have been highly recrystallised and display intersecting quartz grain boundaries of 120° (Bailie, 1997). They may consist of up to 99 % quartz with accessory magnetite and/or sericite.

Many of these meta-sedimentary blocks have provided favourable sites for mineralisation and are often heavily affected by hydrothermal fluids.



a b c d e

Plate 3.3. a) Spherulitic rhyolite with greenish nodules from Slipfontein 551KQ; Sample #ID 11194. b) Heavily weathered spherulitic rhyolite from Blokspruit 157JQ; Sample #ID 11153. c) Typical fine-grained red pseudogranophyre from Ruigtepoort 162JQ; Sample #ID 11070. d) Purplish-brown Rooiberg agglomerate from Elandslaagte 154JQ; Sample #ID 11076. e) Yellowish-brown silicified Rooiberg agglomerate with rhyolitic shards, from Elandslaagte 154JQ; Sample #ID 11202.

Lithified and semi-lithified grits are found around the area. They comprise coarse, rounded to sub-rounded quartz in iron oxide-rich cement (Plate 3.4 (d)). Their usual proximity to modern drainage features raises questions of their age. It has been proposed that they may represent extensive *in situ* weathering of Bushveld granite, although this seems unlikely. Another possibility may be that they represent Karoo aged grits, which are common throughout the Bushveld elsewhere (Hancox, *pers. comm.*).

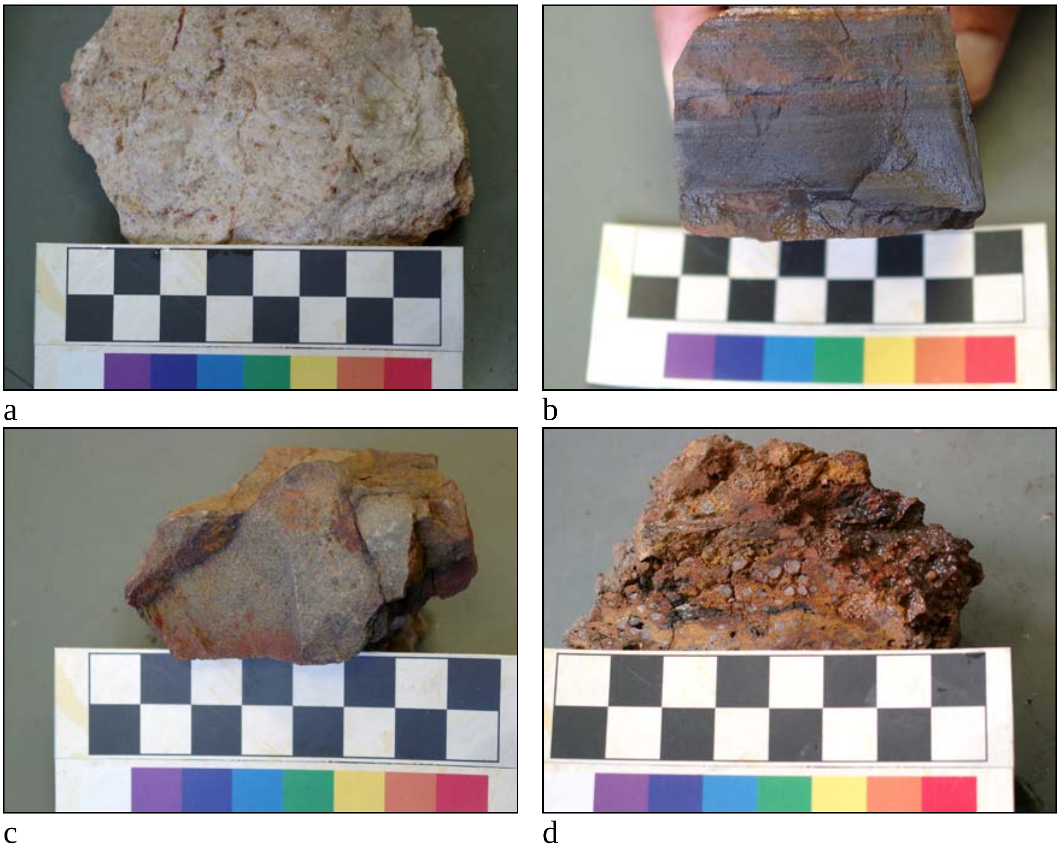


Plate 3.4. a) Clean, highly-recrystallised meta-quartzitic xenolith consisting of up to 99 % quartz from Elandslaagte 154JQ; Sample #ID 11146. b) Finely-laminated, hematite-rich sediment. c) Massive, fine-grained leptite from Ruigtepoort 162JQ. d) Iron oxide-rich grit of possible Karoo age, from Ruigtepoort 162JQ; Sample #ID 11081.

Field Descriptions of Styles of Alteration

As discussed previously, IOCG mineralisation is accompanied by extensive alkali-rich alteration of both sodic-calcic [Na (Ca)] and potassic [K] types (Hitzman *et al*. 1992; Barton & Johnson, 2004). Sodic-calcic alteration tends to occur in deeper and more peripheral zones and its effects may be of the order of hundreds of kms^2. Potassium metasomatism tends to occur at more intermediate depths and its effects may be of the order of 10s of km^2 (Barton & Johnson, 2004). Sericitic and chloritic alteration with accessory silicification is common and occurs in closer proximity to mineralisation, and its effects may be of the order of a few km^2.

Alteration is manifest in a variety of styles depending on various factors including host lithology, fluid chemistry, fluid/rock ratios and pressure-temperature conditions at the time of formation. Changes in the controlling factors effectively results in a zonation of alteration around mineralisation. It thus becomes possible to use the alteration haloes to vector in on fluid conduits and sites of mineralisation. The examples presented in this section represent general cases with the details of petrography and mineral chemistry considered in later chapters of this text.

Sodic alteration is not readily observable in the field as it primarily involves the chemical albitisation of K-feldspar but may manifest as a hardening of the affected granite. No hand specimens from the study area are available for discussion.

The effects of K-metasomatism on the granites observed in the area are some times difficult to distinguish from the ubiquitously-deuterically alteration. This alteration manifests principally as a secondary growth of K-feldspar (and biotite) in the granite, which usually grows at the expense of quartz. Samples exhibit an exaggerated reddening compared to Nebo or Bobbejaankop granites

(Plate 3.5. (a)) and with prolonged alteration may develop episyenitic assemblages (i.e exhibiting a loss of quartz; Plate 3.5 (b)). The resultant episyenite may comprise in excess of 60 % K-feldspar and may become myrialitic. In some instances these cavities have provided suitable sites for precipitation metals and iron-oxides (Plate 3.5 (c)).

Acid alteration of granites near mineralisation is common and primarily indicated by the growth of sericite or chlorite. Sericitisation of the Bushveld granite is characterised by a pinkish discolouration, often with fine but visible white- or bronze-coloured micas (Plate 3.5 (d)). Prolonged and/or intense sericitisation may result in a cream to white colouration of the granite (Plate 3.5 (e)). Silicification may develop together with sericitisation, particularly in intensely altered rocks. The granite may take a whitish or yellow-green colour (Plate 3.5 (f)) and these rocks are commonly contain in excess of 80 wt % SiO_2.

Hematisation is particularly common in close proximity to sites of mineralisation or principal fluid conduits and affects all litho-types (Plate 3.6 (a)). This alteration appears to be a later feature than the previously discussed alteration types and commonly overprints earlier alteration assemblages.

Intense chloritisation tends to be developed exclusively in mineralised zones or in the immediate country rocks (Plate 3.6 (b)), and even in the largest systems does not propagate further than a few metres from the mineralised zone.

Numerous examples of alteration fronts advancing through host lithologies have been observed, often with sharp front boundaries indicating the aggressive and pervasive nature of the alteration and the overprinting of one style of alteration on another. Photographs reproduced in Plate 3.6 (c)-(f) illustrate several examples of alteration where the observed alteration paragenesis is generally sericitisation-silicification-hematisation-chloritisation.

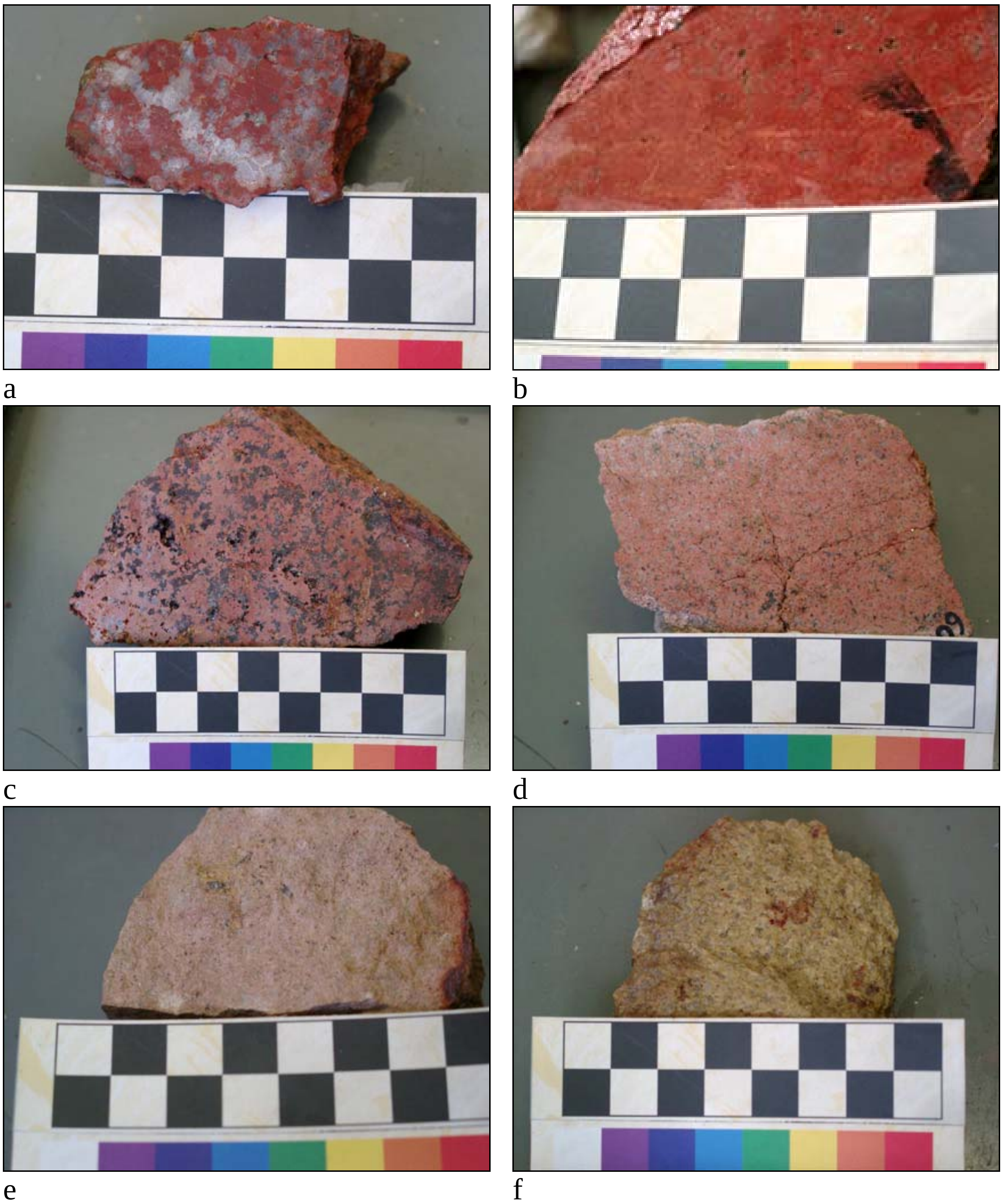


Plate 3.5. a) Exaggerated reddening of Bobbejaankop granite due to K-metasomatism from Blokspruit 157JQ. K-feldspar grains appear to be annealing. Sample #ID 11105. b) Episyenitic granite where quartz comprises less than 10 % of the rock from Ruigtepoort 162JQ. Sample #ID 11177. c) Myrialitic episyenite with hematite cavity fill and anomalous metal contents from Blokspruit 157JQ. d) Sericitised fine-grained granite from Elandslaagte 154JQ. Sample #ID 11060. e) Intensely sericitised fine-grained granite from Elandslaagte 154JQ. Sample #ID 11201. f) Silicified-sericitised medium-grained granite from Elandslaagte 154JQ with yellow-green colouration. Sample #ID 11145.

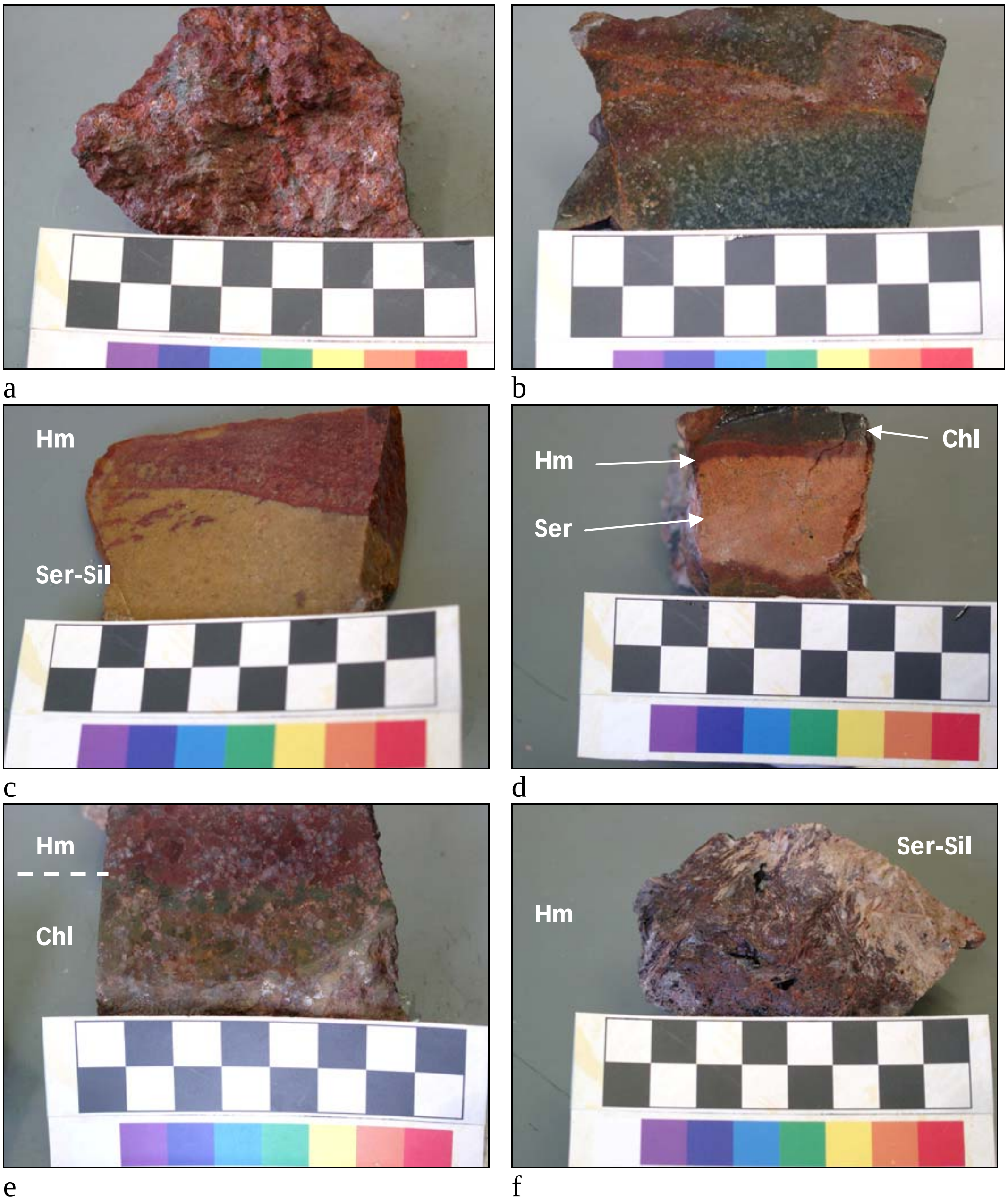


Plate 3.6. a) Intensely hematised coarse Nebo granite from Ruigtepoort 162JQ. Sample #ID 11068. b) Intensely and pervasively chloritised medium-grained granite from Doornfontein 155JQ. Late fracture has introduced oxidised iron oxides and caused local overprinting. Sample #ID 11089. c) Alteration front between earlier sericitisation-silicification of fine-grained granite from Bloksspruit 154JQ, with later hematite overprint. Hm=hematite, Ser-Sil=sericitised-silicified. Sample #ID 11187. d) Compounded alteration overprinting of early sericitisation by intense hematisation, presumably followed by intense chloritisation; from Bloksspruit 154JQ. Hm=hematite, Ser= sericitised, Chl=chloritised. Sample #ID 11122. e) Coarse granite country rock to the Ruigtepoort fluorspar mine; sample taken approximately 10 m from orebody contact. Intense hematisation developed away from the orebody and overprinted by intense chloritisation developed closer to the orebody. Hm=hematite, Chl=chloritised. Sample #ID 11067. f) Sericitised-silicified actinolite rock overprinted by gossanous hematite from Bloksspruit 154JQ. Hm=hematite, Ser-Sil=sericitised-silicified.

Structural Considerations in the Rooiberg District of the Western Bushveld Complex

Regional structure has played an important role in the formation of localised structures on the farms around Ruigtepoort; the same local structures that have often been tied to zones of mineralisation. Some regional structures predated the Bushveld Complex and were reactivated episodically since. Others correspond to the actual emplacement of the Bushveld magmas and to its subsequent cooling and contraction.

Although the focus of this study was not on the temporal relation of these structural elements or how they may have affected mineralisation, they may be important to understanding the controls on IOCG deposit formation and to a potential origin for mineralising fluids.

Figure 3.5 is an illustrated sketch map of the area around Rooiberg. The structures depicted in the diagram are not exhaustive, although may be representative of some of the major prevailing structural elements of the region.

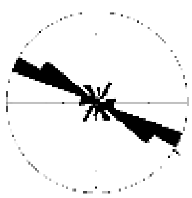
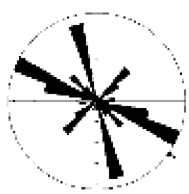
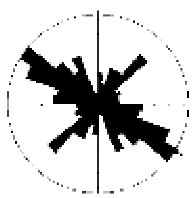
Figure 3.5. Regional sketch map of the area around the Rooiberg fragment depicting the principal regional structures. (modified from Crocker *et al*, 2001).

As discussed previously in Chapter 2, the Rustenburg and Crocodile River faults represent a principal structural orientation of south-southeast (150°) that is prevalent throughout the region. The Thabazimbi-Murchison line lies on an approximate east-northeast (70°) orientation. Other prominent directions, as seen in Figure 3.5, include southeast (120°), northeast (45°) and east (95°). It is not accurately known to which deformational event each of these prominent elements may be attributed.

It is interesting to note that in calculating the principal orientations of structural elements of the farms around Ruigtepoort, that many of these elements are represented, where others are not. Data was collected for the farms Slipfontein 551KQ, Blokspruit 157JQ and Ruigtepoort 162JQ. Data for the other farms were not reproduced, as they were not considered to be representative (Figure 3.6).

The most prominent orientation on the three farms was found to be approximately southeast (120°) and in general corresponded to outcrop joints and smaller scale structures (Table 3.1). In regional terms, this orientation may

Table 3.1. Representation of principal structural orientations on the farms Slipfontein 551KQ, Blokspruit 157JQ and Ruigtepoort 162JQ.

	Slipfontein	Blokspruit	Ruigtepoort
Number of data	162	47	204
Principal Orientations	120 (27.8 %)	115 (23.4 %)	125 (12.7 %)
		160 (19.1 %)	045 (8.8 %)
		045 (12.8 %)	150 (6.9 %)
Mean Resultant Direction	122-302	126-306	122-302
Maximum	53.0% (86 data)	42.6% (20 data)	25.4% (52 data)
95 % Confidence Interval	± 7°	± 23°	± 18°
			

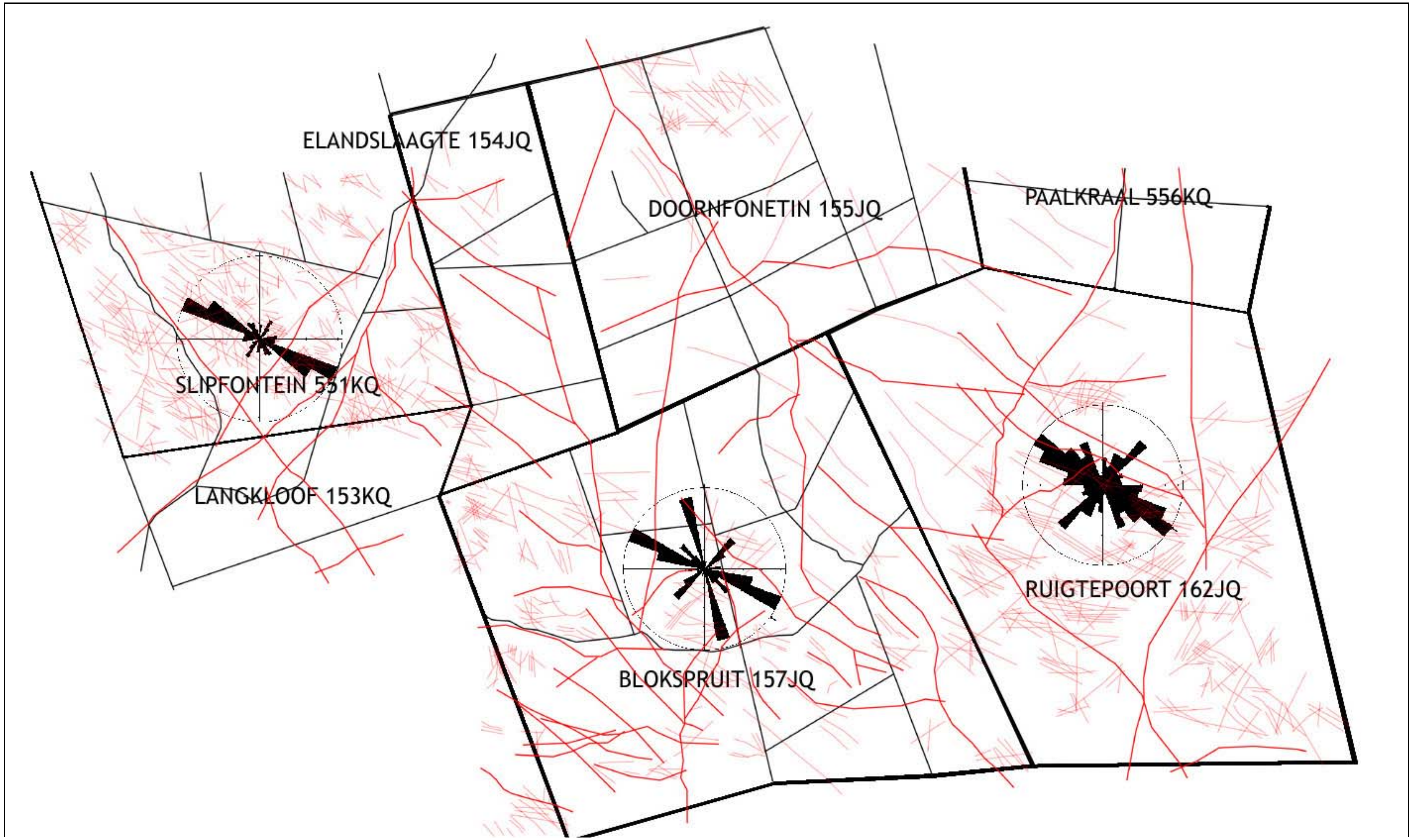


Figure 3.6. Structural traces and principal lineaments of the farms near Ruigtepoort with frequency azimuth rose plots calculated per farm.

correspond to splay faults to the Crocodile River fault which may have been active during cooling and settling of the Bushveld Complex.

Another significant structural orientation on the three farms was found to be south-southeast (150°), in particular on Blokspruit and Ruigtepoort. Many of the structures of this orientation tended to be larger faults and fault zones and in some circumstances variably mineralised with iron oxides. In a regional sense, this orientation corresponds with that of the crustal-scale Crocodile River fault. Another prominent orientation was found to be northeast (45°). It should be noted that nearly all of the iron oxide-polymetallic deposits in the district were found near to or on structural elements of both orientations and their intersections. The suggestion would thus be that mineralising fluids responsible for the formation of IOCG deposits in the area were related to crustal scale events, with fluids migrating along established conduits.

Geophysical Considerations in the Rooiberg District of the Western Bushveld Complex

The success in finding the Olympic Dam deposit using remote geophysical techniques highlights the effectiveness of some methods for the identification and prioritisation of suitable IOCG targets. Regional targets may be quickly generated through an array of airborne techniques. The abundance of iron oxides, in particular magnetite, makes magnetics an obvious choice for implementation. However, it is well known that the number of barren ironstones with respect to metal sulphides far outnumbers those that are mineralised. Radiometrics may provide the necessary target prioritisation tool due to the anomalous abundance of REE associated with many IOCG deposits. ASTERSAT satellite imaging may also be implemented to delineate alteration products or regional chemical signatures, but may require an initial ground-truthing for effectiveness.

In 1997, Rio Tinto Exploration Africa flew a regional airborne radiometric survey over the entire Rooiberg Fragment and its surrounding Bushveld granite lithologies. The results of that survey are presented in Figure 3.7. The image is a three-colour composite of U-Th-K; with uranium in yellow, thorium in red and potassium in blue. As expected, the highly-potassic (and highly-radiogenic) Bushveld granites appear blue, and the sediments of the Rooiberg Fragment appear yellow possibly from detrital uraninite and similar minerals, or from the relative absence of potassium-rich rocks. Regional lineaments appear prominently and correspond to faults and dykes of variable composition.

The study area is located to the bottom of this image, as indicated by the white box. Few features are discernible, although the dark arcuate band in the centre of the box has been related to the prominent aplitic dyke that cross-cuts the mapped portions. In relation to this, other features become apparent, in particular the mineralisation located on the Blokspruit and Ruigtepoort farms, which are shown to have a significant Th enrichment relative to the two other elements. This enrichment may be due to concentration of Th in specific ore-related minerals such as REE-phosphates, xenotime or monazite, or in a nett depletion in K, which may correspond to chloritisation, silicification, sericitisation or other alteration of host rocks. The position of the Elandslaagte REE mineralisation corresponds to a relative Th high, similar to that of the Blokspruit prospect. This may lend support to the idea that the influence of REE minerals is causative of these anomalies. These possibilities will be considered later in this text.

Other features of this image to be considered include a reddening, corresponding to a relative Th enrichment, in the Bushveld granites towards the roof contact with the Rooiberg Group rocks, on the right-hand side of the image. This may correspond to the egress of fluids towards the surface. Another feature is the

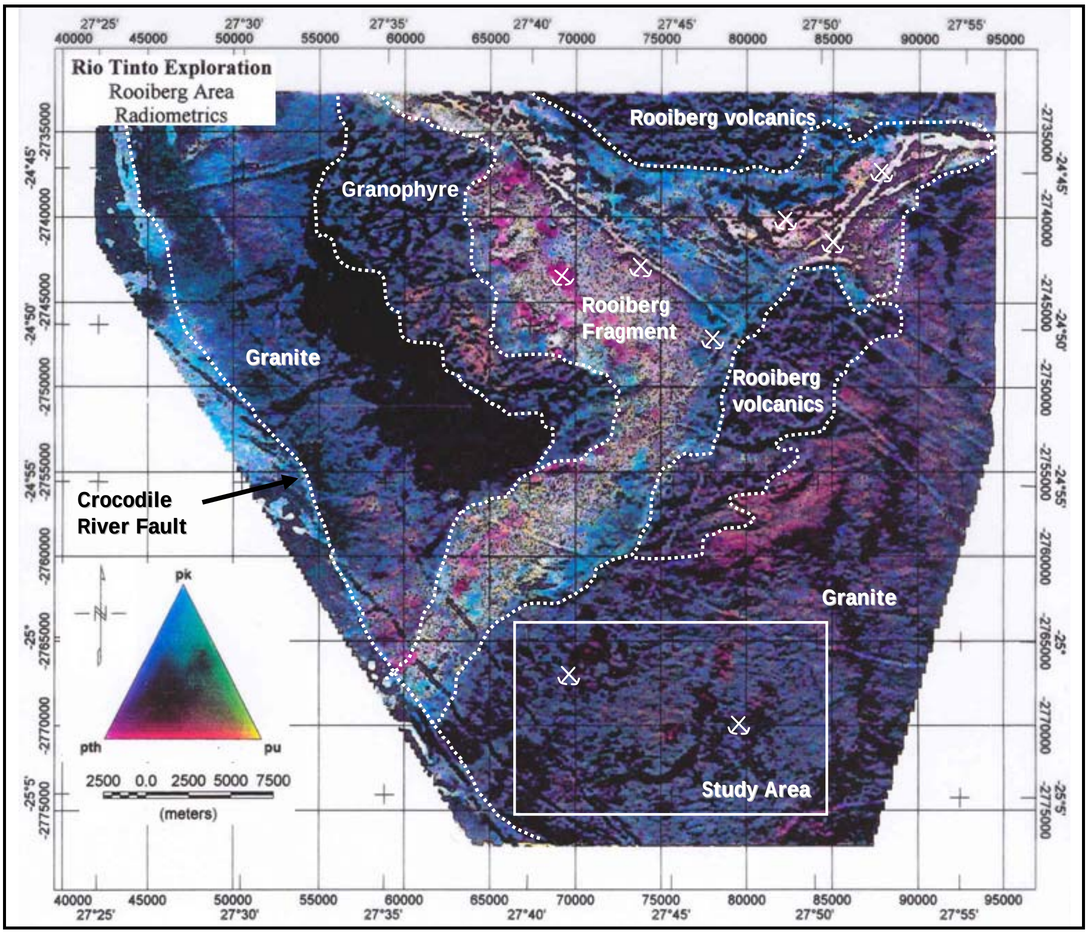


Figure 3.7. Regional airborne radiometric survey of the Rooiberg fragment and surrounding Bushveld granites. Area of study indicated by white square (image reproduced courtesy of Rio Tinto Exploration Africa).

bluish fringe to the Rooiberg Fragment sediments which may represent a regional K-metasomatism related to the emplacement of the Bushveld Complex, although this would necessarily be verified from geochemical sampling or petrography.

Sites of previous mining activity are indicated by white prospecting symbols. Only the position of the Rooiberg Tin "A-Mine" corresponds to a significant Th anomaly, located in the centre-top of the image.

Data derived from the airborne radiometric survey was further compiled into a total count radiometric plan, shown in Figure 3.8. Warm colours indicate high total counts and cold colours indicate low total counts. The positions of the mineral occurrences discussed in the following chapter are marked by red diamonds. The approximate limit of the granites is marked by the dotted white line with sediments of the Transvaal Supergroup occurring to the west.

The granites of the farms Ruigtepoort, Blokspruit and Slipfontein appear most prominently; apparently forming sub-rounded masses, which could potentially correspond to discrete plutonic masses. These granites are presumed to generate a higher response than the surrounding granites due to the better exposure and outcrop on these farms and are not considered to necessarily represent higher values. The central portion of the study area, extending towards the farm of Paalkraal, to the northeast, generated a lower response due to increased transported overburden and alluvium.

Each of the mineralised occurrences (as indicated by the red diamonds) corresponds to anomaly highs. There are several anomaly highs that are not associated to mineralisation, such that this plot is not considered to be a particularly useful discrimination tool, and might only be valuable for verification of targeting derived by other means.

An airborne magnetic survey was flown on a 100 m line spacing, oriented in a north-south direction over the study area, undertaken by Rio Tinto Exploration

Africa in 1997. The processed image of the results of this survey (Figure 3.9; no scale is given for value ranges) possesses a very blotchy appearance and few

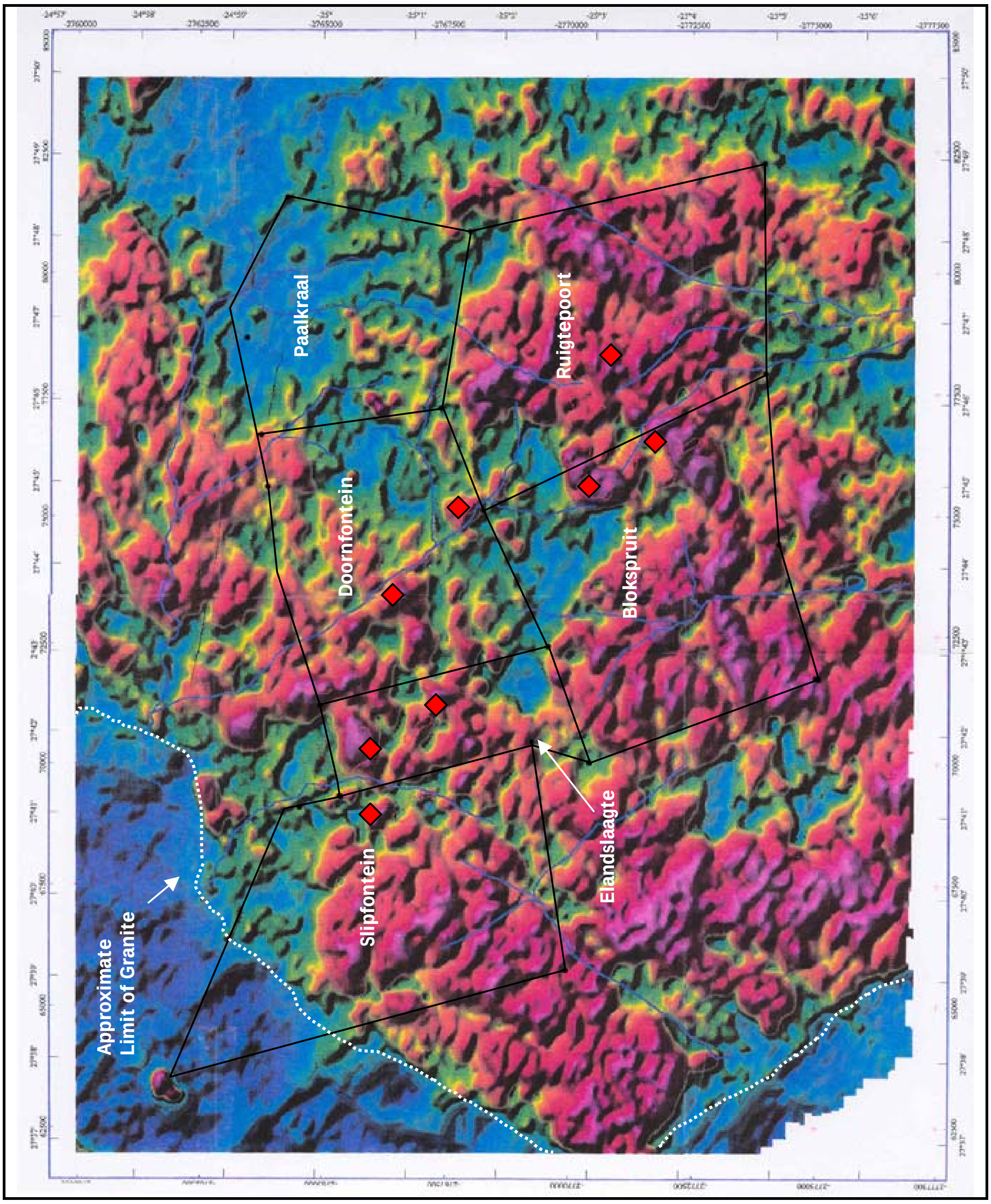


Figure 3.8. Total Count radiometrics for the farms near Ruigtepoort Mine (image reproduced courtesy of Rio Tinto Exploration Africa) (no scale is given for value ranges).

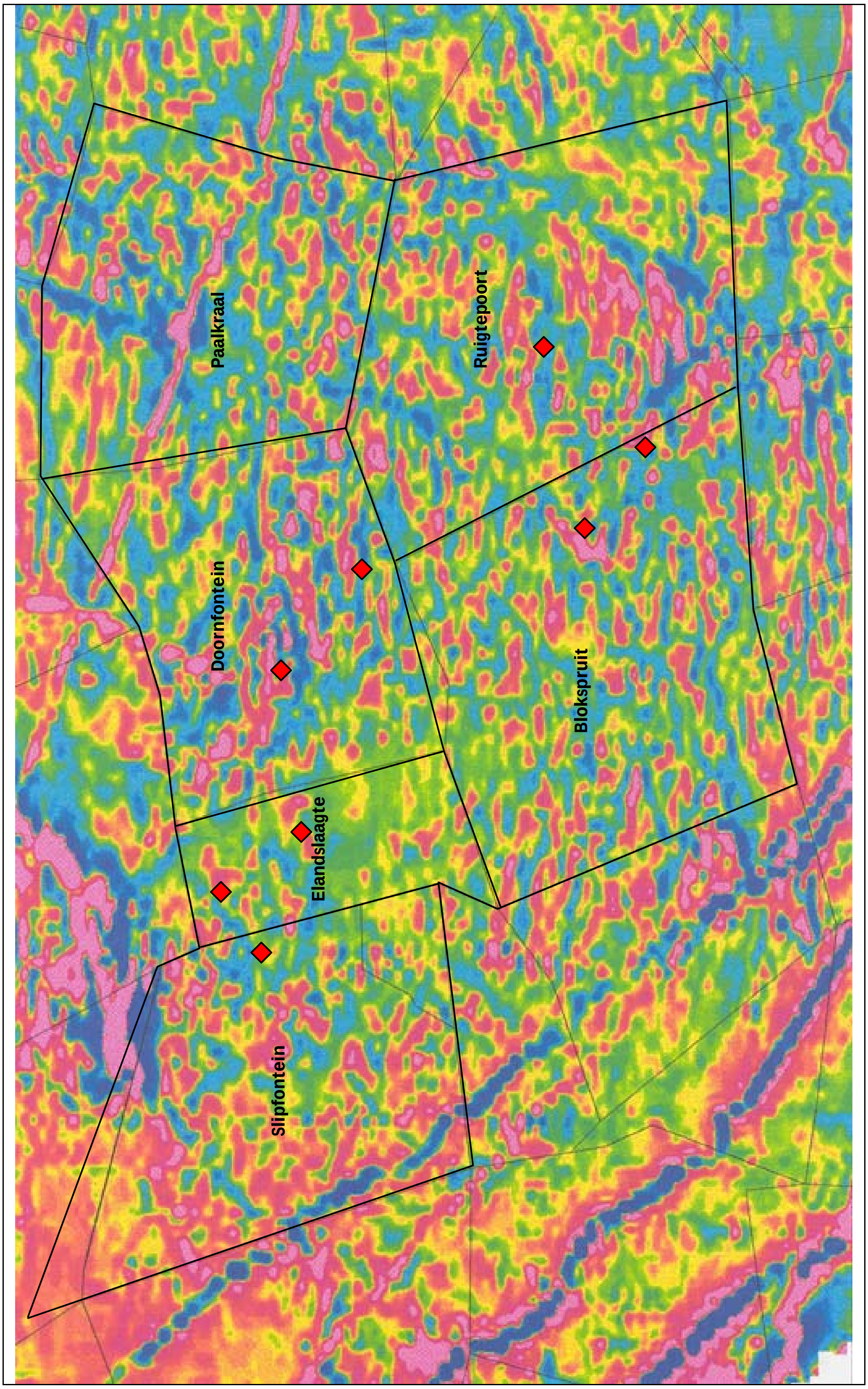


Figure 3.9. Airborne magnetic survey of the farms near Ruigtepoort mine (image reproduced courtesy of Rio Tinto Exploration Africa) (no scale is given for value ranges).

features are discernible, in particular, the expected resolution of the abundant massive iron oxide bodies and veins observed on the ground. The mineralised bodies identified on these farms, as indicated by red diamonds, only loosely correspond with magnetic highs. It is possible that many of the desired features in the area are too closely oriented to the chosen survey flight direction resulting in patchy data, or that the line spacing was too broad for the scale of the features present in the area.

The few linear features that can be discerned have been related to either large-scale faults or cross-cutting aplitic dykes.

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This chapter described the regional and local geological setting with regard to lithology, alteration, structure and geophysics in which the mineralised bodies occur. As discussed, mineralisation is concentrated in the apical phases of the Bushveld granites and the adjacent roof-rocks. Mineralisation appears to have a structural control with brecciation of host lithologies common. This brecciation is suggestive that mineralisation must have occurred late in the evolution of the granites for them to be sufficiently cooled.

The next chapter will consider the above conditions in terms of mineral petrography to assess how the alteration observed in the field is reflected in the changing mineralogy and the growth of new phases.