6

Fe-F (Cu-Au-REE) Mineralisation in the Bushveld Granites

6.1. Locality Descriptions of Mineral Occurrences in the Western Bushveld Granites near the farm Ruigtepoort

The acid rocks of the Bushveld granites are host to numerous small- to medium-sized polymetallic deposits and reflect a range of controls and mineralising environments, which appear to be genetically related. Bailie & Robb (1996, 2004) and Robb et al (2000) proposed a complex paragenetic sequence comprising (Sn-W)-(Mo-Cu-Pb-Zn-As-Au-Ag)-(Fe-F-U) extending from magmatic to late hydrothermal. They identified four main types of deposits based on mineral association (Table 2.4). Many of these mineral occurrences are concentrated in the apical portions of the Bushveld granites and the overlying roof rocks. Other controls of ore deposition include extensive circulation of hydrothermal fluids, concentration of incompatible elements by in situ crystal fractionation, stratigraphic height in the magmatic system, fluid saturation, fluid mixing, and fluid channelling by major structures active pre- and post-Bushveld emplacement (Robb et al, 1994, 2000; Bailie & Robb, 2004).

The paragenetic sequence represents a transition from high temperature orthomagmatic conditions (Sn-W), through to lower temperature hydrothermal conditions (Fe-F-U). The lower temperature assemblages tend to be more highly oxidised indicating an increasingly greater influence by a meteoric/connate fluid component, over an initial magmatic fluid component.

The hydrothermal system of the Bushveld granites was suggested to have lasted for about 1 000 my, radiogenically driven by the anomalously high heat producing granites of the Lebowa Granite Suite (McNaughton et al, 1993).
However, thermal modelling with respect to the emplacement of both the Lebowa Granite Suite and the Rustenburg Layered Suite indicates that the geothermal gradient through the crust would be re-established in only 4 my (Robb et al., 2000), and repeated fluid migration and resultant mineralisation is rather driven by large, cratonic-scale events recorded by isotopic chronology. The longevity of the hydrothermal systems responsible for mineralisation will be discussed in more detail in Section 6.3.

Mineralisation encountered on the farms near Ruigtepoort exhibits characteristics consistent with IOCG-style deposits elsewhere (see Table 1.1). These include:

- felsic country and host rocks;
- abundant iron oxides with variable concentrations of Cu, Au, REE, U and other metals;
- structurally controlled and strongly hydrothermally brecciated; and
- pervasive alteration proximal to mineralisation, from chlorite alteration in closest proximity, followed by K-metasomatism, and sericite (-epidote) alteration furthest away.

Below are general descriptions of mineralisation encountered on each of the farms, detailing the principal deposits and occurrences. Mineralisation was identified on each of the farms Ruigtepoort 162JQ, Slipfontein 551KQ, Blokspruit 157JQ, Elandslaagte 154JQ and Doornfontein 155JQ (Table 6.1).
Table 6.1. Typical base and precious metal contents for the mineral occurrences of the Western Bushveld Complex near the farm Ruigtepoort 162JQ.

<table>
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<th>Occurrence &amp; Sample No.</th>
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<th>Cu ppm</th>
<th>U ppm</th>
<th>Th ppm</th>
<th>Mo ppm</th>
<th>Y ppm</th>
<th>La ppm</th>
<th>Ce ppm</th>
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The Ruigtepoort fluorite-Fe-oxide (-copper-gold) orebody is situated in the centre of the farm Ruigtepoort 162JQ (27° 46.30’ E; 25° 02.25’ S) (Figure 6.1). Access to the now defunct mine is restricted to a poorly maintained track, branching from the minor provincial road between Assen and Leeupoort. The topography surrounding the mine is low and rolling, the mine itself situated on the east side of an open valley. Presumably, before the commencement of mining, the orebody would have formed a slight rise or knoll. The orebody was opencast-mined for fluorite intermittently from 1929-1955. High-grade low-silica ore

![Figure 6.1. Geological interpretation of the geology around the Ruigtepoort Fluorspar Mine. Scale 1:14 285.](image)
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assayed 60-85 % CaF₂ and less than 10 % SiO₂ with broken ore reserves estimated at about 45 000 t CaF₂ (Crocker et al., 1988).

The orebody is hosted in red Bobbejaankop-variety Nebo granite. Fluorite mineralisation is restricted to a core of intensely chloritised actinolite rock, with intense alteration in the wall-rock becoming progressively less altered away from the orebody. The orebody is a fracture-bound, pipe-like structure roughly 100 m in length and 40 m in width (Plate 6.1 (a)). The boundary fractures dip steeply at ~80°, strike 005° and 030°, with numerous parallel fractures apparent in the highly altered granite wall rock (Plate 6.1 (b)). The fractures are responsible for the overall morphology of the deposit and (Crocker et al., 1988). Chlorite altered granite bounds the deposit on all sides (Crocker et al., 2001). No data is available with regards to the extent of mineralisation at depth. Cross-sections of the orebody were presented by Crocker et al. (1988, 2001) based on mine plans and sections which showed horizontal fluorite mantos set in low-grade fluorite-specularite-chlorite ore, with minor quartz (Figure 6.2). According to Crocker et al. (2001), the contact of the orebody is marked by a 2 mm selvage of euhedral muscovite, followed by a fine mat of actinolite 1-10 cm thick. Inwards the actinolite blades grow up to 1 metre in length, and are almost invariably altered to chlorite, kaolinite, hematite and/or silica.

Large, intensely chloritised granite boulders occur within the orebody and between the horizontal fluorite mantos (Crocker et al., 2001) and evidence the presence of an orebody-scale mega-breccia related to the mineralisation.

The mineralisation host, the chlorite rock, consists of chlorite (iron-rich thuringite, daphnite or chamosite), fluorite, hematite, specularite, goethite, and limonite, with minor quartz, pyrite, arsenopyrite, chalcopyrite, covellite, bornite, malachite, azurite, molybdenite, halloysite and kaolinite (Plates 6.1 (b)-(e)) (Crocker et al., 2001). It is postulated that the chlorite represents a direct alteration of an original actinolite-fluorite assemblage as observed at other localities, implied by abundant examples of pseudomorphs after actinolite.
Chlorite rock samples have reported maximum values of 0.45 % Cu and 0.06 g/t Au, but higher values may be expected from discrete high-grade samples.

Peculiar quartz chains occur within the chlorite rock (Plate 6.1 (f)) that appear to be similar to Bobbejaankop quartz chains, which may indicate the genetic parent of the chlorite rock. This would suggest an intense and pervasive alteration of the Bobbejaankop host rock, which becomes a mineralised portion of the orebody.

Fluorite mineralisation occurred as three or more sub-horizontal lenses, ranging in width from 1.0 - 4.5 m, set in completely chloritised granite (Meyer, 1947).

Specularite is developed in low- to high-grade ore (20-75 % CaF$_2$, 10-60 % SiO$_2$) pockets and produces vuggy, friable material filled with massive to flaky specularite, quartz, hematite-goethite and minor fluorite (Plates 6.1 (a)-(b)).

The granitic wall-rock has been highly affected by the mineralising fluids and consists of disseminated quartz, highly altered feldspar, chlorite, hematite, and other iron oxides with minor disseminations of pyrite and chalcopyrite (Plates 6.2 (c)). In places the original quartz chains are preserved, characteristic of the Bobbejaankop-type granite (Plate 6.2 (d)), in other places the quartz has been re-mobilised to form prismatic crystals. At the immediate contact to the orebody, chlorite overprints an earlier generation of hematite alteration of the granites. This chlorite alteration is itself overprinted by a localised but intense sericitisation (Plate 6.2 (e)). Hematite alteration diminishes away from the orebody into the country rock over only a few metres to tens of metres.

Samples of grey, sulphide-rich, silica-carbonate-fluorite epithermal sinter have been taken from dumps, and although their positioning in the orebody is uncertain, they are expected to have been derived from the core of the orebody and along fluid-vapour conduits in direct contact with the chlorite rock orebody (Plate 6.2 (f)). They exhibit forms similar to the large actinolite needles observed elsewhere, particularly well-developed on the Blokspruit property, and are
Figure 6.2. The Ruigtepoort fluorspar mine map and sections (from Crocker *et al.* 2001).
Plate 6.1. a) Defunct Ruigtepoort Fluorite Mine 100 m long by 40 m wide; person in blue for scale.
b) Contact between Bobbejaankop granite country rock and Ruigtepoort Mine ore body. The granites to the left of the contact are chlorite altered nearest the contact, grading into pervasive hematite alteration, grading to common deuterically altered granite. The contact is steeply dipping (~80°), with numerous parallel fractures, and strikes N-S. FeOx=iron oxide, Chl=chlorite. c) Chlorite rock of the Ruigtepoort ore zone, consists of chlorite, fluorite with minor sulphides and quartz; here with large euhedral fluorite and abundant sulphides. The sulphides visible in the photograph are dominated by pyrite with minor chalcopyrite; Chl=chlorite, Py=pyrite, Fl=fluorite. Sample #ID 11215. d) Chlorite rock with milky quartz and chalcopyrite in abundance, oxidised to bornite and covellite. Chl=chlorite, Cp=chalcopyrite, Bn=bornite, Cv=covellite, Qtz=quartz. e) Kaolinite and halloysite associated with the chlorite rock is likely an alteration product after actinolite. f) Vermiform quartz chains in the chlorite rock.
proposed to be pseudomorphs of actinolite-rich ore (Plates 6.3 (a)-(b)). Perfectly formed rhombohedral pyrites have also been recorded, but these have only been observed in friable, amorphous sintery material. These samples have reported up to 1.5 g/t Au with nominal copper results.

Scoriaceous material was observed along the western orebody margin (Plate 6.2 (f)). This rock is composed entirely of hematite, quartz and other iron oxides (Plates 6.3 (c)-(d)). It is gossanous and vuggy and may have contained sulphides and metals, though no assay results are available for these specimens.

Veins of magnetite, hematite and specularitic hematite are found in the surrounding country rock to the orebody, with distinctive signs of hydrothermal brecciation (Plates 6.3 (e)-(f)). The country rocks to these veins are variably affected by alteration, some strongly so, with others unaffected. Vein quartz and fluorite often accompany these veins.
Plate 6.2. a) Specularitic hematite with milky quartz and occasional prismatic quartz crystals, and abundant iron oxides; Sample #ID 11013. b) Hematite-chlorite altered country granite with specularitic vein. Hm=hematite, Chl=chlorite, Spu=specularite. c) Chlorite alteration overprinting earlier hematite alteration of country granite, where the chlorite alteration exists closest to ore body. The hematite alteration will grade into fresh country rock over a few 10’s of metres; Hm=hematite, Chl=chlorite. Sample #ID 11067. d) Sectioned country granite near Ruigepoort mine; quartz chains and deep red colour indicative of Bobbejaankop variety and suggest close proximity to intrusion roof. Chlorite developed along fine fracture in rock; Sample #ID 11089. e) Contact between altered country granite and chlorite rock ore zone. Granite altered to chlorite and sercite; Sample #ID 11004. f) Contact between chlorite rock and high-sulphidation quartz-pyrite-arsenopyrite sinter with conspicuous dividing oxidation front. Qtz=quartz, Py=pYrite.
Plate 6.3. a) Quartz-pyrite-arsenopyrite sinter. Sulphides pseudomorph after actinolite blades with milky vein quartz filling pore spaces; Qtz=quartz, Flu=fluorite, Py + Apy=pyrite + arsenopyrite Sample #ID 11159. b) Quartz-pyrite-arsenopyrite sinter. Minor late generation purple and colourless fluorite; Sample #ID 11159. c) Hand specimen of scoria-like material from Ruigtepoort mine, composed of abundant iron oxides and quartz. d) Scoria-like material in section showing gossanous hematite, limonite and other iron oxides and brecciated vein quartz fragments. FeOx=iron oxide, Hm=hematite, Qtz=quartz. e) Specularite-quartz vein in Bobbejaankop granite, near Ruigtepoort mine; Sample #ID 11181. f) Hydrothermal granite breccia with hematite-magnetite-quartz vein fill. Granite clasts affected by sericite alteration; Sample #ID 11178.
**Slipfontein Fe-F (-Cu-Mo) Deposit**

The defunct Slipfontein mine is situated in the southeast corner of the farm Slipfontein 551KQ (27° 41.15’ E; 25° 00.60’ S) (Figure 6.3). The mine is situated approximately 13 km south of the Leeupoort Tin Mine and is only 50 m from the Assen-Leeupoort minor provincial road, making it easily accessible. The deposit originally formed a domed hill above the relatively flat surroundings. A preserved 10 m high pillar of massive iron oxide, fluorite and quartz represents the original surface (Plate 6.4 (a)). Small tonnage mining commenced in 1939 and continued intermittently until the late 1980’s, producing an estimated 20 000 t CaF₂ (Crocker *et al*, 1988).

**Figure 6.3.** Geological interpretation of the geology around the Slipfontein Fluorspar Mine. Scale 1:14 285.
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The main orebody is a 12 m thick hematite-quartz-fluorite(-sulphide) gossanous breccia which is underlain by a 1-2 m thick sheet of massive quartz-orthoclase pegmatite, all of which is set in Klipkloof and Bobbejaankop-type Nebo granites (Plate 6.4 (b)). The orebody is situated towards the upper portion of the granitic sheet as evidenced by the occurrence of fractionated granite varieties and the proximity of roof-rock xenoliths and pseudogranophyre to the north of the deposit.

The original ore is thought to have consisted of magnetite and siderite with relicts existing in the core of the deposit (Crocker et al., 2001). A 10-20 cm layer of inclusion-rich, purple fluorite and bastnaesite mineralisation is developed at the contact between the hematite-quartz-fluorite manto and the underlying quartz-orthoclase pegmatite. The ellipsoid-shaped deposit is 120 m in length, 95 m in width and 12 m in thickness and forms a discoid lens or manto, as shown by drilling (Figure 6.4) (Crocker et al, 1988). Earlier descriptions of the deposit by Kent et al. (1943), that the deposit comprised a ring-shaped fluorite vein around a central pipe of quartz and hematite, were shown to be incorrect. According to Iannello (1970), the Slipfontein orebody is situated on a northwest trending (~120°-150°), vertical dipping quartz-hematite-fluorspar vein, with a ring-shaped bulge at Slipfontein forming the orebody. Mineralisation could not be traced appreciably along strike; however, a number of aplite dykes/sills were identified in the vicinity following NW-SE orientations. Some of these dykes have associated hematite-quartz-fluorite veining, and the granite country rocks around these dykes have been observed with variable sericite-epidote alteration (Plate 6.4 (c)).

The occurrence of the deposit may also be linked to a large fault (~020°) that traces approximately 100 m west of the mine, from the Rooiberg syncline to the north, or to the large lineament to the east with apparent sinistral displacement, which is marked by a large alluvial accumulation, and separates the Slipfontein deposit from mineral occurrences on the adjacent Elandslaagte farm.
Figure 6.4. The Slipfontein fluorspar mine map and section (from Crocker et al. 2001).
Mineralisation of the hematite-quartz-fluorite breccia consists of at least two generations of quartz, randomly distributed white fluorite, massive hematite and box-work gossan (Plate 6.4 (d)). A first generation of massive pegmatitic vein quartz is observed, which is brecciated and vein-filled by a subsequent generation of hematite, prismatic quartz, colourless fluorite, with minor sulphides and siderite (Plate 6.4 (e)). Fluid inclusion analyses have unequivocally demonstrated that this second episode of quartz can be correlated to the highly saline, metal-charged fluid responsible for sulphide mineralisation (Freeman, 1998). The presence of the earlier generation of vein quartz may be indicative of mineralising fluids taking advantage of pre-existing structure and plumbing. The porous boxwork gossan occurs frequently and consists of hematite, goethite and the clay mineral halloysite (Crocker et al., 1988). The rhombohedral symmetry of intersecting hematite plates indicate the presence of primary siderite, which is only rarely preserved (Plate 6.4 (f)).

A chlorite-fluorite-quartz ore assemblage which occurs up to a metre in diameter may be more locally distributed, with accessory pyrite, chalcopyrite, arsenopyrite and galena. Molybdenite occurs as flakes 2-5 cm in diameter within the massive, pegmatitic quartz (Plate 6.4 (g)). No attempts have yet been made to date the molybdenite using Re-Os isotope ratios. This pegmatite possesses a component of bastnaesite, which occurs together with hematite in small clots, and is responsible for a significant radiometric response, in contrast to the lower response of the overlying hematite-quartz-fluorite (Crocker et al., 1988).

Disappointing grab sample assay results were confirmed for the deposit with negligible copper, but elevated Pb, As and Zn (153 ppm, 158 ppm, and 135 ppm respectively; see Appendices for complete results). Slipfontein samples were not assayed for Au, however, based on As trends obtained from other deposits, ~1 g/t Au may be expected.
Plate 6.4. a) Hematite-quartz-fluorite vein-fill of brecciated quartz blocks. b) Flat-lying manto-shaped orebody with pegmatite sill base. c) Sericite-epidote altered granite near mineralised aplitic dykes; Sample #ID 11015. d) Gossan of hematite quartz and minor sulphides; Sample #ID 11217. e) Brecciated vein quartz with hematite-quartz-fluorite-sulphide vein fill. f) Siderite-magnetite ore in breccia vein fill; Sample #ID 11216. g) Coarse molybdenite flakes in pegmatitic quartz.
Blokspruit Fe-F (-REE-Cu-Au) Prospects

Numerous iron oxide-fluorite-actinolite prospects occur in the eastern portion of the farm Blokspruit 157JQ. The two largest are the Ysterkop North / Blokspruit North and the Ysterkop South prospects, measuring approximately 0.5 km$^2$ and 0.16 km$^2$ in area respectively (Figure 6.5). Drilling has shown these bodies to be sub-horizontal sheeted bodies in excess of 30 m thick, which pinch out laterally although they also occur as narrow vertical northwest striking veins (Crocker et al, 1988).

Figure 6.5. Geological interpretation of the geology around the Ysterkop prospects on Blokspruit 157JQ. Scale 1:16 667.
The Ysterkop North prospect (27° 44.85’ E, 25° 02.55’ S) is a broad elliptical zone 800 m in length by 650 m in width, consisting of abundant quartz-hematite scree and marked by a contrasting dark red brown soil. A plane-tabled, detailed surface map was presented by Crocker et al. (1988, 2001) of the Ysterkop North prospect (Figure 6.6). The mineral occurrence is hosted in red Bobbejaankop-type granite. The main outcrop forms a small hillock and is accompanied by abundant loose scree. It consists of dark massive hematite with quartz, fluorite and amphibole (ferroactinolite). The amphibole commonly forms outwardly-radiating small, delicate to large, blocky aggregates of bladed crystals, with fluorite filling the vugs into which the actinolite crystals projected (Plate 6.5 (a)). Crocker et al. (2001) proposed that the introduction of fluorine-rich fluids may have been responsible for replacement of the calcium- and iron-bearing silicates, caused by the scavenging of Ca. The amphibole crystals are for the most part largely pseudomorphed by silica and hematite; a feature common to the many iron-fluorite occurrences on the farm (Plate 6.5 (b)).

An unaltered outcrop of about 40 m in length is located on the southern side of the prospect and is composed of sheets, each of 1-3 m in thickness, of fine-grained, matted dark-green to black ferroactinolite (Plate 6.5 (c)) with thin granitic partings, totalling a thickness of approximately 30 m (Crocker et al. 2001). These granitic partings may in fact represent the blocks of a deposit-scale mega-breccia. The ferroactinolite blades exhibit a range of sizes from less than 1 cm to over 10cm (Plate 6.5 (d)). This is the only locality in the study area that has such a large and well-preserved example of what is thought to be a primary mineral assemblage. Set within the ferroactinolite are small, pink pellets of yttrium-rich britholite, a rare-earth phosphate of the apatite family; carrying in excess of 2 000 ppm Y. Britholite readily alters to goethite in altered ore (Crocker et al. 2001).

Trenching of the outcrops revealed that the actinolite rock constitutes the matrix fill of a granite mega-breccia. In Plates 6.5 (e)-(f), large rounded to angular boulders of granitic material are plainly visible, set in a deeply weathered matrix, with fine actinolite blades, such as those see in outcrop, are visible. It is presumed
Figure 6.6. The Blokspruit or Ysterkop North actinolite-fluorspar prospect (from Crocker et al. 2001).
that this configuration is similar to the chlorite rock described at Ruigtepoort Mine, albeit having undergone a more pervasive chloritisation such that the primary actinolite crystals are no longer apparent. Evidence for mega-breccias at Ruigtepoort have not been previously described, although may well be expected.

Massive hematite with quartz occurs in numerous veins that variably cross-sect the Ysterkop North prospect, or as horizontal, lensoid mantos. Most of these are completely degraded to quartz-hematite sce. Rare occurrences of adularia are observed with the massive hematite (Plate 6.6 (a)).

The Ysterkop North prospect is subeconomic with 0.01% LREE, 2 000 ppm Y, 0.03% Cu with trace U and Au (higher grades were reported by Rio Tinto; Joubert, pers. comm., but these results are unpublished and unconfirmed). The inferred fluorite resource is 10 000 t CaF$_2$ contained in 67 500 t of ore (Crocker et al, 1988).

Situated about 1 200 m to the southeast is the Ysterkop South prospect (27° 45.45’ E; 25° 02.95’ S). The mineral assemblage at this prospect is essentially the same as the prospects to the north, being hematite, quartz, fluorite and ferroactinolite.

The geological setting of the Ysterkop South prospect differs slightly from the wholly Bobbejaankop-type granite hosted Ysterkop North prospect. Mineralisation straddles the contact between Bobbejaankop-type granite and the large, regional microgranitic dyke. It is characterised by gossanous hematite-quartz-fluorite ore with numerous cross-cutting siliceous veins, trending roughly north-west and north-east. Siliceous veining and pegmatite development are common throughout the aplite dyke. The aplitic dyke is thought to have had a controlling effect in restricting the migration of fluids, and may thus have been responsible for ponding and concentrating mineralising solutions beneath it at its contact to the underlying granite.

The Ysterkop South prospect is subeconomic with 0.1 % LREE, 400 ppm Y, 0.3 % Cu, and trace U and Au. The inferred fluorite resource is estimated at
Plate 6.5. a) Example of hematite-quartz pseudomorphed actinolite crystals with fluorite filling the residual vug. Fl=fluorite. b) Actinolite blades range in size from less than 1 cm to in excess of 10 cm. c) Actinolite rock in outcrop from the Ysterkop North prospect. d) Fresh ferroactinolite blades from Ysterkop North with pink britholite euhedral. In weathered examples the ferroactinolite may alter to lime-green nontrite and the britholite to goethite (Crocker et al., 2001); Act=actinolite, Brith=britholite. Sample #ID 11091. e) Mega-breccia of sub-rounded and angular granite blocks set in disassociated ferroactinolite matrix, from Ysterkop North. f) Mega-breccia from Ysterkop North of granite blocks in ferroactinolite matrix. Field of view approximately 4 m.
7 000 t CaF$_2$ contained in 45 000 t of ore (Crocker et al., 1988). In comparison to the Ysterkop North prospect, the Y and Au grades are double and the Cu and LREE grades an order of magnitude greater. This enhanced concentration of elements is likely due to the effect of restricted fluid egress through the impervious aplite layer.

Numerous smaller iron oxide-fluorite bodies are distributed around the farm (Figure 6.7), with at least another six of these intimately associated with the prominent aplite dyke. They vary in size, form and intensity of mineralisation.

Numerous examples of hematite filled breccias have been identified, in particular, on the eastern side of the farm. The granite host is commonly desilicified (episyenitised) with hematite emplaced in veins or in myrialitic cavities (Plates 6.6 (b)-(c)).

Figure 6.7. The distribution and locations of the numerous iron oxide–fluorite occurrences on the Blokspruit and Ruigtepoort farms (from Crocker et al. 2001).
The prominent hills and ridges of Bobbejaankop-type granite in the middle to southern portions of the farm are largely barren of significant mineralisation, but have nonetheless been exploited for a different commodity. The massive hills of deuterically-altered, red granite have been quarried for dimension stone, with two pits of about 100 m in diameter each excavated into the ridges (27° 42.20’ E; 25° 02.95’ S). Production figures are unavailable, although production was ceased as it was found that the biotites were too heavily chloritised to provide a good polishing surface.

Plate 6.6. a) Massive hematite with intermingled white adularia, from Blokspruit 157JQ. b) Black hematite veining in fine-grained granite episyenite, the granite taking a deep red to purplish hue; Sample #ID 11057. c) Hematite infilling pore-spaces of granite episyenite. Fe₂O₃ now accounts for 26 wt% of bulk rock; Sample #ID 11053.
Elandslaagte Fe-REE (-F-Cu-Sn-Mo) Occurrences

The main mineralised body on Elandslaagte 154JQ shows no indication of ever having been prospected. It is situated in the northernmost portion of the farm (27° 41.75’ E; 24° 59.90’ S) forming a prominent hill, which rises 20-30 m above the unbroken, relatively featureless surrounding countryside, and is approximately 1 km in length and 0.5 km in width (Figure 6.8).

The host rock to the main mineralisation is a highly silicified rock of disputed origin, which may possibly represent a sedimentary xenolith in the apical

Figure 6.8. Geological Interpretation of the geology around the Elandslaagte REE occurrence. Scale 1:14 285.
portions of the Bushveld granites or Rooiberg pseudogranophyres, or it may also be a highly-altered and reconstituted apical chill phase of the granite, although this seems less likely. The country rock consists largely of granophyric, coarse- and fine-grained granite, which may be recrystallised Rooiberg rhyolites, or the uppermost portions of the granite sheet. No contact is discernible. Restricted quantities of Rooiberg agglomerates outcrop to the north.

The main body of the occurrence is a large, highly-brecciated zone of granite with hematite-quartz filled veins (Plate 6.7 (a)). The brecciated rock begins near the base of the hill and continuous towards the top. The summit of the hill consists of a fine-grained, highly-silicified rock with equigranular grains of quartz (Plate 6.7 (b)). Specularite is developed interstitially and the rock possesses a red-grey colour, presumably from the oxidation of the alteration mineral assemblage to hematite (Plate 6.7 (c)). Other accessory phases are not discernible in hand specimen, although the rock contains nearly 1% LREE and anomalous amounts of Y, Nb, Sn, Mo, U, and W. Rare-earth minerals such as bastnaesite, monazite or xenotime may be expected.

A vein-like, linear outcrop 300 m in length and 30 m in width of massive hematite-quartz is located to the east of the hillock, and is discontinuous to the south. No accompanying mineralisation has been identified such as that observed at other nearby deposits (e.g. Slipfontein Mine). The orientation of the hematite-quartz outcrop is uncertain and it is not known whether it forms a sub-horizontal manto, such as those observed at other nearby deposits, extending around and beneath the hill.

A smaller occurrence is located in the geographic centre of the farm (27° 42.40’ E; 25° 01.10’ S) exhibiting a similar host lithology of probable sedimentary origin set in coarse granite (Figure 6.9). Unlike the occurrence to the north, the equigranular siliceous rock is deficient iron oxide; the quartz white in colour (Plate 6.7 (d)). Intense sericite-epidote alteration has affected the immediate country rock (Plate 6.7 (e)). The sub-horizontal xenolith is 100 m² in area and
forms the locus of the occurrence, with cross-cutting massive hematite-quartz veins (Plate 6.7 (f)) and granite breccias with hematite-quartz fracture fill, similar to those observed to the north. Grades are generally an order of magnitude lower than the larger deposit to the north, but the deposit is enriched in Cu, Mo, and U with 1 800 ppm Mo reported.

The mineralisation at this locality has not been correlated to that at Slipfontein. It should be noted, however, that the occurrence lies approximately 1 350 m along a strike of ~120°, which may be sufficiently close to have been derived from a similar genetic source. The principal difference between the occurrences at Elandslaagte and the Slipfontein Mine is the conspicuous absence of significant fluorite mineralisation.

Figure 6.9. Geological interpretation of the geology around the Elandslaagte Central REE occurrence. Scale 1:14 285.
Plate 6.7. a) Hydrothermal granite breccia with hematite-quartz fracture fill associated with several mineralised occurrences on Elandslaagte 154JQ; Sample #ID 11147. b) Siliceous host rock to hematite-REE mineralisation, possibly bastnaesite-bearing; from Elandslaagte 154JQ; Sample #ID 11150. c) Siliceous host rock with abundant purplish hematite and fine specularite; Sample #ID 11152. d) White, crystalline quartzitic xenolith found in association with centres of hydrothermal activity; Sample #ID 11146. e) Intensely sericite-epidote altered granite country host rock; Sample #ID 11145. f) Massive hematite-quartz veins; Sample #ID 11079.
Doornfontein Fe-F (-REE-Au-Cu-U) Prospects

The farm Doornfontein 155JQ is for the most part extremely flat, with poor outcrop and few occurrences of significant massive iron-oxide mineralisation.

The most prominent site of this style of mineralisation is a single hill located in the southeastern corner of the farm (27° 44.75’ E; 25° 01.05’ S), which consists virtually totally of massive iron oxide, predominantly hematite, and crystalline quartz (Figure 6.10 (a)). The body is 150 m in length, 100 m in width and forms a 20-30 m rise above the flat surrounding topography of Bobbejaankop-type granite. The extent of the body at depth is not known. The body has been extensively prospected with trenches that crosscut the entire hill, and two small shafts have been sunk to depth of about 5 m.

Approximately 200 m to the northwest of the hill are numerous prospects and shallow trenches through mineralised veins of massive iron oxide-quartz with minor fluorite, which is considered to be a stringer-zone extension of the larger body to the southeast. The total economic potential of these bodies in terms of iron ore, fluorite or other metals has not been determined.

The only other significant evidence of mineralisation on the farm is indicated by two small pits (27° 43.10’ E; 25° 00.60’ S), which lie approximately 300 m apart from each other (Figure 6.10 (b)). The southern pit/shaft is roughly 10 m in diameter and extends steeply to an approximated depth of 15 m. Highly chloritised rock and chloritised country rock, as observed in the larger Ruigtepoort Mine, is developed here (Plate 6.8 (a)). The country rock is presumed to be Bobbejaankop-type granite, although outcrop is sparse to non-existent in the immediate vicinity of the pit. Mineralisation is sparse with 0.05% LREE and anomalous but trace amounts of Au, Cu, Ni, Zn, Sn, and W.
Figure 6.10. Geological Interpretation of the geology around some mineralised bodies on the farm Doornfontein 155JQ. Scale 1:14 285. a) The prospect in the southeast corner of the farm is of a large massive iron oxide-quartz plug, approximately 100 m in diameter, which forms a low hill 20-30 m above the otherwise flat granitic plain. b) A number of small diggings located on the western side of the farm intersect chloritised granites, sedimentary xenoliths and thin magnetite-hematite veins.
The pit to the north is roughly 10-15 m in diameter and only 5 m in depth. The host lithology is thought to be a sedimentary roof-rock xenolith. The rock is highly brecciated with small angular fragments set in a matrix of hematite after amphibole and chalcedonic quartz (Plate 6.8 (b)). Intense kaolinitisation and sericitic alteration of the country rocks is noted (Plate 6.8 (c)). Up to 0.15% LREE and 200 ppm Y is reported.

Other localities exist on the farm with signs of mineralisation and hematite-quartz filled breccias. These breccias contain abundant angular fragments of granitic rocks and hematite-quartz gossans (Plate 6.8 (d)). They are hydrothermal in nature and post-date at least one episode of prior mineralisation. Hematite-quartz mineralisation is known to have been punctuated and episodic at other localities.

Plate 6.8. a) Chlorite-altered granite from Doornfontein 155JQ; Sample #ID 11085. b) Breccia of gossanous hematite after amphibole and chalcedonic quartz; Sample #ID 11073. c) Intense kaolinitisation of granite country rocks in immediate vicinity to mineralisation; Sample #ID 11083. d) Hydrothermal breccia with fragments of hematite-quartz gossan and granitic rocks; Sample #ID 11203.
Table 6.2. Summary of Characteristic Features of Mineral Occurrences in the Western Bushveld Granites near the farm Ruigtepoort.

<table>
<thead>
<tr>
<th>Deposit</th>
<th>Ruigtepoort Fe-F (-Cu-Au-REE)</th>
<th>Slipfontein Fe-F (-Cu-Mo-REE)</th>
<th>Blokspruit Fe-F (-REE-Cu-Au)</th>
<th>Elandslaagte Fe-REE(-F-Cu-Sn-Mo)</th>
<th>Doornfontein Fe-F(-REE-U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineralisation Type</td>
<td>Type III; Type IV</td>
<td>Type II; Type IV</td>
<td>Type II; Type IV</td>
<td>Type II; Type IV</td>
<td>Type III; Type IV</td>
</tr>
<tr>
<td>Hematite-Quartz</td>
<td>Massive Hematite, prismatic quartz specularitic veins</td>
<td>Gossan of massive Hematite, prismatic quartz, siderite</td>
<td>Massive Hematite and pseudomorphs after amphibole</td>
<td>Massive hematite; specularite</td>
<td>Massive hematite</td>
</tr>
<tr>
<td>Fluorite</td>
<td>Abundant, colourless and purple varieties</td>
<td>Abundant, colourless and purple varieties</td>
<td>Abundant in vugs</td>
<td>Not observed</td>
<td>Not observed</td>
</tr>
<tr>
<td>Sulphides</td>
<td>Pyrite, chalcopyrite, arsenopyrite, bornite</td>
<td>Pyrite, chalcopyrite</td>
<td>Minor</td>
<td>Pyrite, chalcopyrite</td>
<td>Pyrite</td>
</tr>
<tr>
<td>REE minerals</td>
<td>Minor (&lt;0.1 %)</td>
<td>Bastnaesite</td>
<td>Britholite (0.2%)</td>
<td>Bastnaesite (?) (1 %)</td>
<td>Unidentified (0.4 %)</td>
</tr>
<tr>
<td>Orebody Morphology</td>
<td>Vertical Pipe with sub-horizontal mantos</td>
<td>Flat-lying mantos</td>
<td>Sub-horizontal sheets</td>
<td>Breccias and veins</td>
<td>Sheeted mantos, breccias and veins</td>
</tr>
<tr>
<td>Host rock</td>
<td>Chlorite-altered actinolite rock</td>
<td>White pegmatitic quartz</td>
<td>Chlorite-altered actinolite rock</td>
<td>Quartzitic xenolith</td>
<td>Chlorite-rock; quartzitic xenoliths</td>
</tr>
<tr>
<td>Country rock</td>
<td>Bobbejaankop granite</td>
<td>Klipkloof granite</td>
<td>Bobbejaankop granite</td>
<td>Pseudogranophyre</td>
<td>Pseudogranophyre</td>
</tr>
<tr>
<td>Alteration</td>
<td>Silicic-chlorite-K-metasomatism-sericite grading outwards</td>
<td>Sericite-epidote</td>
<td>Chlorite, episyenitisation</td>
<td>Sericite-epidote</td>
<td>Chlorite, kaolinitisation</td>
</tr>
<tr>
<td>Structural Control</td>
<td>Fracture bound; Major fault (000°)</td>
<td>Major fault (020°); mineralised veining (120°)</td>
<td>Mineralised veining (120°)</td>
<td>Mineralised veining (120°)</td>
<td>Unknown</td>
</tr>
</tbody>
</table>
6.3. Discussion on the Longevity of Hydrothermal Mineralisation in the Bushveld Complex

Age determinations for the Lebowa Granite Suite have yielded a range of ages spanning over 1 100 my. These are derived by numerous authors (for compiled results see Freeman, 1998), reflecting differing determination techniques (Figure 6.11), such as **U-Pb zircon data** (Coertze et al. 1978; Walraven et al. 1981, 1982, 1983; Walraven & Hattingh 1993; Walraven 1997), **Rb-Sr whole rock data** (Walraven et al. 1985; Walraven 1987; Walraven et al. 1990; Hamilton 1977; Davies et al. 1970), **Pb-Pb whole rock and mineral data** (Walraven 1988; McNaughton et al. 1993; Robb et al. 1994), and **U-Pb monazite data** (Nicolaysen et al. 1958; Burger et al. 1967). These dispersed results are interpreted as reflecting the episodic open-system behaviour of the Bushveld granites after emplacement, of superimposed events (Robb et al. 2000).

![Figure 6.11. Frequency histogram of age determinations from the LGS and Rooiberg Group from 2100 Ma to 950 Ma (taken from Robb et al. 2000).](image)

Figure 6.12 (Robb, unpubl.) represents the distribution of age data pertaining specifically to the Lebowa Granite Suite, and represents different components of the Suite individually and according to the method of determination. Note the best derived ages for each with its error distribution represented by the horizontal error bars.

The currently accepted age of emplacement for the Nebo granites of the Lebowa Granite Suite is 2 054 ± 1.8 Ma (Pb-Pb Zr, Walraven & Hattingh, 1993). Younger ages are interpreted to be a consequence of post-crystallisation processes and subsequent isotopic exchange related to: late-stage magmatic-hydrothermal fluids, affecting Sr systematics; the high-heat producing capacity of the granites themselves, affecting Pb systematics; metamictisation of zircons, affecting U-Pb systematics; and generally responses to orogenic activity on the craton margins, which may have driven regional-scale fluid flow and caused isotopic resetting (Robb et al. 2000).
The correlation of major orogenic events to episodes of fluid ingress and dynamism has been an important revelation to the understanding of both the timing and causation of mineralisation. Robb et al. (2000) dated polymetallic, fracture-related sulphide mineralisation associated with the Lebowa Granite Suite at 1 957 ± 15 Ma by analysing small (<100 micron) authigenic zircons in late-stage hydrothermal quartz (Figure 6.13). The sulphides present represent an intermediate stage in the mineralisation paragenesis and were shown to occur some 100 my after emplacement.

**Figure 6.13.** \( ^{207}\text{Pb}/^{206}\text{Pb} \) versus \( ^{238}\text{U}/^{206}\text{Pb} \) plot (Tera-Wasserburg concordia) for analyses of authigenic zircons associated with late hydrothermal quartz in the Spoedwel mine (taken from Robb et al. 2000, for data see same reference).
This further supports the idea that hydrothermal activity was episodic, with the principal period of mineralisation occurring at this time. Additional ages derived from U-Pb isotopic data for monazite separates by Nicolaysen et al. (1958) and Burger et al. (1967) produced a range of ages from 1,993 ±90/-78 Ma to 1,955 ±37 Ma. Rb-Sr isochrons were obtained by Walraven et al. (1985) and Davies et al. (1970) of 1,982 ± 63 Ma and 1,946 ± 45 Ma respectively, which represent ages 70-100 my younger than the emplacement of the Bushveld Complex.

However, hydrothermal activity during this 100 my period subsequent to the emplacement of the Bushveld Complex cannot be attributed solely to magmatically derived fluids. Hypothetical thermal modelling profiles were generated for the Lebowa Granite Suite by Cawthorn & Walraven (1998) to place constraints on the duration of convective/hydrothermal fluid flow. The modelling clearly demonstrated that conductive heat loss for a Bushveld Complex sized intrusion* degenerates to an ambient geothermal gradient within only 5 my, with the high heat productive capacity of the LGS having a minimal effect on increasing this period. The significant conclusion of this result is simply that any hydrothermal activity in the Bushveld Complex beyond this parameter must likely have been externally derived and not of magmatic origin.

The 100 my period following the emplacement of the Bushveld is significant in that it is coincident with the Kheis (Eburnian) orogeny between 1,999 – 1,928 Ma (Kruger et al. 1999). The suggestion is thus that a significant period of fluid ingress and associated mineralisation was propagated by continental accretion along the western margin of the Kaapvaal craton.

Other reset ages have been identified: notably between 1,870 to 1,780 Ma (Hamilton 1977; Walraven 1987) which are thought to be related to the progressive exhumation of the Bushveld Complex during the deposition of the

*The modelled package incorporated a 7 km-thick mafic sill, followed by a 1.5 km composite felsic sill. Other parameters: Depth of intrusion 4 km; interval; liquidus temperature of 800 °C; thermal gradient of 20 °C.km⁻¹; radiothermal heat production 30 µW.m⁻³ (see Robb et al. 2000 for detailed examination of the model).
Waterberg stratigraphy which commenced c. 1 770 Ma and could have exposed the Complex to meteoric fluids. In addition, two extremely late events at 1 187 ± 51 Ma and 961 ± 129 Ma (McNaughton et al., 1993) have been correlated with the Kibaran (Grenville) orogeny between 1 220 – 1 170 Ma (Robb, et al. 2000), and the Namaquan orogeny between 1 060 – 1 030 Ma (Robb, et al. 2000) respectively. These associations are depicted below in Figure 6.14.

**Figure 6.14.** Frequency histogram showing ages for the LGS selected on the basis of accuracy and precision (i.e. single or small grain population U-Pb zircon or monazite ages or reasonably well-constrained Rb-Sr and Pb-Pb isochrons). Also shown are presently available age constraints for the Kheis orogeny (Kruger et al., 1999), Soutpansberg/Waterberg deposition (SACS, 1980), and the Kibaran and Namaquan orogenies (Robb et al., 1999). (taken from Robb et al. 2000).
The geological characteristics and controls on mineralisation indicate the importance of hydrothermal-connate fluid mixing zones, the relationship between K-metasomatism and Fe-metasomatism, structural control on mineralisation and the abundant and pervasive alteration of the country rocks and host rocks to the mineralisation. The following chapter will discuss the features of the Bushveld-type mineralisation compared with those of recognised IOCG deposits from elsewhere.