# CHAPTER 3: STUDY AREA

## 3.1 Western Central Bushveld Bioregion

### 3.1.1 Geographic location

The study area is located within the vast Savanna biome, which covers large parts of southern Africa and comprises the western portion of the Central Bushveld Bioregion (figure 3.1). Winterbach *et al*. (2000) define the Central Bushveld as the bushveld of the North-West and Northern Provinces situated north of the Magaliesberg between the Kalahari in the west and the Lowveld in the east.

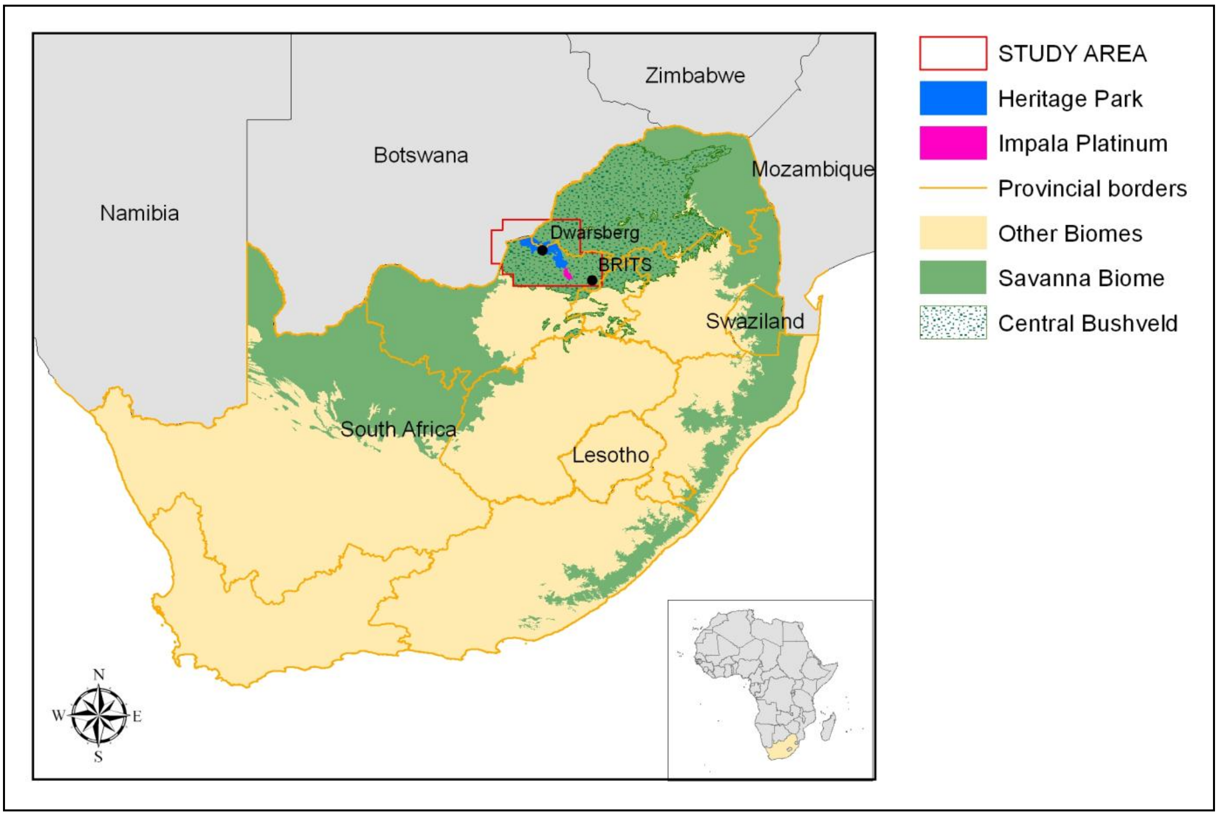


**Figure 3.1: Geographical location of the study area in South Africa within the Central Bushveld Bioregion, Savanna Biome.**

The western Central Bushveld occupies an area of about 33,750 km$^2$ (675 km$^2$ x 50 grids) encompassing 50 quarter degree grids between 24º15’ to 25º45’ S and 25º30’ to 28º00’ E (figure 3.1). The boundary runs roughly from Brits westwards to Zeerust in the south and from Thabazimbi westward to Gaborone in Botswana in the north.

The study focuses on two areas specifically, namely the Heritage Park conservation initiative and the Impala Bafokeng Mining Complex (figure 3.1), which will be introduced in section 3.2 and 3.3. Both areas are located in North-West and are owned by the Royal Bafokeng Nation.

## 3.1.2 Physical environment

### *3.1.2.1 Topography*

The western Central Bushveld is counted among the various landscapes found on the extensive, undulating interior Plateau of South Africa. Encircled by the Great Escarpment in the east, south and west, the Central Plateau gradually loses altitude towards the northwest where the Transvaal Bushveld Basin is found.

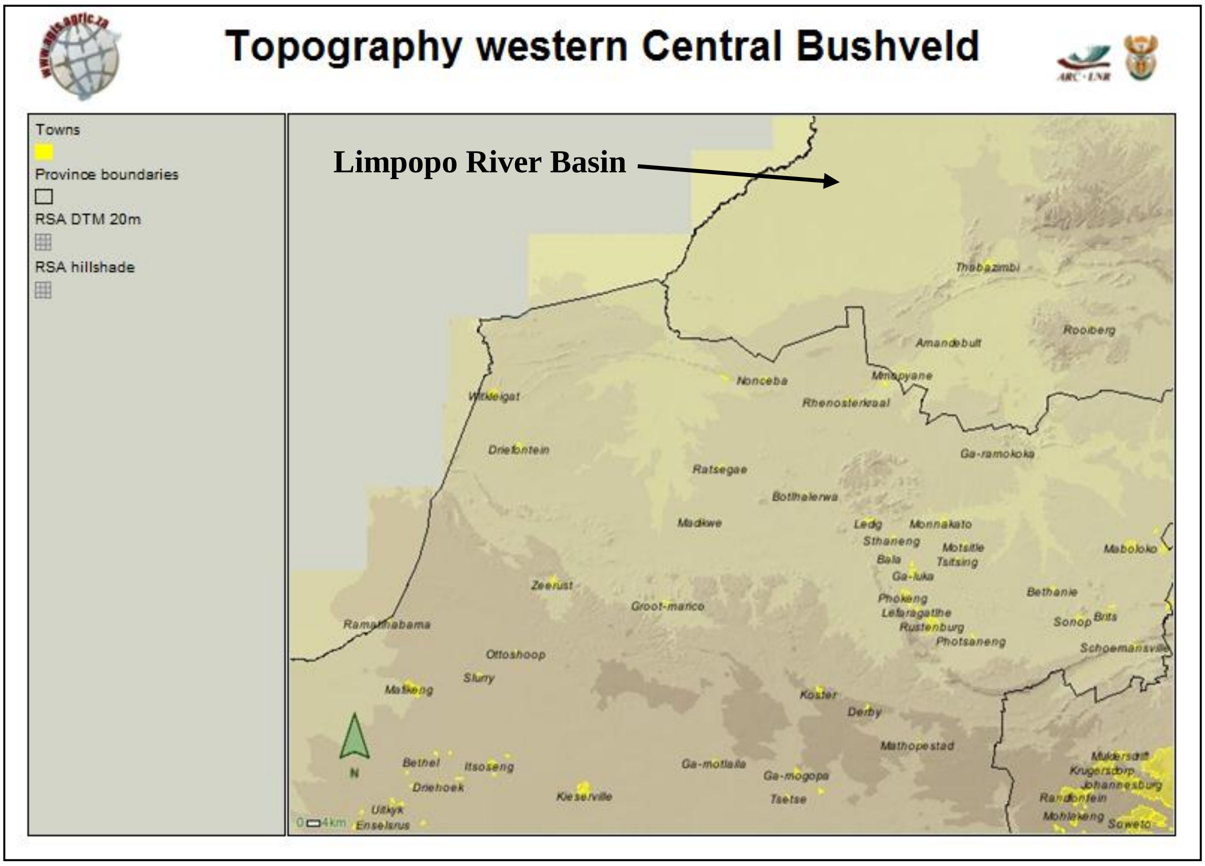


**Figure 3.2: Topography of the western Central Bushveld Bioregion reflecting elevation and relief. Source: AGISMap Atlas, http://www.agis.agric.za (Retrieved: 15.09.2010).**

The geographic region encompasses the western part of the Bushveld Basin and its surrounding uplands with elevations between 900 to 1,500 m (Van der Meulen, 1979). To the south lies the Magaliesberg mountain range and uplands that gradually rises south onto the Highveld Plateau (Van der Meulen & Westfall, 1979). In the northern part of the Bushveld Basin, the Dwarsberg Mountains in the northwest and the hills of the Waterberg Plateau in the Thabazimbi area form the border to the lower lying areas of the Limpopo River valley (figure 3.2).

## EVOLUTION OF THE BUSHVELD BASIN

According to (Cowling *et al.*, 1997), the Bushveld Basin was created by geological events in the Pliocene via lowering along marginal faults. Similarly, the present geomorphology of the western Central Bushveld landscape is closely linked to the geological history of the region (Van der Meulen, 1979; FAO, 2004). Since the break-up of the Gondwana super-continent in the early Cretaceous period, the African landscape has been denuded and dissected through repeated cycles of rifting, uplift and erosion (Cowling *et al.*, 1997).

This progressive fragmentation of habitats in the geomorphological history of the interior plateau can also be observed in the western Central Bushveld. The terrain morphology of the study area has been largely determined by repeated Post-African I cycles of erosion (at the end of the Miocene between 23.7 to 5.3 million years ago), which produced irregular planed surfaces that cut up to 250 m below the original African surface and are locally overlain by marine or terrestrial sediments (Encyclopaedia Britannica, 1995; Cowling *et al.*, 1997). This gave rise to a highly dissected landscape with undulating topography and frequent occurrence of rugged hills or koppies.

## PHYSIOGRAPHIC REGIONS OF THE WESTERN BUSHVELD BASIN

The geomorphological history of the Bushveld Basin gave rise to four discrete physiographic regions found in the study area:

### 1) Bushveld Basin

In the centre of the study area lays the warmer and drier plains of the Bushveld Basin floor formed by rocks of the Bushveld Igneous Complex (Van der Meulen, 1979; Van der Meulen & Westfall, 1979). The terrain comprises mainly level plains with some relief, and plains with open low hills and ridges (figure 3.3). Uplifted ridges have formed from erosion resistant Transvaal quartzites and mafic Bushveld Complex rocks (Fox, 2000). Terrain morphology generally ranges from flat to gently undulating lowlands owing to the underlying igneous norite and granite rocks respectively. Thus, local relief does not vary more than 130 m and over 80% of the area has slopes of less than 5° (Van der Meulen, 1979). Elevations range between 900 to 1,200 m, with occasionally occurring small rocky hills or outcrops of bedrock.

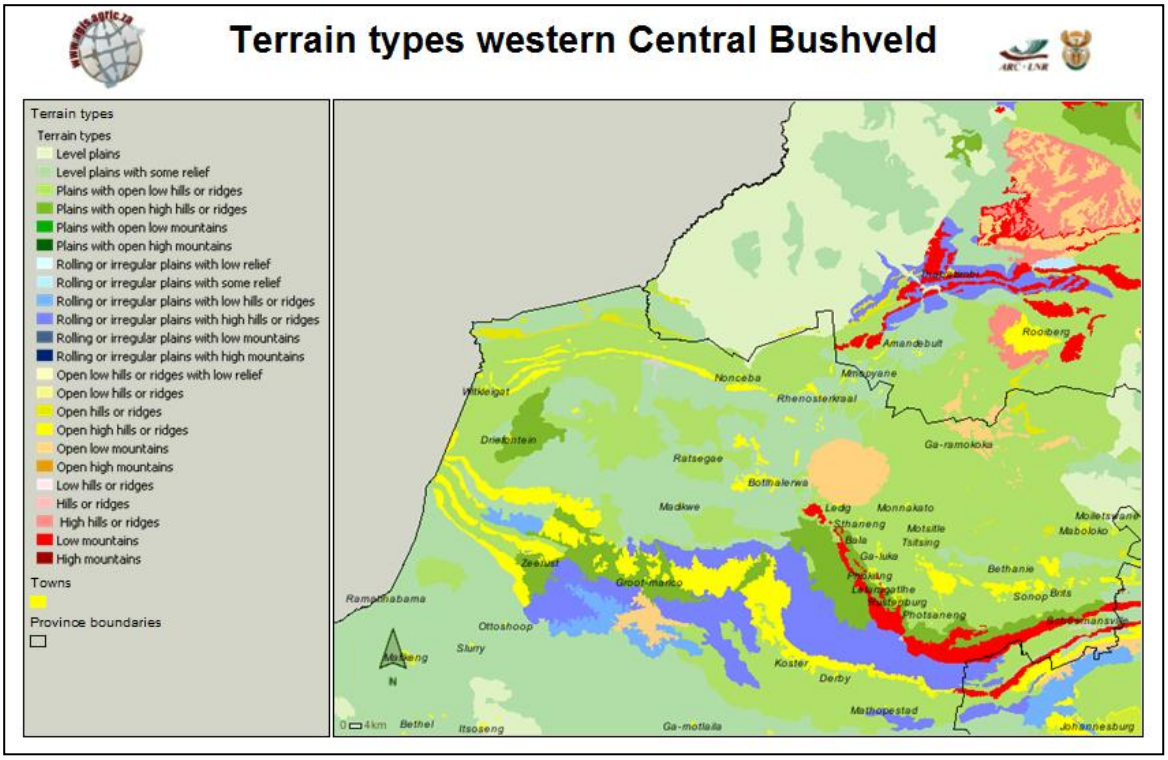


**Figure 3.3: Terrain morphology of the western Central Bushveld. Source: AGISMap Atlas, http://www.agis.agric.za (Retrieved: 15.09.2010).**

### 2) Pilanesberg Alkaline Ring Complex

An isolated ring of alkaline rocks occurs in the centre of the study area, called the Pilanesberg Alkaline Ring Complex, which arises from the surrounding flat bushveld plains (figure 3.2 and 3.3). It is a product of volcanic eruptions that took place some 1,300 million years ago (North-West Parks & Tourism Board, 2005). The now extinct volcano, once towering 7,000 m above the bushveld, has collapsed upon itself and weathered into four concentric rings of rocks that crop out only 700 metres (Pilanesberg Safaris & Tours, 2010). The rugged landscape of the crater offers a wide topographical variety, consisting of rocky outcrops, koppies and ravines with intervening valleys (North West Parks & Tourism Board, 2005).

### 3) Bankenveld

Cooler and moister hilly uplands of 1,200 to 1,500 m altitude consisting of a series of ridges and valleys, termed the 'Bankenveld', form a virtually continuous girdle around the Bushveld Basin (figure 3.3) (Cole, 1996). They are the result of a recent resurrection of ancient landscape following the removal of Karoo Series rocks during the course of drainage superimposition, and subsequent differential erosion and hardness of the underlying tilted sedimentary rock strata of the Pretoria Series (Van der Meulen, 1978; Cole, 1996).

Outcrops of the Pretoria rocks emerge from the Karoo cover in the east of the Bushveld basin, where they widen towards the west to form distinct east-west trending ridges, with the Magaliesberg, Daspoort and Hill mountain ranges in the south derived from the robust quartzite horizons while weatherable shales and diabases formed the intervening valleys; next the outcrop forming the Enzelberg swings round the western end of the study area from where it trends north-east to make up the Dwarsberg and Gatkop range in the north of the Bushveld Basin (Cole, 1996).

These hills and associated parallel running bottomlands are said to be of a cuesta type with gentle dip slopes of 5– 10° facing towards the basin and steep scarp slopes of 10– 35° on the other side, a pattern which causes the local relief to vary between 100 and 300 m with the majority of slopes greater than 5° (Van der Meulen, 1979).

### 4) Mafikeng Plateau

A small part of the study area in the far southwest between Zeerust and Mafikeng consists of a plateau at an elevation of about 1,400 m (Van der Meulen, 1979). This relative level plateau is characterized by minor relief variations of about 50 m, as there are only occasional open low hills and ridges present (figure 3.3).

## *3.1.2.2 Geology*

### THE TRANSVAAL BASIN

The Transvaal Basin is one of three sedimentary basins of the Transvaal Supergroup succession on the Kaapvaal Craton that have formed in the late Achaean to early Proterozoic period after the continental crust had been stabilized (Fox, 2000; Eriksson *et al*., 2001;

Johnson *et al.*, 2006). The Transvaal Basin comprises the Bushveld Basin with a surrounding belt of ridges and valleys termed the 'Bankenveld', and to the north the Waterberg, Soutpansberg and Polokwane plateaux (Cole, 1996). It lies roughly between Mafikeng in the west, Nelspruit in the east, Pietersburg in the north and Vredefort in the south (Schlüter, 2008).

Built of granites, gneisses and greenstones, the Kaapvaal Craton constitutes the basement for the accumulation of different clastic cover sequences and the intrusion of the Bushveld Igneous Complex (Fox, 2000; Groves, 2003). An outcrop of the Achaean gneiss basement is found in the northern and north-western part of the study area, forming a band from Lobatse over Gaborone in Botswana and stretching further northeast from Derdepoort towards the Limpopo River Basin where it forms flat to slightly undulating landscapes (De Wit & Bekker, 1990; Hepworth & Jones, 1973; De Villiers & Mangold, 2002).

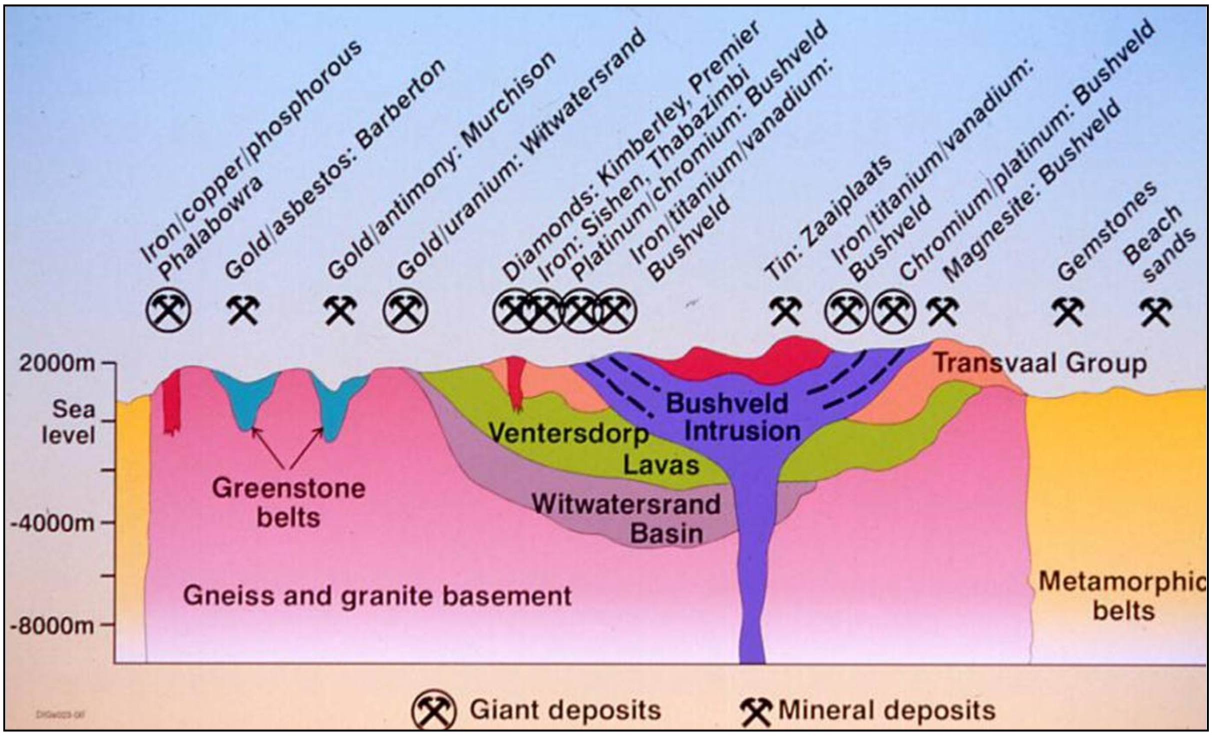


**Figure 3.4: The Kaapvaal Craton and the associated geological sequences. Source: Groves (2003).**

Deposition of the calcareous rocks, shales and banded iron formations of the Transvaal Supergroup took place about 2,700 million years ago as large parts of the Kaapvaal Craton were covered by a shallow epicontinental sea (Du Toit, 1954; Fox, 2000). Sedimentation was controlled by glacio-eustatic sea level changes caused by cycles of extensional or thermal subsidence and uplift accompanied by marine transgression and regression respectively (Catuneanu & Eriksson, 2002).

In turn, the rocks of the Transvaal Supergroup are unconformably underlain by the volcano-sedimentary and sedimentary rocks of the Ventersdorp and Witwatersrand Supergroup respectively (figure 3.4) (Johnson *et al.*, 2006). The Vendersdorp lavas discharged into the epeiric basin, while a major mantle plume caused thermal subsidence and rifting of the basin (Fox, 2000). In the study area, rocks of the Ventersdorp System occur in the far southwest in the vicinity of Mafikeng and extending into south-eastern Botswana where they form plains of low relief (Van der Meulen, 1979; De Villiers & Mangold, 2002). The Ventersdorp rocks consist mainly of andesitic volcanic lava and related metamorphic pyroclastic rocks (e.g. plagioclase) together with conglomerates and shales.

## THE BUSHVELD BASIN

The evolution of the Transvaal System ended 2,060 million years ago when a second major mantle plume beneath the Kaapvaal Craton led to the emplacement of the world's largest mafic layered intrusion, the Bushveld Igneous Complex (Fox, 2000; Catuneanu & Eriksson, 2002; Johnson, 2006; Elston, 2008). Because of the enormous weight of the overlying igneous masses, the Transvaal Supergroup strata were presumably tilted towards the centrally located Bushveld intrusive rocks by which they have become metamorphosed (Du Toit, 1954; Fox, 2000; Johnson *et al.*, 2006; Van der Meulen, 1979).

The Bushveld Basin lies in the centre of the Transvaal Basin with the groups of the Transvaal System forming concentric beds in the following order from the margin inwards: (1) Black Reef-, (2) Dolomite-, (3) Pretoria- and (4) Rooiberg Series (Du Toit, 1954; Krenkel, 1957).

### 1) The Black Reef Series

The Series is a thin and dark-coloured layer of rocks owing to its pyritic and chloritic components consisting of alternating bands of quartzite and shale (figure 3.5) with conglomerate pebbles at the base (Du Toit, 1954). In the study area Black Reef rocks crop out to the west and northwest of the Borakalalo Nature Reserve contained in the Crocodile River inlier of Transvaal rocks within the bed of intrusive Bushveld rocks (Johnson *et al*., 2006).

### 2) The Dolomite Series

Dolomite beds are mainly composed of magnesian limestone with some subordinate bands of chert, a compact siliceous rock present in the form of nodules, lenses and layers (Du Toit, 1954; Van der Meulen, 1979). The massive limestone formation encircles the Bushveld region in the north and south forming a general outcrop width of about 6–15 km, but broadens considerably in the Marico region to form the above introduced extensive plateau between Zeerust and Mafikeng together with the Ventersdorp lavas further west (figure 3.5) (Du Toit, 1954; Van der Meulen, 1979).

To the northwest of Zeerust, bands of chert make up the upper part of the Dolomite beds which gradually go over to ferruginous and cherty quartzites and finally turn into brown and black banded ironstones (figure 3.5) (Du Toit, 1954). Due to their hardness they have formed a series of low hills (Dinokana Hills) capping the dolomite and extending further northwest towards the Botswana border (Du Toit, 1954; Van der Meulen, 1979).

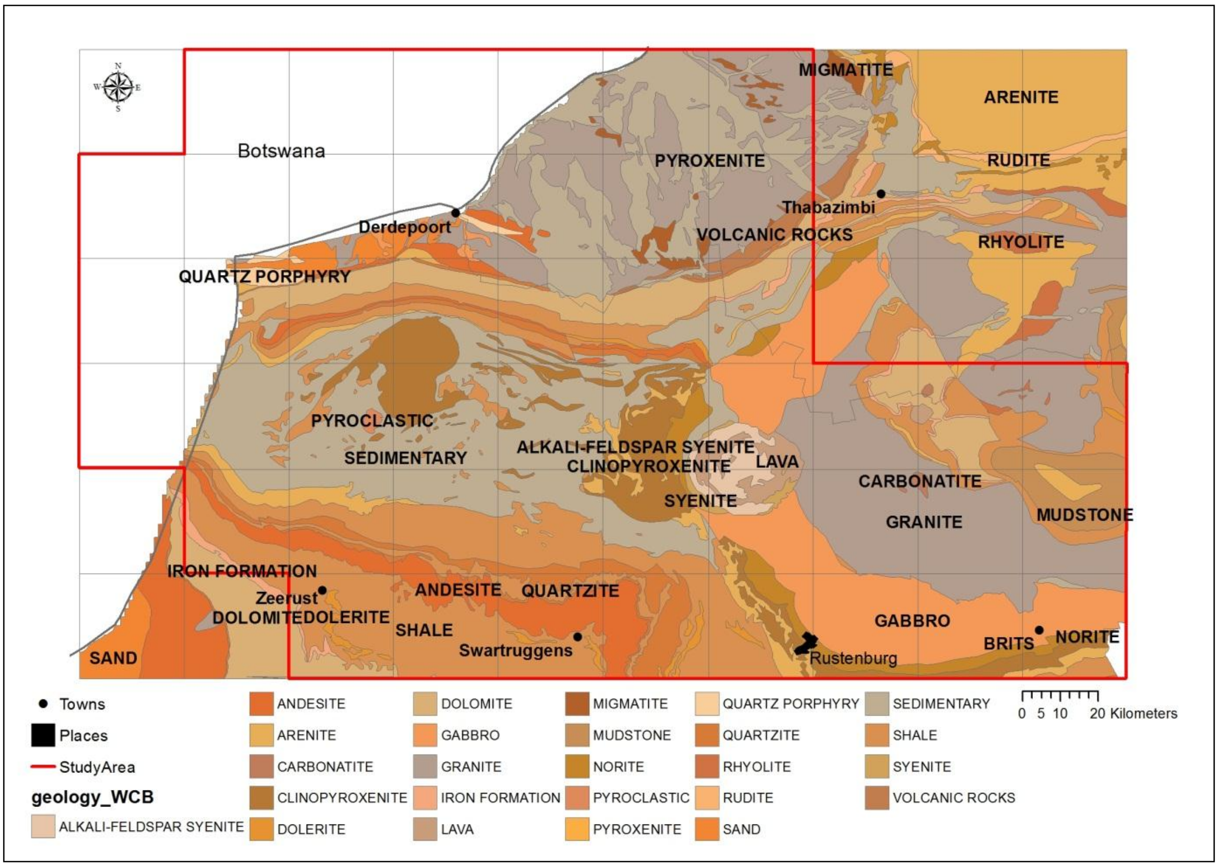


**Figure 3.5: Geological map showing the rock types of the western Central Bushveld.**

Banded ironstone formations (BIF) occur as finely banded siliceous, iron-oxide bearing rocks (Van der Meulen, 1979). Economically valuable deposits of BIF containing haematite ores occur in the Thabazimbi area where they attain a thickness of about 240 m while trending east from a point north of Pilanesberg (Du Toit, 1957).

### 3) The Pretoria Series

The rocks of the Pretoria Series follow directly upon the Dolomite Series forming a broad ring to the inside as it is overlain or replaced by the intrusive plutonic rocks of the Bushveld Complex in the centre of the study area (Du Toit, 1957; Van der Meulen, 1979). It consists mainly of alternating quartzite and shales with associated flagstones and intrusions of diabase sills (Du Toit, 1954; Van der Meulen, 1979). Three groups can be recognized in the study area occurring in the following order towards the centre: (a) Timeball Hill, (b) Daspoort and (c) Magaliesberg.

#### *a) Timeball Hill Stage*

Outcrops of the Timeball Hill Stage are mainly found in the south of the study area where it runs as a broadening band from Lobatse in Botswana southeast towards Zeerust and Rustenburg; but in the north it occurs merely as a thin band along the Dwarsberg range consisting of white and red quartzites parted by shales (Du Toit, 1954; Van der Meulen, 1979). This group is discerned from other stages by the presence of siliceous bands of iron-ore in the quartzites (Du Toit, 1954).

#### *b) Daspoort Stage*

The Daspoort Stage follows conformably on the Timeball Hill Stage in the south, but in the north it forms only a small band running northeast from the Dwarsberg range and ends about 40 km east of Thabazimbi (Van der Meulen, 1979). It is identified in the field by thick bodies of concomitant lavas at the base of the shales, the so called ‘Ongeluk Volcanics’ (Du Toit, 1954). These andesitic lavas appear in the study area to the north of the Zeerust-Swartruggens road where they build up the hills of the Schurvebergen (figure 3.5) (Du Toit, 1954; Van der Meulen, 1979).

#### *c) Magaliesberg Stage*

Rocks of Magaliesberg Stage encircle the Bushveld Igneous Complex and are thus highly fragmented and metamorphosed. In the study area fragments of the Magaliesberg bed crop out predominantly to the west of Pilanesberg, where they form isolated rocky hills and ridges together with the locally occurring norite, referred to as ‘norite koppies’ (Van der Meulen, 1979). Considerable thermal metamorphism can be observed within the Magaliesberg shales, which have been largely altered to hornfelses and slates by the intrusion of the basic igneous rocks (Du Toit, 1954; Van der Meulen, 1979). As the name implies, the massive Magaliesberg range that stretches in a semi-circular arch from Pretoria west of Brits over Rustenburg up to the Elands River close to Pilanesberg, is built up of Magaliesberg quartzites (Du Toit, 1954; Van der Meulen, 1979).

**4) The Rooiberg Series**

Unconformably placed over the Pretoria Series are the intermediate to felsic volcanic rocks of the Rooiberg Group, consisting of basaltic andesite near the base that becomes more felsic upwards with sandstone and shale insertions (Barnes & Maier, 2002; Johnson *et al*., 2006). Hatton and Schweizer (1995) believe that the Rooiberg lavas were the direct precursors of the layered mafic intrusions of the Bushveld Igneous Complex, which erupted below and into the Rooiberg Group (Barnes & Maier, 2002); and for that reason it is assumed that the Rooiberg volcanic rocks preserved in the floor and roof of the Rustenburg Layered Suite are presumably more closely related to the Bushveld Igneous Complex than to the Transvaal Sequence and should be included with the former (Johnson *et al*., 2006; Kinnaird, 2005).

## THE BUSHVELD IGNEOUS COMPLEX

The Bushveld Igneous Complex (BIC) is the oldest, largest and best preserved layered intrusion emplaced into the sedimentary rocks of the Transvaal Supergroup and contains some of the richest ore deposits of platinum group metals (PGM) as well as large quantities of copper, nickel, chromium, iron, tin and vanadium (Cousins, 1959; Johnson *et al*., 2006; Schlüter, 2008). Norite and red granite intruded between the Magaliesberg Formation at the top of the Pretoria Series and the Rooiberg Felsites, representing a climax in geosynclinal sedimentation (Du Toit, 1954; Johnson et al., 2006).

According to the South African Commission for Stratigraphy (1980) as quoted by Barnes & Maier (2002), the Bushveld Igneous Complex can be divided into three components: (1) The mafic and ultramafic layered rocks of the Rustenburg Layered Suite (RLS), (2) the suite of granophyres and granites overlying the RLS and (3) the suite of ultramafic to mafic sills that underlie the RLS and intrude into the sedimentary basement rocks (Johnson *et al*., 2006). These stratigraphical units together with the Rooiberg Group Volcanic Province make up the so-called Palaeoproterozoic Bushveld Igneous Province (Kinnaird, 2005). Du Toit (1954) remarks that this assemblage of igneous intrusive rocks constitutes one of the most outstanding geological occurrences in the world due to its extraordinary magmatic differentiation and thermal metamorphism.

According to Schlüter (2008), the remarkably continuous mineral layering can be attributed to a slow cooling process of the Bushveld magma where minerals of diverse composition, crystallisation temperatures and density formed. Hatton & Schweizer (1995) proposed a model of crustal and mantle melt produced by the rise of a mantle plume, whereby the extrusions of mixed and crustal melts first formed the volcanic rocks of the Rooiberg Series below which the uncontaminated mafic magma intruded to form the Rustenburg Layered Suite (Barnes & Maier, 2002). This first plutonic phase involved the introduction of basic magnesium- and iron- rich magma which crystalized mainly as norites and gabbros containing layered strata of highly differentiated minerals making up the Rustenburg Layered Suite; whereas a second plutonic phase involved the introduction of felsic silica rich magma forming the red granite which cut across and spread out above the norite (Du Toit, 1954; Kinnaird, 2005).

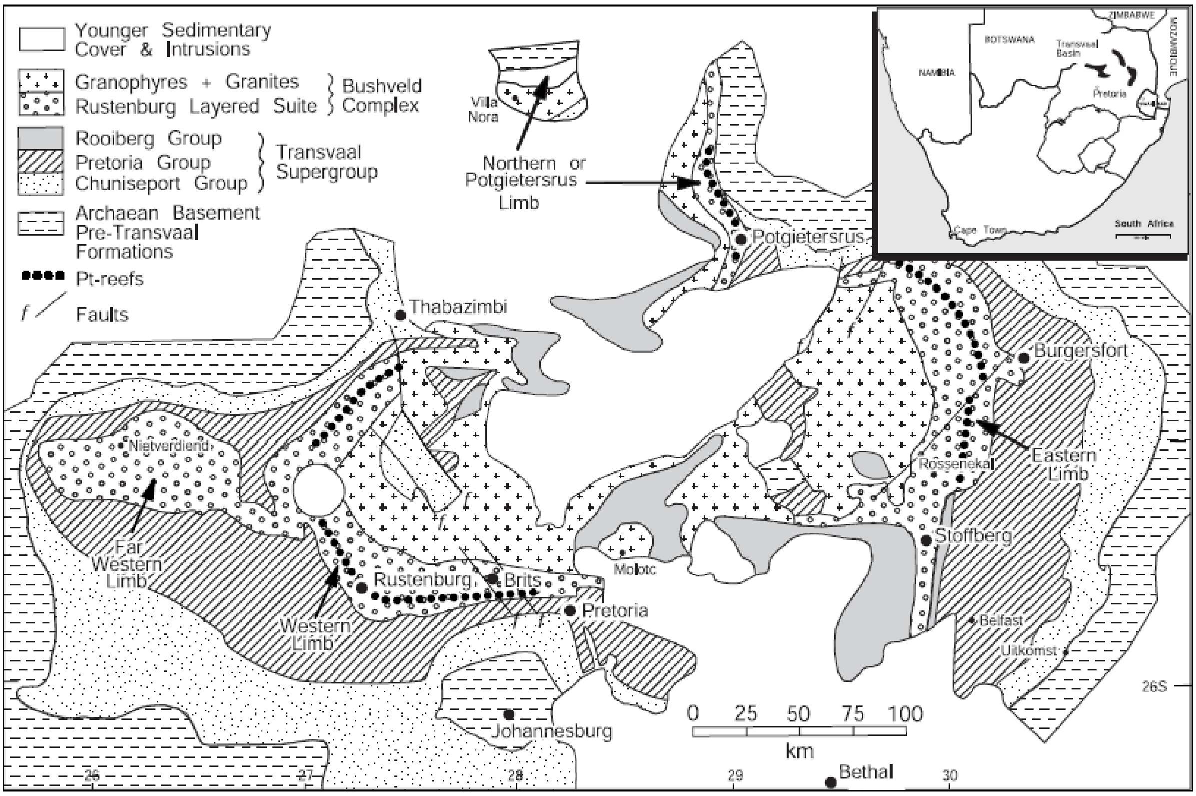


**Figure 3.6: Geology of the Bushveld Igneous Complex and its rocks. Source: Barnes & Maier (2002).**

These plutonic rocks crop out in four circular lobes, comprised of an western, far western, northern and eastern limb, and occupy an area of about 70 000 $km^2$ (figure 3.6) (Porter, 2006). Original dimensions are unknown as large parts of the Complex were denuded and buried beneath Waterberg sediments (Du Toit, 1954). The study area comprises only the western limb of the Bushveld Igneous Complex, traversing the north-eastern part of the North West Province from Lobatse at the Botswana border eastwards towards Pilanesberg where the norite becomes overlain by red granite and splits into two lobes, one trending northeast towards Thabazimbi and the other southeast over Rustenburg and Brits (figure 3.6).

### *The Rustenburg Layered Suite*

The layered mafic rocks of the Rustenburg Layered Suite (RLS), comprising up to 9 km of gabbro, norite, pyroxenite, anorthosite, harzburgite and diorite, were emplaced about 2050 million years ago followed by the thick upper segment of granophyres and granites dated back 2,000 to 1,650 million years ago (Porter, 2006).

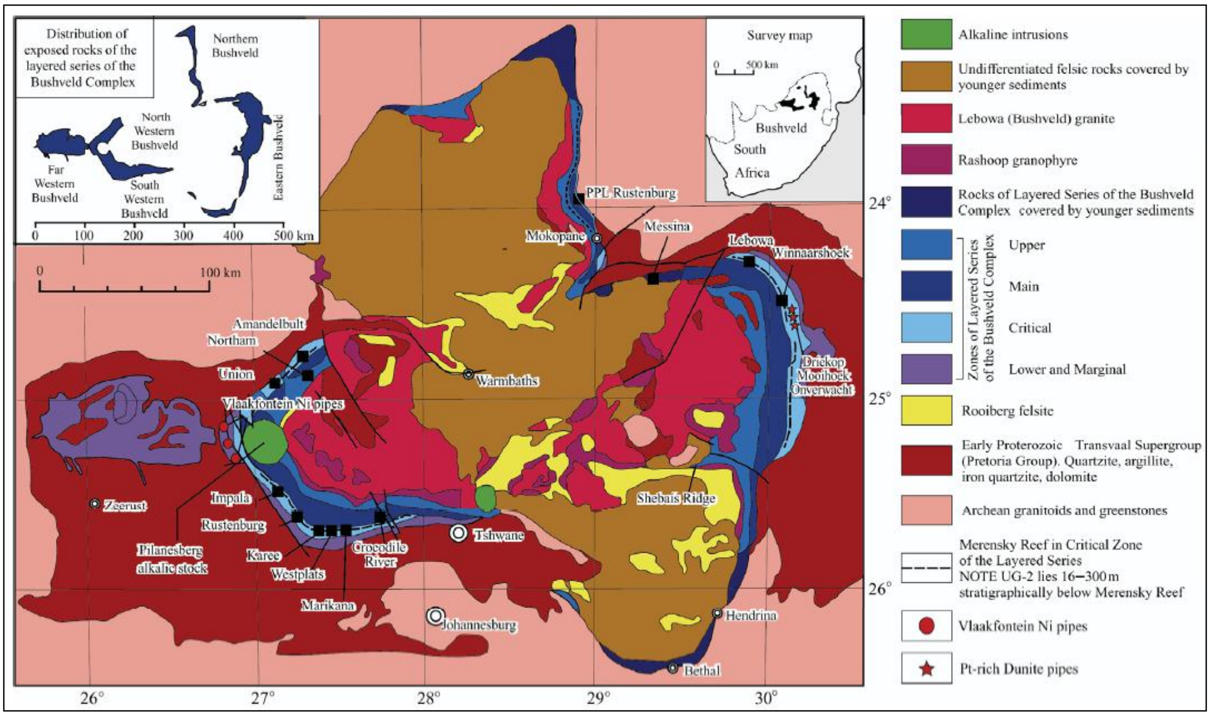


**Figure 3.7: Zonation of the Rustenburg Layered Suite and associated Bushveld Granites and Granophyres which together form the Bushveld Igneous Complex. Source: Naldrett *et al.* (2008).**

The RLS can be subdivided into the following zones: (1) the basal Marginal Zone (0 to 800 m), which consists mostly of norite, but also some clinopyroxene, quartz, biotite and hornblende, reflecting varying degrees of contamination from the underlying sediments; (2)

the Lower Zone (800 to 1,300 m) is composed of cyclic units of harzburgites and pyroxenites; (3) the Critical Zone (1300 to 1800 m), which is characterized by a spectacular stratification that hosts the world-class platinum and chromite deposits in several different layers termed reefs (e.g. Merensky and UG2 Reef), and encompasses a lower orthopyroxenitic layer as well as an upper, strongly layered anorthosite series of norite, anorthosite and chromitites; (4) the Main Zone (3,000 to 3,400 m), which consists of massive gabbro, norite and anorthosite strata with the Merensky Reef at its base; and (5) the Upper Zone (2,000 to 2,800 m) of layered gabbronorites, diorites and magnetites (figure 3.7) (Barnes & Maier, 2002; Kinnaird, 2005; Johnson *et al*., 2006).

In the study area PGMs are mainly mined along the Pt-reefs to the east and north of Rustenburg where significant concentrations of PGM ores are found (figure 3.6). This comprises the Merensky Reef and the UG2 Chromitite Layer contained in the Rustenburg Layered Suite, which both sub-outcrop on the Impala Platinum mining lease area and dip approximately 9 to 10 degrees towards the centre of the Complex (Impala Platinum, 2009). The Merensky reef especially represents the world's greatest reservoir of platinum and platinum group metals (palladium, ruthenium, rhodium, osmium, iridium and traces of gold), as well as associated sulphides of iron, copper and nickel that are mined as bye-products (Cousins, 1959).

### *The Bushveld Granites*

The Bushveld Granites are a series of sheeted intrusions introduced between the RLS and the Rooiberg Series that can be generally discerned as two groups: 1) the Lebowa Granite Suite and 2) the Rashoop Granophyre Suite (Kinnaird, 2005). Within the granophyres, intrusive and metamorphic rocks can be recognized, the latter of which originated from contact metamorphism with rocks of the Pretoria and Rooiberg Series (Johnson *et al*., 2006). These granitic rocks, composed mainly of quartz and alkali feldspar, occupy the vast area between Pilanesberg and Brits in the western Central Bushveld, where they give rise to gently rolling terrain with scattered occurrence of koppies (figure 3.6 and 3.8) (Du Toit, 1954; Van der Meulen, 1979).

#### *3.1.2.3 Soils*

*"Soils are dynamic in nature and are constantly evolving and degrading by means of natural and man induced processes"* (De Villiers & Mangold, 2002). The soil types of the western Central Bushveld are closely linked to the prevalent topography, geology and climate of the area.

Soils in semi-arid areas, like those found in the western Central Bushveld, are commonly shallow, stony and low in humus content due to superficial weathering and decomposition of organic matter respectively (Van der Meulen & Westfall, 1979; De Villiers & Mangold, 2002). Additionally, the low rainfall levels associated with semi-arid regions produce soils that are only slightly leached, and thus tend to develop high concentrations of salts in the soil, particularly if evaporation rates are high, resulting in the formation of hardpans or surface duricrusts (De Villiers & Mangold, 2002). As a result, the soil characteristics constitute an influential factor for plant growth in the study area governing the vegetation types that are able to grow there.

According to Van der Meulen (1979), six general soil types can be distinguished in the western Central Bushveld. The lowlands of the Bushveld Basin are mainly occupied by ferruginous lateritic or fersiallitic soils, along with vertic black clay soils (Van der Meulen, 1979; Van der Meulen & Westfall, 1979).

Ferruginous soils are yellow to red residual soils develop from sedimentary, metamorphic or igneous rocks by intensive weathering together with considerable leaching of silica, generally characterized by the presence of kaolinite and hydrous oxides of iron and aluminium (Butt & Zeegers, 1992; Cole, 1996; www.thefreedictionary.com). These non-calcareous, shallow to deep, meso- to eutrophic sands and loams occur on Pretoria quartzites, bushveld granites and dolomite, as well as on Karoo deposits in the study area (Van der Meulen, 1979). They tend to be gravelly with coarse sand grains and may be underlain by iron hardpans that impede drainage (e.g. plinthosols) (Butt & Zeegers, 1992; Van der Meulen & Westfall, 1979). The corresponding soil forms are Hutton, Clovelly and Avalon; especially quartzites and dolomites have weathered to poor red apedal sands, classified as the Hutton Form in South Africa (Van der Meulen, 1978).

Fersiallitic soils are only slightly leached yellow to red latosols rich in iron and aluminium oxides, but still contain a substantial amount of silica, and usually also containing clay minerals such as kaolinite and montmorillonite (Van der Meulen, 1979; www.thefreedictionary.com). They are non-calcareous, shallow to deep, meso- to eutrophic loams and clays which occur on andesitic lavas, Pretoria shales, diabase intrusions, norites and Karoo sediments, forming red, more structured soils that belong mainly to the Shortlands Form (Van der Meulen, 1979).

On the other side, the calcareous, shallow to deep vertic black clay soils (Vertisols, VR; figure 3.8) are typically found on the basic and ultrabasic igneous rocks (e.g. norites and gabbros) in the centre of the study area, but also overlying calcareous argillaceous sediments that occur in the north of the western Central Bushveld (Van der Meulen, 1979; Cole, 1996). These dark coloured, strongly structured soils are also referred to as 'Black Turf' (Du Toit, 1954). They have a high content of montmorillonite, a clay mineral with strong shrinking and swelling properties that causes self-mulching of the soil during the wet season and cracking during the dry season (www.thefreedictionary.com). Because the black turf forms by extensive weathering of the lime-soda feldspars and pyroxenes of the norite with the production of lime, magnesium, soda and gypsum, the soil is of good agricultural value, although difficult to manipulate (Du Toit, 1954). The main soil form occurring as black turf soils in the study area is classified as Arcadia (Van der Meulen, 1979).

Lithosols and bedrocks are commonly found in the uplands (Van der Meulen, 1979). Based on the soil map developed by Werger (1978), lithosols are mainly located on arenaceous sediments surrounding the Bushveld Igneous Complex in the study area, that is to say on clastic sedimentary rocks such as quartz sandstone and arkoses (www.encyclopedia.com), but are also found overlying the bushveld granites and the calcareous rocks to the north of Mafikeng. Furthermore, scattered outcrops of bedrock have been shown to occur throughout the basin floor. Lithosols have a weak profile differentiation primarily found on steep slopes where it is made up of coarse, only partly weathered rock fragments and solid rock at depths of 30 cm and less (Werger, 1978; www.thefreedictionary.com). Mispah and Glenrosa is the main soil forms associated with lithosols in the study area (Van der Meulen, 1979).

A more detailed description of the general soil patterns found in the western Central Bushveld is given in figure 3.8. It shows that alongside the black vertic clays (Vertisols, VR) the central lowlands are mainly covered by Cambisols (CM), defined as red, well-drained soils of high base status that lack a strong texture contrast (FAO, 2005). These soils develop from a wide range of rock types by slight to moderate weathering with only low accumulation of organic matter, illuviated clay and Fe-/Al-containing components (IUSS Working Group, 2006).

However, the uplands and plains with more contrasting relief display a more complicated picture of soil patterns. For example, red, yellow and greyish soils with a plinthic catena, also referred to as Plinthosols (PT1 and PT2), are found to occupy plains of low to high hills and ridges (FAO, 2005). Plinthosols are a Fe-rich, humus-poor mixture of kaolinitic clay with quartz and other constituents that change irreversibly to a layer with hard nodules or hardpans as a consequence of repeated wetting and drying, for example by exposure to a seasonally fluctuating groundwater table (IUSS Working Group, 2006).

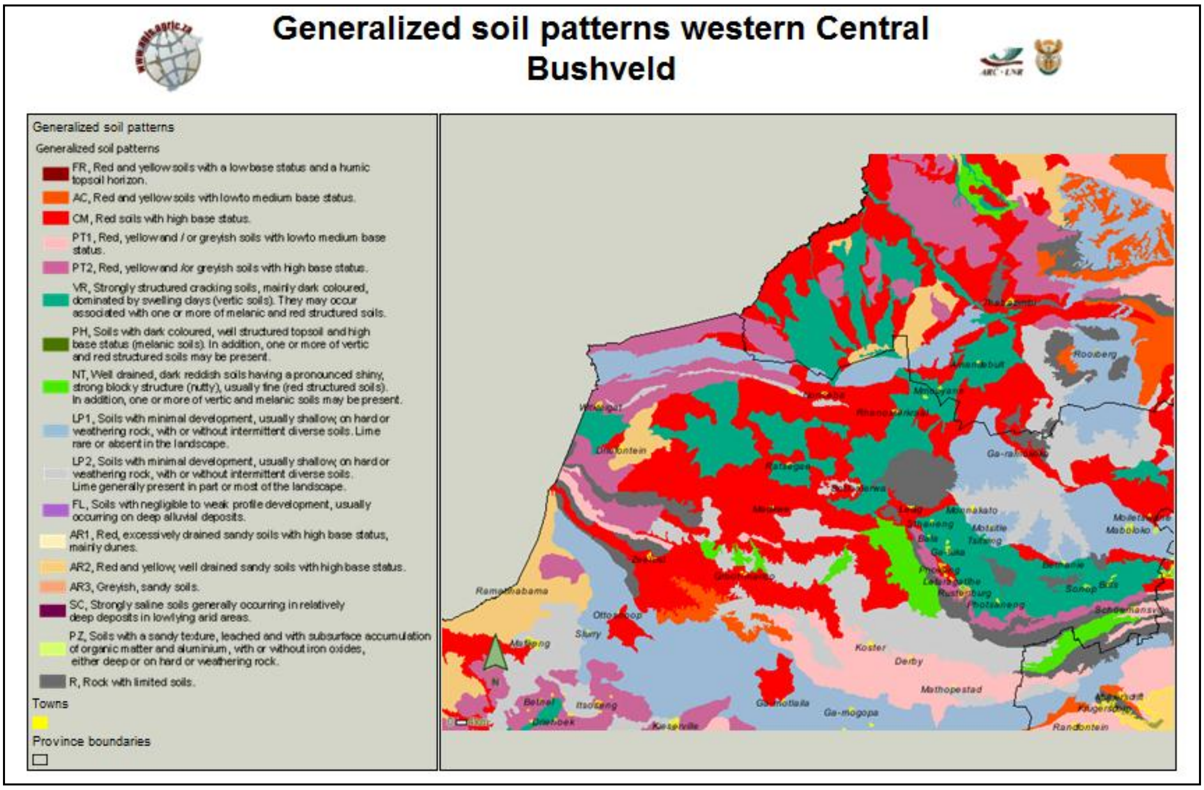


**Figure 3.8: Broad soil patterns of the western Central Bushveld. Source: AGISMap Atlas, http://www.agis.agric.za (Retrieved: 15.09.2010).**

On the other hand, Leptosols (LP1 and LP2) and Regosols (R) are found on mountainous terrain in the study area. Leptosols are defined as very shallow, azonal soils overlying continuous rock or extremely gravelly and stony basements, which develop in the presence of hard and weathering rock that allows only minimal pedological development (FAO, 2005). For example, Leptosols occur on the rolling plains with high hills and ridges to the west of the

Magaliesberg mountains, but also overlying the bushveld granites to the east of Pilanesberg where outcrops of hard bedrock are common (figure 3.3 and 3.8).

Regosols are defined as weakly developed soils over unconsolidated, finely-grained material, mostly due to aridity, found in rocky terrain of high hills and low mountains with steep slopes (FAO, 2005; IUSS Working Group, 2006).

### *3.1.2.4 Climate*

The western Central Bushveld Bioregion is unified with other Savanna regions by a seasonal but predictable rainfall regime, generated through the influence of a subtropical summer rainfall climate (Cole, 1996; FAO, 2004). Climate in the study area is subject to air masses of different origins:

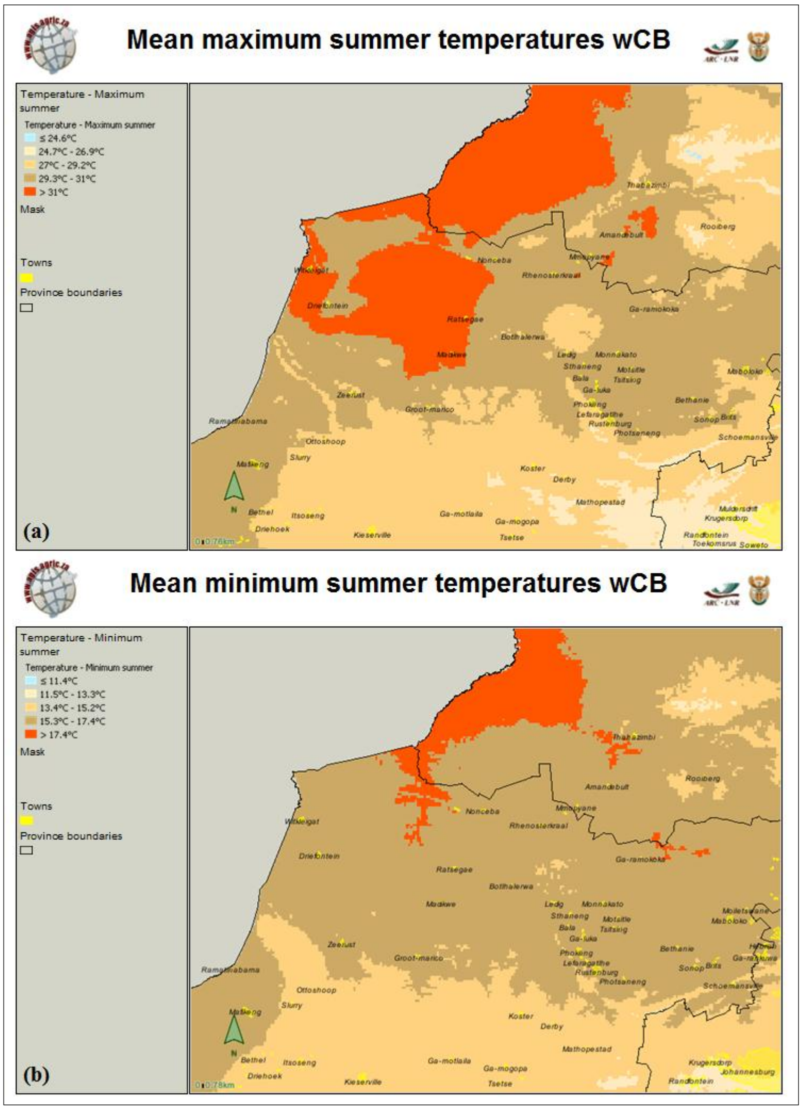


**Figure 3.9: Mean maximum and minimum temperature for the summer season experienced by the western Central Bushveld. Source: AGISMap Atlas, http://www.agis.agric.za (Retrieved: 15.09.2010).**

1) trade winds from the equatorial convergence zone that distribute humid tropical air masses in north-west direction, which means a progressive reduction in rainfall feeding moisture coming from the coast and 2) subtropical eastern continental moist maritime air masses that cause the incidence of regular cyclones (FAO, 2004).

According to Köppens climate classification (Köppen, 1918; Rosenberg, 1999) the western Central Bushveld can be assigned to the BSh climate class having a semi-arid, dry and hot climate (FAO, 2004).

Thus, seasons in the study area are sharply contrasted; with hot, wet summer months were rainfall events are mostly in the form of thunderstorms, and with dry, mild to sunny warm winters experiencing only slight frosts a few times per year (Burgess *et al*., 2004; Van der Meulen, 1979).

## TEMPERATURE

The interiors of the Bushveld Basin and the Mafikeng plateau in the south-west are exposed to a strong continental climate, which give rise to the highest maximum temperatures in summer and the highest minimum temperatures in winter recorded for the study area, compared to the cooler uplands (figure 3.9) (Van der Meulen, 1978).

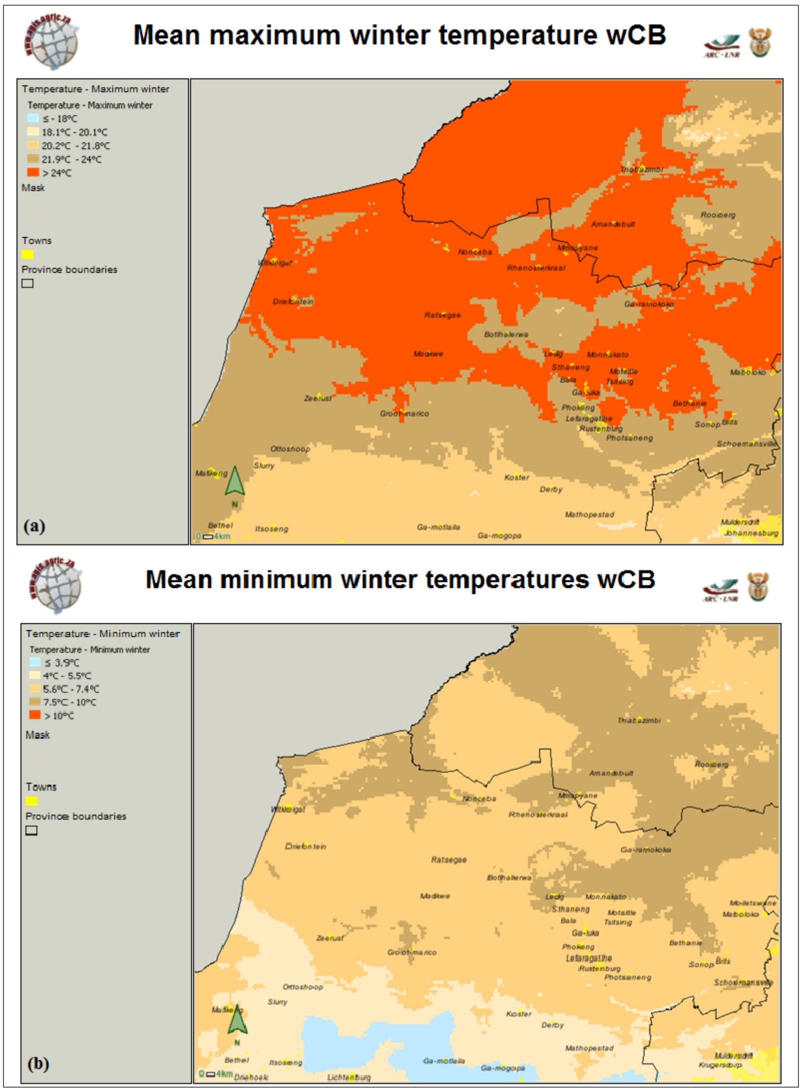


**Figure 3.10: Mean maximum and minimum temperature for the winter season experienced by the western Central Bushveld. Source: AGISMap Atlas, http://www.agis.agric.za (Retrieved: 15.09.2010).**

The climate of the Highveld plateau to the south is much cooler compared to that of the Bushveld Basin (Van der Meulen, 1978). As a result, the temperatures generally increase towards the north and northwest of the study area, also influenced by the proximity to the hot and dry climate of the Kalahari Basin covering most of Botswana (figure 3.9 and 3.10).

Moreover, the temperatures of the uplands in the southern part of the study area are primarily governed by topography, which is characterized by east-west trending ridges that shelter the north-facing slopes against cool air masses coming from the south (Van der Meulen, 1978).

This is quite well exemplified by figure 3.9 and 3.10, which indicate lower mean annual temperatures for the southern side of the Magaliesberg Range, which appear to vary about 2–4°C compared to the part facing north. These figures are also consistent with Theron (1973) who suggested a 0.2–4°C fluctuation between the north- and south-facing slopes (Van der Meulen, 1978).

Summers in the study area are warm to hot, with daily maximum temperatures that may exceed 40°C (FAO, 2004). The mean maximum summer temperatures are highest for the bottomland and low lying plains of the Bushveld Basin (29.3°C–>31°C); while they are lowest for the uplands ranging between 27°C–29.2°C, but values are especially low for the high hills of the Rooiberg, Waterberg and Magaliesberg mountains (24.7°C–26.9°C) as illustrated in figure 3.9 (a). Likewise, the mean minimum temperatures recorded for the summer season over most of the Bushveld Basin interiors hardly ever drop below 15.3°C–17.4°C, but may reach 13.4°C in the uplands as seen in figure 3.9 (b).

Winters in the western Central Bushveld are generally mild with daily maximum temperatures of about 20°C to over 24°C, but experience large diurnal variations of approximately 16.7°C (figure 3.10; Van der Meulen, 1978; FAO, 2004). Daily mean minimum temperatures increase northwards with only 4°C–5.5°C for the southern uplands, and may reach 7.5°C–10 °C for the central and northern higher lying areas (figure 3.10). Furthermore, the study area generally experiences mild frosts, especially in the southern part where annual minimum temperatures of 0°C–2°C has been measured (AGIS, 2010).

**RAINFALL**

Temperature fluctuations generally correspond with those of the rainfall patterns of the study area (Van der Meulen, 1978). Rainfall is highly seasonal with about 90% of the annual precipitation recorded for the summer months between October and April as mostly isolated rainfall events that rarely exceed 50 rainfall days per year (Van der Meulen, 1978; FAO, 2004).

The mean annual rainfall for the study area varies between 400–800 mm, where rainfall generally increases from the north-west (400–600 mm) to the south-east (600–800 mm), with higher levels of precipitation also recorded for the Pilanesberg National Park and the Thabazimbi area (figure 3.11) (Van der Meulen, 1978). As stated by Van der Meulen (1978), the lowest rainfall values are reported for most of the lower lying parts of the Bushveld Basin and the plateau near Mafikeng.

The rainiest months in the study area are December and January with a precipitation range of 75–125 mm increasing towards the south and south-east. Rainfall gradually decreases to less than 10 mm for the three winter months June, July and August (table 3.1).

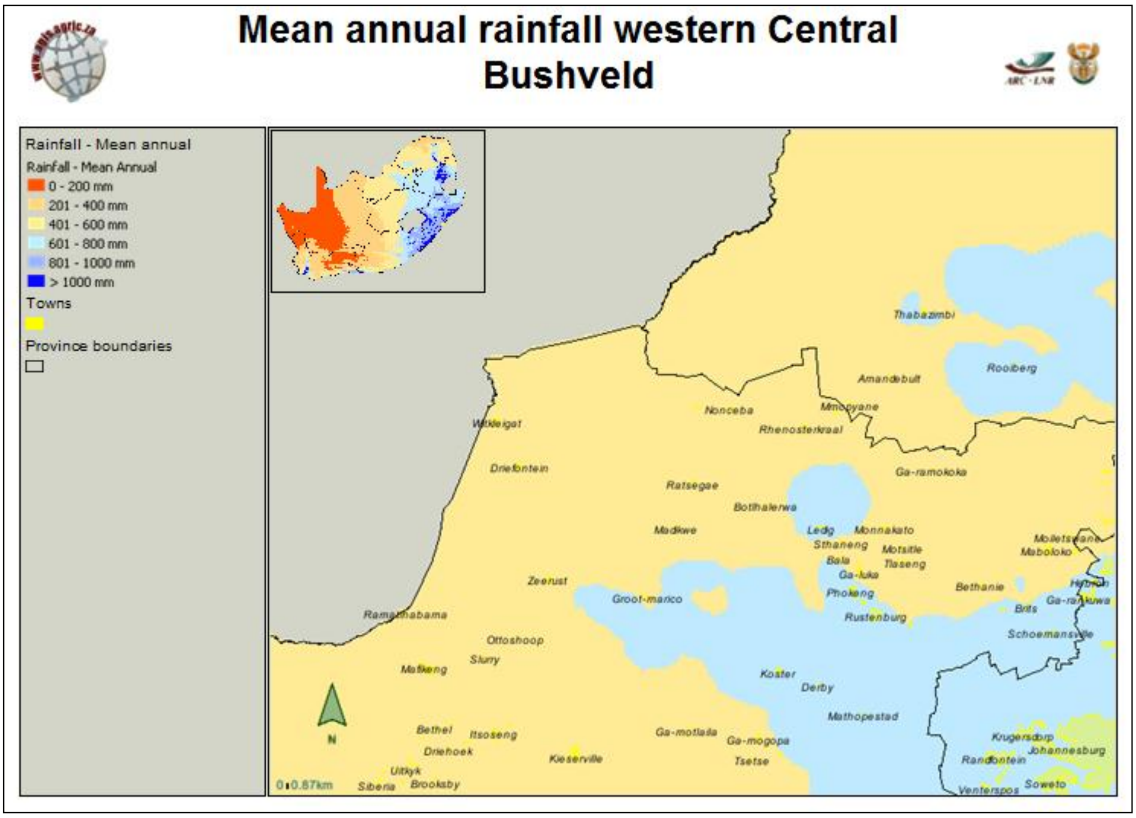


**Figure 3.11: Mean annual rainfall for the western Central Bushveld. Source: AGISMap Atlas, http://www.agis.agric.za (Retrieved: 21.09.2010).**

**Table 3.1: Long-term average monthly precipitation recorded for the western Central Bushveld. Source: AGISMap Atlas, http://www.agis.agric.za (Retrieved: 21.09.2010).**

| ***MONTH*** | ***PRECIPITATION*** | ***LOCATION*** |
|---|---|---|
| January | 75–100 mm | NW |
| | 100–125 mm | S + SE |
| February | 75–100 mm | Most of study area |
| | 100–125 mm | Rustenburg, Magaliesberg Range, Rooiberg |
| March | 50–75 mm | NW + E, Mafikeng plateau |

| | | |
|---|---|---|
| | 75–100 mm | S + N |
| April | 25–50 mm | Whole study area |
| May | 10–25 mm | Whole study area |
| June, July & August | < 10 mm | Whole study area |
| September | 25–50 mm | Whole study area |
| October | 25–50 mm | Most of study area |
| | 50–75 mm | Extreme SE |
| November | 50–75 mm | W + NW |
| | 75–100 mm | S + SE + E |
| December | 75–100 mm | Most of study area |
| | 100–125 mm | N–S from Thabazimbi to Pilanesberg; W–E from Groot-Marico to Brits |

### *3.1.2.5 Hydrology*

The topography, geology and climate discussed above form the key determinants for the regional drainage patterns found in the western Central Bushveld. All the major rivers draining the study area form part of the Limpopo drainage basin and arise from the uplands in the south, from where they flow in a northerly direction (Frost, 1987; FAO, 2004). Three sub-basins exist in the western Central Bushveld drained by the following main stem rivers:

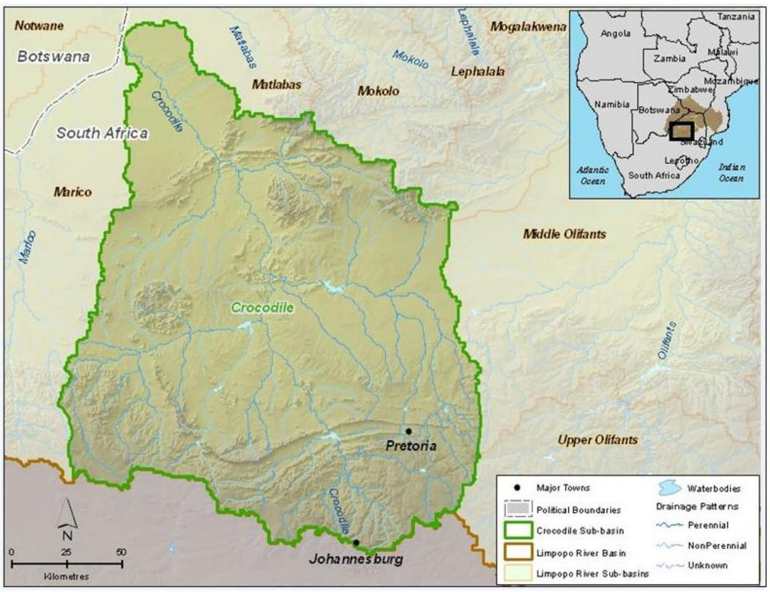


**Figure 3.12: Crocodile River sub-basin. Source: www.limpoporak.com (Retrieved: 17.08.2010).**

**CROCODILE RIVER**

The Crocodile River drains the east of the study area. It arises in the Witwatersrand Range and enters the study area south of Brits from where it runs north-west.

The tributaries Elands, Hex and Pienaars River originating in the uplands between

Swartruggens and Pretoria join the Crocodile River at the height of Pilanesberg, together forming the largest drainage basin in the region with a catchment area of 29,572 km$^2$ and an annual runoff of 391 million m$^3$ (Limpopo River Awareness Kit, 2010). After passing Thabazimbi it leaves the study area and joins the Marico River further north to form the Limpopo River (SARDC, 2002).

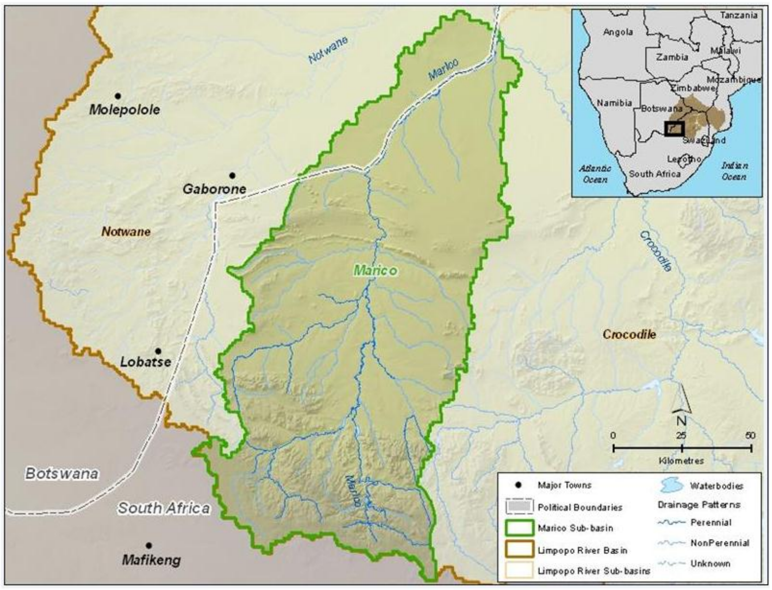


**Figure 3.13: Marico River sub-basin. Source: www.limpoporak.com (Retrieved: 17.08.2010).**

## GROOT MARICO RIVER

The Groot Marico drains most of the western part of the study area, with a catchment area of 13,208 km$^2$ and an annual runoff of 172 million m$^3$ (Limpopo River Awareness Kit, 2010).

It originates from a large dolomitic hole in the Marico district, from where the river trends north until it reaches and follows the Botswana border before the confluence with the Crocodile River (South Africa, 2010).

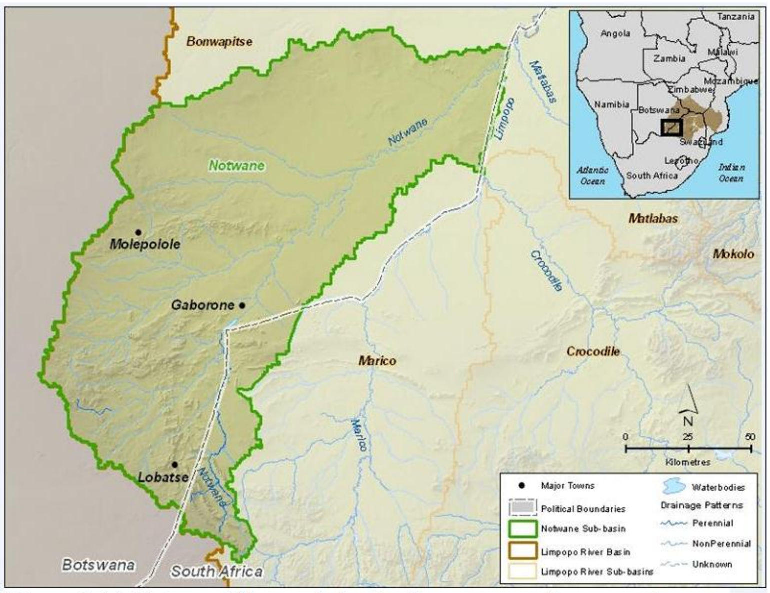


**Figure 3.14: Notwane River sub-basin. Source: www.limpoporak.com (Retrieved: 17.08.2010).**

## NOTWANE RIVER

The far west bordering Botswana is drained by the Notwane River, the third major tributary of the Limpopo River.

It rises on the edge of the Kalahari in Botswana, from where the river flows in a north-easterly direction until it joins the Limpopo River about 50 km downstream of the confluence of the Marico and Crocodile Rivers (SARDC, 2002). The catchment area of the Notwane River Basin is 1,852 $km^2$ and comparatively small and thus contributes only 55 million $m^3$ runoff volume annually (Limpopo River Awareness Kit, 2010).

These hydrological patterns form an important part in the study of the distribution of plant diversity. Rivers and streams constantly modify the landscape through erosion and deposition, along with the release and redistribution of minerals as a result of associated geomorphological processes, and thereby influencing the dynamics of the biotic communities established on these substrates (Frost, 1987).

### 3.1.3 Vegetation and flora

The Transvaal Bushveld is considered as one of the most southerly types of savanna woodland in Africa, comprising of various vegetation types with a continuous and dominant grass stratum interspersed with woody elements of varying height and density (Van der Meulen, 1979; Cole, 1996). According to the vegetation classification by Acocks (1975) and Low & Rebelo (1996), several broad veld types can be assigned to the western Central Bushveld (table 2.2) that correspond with the physiographic divisions of the study area.

**Table 3.2: The broad veld types identified for the western Central Bushveld in order of significance. Source: Cole (1996), Low & Rebelo (1996) and Van der Meulen (1979).**

| ACOCKS (1975) | LOW & REBELO (1996) | HABITAT |
|---|---|---|
| Sourish Mixed Bushveld (A19) | Mixed Bushveld (L&R18) | **Hills and plateaux**<br>(e.g. ridges and hills of the Bankenveld; Norite Koppies) |
| Mixed Bushveld (A18) | | **Low-lying plains and valleys**<br>(e.g. overlying the Bushveld Granites) |
| Other Turf Thornveld (A13) | Clay Thorn Bushveld (L&R14) | **Low-lying flat bottomland**<br>(overlying the Bushveld Complex) |
| Kalahari Thornveld (A16) | Kalahari Plains Thorn Bushveld (L&R30) | **Low-lying flat bottomland**<br>(far north-west at Botswana border) |
| Arid Sweet Bushveld (A14) | Sweet Bushveld (L&R17) | **Low-lying valley** |

| | | |
|---|---|---|
| | | (along Limpopo River at Botswana border) |
| Sour Bushveld (A20) and Mountain Sourveld (A8) | Waterberg Moist Mountain Bushveld (L&R12) | **Hills and low mountains** (e.g. Pilanesberg, Magaliesberg, Gatkop) |

### *3.1.3.1 Physiography of western Central Bushveld Savanna*

**SAVANNA PARKLAND**

Savanna parkland is the characteristic form of savanna over most of the Bushveld Basin, where largely microphyllous thorny *Acacia* tree species occupy the extensive calcareous vertic black clay soils in the drier lowlands underlain by norite and basalt (Cole, 1996). This *Acacia*-dominated vegetation of the lowlands is a type of 'Arid Savanna' (Huntley, 1978), which is also referred to as 'Microphyllous Thorny Plains Bushveld' by Werger & Coetzee (1978) (Van der Meulen, 1979; Winterbach *et al*., 2000).

These flat bottomlands of the Bushveld Basin are dominated by 'Turf Thornveld', with representative species such as *Acacia tortilis*, *A. nilotica*, *A. karroo*, *Grewia flava* and *Ziziphus mucronata* trees together with dense grass swards of *Panicum coloratum*, *Setaria incrassata*, *Ischaemum afrum* and *Eragrostis chloromelas* (Van der Meulen, 1979; Cole, 1996; Low & Rebelo, 1996). The open, low *Acacia* parkland over black clays in the Rustenburg area can be named as a representative example. However, where the black clay grades into dark brown loams the tree density increases with occasional interlocking canopies (Cole, 1996). Substantial increase of woody cover is also triggered by deterioration of the grass sward associated with overgrazing (Low & Rebelo, 1996).

'Mixed Bushveld' savanna parkland occurs predominantly in the gently undulating terrain underlain by the Bushveld Granite (Cole, 1996). The red to greyish gravelly sands of this area have a neutral to slightly alkaline pH caused by high levels of Na and K in the soil, which support a mixture of closed parkland and open woodland savanna characterized by the following vegetation elements: *Spirostachys africana*, *Acacia tortilis and A. nilotica* trees, *Carissa bispinosa* and *Euclea undulata* shrubs, as well as the grasses *Sporobolus iocladus* and *Heteropogon contortus* (Cole, 1996).

In the lowest and driest part of the Bushveld Basin, where red sandy soils prevail, the savanna parkland displays affinities with the low tree and shrub savanna of western Botswana indicated by the dominant tree species *Acacia erioloba* and *Boscia albitrunca* with scattered woody elements such as *Acacia leuderitzii*, *Grewia flava* and *Tarchonanthus camphoratus*; as well as a grass cover of *Eragrostis lehmanniana*, *Schmidtia kalihariensis* and *Stipagrostis uniplimis*, a vegetation type termed 'Kalahari Thornveld' by Acocks (1975) (Van der Meulen, 1979; Cole, 1996; Low & Rebelo, 1996).

**DEPAUPERATE MESIC SAVANNA WOODLAND**

However, in the higher lying terrain the savanna parkland vegetation grades into depauperate savanna woodland characterized by mesophyllous trees **(**Cole, 1996). These broad-leaved sparse woodlands occur on sandy loam underlain by granite, quartzite and dolomite with a rather impoverished floristic diversity compared to the savanna woodlands of Central Africa (Cole, 1996; Winterbach *et al*., 2000). These upland areas are found where relics of King's African surface were not planed during the post-African cycle as is the case for most of the Bushveld Basin (Cole, 1996). The mesophyllous semi-deciduous vegetation of the moist uplands of the Bushveld Basin is also known as 'Broad Orthophyll Bushveld' (Werger & Coetzee, 1978) or 'Moist and Mesic Broadleaf Savanna' (Huntley, 1978) (Van der Meulen, 1979).

For example, outcrops of Transvaal Supergroup rocks have formed prominent hills and ridges with shallow, weakly developed soils vegetated by open *Combretum apiculatum* and *Spirostachys africana* woodlands on quartzites and dolomites respectively (Cole, 1996). But along the south of the western limb of the Bushveld Igneous Complex where the norite forms low hills—the so-called 'Norite Koppies'—vegetation is representative of Acocks 'Sourish Mixed Bushveld' with a tree layer characterized by *Acacia caffra*, *Ziziphus mucronata*, *Dombeya rotundifolia*, *Croton gratissimus*, as well as *Combretum*, *Ficus* and *Grewia* species, and a grass stratum of *Cymbopogon plurinoides*, *Chrysopogon serrulatus* and *Setaria lindenbergiana* (Van der Meulen, 1979; Cole, 1996). On comparable granite koppies similar mesophyllous vegetation occurs with *Rotheca myricoides* and *Mimusops zeyheri* as additional distinguishing species (Cole, 1996).

Depauperate broad-leaved savanna woodland is also found on the Rooiberg uplands in the study area where Rooiberg felsites have formed the roof of the Bushveld Complex, attributable to unfavourable variations in soil and micro-climatic conditions that form a gradient from open savanna woodland on upper slopes with shallow well-drained soils, to nearly treeless savanna grassland on poorly drained soils of the lower ground where severe frost may occur (Cole, 1996).

**THE BANKENVELD**

The Bankenveld forms the periphery of the Bushveld Basin, and thus the open savanna vegetation displays different affinities due to varying climatic and edaphic conditions along the east-west gradient: scattered *Acacia caffra* trees in a grassland made up of *Themeda triandra* and *Cymbopogon plurinodis* in the drier western part of the study area, of more wiry *Trachypogon spicatus* and *Tristachya leucothrix* in the central south, and of very wiry sour grasses such as *Eragrostis racemosa* and *Heteropogon contortus* on the sandy loose soil in the east (Cole, 1996). However, the *Acacia* woodlands grade into a stands of *Burkea africana*, *Combretum zeyheri*, *Protea caffra* and *Faurea saligna* on the gravelly dark brown soils of the flat northern dip slopes of the Magaliesberg (Cole, 1996).

### *3.1.3.2 Vegetation of the western Central Bushveld Bioregion*

According to the vegetation classification by Mucina & Rutherford (2006), more discrete vegetation units can be demarcated for the western Central Bushveld Bioregion (figure 3.15). The Savanna biome in South Africa can be divided into six bioregions, one of which is the 'Central Bushveld Bioregion', characterized by a high number of vegetation types, and thus of a rich biodiversity (Mucina & Rutherford, 2006). Within the study area fourteen of the Central Bushveld vegetation types could be identified.

**SVCB1 DWAALBOOM THORNVELD**

The 'Dwaalboom Thornveld' is the most widespread vegetation unit of the western Central Bushveld, occupying the flat terrain of the central and northern areas and dominated by soils of varying clay content that creates a mosaic of different vegetation patches (figure 3.15). It consists mainly of deciduous microphyllous tree species with only a few mesophyllous trees scattered in a continuous herbaceous layer dominated by grass species. Species diversity is rather low, especially on the black, vertic ultramafic clay soils, owing to their strong shrinking and swelling capacity.

Dominant forbs are for example *Heliotropium ciliatum*, *Kohautia caespitosa* and *Nidorella hottentotica*, while dominant grass species include *Aristida biparta*, *Bothrichloa insculpta*, *Digitaria eriantha* and *Panicum maximum*. The climber *Rhynchosia minima* is locally found.

The tree-shrub layer shows a low to medium high growth habit with different tall-growing *Acacia* species as the most dominant. But broad-leaved species are found among the shrubs: tall shrubs such as *Combretum hereroense*, *Diospyros lycioides* and *Euclea undulata*, as well as the low-growing shrubs *Abutilon austro-africanum* and *Hirpicium bechuanense* are important taxa. Succulent shrubs such as *Kalanchoe rotundifolia* and *Talinum caffrum* are common.

Conservation status is medium-low with only about 6% of the vegetation conserved, mainly within the Madikwe Game Reserve. Although classified as least threatened, the vegetation is under pressure by cattle grazing and especially cultivation.

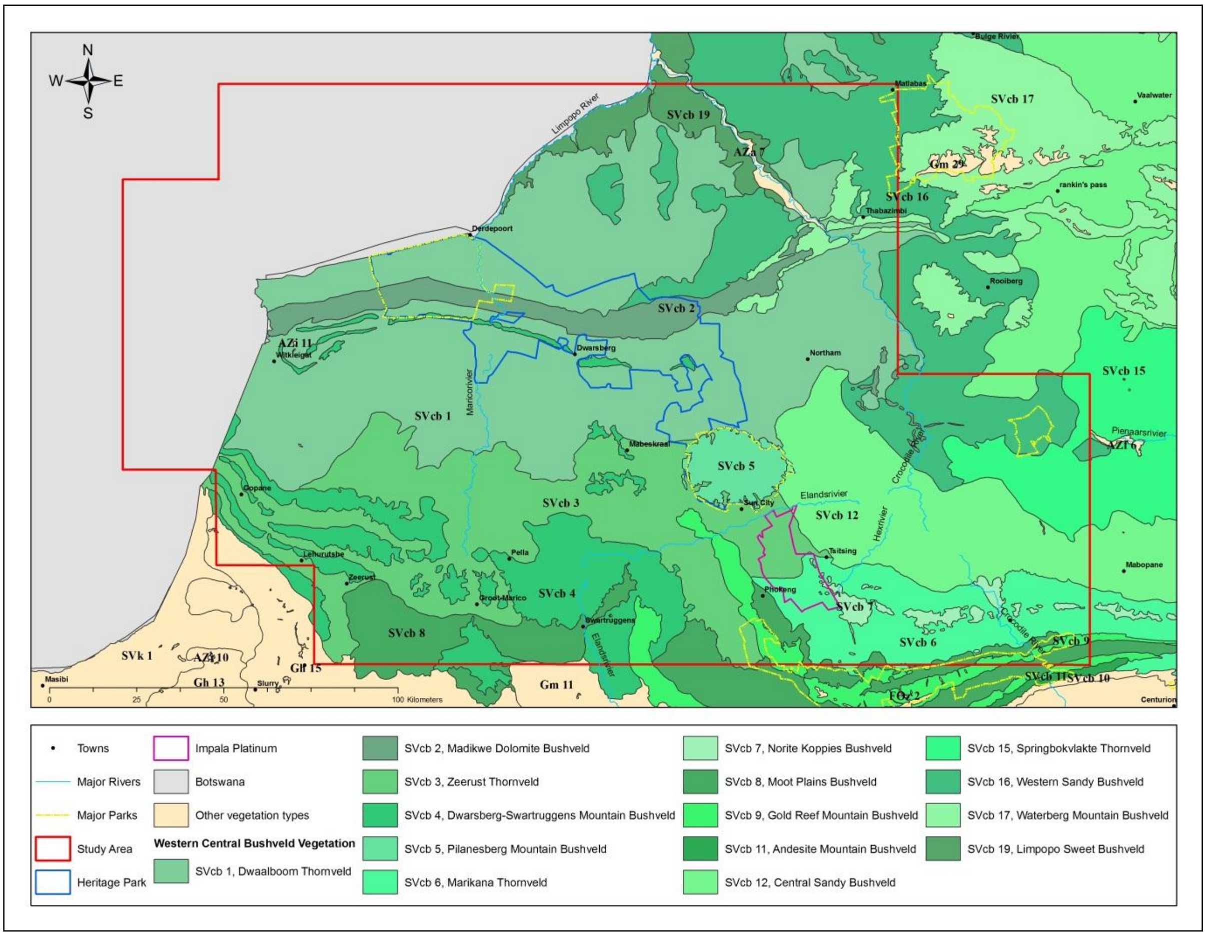


**Figure 3.15: Vegetation of the western Central Bushveld as classified by Mucina & Rutherford (2006).**

## SVCB2 MADIKWE DOLOMITE BUSHVELD

The vegetation unit is found as a broad east-west band along the gentle low hills and ridges extending from the Botswana border north of Witkleigat towards Thabazimbi (figure 3.15). Since most of the terrain is steeply sloping and characterized by stony, shallow soil underlain by dolomite, the shrub-tree layer is not so well-defined (figure 3.8). Dominant species of the tree-shrub layer are deciduous small trees like *Combretum apiculatum*, *Kirkia wilmsii*, *Ozoroa paniculosa* and *Ximenia americana*, along with tall-growing shrubs like *Clerodendrum glabrum*, the *Grewia* species *flava*, *bicolor* and *monticola*, and *Vitex zeyheri*. Again, the herbaceous layer is continuous, with grass species such as *Aristida congesta*, *Enneapogon scoparius* and *Heteropogon contortus* as important taxa.

Conservation status is fairly good with 17% of the area protected within the Madikwe Game Reserve and only 1% transformed by cultivation. However, bush encroachment may occur locally on red clay loams of the more flat terrains in between the rocky ridges.

## SVCB3 ZEERUST THORNVELD

The open to dense growing thorny woodland occurs predominantly on red apedal high base-status soils of 1) the plains amidst the rocky ridges of the 'Dwarsberg-Swartruggens Mountain Bushveld' between Lobatsi River and Groot Marico, and 2) the associated lowlands to the north that stretch as far as Pilanesberg (figure 3.15).

*Acacia* is the most dominant species in the tree-shrub layer alongside *Peltophorum africanum* and *Terminalia sericea*; whereas the herbaceous layer is dominated by grasses such as *Cymbopogon pospischilii*, *Eragrostis lehmannia* and *Panicum maximum*. The following forbs are commonly found: *Blepharis integrifolia*, *Chamaecrista mimosoides*, *Dicoma anomala* and *Kyphocarpa angustifolia*. The shrub species *Searsia maricoana* is endemic to this vegetation unit.

Conservation status is low, with only 4% officially conserved in the Pienaar and Marico Bushveld Reserve, and with 16% affected by cultivation and urbanisation accompanied with the invasion of several alien plant species.

**SVCB4 DWARSBERG-SWARTRUGGENS MOUNTAIN BUSHVELD**

The habitats occupied by the 'Dwarsberg-Swartruggens Mountain Bushveld' are the rocky hills and ridges east of the Lobatsi River and parallel to the Dwarsberg mountains rising up to 300 m above the surrounding plains (figure 3.15).

Highly variable vegetation structure is locally found that is differentiated by diverse tree and shrub layers defined by variations in slope, aspect and habitat characteristics. Dominant trees include *Acacia robusta* and *A. erubescens*, *Burkea africana*, *Faurea saligna*, *Protea caffra*, as well as the succulent tree species *Aloe marlothii*. Locally common shrubs include *Athrixia elata*, *Ehretria rigida*, *Mundulea sericea*, *Searsia magalismontana* and *S. rigida*. In some places the woody layer may occur as bush clumps.

The grass layer is generally very dense with a great variety of grass species; inter alia *Cenchrus ciliaris* and *Loudetia simplex*. Common herbs thriving amongst the grasses include *Barleria macrostegia*, *Commelina africana* and *Hermannia depressa*. Some geophytic herbs are found in this vegetation unit, for example *Hypoxis hemerocallidea*.

Moreover, the 'Dwarsberg-Swartruggens Mountain Bushveld' provides habitat for the Central Bushveld endemic *Erythrophysa transvaalensis* and the South African endemic *Euphorbia perangusta*.

The conservation status is extremely low with only 2% conserved within the Marico Bushveld Reserve. Although classified as least threatened, 7% of the vegetation unit is affected by transformation through cultivation and the spread of alien species.

**SVCB5 PILANESBERG MOUNTAIN BUSHVELD**

The 'Pilanesberg Mountain Bushveld' occupies the geologically unique, eroded volcanic crater composed of several rings of high hills and low mountains interspersed with valleys of 1–2 km width (figure 3.15).

The valleys and mountain tops are mainly grassy with *Chrysopogon serrulatus*, *Elionurus muticus* and *Themeda triandra* as the most dominant taxa. In contrast, the slopes are governed by a broad-leaved deciduous bushveld stratum of low-growing trees and shrubs. Various *Combretum* tree species dominate the open woodland on the slopes: *C. apiculatum*, C. *molle* and *C. zeyheri*. *Diplorhynchus condylocarpon*, *Elephantorrhiza burkei* and *Hibiscus calyphyllus* are the predominant taxa of the shrub layer.

The Central Bushveld endemic shrub species *Erythrophysa transvaalensis* constitutes a biogeographically important taxon in the 'Pilanesberg Mountain Bushveld' as well. Noteworthy is also the occurrence of several species of *Grewia* in this vegetation unit, which constitutes the meeting point of their biogeographical distributional limits: *G. hexamixta*, *G. monticola*, *G. occidentalis* and *G. retinervis*.

The conservation status exceeds the target of 24% with 96% of the area incorporated within the Pilanesberg National Park. Yet, the valley woodlands in the crater have been transformed by past agricultural use, and present pressure stems from urban and infrastructural development around the reserve.

**SVCB6 MARIKANA THORNVELD**

Similar to the 'Zeerust Thornveld' the 'Marikana Thornveld' is an open *Acacia*-dominated clay thornveld occurring in the plains between Rustenburg and Brits on primarily vertic melanic clays underlain by mafic rocks of the Rustenburg Layered Suite. It locally grades into *Acacia* woodlands were deep, more freely drained soils prevail. Dominant *Acacia* species include *A. caffra*, *A. gerrardii* and *A. karroo* alongside with the following common broad-leaved woodland species: *Celtis africana*, *Combretum molle* and *Searsia lancea*. The shrub layer tends to be quite dense along drainage lines and rocky outcrops, widely dominated by *Asparagus cooperi*, *Euclea crispa*, *Indigofera zeyheri* and *Olea europaea*.

The herbaceous layer is characterized by a mostly continuous grass stratum of *Elionurus muticus*, *Eragrostis lehmannia* and *Setaria sphacelata*, with the co-existence of several dominant species of climbers and herbs, e.g. *Clematis brachiata* and *Ipomaea obscura* respectively. Additionally, geophytic herbs are locally found such as *Ledebouria revoluta*, *Ornithogalum tenuifolium* and *Sansevieria aethiopica*.

Nearly half of the 'Marikana Thornveld'—that is 48%—is transformed mainly as a result of cultivation and urban or industrial developments. Furthermore, only 1% of the vegetation unit is officially conserved within the Magaliesberg Biosphere Reserve.

**SVCB7 NORITE KOPPIES BUSHVELD**

The 'Norite Koppies Bushveld' is embedded within the 'Marikana Thornveld' found on the series of rocky noritic outcrops and koppies north of the Magaliesberg Range between Rustenburg and Brits (figure 3.15).

It is described as a low, semi-open to closed woodland, entailing dense stands of trees and shrubs up to 5 m tall with rather sparse undergrowth. Important tree species found on the norite outcrops include: *Combretum molle*, *Ficus abutifolia*, *Pappea capensis* and *Sclerocarya birrea*, as well as the succulent tree *Euphorbia cooperi*. The shrub layer is characterized by plant species of different growth forms such as the semi-parasitic *Osyris lanceolata* and the succulent *Tetradenia brevispicata*.

A feature of the herbaceous layer is the presence of a wide variety of climbers, especially *Helinus integrifolius*, *Rhoicissus tridentata* and *Turrea obtusifolia* (woody), *Sarcostemma viminale* (woody succulent) and *Cyphostemma lanigerum* (herbaceous). *Aristida congesta*, *Chrysopogon serrulatus* and *Setaria lindenbergiana* are the dominant species of the grass stratum. The two ferns *Pallaea calomelanos* and *P. viridis* are common occurring geophytes.

The conservation status of the 'Norite Koppies Bushveld' is considered as important, as none of the vegetation type is conserved officially so far. Furthermore, the vegetation unit is highly endangered by mining activities in the area, namely granite and platinum mining. In some areas the vegetation experiences severe degradation by nearby human settlements, especially through the harvesting of woody species for fuel and building material and the increase in weeds and alien plant species.

**SVCB8 MOOT PLAINS BUSHVELD**

In the study area the 'Moot Plains Bushveld' exists mainly as a broad band on the rolling plains to the south of Zeerust and Swartruggens, but also as a narrow band on the hillsides to the north and south of the Maagaliesberg Range, predominantly on stony clay-loam soils (figure 3.3 and 3.15).

The vegetation is characterized by open to closed low-growing thorn savanna dominated by *Acacia* in the bottomlands and plains, but by woodlands of varying height and density on the lower hillsides. The woody layer is dominated by *Acacia nilotica*, *A. tortilis*, *Buddleja* *saligna*, *Euclea undulata*, *Olea europaea* and *Searsia lancea*; as well as the woody succulent *Kalanchoe paniculata*.

The herbaceous layer is dominated by grasses like *Heteropogon contortus*, *Searsia sphacelata* and *Themeda triandra*. Local herbs include for example: *Corchorus asplenifolius*, *Evolvulus alsinoides* and the herbaceous climber *Lotononis bainesii*.

Conservation efforts are considered as important for the 'Moot Plains Bushveld' as well, since this vegetation unit is classified as vulnerable. Even though 13 % of it is officially conserved within the Magaliesberg Nature Reserve, there is a growing threat by the increase of urban and built-up areas accompanied by the intensification of cultivation, with 28 % already transformed so far.

**SVCB9 GOLD REEF MOUNTAIN BUSHVELD**

The 'Gold Reef Mountain Bushveld' runs parallel to the 'Moot Plains Bushveld' on its southern side, mainly along the rocky quartzite ridges of the Magaliesberg area, but also on the hills and ridges between Koster and Swartruggens (figure 3.3 and 3.15).

Shallow, gravelly soils on these rocky hills and ridges generally support dense woody vegetation, often with a continuous tree and shrub layer *inter alia* composed of *Acacia caffra*, *Celtis africana*, *Combretum molle*, *Grewia occidentalis*, *Gymnosporia buxifolia*, *Protea caffra* and *Searsia magalismontana*.

The herbaceous layer is again dominated by grass species, particularly *Loudetia simplex*, *Schizachyrium sanguineum* and *Trachypogon spicatus*, but the following herbs form important indicators of this mountain bushveld: *Helichrysum nudifolium* and *H. rugulosum*, *Senecio venosus*, *Xerophyta retinervis*, as well as the geophytes *Cheilanthes hirta*, *Hypoxis hemerocallidea* and *Pellaea calomelanos*.

Of special conservation importance in the 'Gold Reef Mountain Bushveld' are the endemic taxa *Aloe peglerae* (succulent shrub) and *Frithia pulchra* (succulent herb). The conservation status of the vegetation unit is high with 22% officially conserved within the Magaliesberg and Rustenburg Nature Reserves. However, 15% was identified as being transformed due to cultivation and human urban development.

**SVCB12 CENTRAL SANDY BUSHVELD**

This vegetation unit is found to the east of Pilanesberg in the study area, trending south-east. As the name implies, the bushveld occurs largely on the sandy soils of the low-lying plains slightly undulating terrain underlain by granite and granophyre of the Bushveld Complex. Plains with deep sandy soils are characterized by tall, deciduous *Burkea africana* and *Terminalia sericea* woodland, whereas the shallow rocky and gravelly soils of more mountainous sites are dominated by low, mesophyllous *Combretum* woodland. Less sandy plains and valleys are featured by *Acacia, Euclea* and *Ziziphus* species.

The herbaceous layer is dominated by grasses such as *Brachiaria nigropedata*, *Eragrostis pallens, E. rigidor and Hypertelia dissoluta*, but often with a rather low basal cover associated with dystrophic sandy soils. Nevertheless, the herb *Dicerocaryum senecioides* is a prevalent species alongside the grasses. Biogeographically important taxa of the herbaceous layer include the Central Bushveld endemics *Mosdenia leptostachya* (graminoid) and *Oxygonum dregeanum* subsp. *cenescens* var. *dissectum* (herb).

The conservation status is relative low with only 5% officially conserved, while as much as 24% of the vegetation has been transformed already—mainly by cultivation and urban development of the dense rural population in the area. Several alien species such as *Lantana camara* and *Opuntia ficus-indica* constitute a conservation concern.

**SVCB15 SPRINGBOKVLAKTE THORNVELD**

Bordered by the ‘Western Sandy Bushveld’ and ‘Central Sandy Bushveld’, the ‘Springbokvlakte Thornveld’ occurs in the far east of the study area as a band to the south of the Nysvley Nature Reserve, found on flat to slightly undulating terrain underlain by the volcano-sedimentary rocks of the Karoo Supergroup with mostly red, apedal soils of high base-status, but also black vertic clays further east (figures 3.5, 3.8 and 3.15).

The vegetation constitutes an open to dense shrubby thorn savanna dominated by microphyllous tree species, specifically *Acacia karroo, A. luederitzii*, *A. mellifera*, *A. nilotica* and *A. tenuispina*, particularly on the black clay soils. Other dominant woody elements of the tree-shrub layer include *Euclea undulata*, *Searsia engleri* and *Ziziphus mucronata*.

Grass species such as *Aristida bipartita*, *A. canescens*, *Dichanthium annulatum*, *Ischaemum afrum* and *Setaria incrassata* dominate the herbaceous layer, alongside with the following typical herbs found in the 'Springbokvlakte Thornveld': *Aspilia mossambicensis*, *Nidorella hottentotica* and *Senecio apiifolius*, as well as the herbaceous climbers *Momordica balsamina* and *Rhynchosia minima*.

The 'Springbokvlakte Thornveld' is an endangered vegetation type, since only 1% is officially conserved and more than 49% is already transformed, mainly by cultivation, which can be attributed to dense population by rural communities.

**SVCB16 WESTERN SANDY BUSHVELD**

Located in the north-eastern part of the study area on the flat and undulating plains west of the Waterberg Mountains trending down towards Thabazimbi and further west appearing again as patches in the 'Dwaalboom Thornveld', the 'Western Sandy Bushveld' is underlain by granites and gneisses of the Swazian Erathem (figures 3.8 and 3.15).

The 'Western Sandy Bushveld' is distinguished from the 'Central Sandy Bushveld' by a drier climate that results in the presence of the more xeric species *Acacia erubescens*, *A. nigrescens* and *Combretum imberbe*, and the lack of the mesic species *Burkea africana* and *Ochna pulchra*.

Vegetation ranges from tall to low woodland dominated either by mesophyllous or microphyllous trees depending on relief and substrate. For instance, flat areas are generally dominated by *Acacia* species, whereas *Combretum apiculatum* is found on shallow and gravelly soils of upland locations.

The herbaceous layer is mainly composed of grasses of which *Antephora pubescens*, *Digitaria eriantha*, *Eragrostis pallens*, *E. rigidior* and *Schmidtia pappophoroides* can be named as the most prevalent. Yet, characteristic herbs of this vegetation unit comprise *Blepharis integrifolia*, *Limeum fenestratum* and *Monsonia angustifolia*.

With 6% officially conserved and only 4% transformed so far, the conservation concern of the 'Western Sandy Bushveld' is rather low.

## SVCB17 WATERBERG MOUNTAIN BUSHVELD

In the study area the 'Waterberg Mountain Bushveld' occurs as an outlier of the vegetation unit along the Witfontein and Vlieëpoortberge near Thabazimbi (figure 3.15) (Van der Meulen, 1979).

Higher slopes of the rugged mountain terrain are composed of *Faurea saligna–Protea caffra* bushveld, which goes over to *Burkea africana–Terminalia sericea* savanna in the lower-lying valleys. On the rocky terrain the grass stratum is often only moderately developed, with dominant occurrence of *Loudetia simplex*, *Schizachyrium sanguineum* and *Trachypogon spicatus*.

The vegetation unit harbours a variety of biogeographically important taxa, namely the Central Bushveld endemics *Erythrophysa transvaalensis* and *Mosdenia leptostachys*, the Northern Sourveld endemics *Chorisochora transvaalensis* and *Encephalartos eugene-maraisii*, as well as the 'Waterberg Mountain Bushveld' endemics *Grewia rogersii*, *Oxygonum dregeanum* subsp. *canescens* var. *pilosum* and *Pachystigma triflorum*.

The 'Waterberg Mountain Bushveld' is relatively well conserved with 9% officially protected mainly within the Marakele National Park, and the 3% transformation is of only little concern.

## SVCB19 LIMPOPO SWEET BUSHVELD

The 'Limpopo Sweet Bushveld' is found on the plains of the Limpopo River valley in the north of the study area, where it runs along the Marico River towards Derdepoort and along the Crocodile River towards Thabazimbi (figure 3.15). Dominant soil types supporting the vegetation unit are mainly sandy clayey-loams on the plains and low-lying areas and shallow, gravelly and sandy soils on the slightly undulating terrain, with some black clay soils at its southern border (figure 3.8).

Short open woodland characterized by various *Acacia* tree species such as *A. erubescens*, *A. fleckii*, *A. robusta* and *A. senegal* along with the trees *Albizia anthelmintica*, *Boscia albitrunca*, *Combretum apiculatum* and the shrubs *Dichrostachys cinerea* and *Rhigozum obovatum*.

The grass stratum is the dominant ground cover with species such as *Digitaria eriantha*, *Enneapogon cenchroides*, *Eragrostis lehmannia* and *Panicum coloratum*. Some of the common encountered herbs are *Acanthosicyos naudinianus*, *Harpagophytum procumbens* and *Indigofera daleoides*.

The Central Bushveld endemic *Piaranthus atrosanguineus* (succulent herb) constitutes a biogeographically important taxon in the 'Limpopo Sweet Bushveld'. Although less than 1% of the vegetation unit is conserved thus far, it would constitute a good area for game farming within the borders of a Nature Reserve due to the high grazing capacity of the sweet bushveld.

## 3.2 Specific study areas

### 3.2.1 Heritage Park

The Heritage Park is a vision of local communities, landowners, nature conservationists and government to enhance socio-economic development while contributing to nature conservation in a poor and underprivileged region of the North-West Province (Heritage Park, 2005). This will be achieved by the successive integration of more land to expand the conservation areas of Pilanesberg National Park (47,000 ha) and Madikwe Game Reserve (62,000 ha) into a big wildlife reserve of about 280,000 hectares (figure 3.16). The conservation corridor (172,000 ha) will run in a band north of Pilanesberg towards Dwaalboom, before turning west to follow the Dwarsberg Mountain to join Madikwe west of Molatedi dam (Boonzaaier & Lourens, 2002).

Key objectives are to increase the carrying capacity and sustainability of the two nature reserves as well as that of the expansion area itself, and in this way to improve conservation of the indigenous flora and fauna in this region of the North-West Province. Furthermore, the development of an eco-tourism infrastructure with the involvement of local people and communities aims at creating new job and business opportunities and thus will lead to the required economic growth and social upliftment in this remote region in the North-West Province (Heritage Park, 2005).

The great diversity of the natural landscape in the Heritage Park offers different zones of game and biodiversity management for the purpose of various touristic recreational activities, e.g. mountain ranges (Dwarsberg), hills (Spitzkop and Pilanesberg volcanic crater) and water features (Molatedi dam) (Boonzaaier & Lourens, 2002; Heritage Park, 2003).

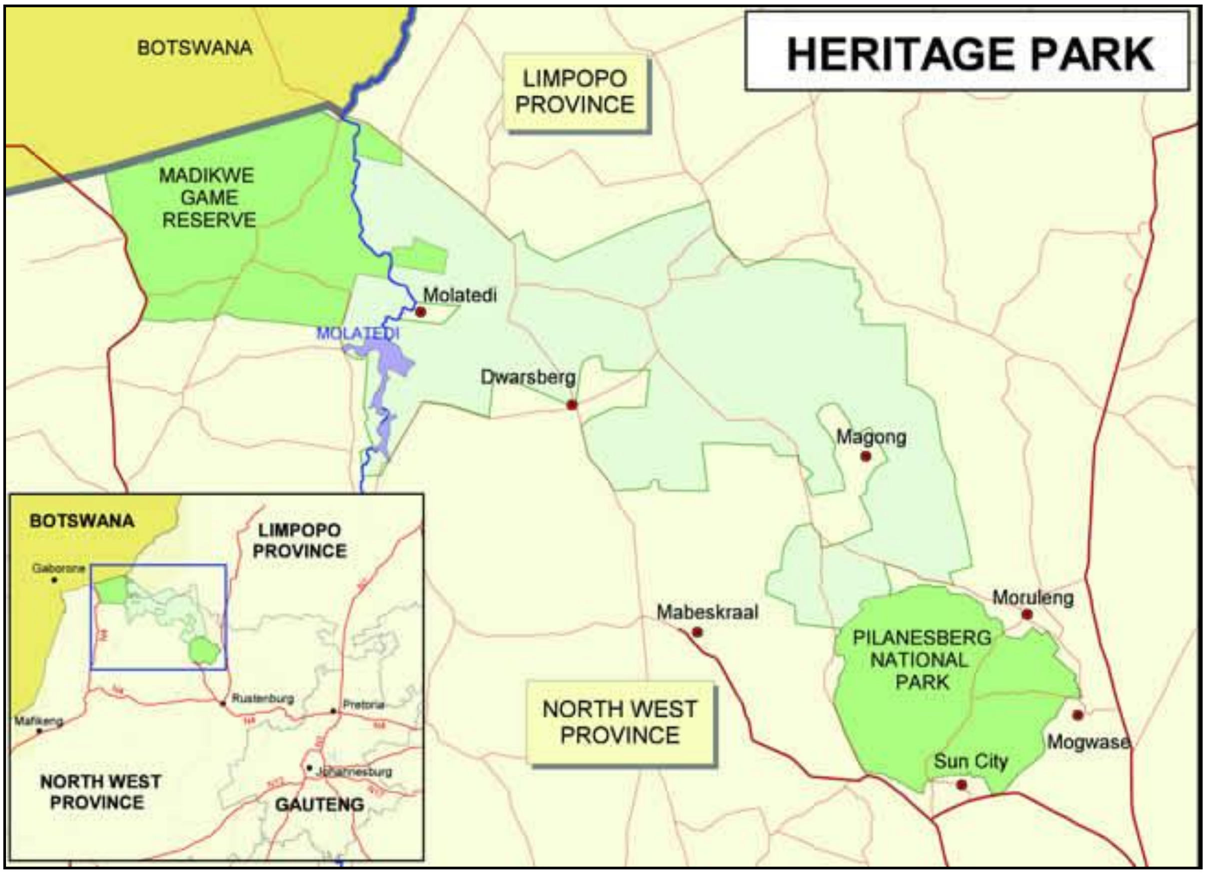


**Figure 3.16: Geographical outline and location of proposed Heritage Park in North-West Province South Africa. Source: www.heritage-park.co.za.**

Moreover, the proposed Heritage Park is also strategically located between other existing Protected Areas (e.g. Gaborone and Welgevonden Game Reserve, Mokolodi and Atherstone Nature Reserve, and Marakele National Park), and consequently can become an important catalyst for regional nature-based ecotourism and conservation initiatives, with the potential to form a significant conservation area of some one million hectares (Boonzaaier & Lourens, 2002). Therefore, the Heritage Park could serve as a national and international example for successful integration of conservation issues and socio-economic development (Heritage Park, 2005).

The Heritage Park area is predominantly rural in nature with private and community owned land used for cattle grazing, crop production and game farming (Boonzaaier & Lourens, 2002; Heritage Park, 2005). However, studies by Stalmans & De Wet (2003) have shown that past and current land use practices had profound negative impacts on vegetation and soils in the ecological sensitive semi-arid area. They identified significant habitat degradation in the form of change of natural plant communities, increase in weedy and alien invader plants, bush encroachment, erosion and increase in desertification. Further environmental degradation by continued unsustainable land-use, would eventually lead to a decline in natural and cultural heritage of the region and thus reduce income possibilities and increase poverty through the diminished value of the region for touristic developments.

Therefore, the feasibility and potential of linking Pilanesberg National Park and Madikwe Game Reserve into a large protected wildlife area is presently being researched by a multidisciplinary approach initiated by the North West Parks and Tourism Board (Rensburg, 2005). Present knowledge and research output from the various subprojects (soil and vegetation, land and biodiversity, socio-economic impact, game carrying capacity, spatial planning, traditional knowledge and water management) will be analysed and combined into a sustainable integrated development framework. The present floristic study of the western Central Bushveld Bioregion is part of subproject biodiversity.

### 3.2.2 Impala Bafokeng Mining Complex

Impala Platinum, Implats' primary operational mining unit, is located on the mining lease area on the western limb of the world-renowned Bushveld Igneous Complex north of Rustenburg in the North-West Province (figure 3.17). Since 1968, Implat's holds both mining and prospecting rights over 260 $km^2$ of land across 20 farms predominantly owned by the Royal Bafokeng Nation (Impala Platinum Limited, 2011a, 2011b).

Mining focus on two platiniferous horizons in the Critical Zone of the Rustenburg Layered Suite, namely the Merensky Reef and the UG2 Chromitite Layer, which host economically exploitable quantities of Platinum Group Metals (table 3.3) (Impala Platinum Limited, 2010b). They sub-outcrop throughout the lease area and dip about 9 to 10 degrees in a north-east direction, locally even 15 degrees, towards the centre of the Bushveld Complex; these so-called reefs are mined underground focusing only on the relatively narrow mineralised channels (Impala Platinum Limited, 2010b). This takes place with the aid of 14 operational shafts throughout the lease area, mainly using the conventional breast mining technique, but also mechanized board and pillar mining takes place in some selected areas, while limited opencast mining is only used at the outcrop positions (Impala Platinum Limited, 2011b). Mineral processing of the approximately 15,102 million tonnes of ore yielded per year is partly housed on the Impala mining area involving concentrator and smelter operations, whereas the refining operations are located at the Springs section (Impala Platinum Limited, 2010a, 2010b).

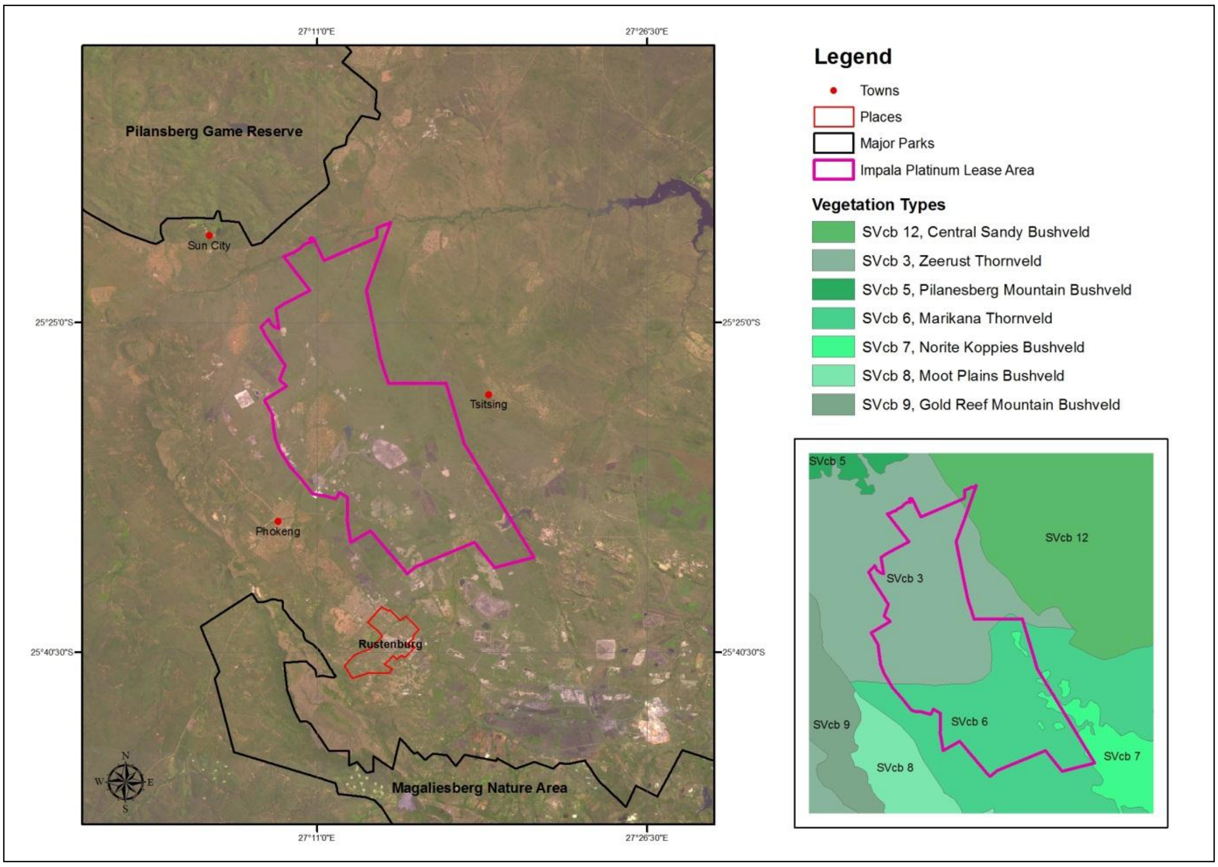


**Figure 3.17: The Impala Platinum Bafokeng Mining Complex located between Pilanesberg Game Reserve and Magaliesberg Nature Area shows four dominant vegetation types.**

**Table 3.3: Percentage of Platinum Group Metals contained within the Merensky and UG2 reef. Source: Impala Platinum (2010).**

| 5 PGE + Au | Platinum (Pt) | Palladium (Pd) | Ruthenium (Ru) | Rhodium (Rh) | Iridium (Ir) | Gold (Au) |
|---|---|---|---|---|---|---|
| ***Merensky Reef*** | 56.7 % | 24.9 % | 8.4 % | 4.6 % | 1.8 % | 3.6 % |
| ***UG2 Reef*** | 47.9 % | 25.8 % | 13.4 % | 8.8 % | 3.4 % | 0.6 % |

Impala Platinum is aware of the potential impacts on the environment caused by its prospecting, mining, smelting and refining operations, and is therefore committed to invest in the conservation of biodiversity in the areas of its mining activities (Impala Platinum Limited, 2009). Environmental degradation in the area is partly also caused by the farming and granite mining activities of the local residents in the mining area.

Various damages to the environment in the Impala Platinum Mining Complex have been identified by previous assessments. First of all, the study area is characterized by severe habitat fragmentation of the natural veld as a result of the mining operations and infrastructure, with remnants of undisturbed veld only occurring as patches in the mining area (North-West University, 2008a). However, these natural habitat patches serves as (1) essential seed banks for the recovery of the local natural vegetation, (2) an important refuge for species of indigenous flora and fauna, especially for rare and threatened species, and (3) a dispersal corridor for species (North West University, 2008a, 2008b).

For example the ‘Norite Koppies Bushveld’ embedded in the ‘Marikana Thornveld’ occurs largely in isolated locations where norite outcrops as bedrock and koppies (figure 3.17), and is thus considered as one of the three most eco-sensitive vegetation types in North-West (Lamprecht et al., 2011), mainly because unsustainable granite mining is presently destroying the norite koppies and its vegetation, thereby scarring the landscape forever (Loubser, 2010).

Furthermore, the natural watercourses and the associated riparian vegetation have been identified as ecologically sensitive habitats that need to be conserved. The occurrence and spread of several weed and alien species, especially in degraded areas such as on the mining dumps, are observed with concern.

Therefore, a Biodiversity Action Plan is currently being developed in cooperation with North-West University. The systematic conservation planning for the mining lease area is based on detailed biodiversity studies, which involves the inventory of all species and habitats, the assessment of the conservation status of the species and habitats within the specified ecosystems, and the subsequent development of a management plan for conservation and restoration of biodiversity in the mining area.

The present floristic study forms part of this assessment by evaluating the floristic elements of the Impala Platinum Mining Complex in the context of the phytogeography of the western Central Bushveld flora.