Field Guide

of the

5th International

Soil Classification Congress

held in

South Africa

from

1-4 December 2016

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International
Decade of Soils
2015 - 2024

Programme

Start	End	Thursday (1 December 2016)
07:30	08:00	Depart St George Hotel
08:00	09:30	Profile SCC01 (Pretoria)
09:30	11:00	Profile SCC02 (Pretoria)
11:00	12:30	Profile SCC03 (Pretoria)
12:30	14:00	Profile SCC04 (Pretoria)
14:00	17:30	Drive to Lichtenburg [270 km; 3:30]
		Lunch on bus (Sponsored by TerraSoil Science)
18:30	21:00	Dinner (Sponsored by NWK)
21:00		Return to lodges
		Friday (2 December 2016)
Start	**End**	
07:30	08:15	Depart & drive to profile SCC05 [40 km; 0:45]
08:15	09:15	Profile SCC05 (Lichtenburg)
09:15	09:45	Drive to profile SCC06 [30 km; 0:30]
09:45	10:45	Profile SCC06 (Lichtenburg)
10:45	11:45	Drive to profile SCC07 [60 km; 1:00]
		Lunch on bus (Sponsored by NWK)
11:45	12:45	Profile SCC07 (Lichtenburg)
12:45	13:45	Profile SCC08 (Lichtenburg)
13:45	16:30	Drive to Parys (Thabela Thabeng) [170 km; 2:45]
18:30	21:00	Dinner (Sponsored by NWU)
		Saturday (3 December 2016)
Start	**End**	
07:30	08:30	Depart & drive to profile SCC09 [60 km, 1:00]
08:30	10:00	Profile SCC09 (Parys)
10:00	11:30	Profile SCC10 (Parys)
11:30	12:15	Drive to profile SCC11 [45 km; 0:45]
		Lunch on bus (Sponsored by NWU)
12:15	13:45	Profile SCC11 (Eleazer)
13:45	15:15	Profile SCC12 (Eleazer)
15:15	16:30	Return to Thabela Thabeng [75 km; 1:15]
18:30	21:00	Dinner (Sponsored by Omnia)
		Sunday (4 December 2016)
Start	**End**	
07:30	08:00	Depart & drive to profile SCC13 [45 km; 0:45]
08:00	09:30	Profile SCC13 (Parys)
09:30	11:00	Profile SCC14 (Parys)
11:00	12:30	Profile SCC15 (Parys)
12:30	16:00	Drive to Bloemfontein (Bain's Lodge) [300 km; 3:30]
		Lunch on bus (Sponsored by NWK)
		Free time / Dinner (own arrangements)

Contents

<u>Request</u>: The XRD & XRF analytical results contained herein have kindly been sponsored by the Geology department at the University of the Free State, with the request that the responsible scientist (Megan Purchase) be included as co-author in any publications that might ensue in the use thereof.

1. Introduction

This field workshop aims to highlight the soils of the maize producing north-western South Africa. South Africa is an extremely dry country, annually receiving well below the world's average rainfall. Exacerbating this, only about 14% of the soils of South Africa can be deemed high potential agricultural land – the majority of which occurs in the Mpumalanga province. Successful crop production in this rather hostile environment therefore requires careful planning and optimal utilization of the natural resources, especially soils. It is the latter aspect that will form the focus of this field workshop.

Table 1 Land utilisation in South Africa (Census of Commercial Agriculture 2002)

Land use	Area	
	(ha)	(%)
Grazing	83 928 120	68
Nature conservation	11 785 999	10
Potential arable	16 737 672	14
Other	8 434 345	7
Forestry	1 433 964	1
Total	122 320 100	100

The field workshop will commence in Pretoria at the St George Hotel. We will then travel a very short distance to the first stop, focussing on four dolomite-derived soils. From here we travel to Lichtenburg where we will discuss a selection of four soils typically of this production region. Day three takes us to one arable soil and one deemed unsuitable for profitable production and two anthropogenic soils. On day four we will discuss four widely varying soils in the Vredefort dome. An overview of the route is given in Figure 1, while the detailed route and profile stops is given in Figure 2.

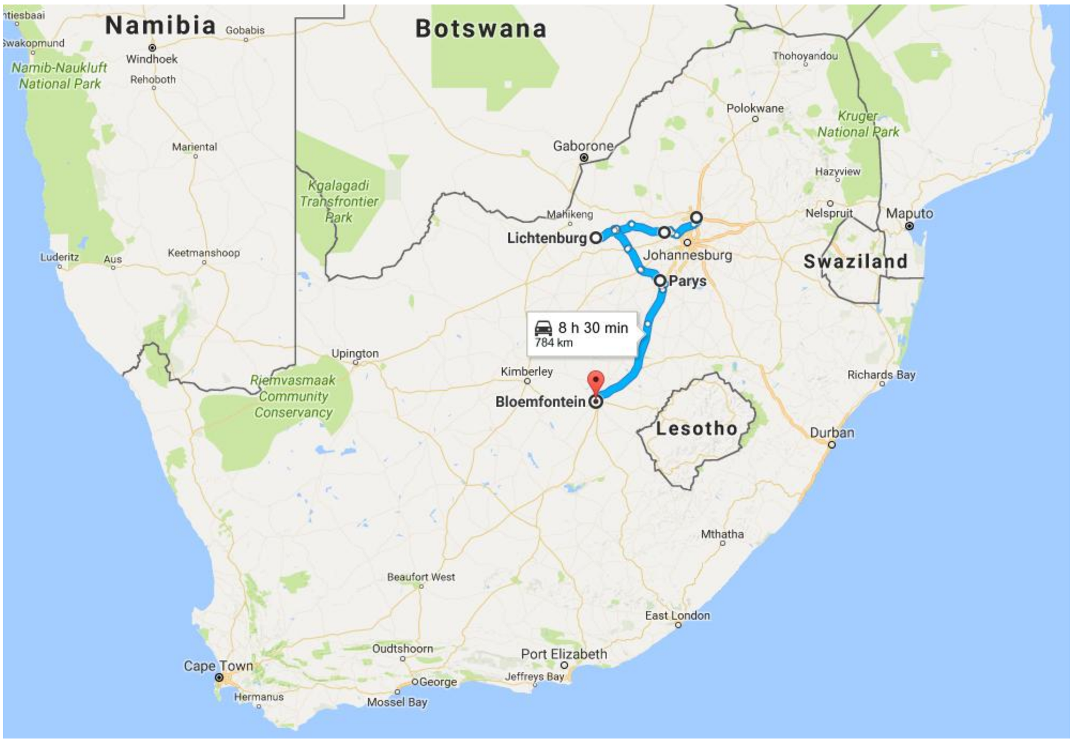

Figure 1 Overview of the Soil Classification Field Workshop route (Google Maps)

2. Short history of South Africa

[Verbatim from https://en.wikipedia.org/wiki/History_of_South_Africa]

The history of South Africa starts more than 100 000 years ago, when the first humans inhabited the region. The historical record of this ethnically diverse country is generally divided into four distinct periods: the pre-colonial era, the colonial era, the post-colonial and apartheid era, and the post-apartheid era. Much of this history, particularly of the colonial and post-colonial eras, is characterized by clashes of culture, violent territorial disputes between European settlers and indigenous people, dispossession and repression, and other racial and political tensions.

The discoveries of diamonds and gold in the 19th century had a profound effect on the fortunes of the region, propelling it onto the world stage and introducing a shift away from an exclusively agrarian-based economy towards industrialisation and the development of urban infrastructure. The discoveries also led to new conflicts culminating in open warfare between the Boer settlers and imperial Britain, fought essentially for control over the nascent South African mining industry.

Following the defeat of the Boers in the Anglo-Boer or South African War (1899–1902), the Union of South Africa was created as a dominion of the British Empire in terms of the South Africa Act 1909, which unified into one entity the four previously separate British colonies: Cape Colony, Natal Colony, Transvaal Colony and Orange River Colony. The country became a self-governing nation state within the British Empire in 1934 following enactment of the Status of the Union Act. The dominion came to an end on 31 May 1961 in consequence of a 1960 referendum, which legitimised the country becoming a sovereign state named Republic of South Africa. A republican constitution was adopted.

From 1948 to 1994, South African politics were dominated by Afrikaner nationalism centred on racial segregation and white minority rule known officially as apartheid, an Afrikaans word meaning "separateness". It was an extension of segregationist legislation enacted prior to the 1934 Union Act. On 27 April 1994, after decades of armed struggle and international opposition to apartheid, during which military and political support was provided primarily by the Soviet Union to the non-racial African National Congress (ANC), the ANC achieved victory in the country's first democratic election. Since then the ANC has dominated the politics of the country in an uneasy alliance with the South African Communist Party and the Congress of South African Trade Unions.

3. Physiography

The physiography of South Africa is basically like and upside-down saucer (Figure 3). The major part of South Africa is therefore drained by only two rivers: the Vaal and Orange Rivers (Figure 4; Figure 5). We will therefore pass the continental divide shortly after leaving Pretoria. In the east, in the area of the Drakensberg of Natal and in the Kingdom of Lesotho, it reaches heights of almost 4 000 m. In the south and west, the highest peaks are at about 2 000 m. The central plateau of South Africa, called the Highveld, has heights of between 1 000 and 1 700 m. The precipitation on the Highveld is low which results in arid, semi-desert conditions due to the surrounding mountain chain that shields the Highveld for the clouds from the sea.

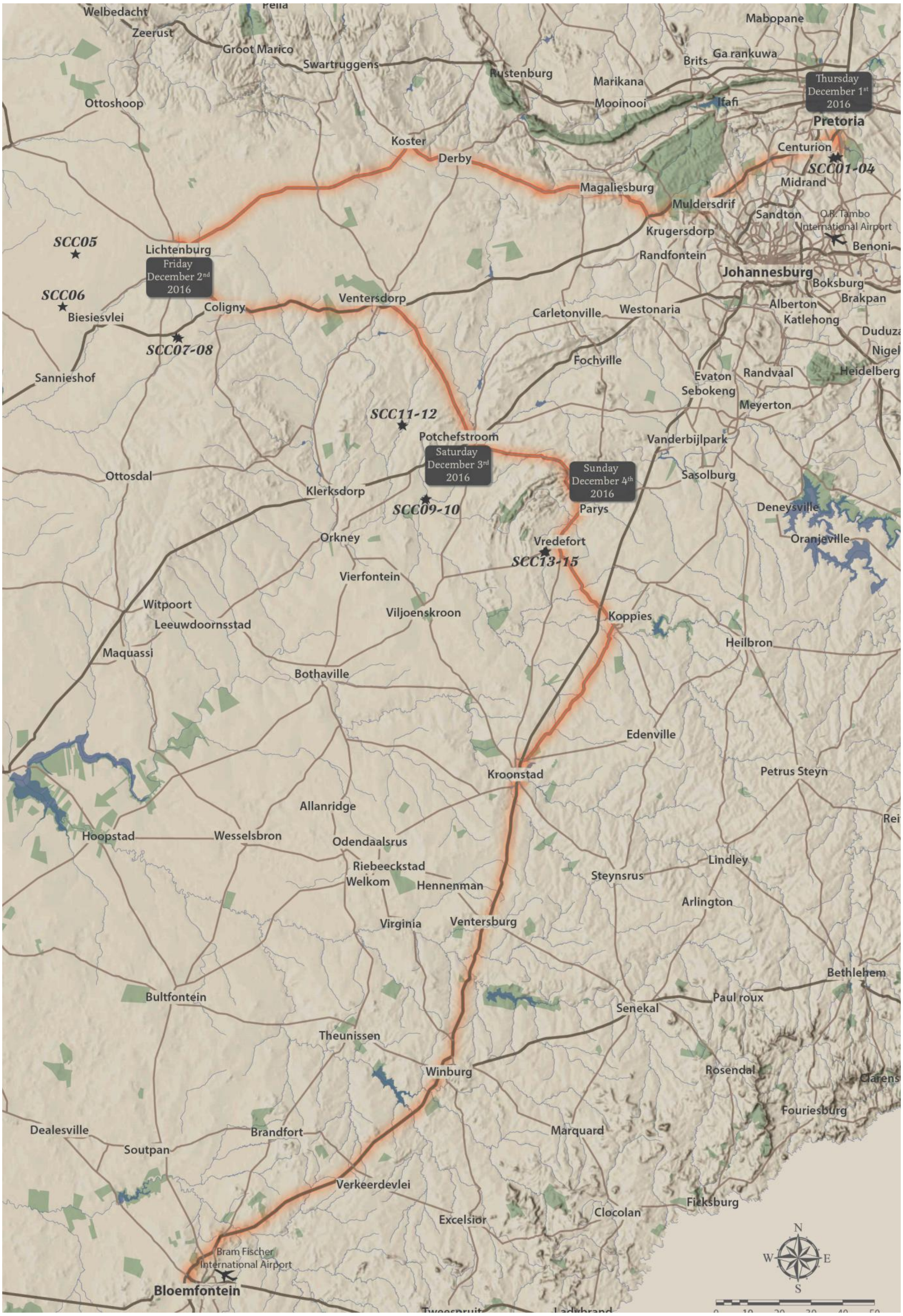

Figure 2 Detail of the Soil Classification Field Workshop route and the profile locations (TerraGis)

Figure 3 Physiography of South Africa (http://www.south-africa-tours-and-travel.com/map-of-south-africa.html).

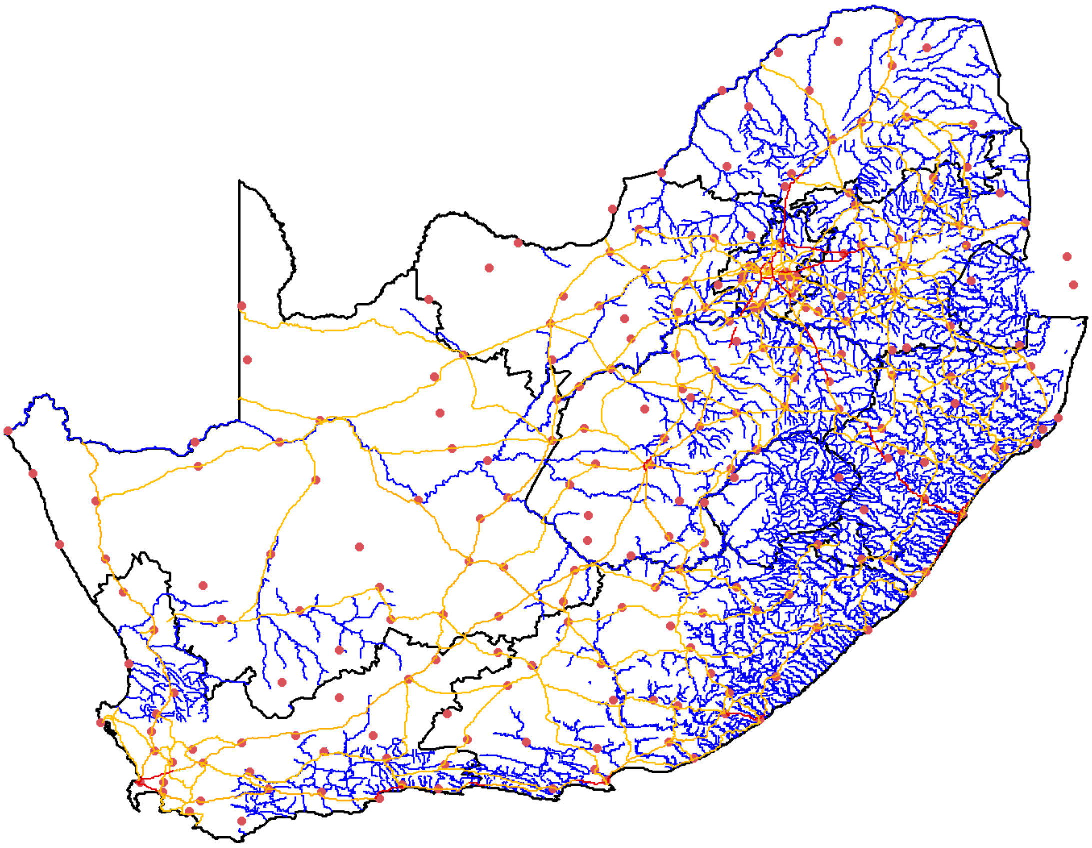

Figure 4 Major rivers and highways of South Africa (Schulze, 1997).

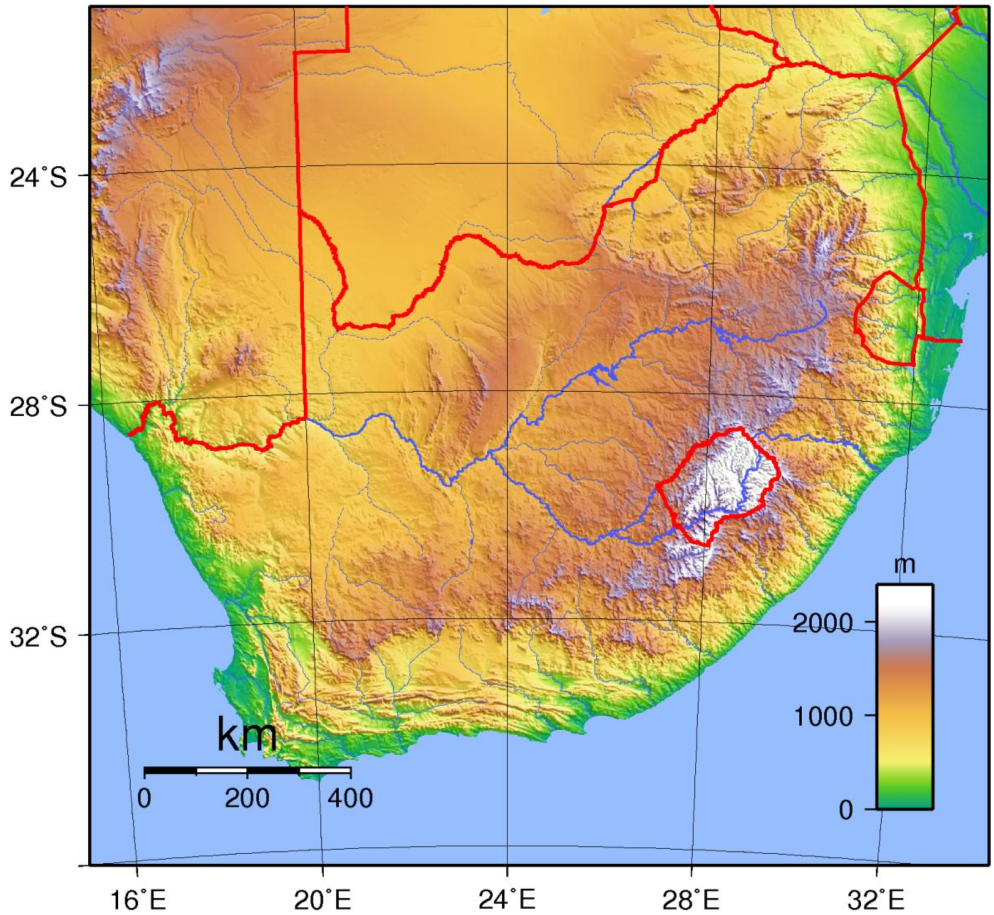

Figure 5 Altitute of South Africa (https://en.wikipedia.org/wiki/Outline_of_South_Africa).

4. Geology

Geologically speaking, the subcontinent of South Africa is very old and rich in mineral resources. Some of the oldest rocks (dated at 4.5 Ma) on earth can be found in the Barberton area. The subcontinent as we know it today basically came into being when the Gondwanaland supercontinent broke apart some 300 to 100 million years ago.

5. Climate

The average annual rainfall for South Africa is 450 mm, well below the global average of 860 mm. Rainfall drastically decreases from east to west and from south to north, with semi-desert areas in the western half of South Africa (Figure 7). For the major part of South Africa rainfall occurs mainly in the summer months, in the form of brief afternoon thunderstorms. The exception is the Western Cape which has a typical Mediterranean climate where rainfall is concentrated in winter. Snow is uncommon in South Africa, but can occur in the winter months on the mountain peaks of the Southern Cape and Drakensberg.

South Africa has cold winters (June - August) and warm summers (November - February). Minimum temperatures in winter can drop below freezing, primarily due to the altitude. Exacerbating the low rainfall is the high potential evapotranspiration, which is well above 2 000 mm a^{-1} for the major part of South Africa (Figure 8). Given the above, it is not surprising that the soil moisture regime is Ustic and Aridic for the major part of South Africa (Figure 9), while the soil temperature regime is Thermic for almost the entire country (Figure 10).

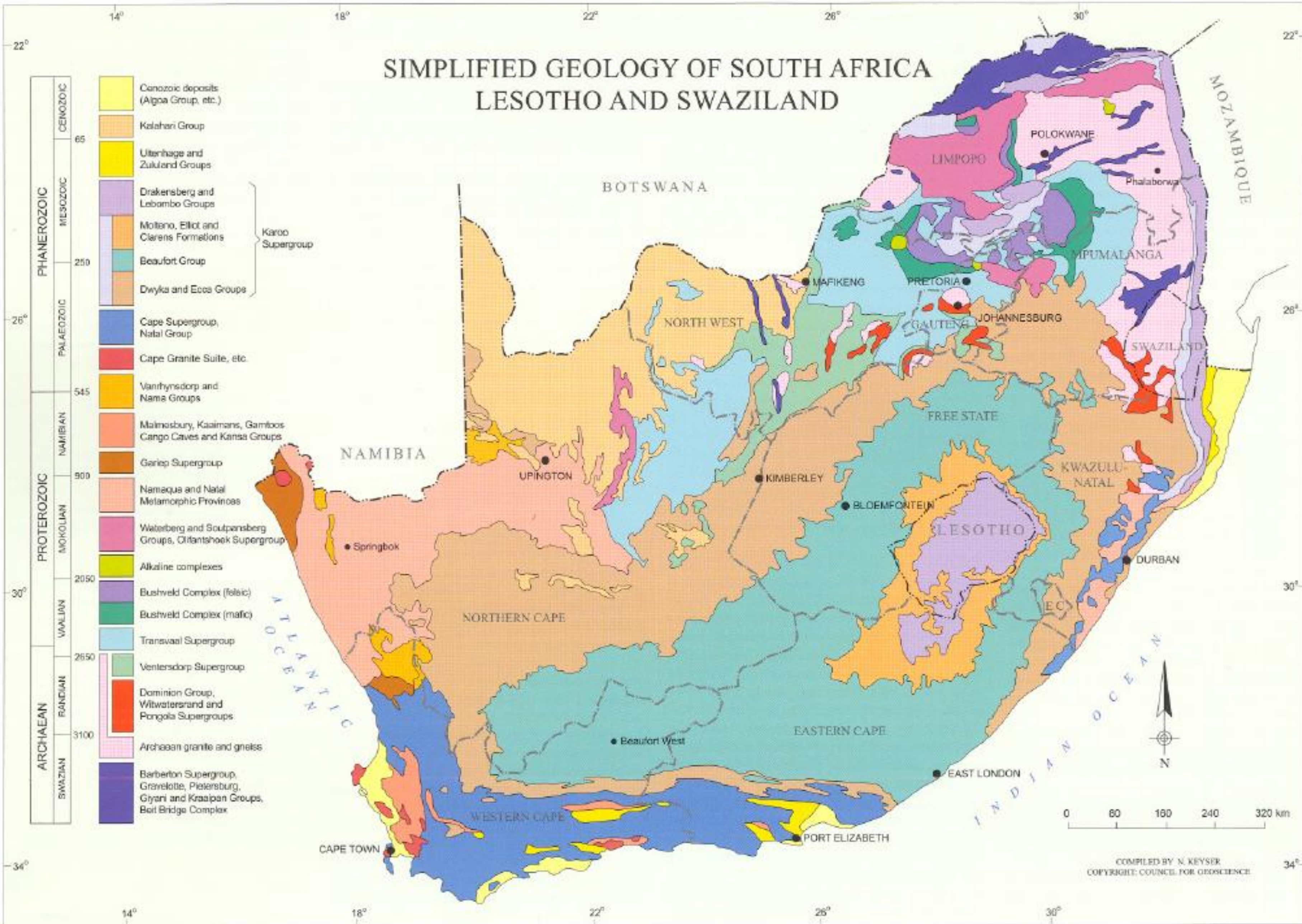

Figure 6 Simplified geology of South Africa, Lesotho, and Swaziland (Council for Geoscience 2016).

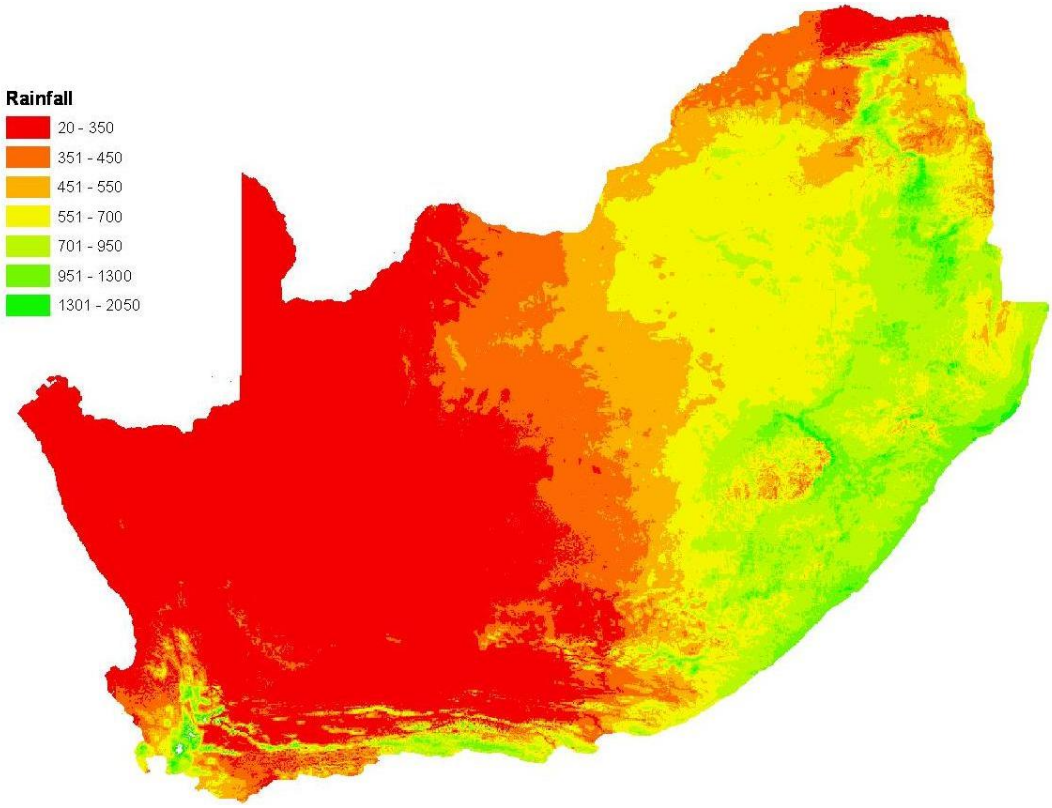

Figure 7 Average mean annual precipitation for South Africa (Schulze, 1997)

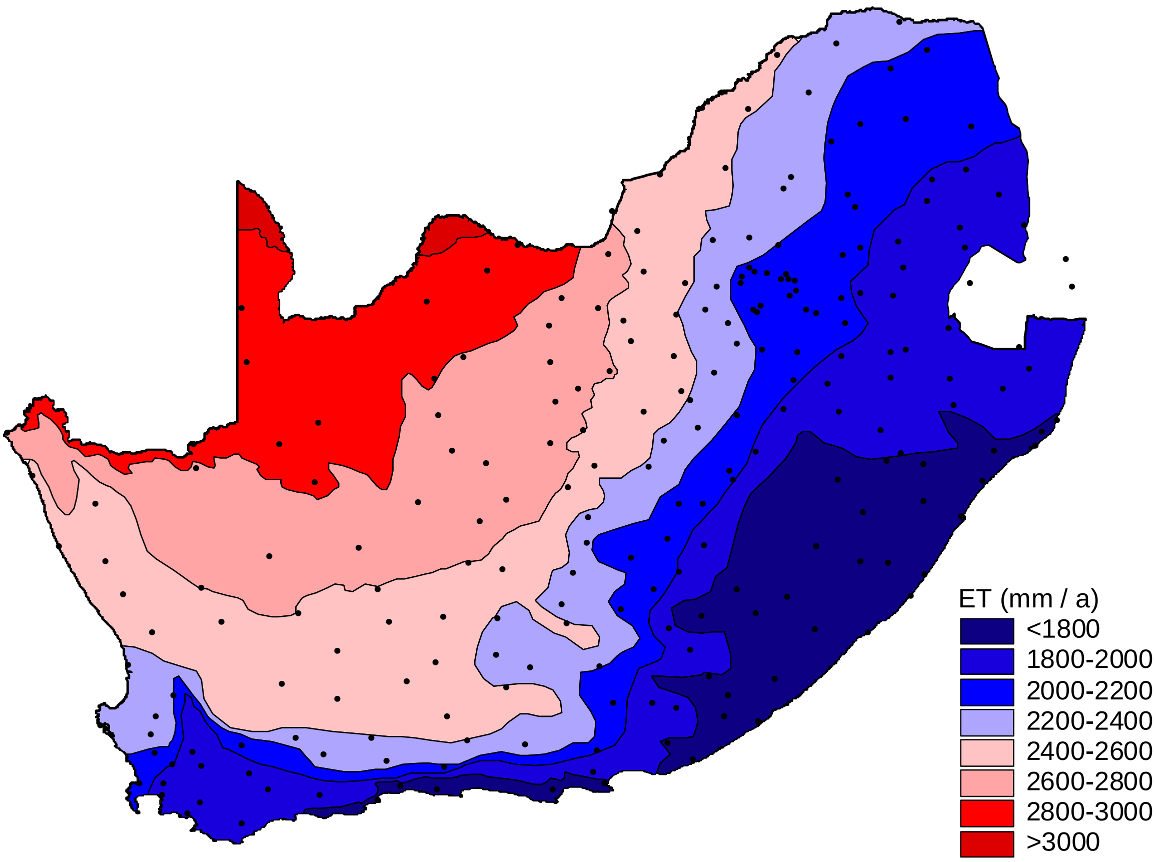

Figure 8 Average mean annual evapotranspiration for South Africa (Schulze, 1997)

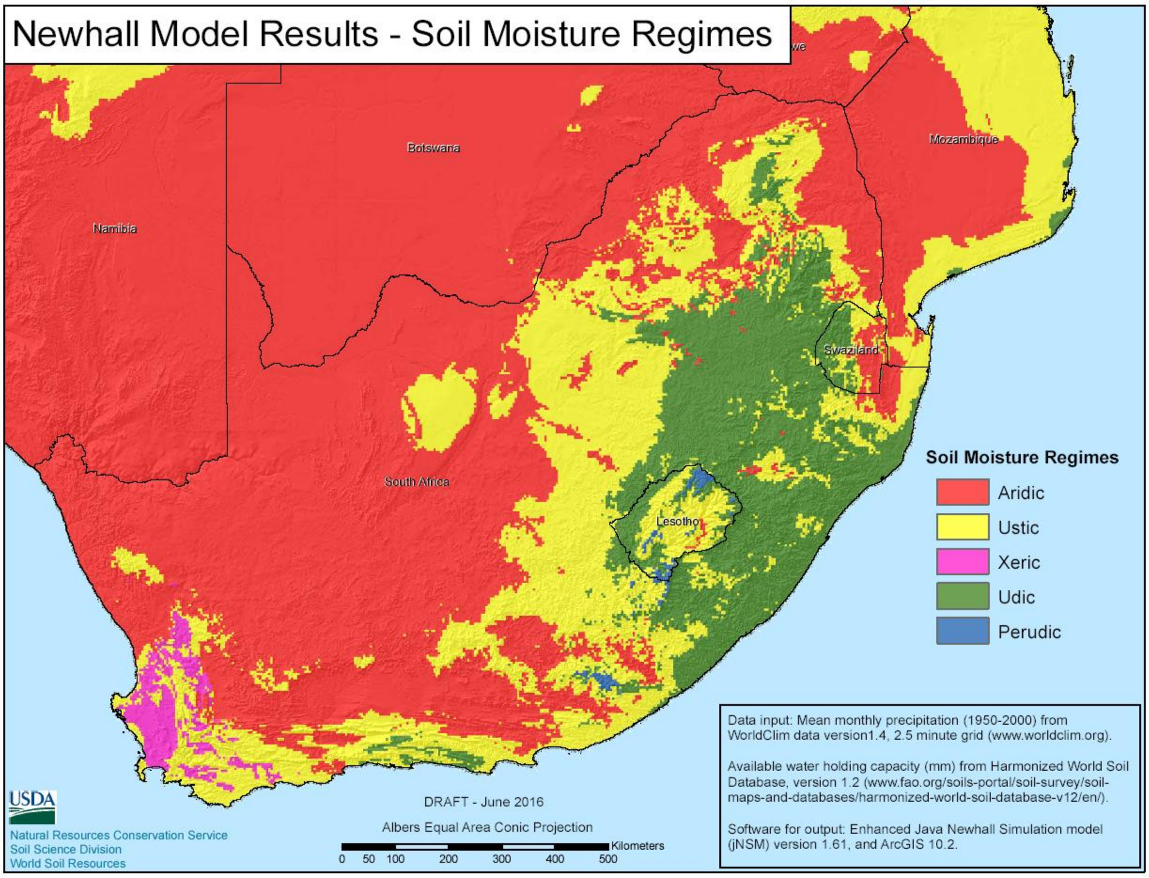

Figure 9 Soil moisture regimes for South Africa (NRCS, 2016)

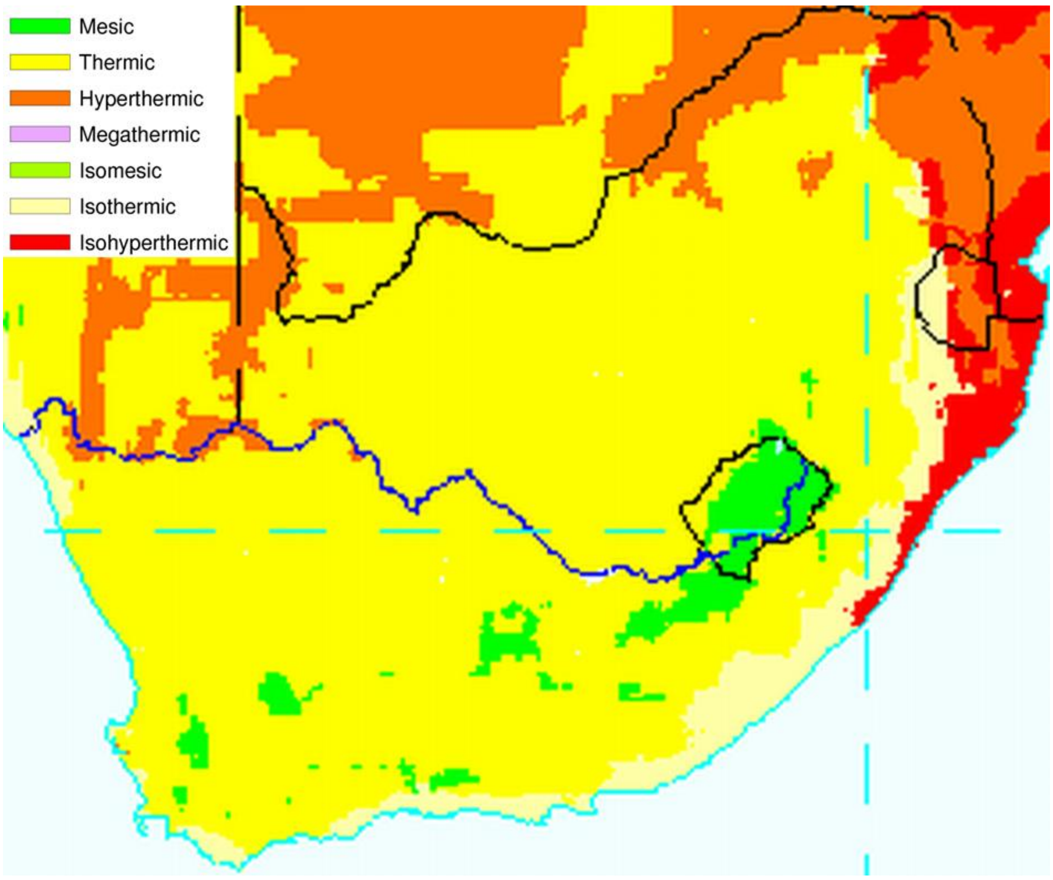

Figure 10 Soil temperature regimes for South Africa (NRCS, 2016)

6. Crop production in South Africa

Crop production (field crops and horticulture) contributes roughly 62.4% towards the total gross value of agricultural production in South Africa. This is astonishing considering that only 13% of South Africa's surface area (122.3 million ha) can be used for production of rain-fed crops, while approximately 1.5 million ha are under irrigation. Most of the land surface (69%) is suitable for grazing and livestock farming, which is by far the largest agricultural sector in the county (Figure 11).

Figure 11 Land-use pattern in South Africa (Department of Agriculture).

South Africa is suitable for the cultivation of a large variety of crops. The largest area of cultivated land is planted with maize, followed by wheat and, on a lesser scale, oats, sugar cane and sunflower. Although agricultural production has almost doubled over the last 30 years, the yield has been erratic in the last decade, primarily because of severe droughts. The country is, however, still self-sufficient as far as most primary foods are concerned, with the exception of wheat, oilseeds, rice, tea and coffee.

Maize is produced mainly in the North West, the north-western, northern and eastern Free State, the Mpumalanga Highveld, and the KwaZulu-Natal Midlands. Local production is generally sufficient to supply in local needs and surplus maize is usually exported.

Wheat is produced in the winter-rainfall areas of the Western Cape and the eastern parts of the Free State. Production in the Western Cape is the highest, but there are considerable annual fluctuations. As a result of varying weather conditions, wheat has to be imported during some years.

Barley is produced mainly on the southern coastal plains of the Western Cape. The area where barley is planted was estimated at 72 400 ha for the 2002/03 production season.

Groundnuts are grown mainly in the Free State, North West and Northern Cape. Groundnut plantings decreased by 47%, from 94 160 ha in 2001/02 to 50 300 ha in 2002/03.

South Africa is the world's 11th-largest producer of sunflower seed. Sunflower seed is produced in the Free State, North West and on the Mpumalanga Highveld, as well as in Limpopo.

For many years, Oudtshoorn, De Rust and Douglas were the only areas in South Africa in which lucerne seed was produced in reasonable quantity. Today, the Oudtshoorn district is responsible for about 90% of the lucerne seed produced in South Africa.

Sorghum is cultivated mostly in the drier parts of the summer-rainfall areas such as Mpumalanga, Free State, Limpopo and North West.

Cotton is cultivated in Mpumalanga, Limpopo, Northern Cape, KwaZulu-Natal and North West. It constitutes 74% of natural fibre and 42% of all fibre processed in South Africa. Cotton is grown under irrigation as well as in dry-land conditions. Cotton under irrigation usually contributes almost as much to the national crop as that grown in dry-land conditions, although the number of hectares under dry-land conditions is much more than those under irrigation. Of locally produced cotton, 75% is harvested by hand.

Virginia tobacco is produced mainly in Mpumalanga and Limpopo, with smaller quantities of Oriental tobacco being produced in the Western and Eastern Cape. There are more than 1 000 growers in the country, who produce an annual average of 34 million kg on about 24 000 ha of land.

South Africa is ranked as the world's 12th-largest sugar producer. Sugar cane is grown in 15 cane-producing areas extending from northern Pondoland in the Eastern Cape, through the coastal belt and Midlands of KwaZulu-Natal, to the Mpumalanga Lowveld. About 50% of sugar produced in this country is marketed in southern Africa. The remainder is exported to numerous markets in Africa, the Middle East, North America and Asia. Based on actual sales and selling prices in 2002/03, it is estimated that the South African sugar industry contributed R2.0 billion to South Africa's foreign exchange earnings.

Deciduous fruit is grown mainly in the Western Cape and in the Langkloof Valley in the Eastern Cape. Smaller production areas are found along the Orange River and in the Free State, Mpumalanga and Gauteng. This industry's export-earnings represent 11% of the country's total earnings from agricultural exports. In 2002, apples made up the largest percentage of the crop (38%), while pears total 21% and table grapes 19%. Approximately 76% of the total crop was produced in the Western Cape, 11% in the Northern Cape, and 13% in the Eastern Cape.

The wine industry in South Africa is a very important part of the agricultural sector. South Africa is ranked as the 8^{th}-largest wine producer in the world. About 106 330 ha of land are under cultivation with about 317 million vines. About 84% of wines are still produced by co-operatives. Some 4 390 primary wine producers employ about 67 000 people.

Citrus production is largely limited to the irrigation areas of Limpopo, Mpumalanga, the Eastern and Western Cape, and KwaZulu-Natal. South Africa is the 3^{rd}-largest exporter of sweet oranges in the world. Pineapples are grown in the Eastern Cape and northern KwaZulu-Natal. Other sub-tropical and tropical crops such as avocados, mangoes, bananas, litchis, guavas, papaws, granadillas, and macadamia and pecan nuts are produced mainly in Mpumalanga and Limpopo at Levubu and Letaba, and in the subtropical coastal areas of KwaZulu-Natal and the Eastern Cape.

About 40% of the country's potato crop is grown in the high-lying areas of the Free State and Mpumalanga. Limpopo, the Eastern, Western and Northern Cape, and the high-lying areas of KwaZulu-Natal are also important production areas. About two-thirds of the country's total potato crop is produced under irrigation. Of the total crop, 50% is delivered to fresh-produce markets and a further 16% is processed. The South African potato-processing industry grew by more than 100% over the past five years. This growth took place primarily in the processing industry.

In terms of gross income to the grower (apart from potatoes), tomatoes, onions, green mealies and sweet corn are probably the most important vegetable crops. These crops contribute 37% to the income derived from vegetables. Tomatoes are produced countrywide, but mainly in Limpopo, the Mpumalanga Lowveld and Middleveld, the Pongola area of KwaZulu-Natal, the southern parts of the Eastern Cape, and the Western Cape. Onions are grown in Mpumalanga; in the districts of Caledon, Ceres and Worcester in the Western Cape; and at Venterstad and the adjoining areas in the southern Free State. Cabbages are also grown countrywide, but are more concentrated in Mpumalanga and the Camperdown and Greytown districts of KwaZulu-Natal.

Rooibos tea is an indigenous herb produced mainly in the Cedarberg area of the Western Cape. In 2002, the demand for *rooibos* was estimated to be 3 500 t compared with 3 200 t exported in 2000. The active producers of *rooibos* tea are estimated at 320, ranging from small to large farming enterprises. Honeybush tea grows mainly in the coastal and mountainous areas of the Western Cape but also in certain areas of the Eastern Cape. From a small beginning in 1993, the honeybush has grown to a commercial crop, with a production of more than 100 t of processed tea per annum. In the last eight years, the industry has seen an improvement in the quality of tea and the establishment of export standards, the construction of a large processing and packaging facility in Mossel Bay, increased consumer awareness, appearance of several brand names on supermarket shelves, and a growing overseas market.

Ornamental plants are produced throughout the country, with greenhouse and open-field production aimed particularly at the export market, concentrated mainly in Limpopo, Mpumalanga and Gauteng. Ornamental-plant production includes nursery plants, cut flowers and pot plants. The country's most important plant export products are gladioli, proteas, bulbs, chrysanthemum cuttings and roses. Amaryllis bulbs are a lucrative export product to the USA. South Africa's indigenous flowers, such as, gladioli, nerine, freesia and gerbera, have undergone many years of extensive research in Europe and have become major crops throughout the world. South Africa is the leading exporter of protea cut flowers, accounting for more than half of proteas sold on the world market. The protea industry is mainly concentrated in the Western Cape. South African proteas and so-called Cape greens (*fynbos*) are mainly marketed in Europe.

7. Methods

Soil samples were air dried, ground by hand using a wooden pestle and porcelain pestle and passed through a 2 mm sieve.

All chemical and physical analyses were done according to the standard methods of The Non-Affiliated Soil Analysis Work Committee (1990), at the Department of Soil, Crop, and

Climate Sciences at the University of the Free State. Texture was analysed by determining the sand fractions through sieving, and the silt and clay fractions through settling. Chemical analyses included organic carbon, and total nitrogen (dry combustion), pH (water), electrical resistance, exchangeable cations, and cation exchange capacity (NH_4OAc at pH 7). Phosphorus was determined using the Olsen extraction method.

The clay fraction (collected during the texture analysis) was characterised using X-ray diffraction (XRD). XRD patterns were obtained with a Panalytical Empyrean theta-theta diffractometer equipped with a Cu anode X-ray tube operating at 45 kV and 40 mA. The measurements were carried out in Bragg-Brentano mode. Phase identification and semi-quantitative analysis were performed using the Highscore software.

The elemental composition of the bulk (<2 mm) soil sample was determined using X-ray fluorescence (XRF). A Panalytical Axios was used to determine both the major and trace elements in the soil. The Pananlytical Axios contains an Rh end window tube, with a 4 kW anode (consisting of Rh) and a W cathode (filament). This is a sequential wavelength dispersive XRF, which measures one element at a time and the wavelength of the X-rays are measured instead of the energy.

Both XRD and XRF determinations were done by the Department of Geology at the University of the Free State.

8. Day 1, Thursday 1 December 2016 (Pretoria)

The SCC16 Field Excursion starts off with a visit to four profiles on dolomite/chert geology in the Olifantsfontein area of the Gauteng Province (Land Types Ab1 and Ab2). The general area is characterised by increasing urbanisation pressures and this in turn leads to an increase in environmental authorisation applications and specialist investigations. In this regard the main environmental investigations are assessments pertaining to 1) wetlands and hydrological functioning of the landscapes; 2) biodiversity; and 3) agriculture potential. The varied geology of the Gauteng Province leads to a wide range of soils and expression of redox morphology, which in turn leads to challenges regarding the interpretation of wetland parameters in the context on one broad national wetland delineation guideline. In this regard the soils derived from dolomite are particularly challenging.

The dolomite geology of the Gauteng Province is old and as such the soils are highly weathered to exhibit clearly defined profiles with a dominance of Fe minerals in a well-drained matrix. Inherited from the geology are large concentrations of Mn that can approach several parts per thousand. The presence of the Mn renders the soils "hyperoxic" in the sense that these soils exhibit very high total electron demand (TED) and manganese electron demand (MED) levels upon analysis. The implication of the high Mn levels is that redox reactions are buffered (poised) in the region of Mn reduction with a consequent lack of Fe reduction – that would have yielded visible Fe redox morphology associated with regular saturation and lateral seepage conditions. Manganese minerals in soils have been shown to undergo solid-state reduction/oxidation with the effect that Mn is not readily mobilised and translocated *en masse* through the soil profile. Manganocrete deposits occur in many areas and within soil profiles, but the overlying red soil matrix often masks significant concentrations of Mn.

The profiles at this site (SCC01, SCC02, SCC03, and SCC04) represent a toposequence from crest to footslope in the Ab1 land type (Land Type Survey Staff, 2000). The crests are dominated by chert minerals (resistant to chemical and physical weathering) with well-drained, apedal, stony soil profiles. The footslope positions are dominated by deeper soils with an increase in clay accumulation and structure formation. Very characteristic of the toposequence is the dominance of red colours throughout down to the watercourse – an aspect that renders a Fe redox morphology based wetland delineation procedure moot.

The classification of the soils in the South African Taxonomic system (Soil Classification Working Group, 1991) places all four profiles in the Hutton form. The classification in the WRB and Soil Taxonomy is more challenging and warrants a detailed discussion in the field.

9. Day 2, Friday 2 December 2016 (Lichtenburg)

The SCC16 Field Excursion to Lichtenburg involves a visit to four profile pits. The four profiles are on four different land types, with the geology also differing. Profile SCC05 is on Ventersdorp lava (Adesitic), covered by calcrete and ferricrete in places (Land type Bd5). Profile SCC06 is also on Ventersdorp lava (Land type Bd7). Profile SCC07 is on Ventersdorp and Dominion lava (Land type Bd10). Profile SCC08 is on Basement Complex Granite (Land type Ba25). Because of the varying geology of the region, a wide range of soils with different soil properties exists.

Lichtenburg falls within the summer rainfall area of the country. The long term average rainfall for profiles SCC05 and SCC06 varies from 550 mm to 575 mm per annum. The long term average rainfall for profiles SCC07 and SCC08 is 613 mm per annum. The average daily maximum temperature for profiles SC005 and SC006 varies between 30.2°C for December and 19.6°C for July and for profiles SCC07 and SCC08 between 29.2°C for December and 17.6°C for July. The average daily minimum temperature for profiles SCC05 and SCC06, varies between 16.8°C for January and 2.2°C for July, and for profiles SCC07 and SCC08 between 15.3°C for January and -0.4°C for July. Frost can be expected over a period of 100 days of the year for profiles SCCO5 and SCC06 and over a period of 113 days of the year for profiles SCC07 and SCC08. The earliest occurrence of frost is 7 April and the latest date of frost is 13 September. The cumulative heat units for October to March is 2226 units for profiles SCC05 and SCC06 and 1919 units for profiles SCC07 and SCC08. The natural vegetation of the area is known as mixed grasslands with the occurrence of sweet thorn (*Acacia Karroo*) at some places. The aridity-index for profiles SCC05 and SCC06 is 0.205 and for profiles SCC07 and SCC08 it is 0.223.

The cash crops produced in the Lichtenburg region are mainly maize and sunflower in rotation. Soya or dry beans are also produced. Maize is generally planted in 2.1 meter, 1.5 meter or 0.9 meter inter-row spacing, with the optimum plant density for maize being between 16 000 and 18 000 plants per hectare. Sunflower, soya and dry beans are commonly planted in 0.9 meter rows. The optimum plant density for sunflower is 35 000 plants per hectare, for soya 250 000 and for dry beans 120 000 plants per hectare. BT maize hybrids are very commonly planted and if problems arise with hardy weeds, roundup ready cultivars are also planted. The optimum planting date for maize and soya are the first two weeks of December. Sunflower and dry beans are commonly planted later. Long-term yields for the individual sites are given below.

Conservation tillage is applied by most of the producers, since conventional tillage practices exacerbates wind and water erosion. The typical conservation tillage system involves the following: After harvesting the crop residues are flattened with a knife-roller. Tillers with wide shares are used for weed control during winter. Herbicides are sometimes used for controlling winter weeds. Primary cultivation operations involve full cover ripping or rip-on-row. Some producers apply traffic control practices. Seedbed preparation is done with cultivators. Fertilizers are pre-planted and or applied with planting. Topdressing is generally done by means of a row applicator or spread by means of a fertiliser spreader. Weed control is commonly done with herbicides during the growing season. Mechanical inter row weed control is only done in extreme cases.

Table 2 Long term yields for site SCC05 (P1 / Danie vd Walt - Kalkgrond)

Year	Crop	Yield ($Mg\ ha^{-1}$)	Rainfall (mm)
2016	Yellow maize	0.41	420
2015	Soya beans	0.87	253
2014	Yellow maize	3.48	494
2013	Soya beans	1.54	416
2012	Yellow maize	3.29	334
2011	Soya beans	1.46	754
2010	Yellow maize	4.33	739
2009	Soya beans	1.37	776
2008	Yellow maize	2.35	457
2007	Soya beans	1.22	298
2006	Yellow maize	3.30	583
Average	**Soya beans**	**1.29**	**502**
	Yellow maize	**2.86**	

Table 3 Long term yields for site SCC06 (P2 / Frans van der Linden-Nico)

Year	Crop	Yield ($Mg\ ha^{-1}$)	Rainfall (mm)
2016	Maize	1.48	466
2015	Maize/Sunflower	2.3/0.94	325
2014	Maize/Sunflower	6.27/1.92	559
2013	Maize/Sunflower	2.31/0.66	343
Average	**Maize**	**3.09**	**423**
	Sunflower	**1.25**	

Table 4 Long term yields for site SCC07 (P3 / Dieter Hansen-Geelgrond)

Year	Crop	Yield (Mg ha^{-1})	Rainfall (mm)
2006	White maize	5.5	714
2007	White maize	1.3	411
2008	Soya beans	1.8	545
2009	White maize	9.0	720
2010	White maize	5.8	639
2011	Soya beans	1.9	903
2012	White maize	5.5	327
2013	White maize	1.64	479
2014	Soya beans	2.3	684
2015	White maize	1.9	328
2016	White maize	1.08	438
Average	**White maize**	**2.00**	**563**
	Soya beans	**3.97**	

Table 5 Long term yields for site SCC08 (P4 / Dieter Hansen Rooigrond)

Year	Crop	Yield (Mg ha^{-1})	Rainfall (mm)
2006	White maize	6.0	666
2007	White maize	1.6	362
2008	Soya beans	1.8	504
2009	White maize	9.3	589
2010	White maize	5.95	587
2011	Soya beans	1.9	581
2012	White maize	5.28	325
2013	White maize	1.46	464
2014	Soya beans	2.3	691
2015	White maize	3.68	325
2016	White maize	2.45	383
Average	**White maize**	**4.47**	**498**
	Soya beans	**2.00**	

10. Day 3, Saturday 3 December 2016 (Potchefstroom)

The two soil profiles to be visited this morning lies just south of the Vaal river and within 400 metres of the river. The geology of the area where the two soil profiles (SCC09 and SCC10) lies is of Quaternary origin, underlain by intrusive diabase. Soil profile SCC09's parent material is aeolian sand and that of soil profile SCC10 is alluvium. These two soils both fall in Land Type Bd13.

The classification of soil profile SCC09 according to the South African Taxonomic system is a Pinedene form. The classification in the WRB is that of an Arenosol. Profile SCC10 was classified as a Sepane form according to the South African Taxonomic system and as a Lixisol in the WRB. Both soils are currently being cultivated with annual crops like maize and wheat under irrigation.

The Eleazer (New Machavie) gold mine was periodically mined from as early as 1904 and was actively mined between the 1930s and early 1940s. During this time five tailings dams (discard dumps) were constructed, while approximately 5200 kg of gold was produced by exploiting 1400 m of the conglomerate unit of the Black Reef Formation to a maximum depth of 130 m. The reopening of the New Machavie mine was scheduled for 2003 but was delayed due to problems regarding surface mining rights.

Pyrite, chlorite, and carbonaceous material are found in the Black Reef Formation. The lower portion consists of siliceous quartzite with layers of conglomerates. On top of this lower portion, carbonaceous shale and alternating layers of quartzite and shale are found. The basal conglomerate consists of vein-quartz pebbles, chert, quartzite, quartz porphyry, shale, lava, agate and pyrite and is known as one of the principal ore bodies. A layer of well-mineralized conglomerate, rich in gold, is found above the basal conglomerate. This layer also contains accessory pyrite and carbon. The conglomerate layer is in turn overlain by quartzite and carbonaceous shale. Ore minerals found in the Black Reef includes: gold, pyrite, carbon, sphalerite, chalcopyrite, chromite, pyrrhotite, and ilmenite.

During the mineral extraction process the ore is ground to finer than silt size and treated with hydrochloric acid to solubilise the minerals. The tailings are then deposited in the tailings dams where the water evaporates. One would expect these tailings to be quite inert due to the siliceous nature of the ore and the added acid. The resulting tailings therefore poses serious challenges in vegetative rehabilitation as well as environmental issues such as stream pollution and health risks through breathing the tailings dust (tailings are quite easily eroded by wind). However, the tailings are not immune to soil formation, as can be seen from the pedogenic features that have developed within a few decades. The purpose of this stop is to explore these pedogenic features and its classification.

Onsite, profiles SCC10 and SCC11 will indicate the distribution of oxidative zonation within the tailings dams, which creates preferential mobilization of metals and metalloids including uranium, iron, arsenic, cadmium, etc. Secondary mineralization of iron oxides and oxy-hydroxides as well as the formation of amorphous gypsum and jarosite as the result of pyrite oxidation will also be seen.

11. Day 4, Sunday 4 December 2016 (Vredefort)

The 3 profiles are located on the farm Wonderfontein, near the town of Vredefort in the Vredefort impact crater.

The geology is described as Archaean Basement Complex with influences of the Karoo Super Group. This mix in geology give rise to relative big changes in soil properties over short distances as can be seen in the three chosen profiles. The farm is located in the Land type Ba38. This land type is dominated by red, highly weathered, structureless soils.

Profile SCC13 is at the bottom of the midslope. The Katspruit soils are prone to water logging. The G horizon limits water infiltration causing waterlogging conditions and poor root development. The potential of the soils vary according to climatic conditions.

Profile SCC14 is situated more or less in the middle of the midslope. The soft plinthite occurs at shallow depths causing waterlogging under high rainfall conditions. As the depth to the plinthite decreases, waterlogging conditions also increase. This will lead to saturated conditions as water drainage through this soil form is very slow. These soils are usually located in lower lying areas where excess water accumulates either through surface run-off or lateral drainage.

Profile SCC15 is located on the upper midslope. The soil is characterised by larger structure units, shrinking and swelling characteristics, and subsoil prone to water logging. Root development will be poor. When dried out, the roots may be broken off due to the shrinking of the structure units. The potential of the soils vary according to climatic conditions. The wet vertic soils are usually associated with lower foot slope and valley bottom landscape positions. This is, however, not the case here.

Potential for crop production varies greatly between the 3 soil types.

Maize and grain sorghum are cultivated in a crop rotation system. Topsoil clay content determines the cultivation actions. A conservation tillage system is followed. Topsoil is sampled on a grid basis every 3 years. Lime application is done every year according to chemical analyses and the applied lime is incorporated into the soil using a disc, followed by a chemical weed control. A shallow tine fitted on the planter is used to break up compaction layers that might have formed in the low clay topsoil horizons of profiles SCC14 and SCC14. Site SCC15 does not need any deep cultivation due to the swelling and shrinking of the clays.

Rainfall distribution plays a bigger role in crop production here than the mere annual total rainfall.

The normalized difference vegetation index (NDVI) values range between 1 and -1. The values are low (Table 6) due to the below average rainfall the past 3 seasons. According to these values there is not a big difference in plant growth potential between 2014 and 2016. The 2015 season was a bit better, most likely due to rainfall distribution.

During 2014 the crops on site SCC15 performed the best and the crops on the SCC14 the worst. The crops on SCC14 performed the best during 2015 and the crops on site SCC13 the worst. The NDVI for 2016 shows that the crops on site SCC13 performed the best and on site SCC14 the worst.

Table 6 The NDVI index values of sites SCC13, SCC14, and SCC15 at Wonderfontein for the 2014, 2015, and 2016 growing season.

Site	NDVI_2016	NDVI_2015	NDVI_2014
SCC13	0.21472	0.48296	0.32151
SCC14	0.20179	0.51370	0.27724
SCC15	0.20667	0.50854	0.35081

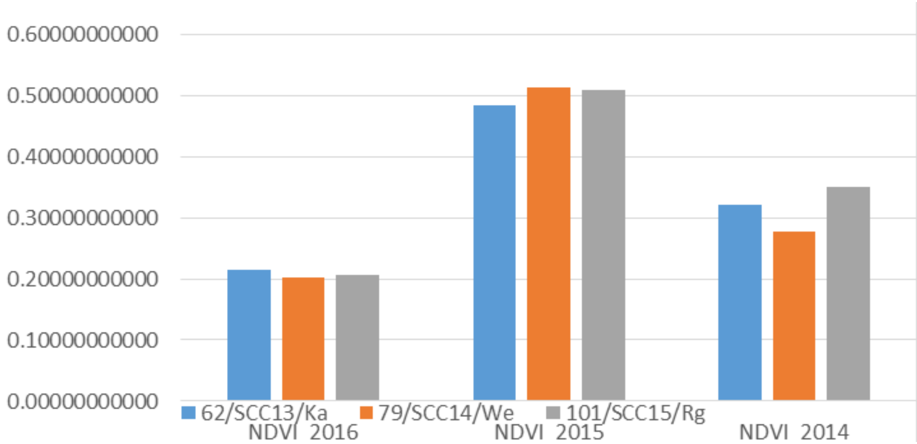

Figure 12 NDVI index values of sites SCC13, SCC14, and SCC15 at Wonderfontein for the 2014, 2015, and 2016 growing seasons.

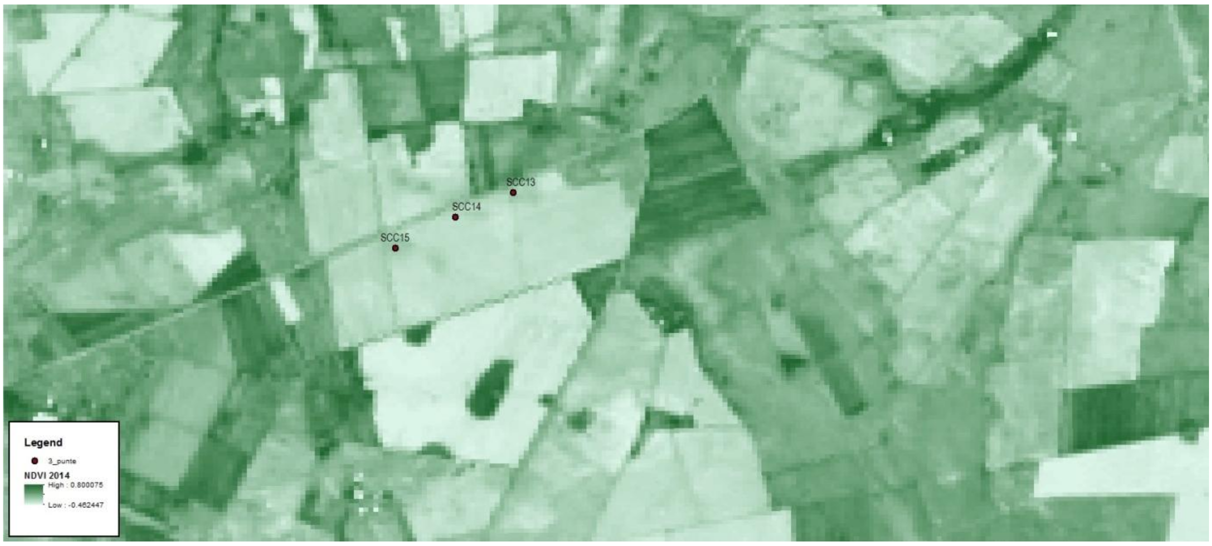

Figure 13 NDVI image of sites SCC13, SCC14, and SCC15 at Wonderfontein for the 2014 growing season.

Figure 14 NDVI image of sites SCC13, SCC14, and SCC15 at Wonderfontein for the 2015 growing season.

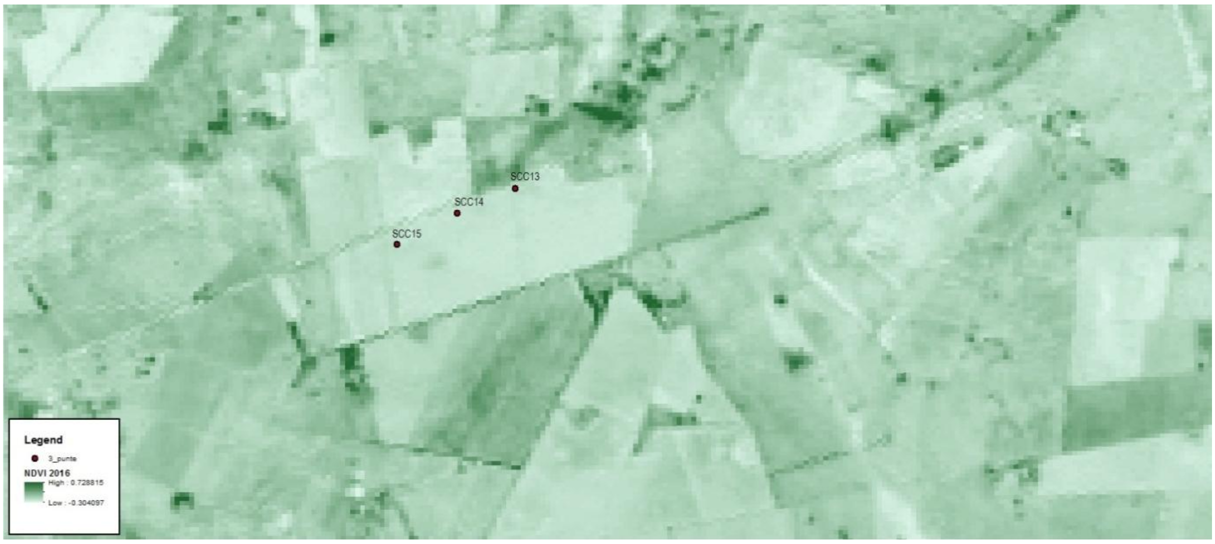

Figure 15 NDVI image of sites SCC13, SCC14, and SCC15 at Wonderfontein for the 2016 growing season.

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Specifically: Prof Nico Smit (Director: Unit for Environmental Sciences and Management, Potchefstroom campus, North West University); Me Cindy Faul and Mr Piet van Deventer (Boscia Environmental Solutions); Mr Mike Seiderer (Greenthorne Enviroment); Mr Ray van Rensburg (Geotron: Geophysical electronic systems); Mr Jaco Koch (Soil Science Division of North West University); Mr Jasper Dreyer: (Soil Science Division of North West University)

Profile No: SCC01 (Pta - R1)
Latitude & Longitude: 25°53'58"S; 28°14'44"E
Surface stoniness: class 4 (25-60%) angular stones
Elevation: 1522 m
Terrain unit: crest
Slope: 4%
Slope shape: convex
Aspect: south
Micro relief: none
Parent material solum: single
Underlying material: dolomite & chert
Geological Group: Chuniespoort

Soil form: Hutton
Soil family: 1100
Surface rockiness: class 1 (<2%)
Occurrence of flooding: none
Wind erosion: none
Water erosion: none
Vegetation / Land use: Grassveld, open
Water table: none
Described by: JvdW / CvH
Date described: July 2016
Weathering of underlying material: advanced physical; strong chemical
Alteration of underlying material: kaolinised

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 200	**Moisture status:** dry; **dry colour:** 5YR4/4; **moist colour:** 5YR3/4; moderate medium granular; soft, friable, non-sticky, non-plastic; many normal fine and very fine pores; many normal medium and angular coarse pores; very few angular coarse gravel fragments; water absorption 1 second(s); many normal roots; gradual smooth transition;	orthic A horizon
B1	200 – 400	**Moisture status:** dry; **dry colour:** 5YR4/6; **moist colour:** 5YR3/4; weak fine subangular blocky; soft, friable, non-sticky, non-plastic; many normal fine and very fine pores; many normal medium and coarse pores; very few angular coarse gravel fragments; water absorption 1 second(s); common normal roots; gradual smooth transition;	red apedal B horizon
B2	400 – 1000	**Moisture status:** dry; **dry colour:** 5YR4/6; **moist colour:** 5YR3/4; weak fine subangular blocky; soft, friable, non-sticky, non-plastic; many normal fine and very fine pores; many normal medium & coarse fragments; very few angular coarse gravel fragments; water absorption 1 second(s); few normal roots; gradual smooth transition;	red apedal B horizon
B3	1000 – 1800	**Moisture status:** dry; 2.5YR5/6; **moist colour:** 2.5YR3/4; weak fine subangular blocky; soft, friable, non-sticky, non-plastic; many normal fine and very fine pores; many normal medium and coarse pores; water absorption 1 second(s); few normal roots; transition not reached.	red apedal B horizon

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 1 Soil analyses for profile SCC01 (Pta - R1)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						(cmol$_c$ kg^{-1})							(%)	mg kg^{-1}			
A	200		21.1	27.4	22.6	4.9	12.5	8.6	3.14	0.79	0.12	0.03	4.09	6.85	80	59.7	6.7	15500	995	5.20
B1	400		21.4	17.9	27.0	7.3	16.2	5.7	2.29	0.46	0.06	0.04	2.85	6.74	119	42.3	4.8	6930	589	4.75
B2	1000		16.1	8.8	26.3	2.2	12.0	31.1	2.29	0.60	0.04	0.03	2.96	5.33	17	55.5	3.2	3470	450	4.76
B3	1800		16.6	6.8	21.5	0.5	11.1	42.6	1.53	0.21	0.03	0.05	1.83	5.11	12	35.8	2.9	1280	270	4.80

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
A	6.3	0.1	6.2	0.3	0.2	0.3	0.0	81.0	0.5	0.0	6.3	101.2
B1	6.3	0.1	5.4	0.2	0.2	0.3	0.0	83.8	0.5	0.0	5.2	102.0
B2	7.1	0.1	6.1	0.3	0.1	0.3	0.0	83.0	0.5	0.0	4.7	102.2
B3	7.8	0.0	6.3	0.3	0.1	0.3	0.0	81.9	0.6	0.0	4.8	102.1

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
A	8	106	113	21	45	20	12	5	25	8	13	229	6	<6	412	18	4	<2
B1	8	104	112	22	43	17	8	2	24	7	11	218	6	<6	432	20	3	<2
B2	7	122	136	21	48	22	13	2	30	6	14	259	8	<6	459	16	7	<2
B3	10	127	114	17	46	21	15	<1	30	5	15	273	8	<6	442	14	5	<2

Horizon	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
A	27	32							20	21					
B1	24				28			27	21						
B2	25	28					24				23				
B3	34	36									30				

Profile No: SCC02 (Pta - R2)
Latitude & Longitude: 25°54'04.0"S; 28°14'44.0"E
Surface stoniness: class 4 (25-60%) angular stones
Elevation: 1522 m
Terrain unit: upper midslope
Slope: 3%
Slope shape: concave
Aspect: west
Micro relief: none
Parent material solum: single
Underlying material: dolomite & chert
Geological Group: Chuniespoort

Soil form: Hutton
Soil family: 1200
Surface rockiness: class 1 (<2%)
Occurrence of flooding: none
Wind erosion: none
Water erosion: none
Vegetation / Land use: Grassveld, open
Water table: none
Described by: JvdW / CvH
Date described: July 2016
Weathering of underlying material: advanced physical; strong chemical
Alteration of underlying material: kaolinised

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 200	**Moisture status:** dry; **dry colour:** 2.5YR4/6; **moist colour:** 2.5YR3/4; weak medium granular; soft, friable, non-sticky, non-plastic; many normal fine and very fine pores; many normal medium and angular coarse pores; very few angular coarse gravel fragments; water absorption 1 second(s); many normal roots; gradual smooth transition;	orthic A horizon
B1	200 – 400	**Moisture status:** dry; **dry colour:** 2.5YR4/6; **moist colour:** 2.5YR3/6; weak medium subangular blocky; soft, friable, non-sticky, non-plastic; many normal fine and very fine pores; many normal medium and coarse pores; very few coarse angular gravel fragments; water absorption 1 second(s); common normal roots; gradual smooth transition;	red apedal B horizon
B2	400 – 600	**Moisture status:** dry; **dry colour:** 2.5YR5/6; **moist colour:** 2.5YR3/6; weak medium subangular blocky; soft, friable, non-sticky, non-plastic; many normal fine and very fine pores; many normal medium & coarse fragments; very few coarse angular gravel fragments and few coarse angular stone fragments; water absorption 1 second(s); common normal roots; gradual smooth transition;	red apedal B horizon
C	600 – 1500	**Moisture status:** dry; **dry colour:** 2.5YR5/6; **moist colour:** 2.5YR3/6; non-plastic; common (Mn) sesquioxide cutans; very few coarse angular gravel fragments and many coarse angular stone fragments; water absorption 1 second(s); few normal roots; transition not reached.	saprolite

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 2 Soil analyses for profile SCC02 (Pta - R2)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						(cmol$_c$ kg^{-1})							(%)	mg kg^{-1}			
A	200		47.4	17.3	11.9	1.6	7.0	13.6	3.28	0.93	0.19	0.05	4.45	9.57	70	46.5	7.6	19900	1238	4.89
B1	400		19.9	13.7	23.0	2.5	16.1	21.4	2.40	0.51	0.06	0.04	3.02	6.74	31	44.8	4.9	10100	866	4.66
B2	600		24.5	10.7	16.3	4.3	9.5	35.7	2.67	0.60	0.09	0.04	3.40	8.91	25	38.2	5.5	12400	956	4.60

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
	9.0	0.1	7.1	0.3	0.2	0.3	0.1	76.1	0.6	0.0	8.4	102.2
	9.3	0.1	7.4	0.3	0.1	0.4	0.0	76.5	0.6	0.0	7.2	102.0
	9.2	0.1	7.4	0.3	0.1	0.4	0.1	76.2	0.6	0.0	7.5	101.7

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
	9	125	143	24	55	26	13	6	41	9	16	222	8	<6	467	24	10	<2
	10	142	153	24	64	28	12	5	43	8	16	244	9	<6	548	20	11	<2
	10	134	159	25	66	28	12	5	44	10	16	244	10	11	547	21	10	<2

Horizon	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
	21	21			25						16	17			
	34	34									32				
	34	35									31				

Profile No: SCC03 (Pta - R3)
Latitude & Longitude: 25°54'13"S; 28°13'57"E
Surface stoniness: none
Elevation: 1460 m
Terrain unit: upper footslope
Slope: 5%
Slope shape: concave
Aspect: west
Micro relief: none
Parent material solum: single
Underlying material: dolomite & chert
Geological Group: Chuniespoort

Soil form: Hutton
Soil family: 2200
Surface rockiness: class 1 (<2%)
Occurrence of flooding: none
Wind erosion: none
Water erosion: slight
Vegetation / Land use: Grassveld, open
Water table: none
Described by: JvdW / CvH
Date described: July 2016
Weathering of underlying material: advanced physical; strong chemical
Alteration of underlying material: kaolinised

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 300	**Moisture status:** dry; **dry colour:** 2.5YR4/4; **moist colour:** 2.5YR3/3; weak medium granular; soft, friable, non-sticky, non-plastic; many normal fine and very fine pores; many normal medium and angular coarse pores; very few angular coarse gravel fragments; water absorption 1 second(s); many normal roots; gradual smooth transition.	orthic A horizon
B1	300 – 600	**Moisture status:** dry; **dry colour:** 2.5YR4/6; **moist colour:** 2.5YR3/4; weak fine subangular blocky; soft, friable, non-sticky, non-plastic; many normal fine and very fine pores; many normal medium and coarse pores; very few coarse angular gravel fragments; water absorption 1 second(s); common normal roots; gradual smooth transition.	red apedal B horizon
B2	600 – 900	**Moisture status:** dry; **dry colour:** 2.5YR4/6; **moist colour:** 2.5YR3/4; weak fine subangular blocky; soft, friable, non-sticky, non-plastic; many normal fine & very fine pores; few sesquioxide cutans; many normal medium & coarse fragments; very few coarse angular gravel fragments & many angular stone fragments; water absorption 1 second(s); common normal roots; gradual smooth transition.	red apedal B horizon

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 3 Soil analyses for profile SCC03 (Pta - R3)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						($cmol_c$ kg^{-1})							(%)	mg kg^{-1}			
A	300		17.3	18.0	39.1	5.9	5.2	14.3	5.75	1.70	0.09	0.05	7.59	7.28	51	104.2	4.4	8450	698	5.99
B1	600		18.8	16.3	37.7	4.6	2.9	20.8	3.96	1.26	0.05	0.04	5.31	6.41	31	82.8	3.2	3140	382	6.13
B2	900		15.3	13.7	34.8	4.7	4.3	24.0	3.69	1.04	0.05	0.05	4.83	6.41	27	75.4	4.0	4210	459	6.16

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
A	4.8	0.2	6.2	0.4	0.2	0.8	0.0	82.6	0.8	0.0	4.6	100.6
B1	4.7	0.1	5.9	0.3	0.2	0.9	0.0	84.9	0.7	0.0	3.6	101.6
B2	5.0	0.1	6.4	0.3	0.6	0.8	0.0	83.6	0.8	0.0	3.7	101.4

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
A	4	164	158	30	110	18	17	5	32	13	13	226	6	<6	783	15	3	<2
B1	6	164	179	33	135	19	14	1	30	13	13	217	7	<6	969	16	3	<2
B2	10	171	178	30	128	18	20	4	28	10	13	246	7	6	867	18	6	<2

Horizon	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
A	20	18		7	24										
B1	21			5	30			23	17						6
B2	25			8				25	25				12		

Profile No: SCC04 (Pta - R4)
Latitude & Longitude: 25°54'13"S; 28°13'47"E
Surface stoniness: none
Elevation: 1446 m
Terrain unit: valley bottom
Slope: 1%
Slope shape: concave
Aspect: west
Micro relief: none
Parent material solum: single alluvium
Underlying material: dolomite & chert
Geological Group: Chuniespoort

Soil form: Hutton
Soil family: 2100
Surface rockiness: none
Occurrence of flooding: occasional
Wind erosion: none
Water erosion: none
Vegetation / Land use: Grassveld, open
Water table: none
Described by: JvdW / CvH
Date described: Jul 2016
Weathering of underlying material: advanced physical; strong chemical
Alteration of underlying material: kaolinised

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 300	**Moisture status:** dry; **dry colour:** 2.5YR4/4; **moist colour:** 2.5YR3/4; moderate medium granular; soft, friable, non-sticky, non-plastic; many normal fine and very fine pores; many normal medium and angular coarse pores; water absorption 1 second(s); many normal roots; gradual smooth transition;	orthic A horizon
B1	300 – 600	**Moisture status:** dry; **dry colour:** 2.5YR4/4; **moist colour:** 2.5YR3/4; few fine faint black and red oxidised Fe and Mn oxide mottles; moderate medium subangular blocky; soft, friable, non-sticky, non-plastic; many normal fine and very fine pores; many normal medium and coarse pores; water absorption 1 second(s); common normal roots; gradual smooth transition;	red apedal B horizon
B2	600 – 1000	**Moisture status:** dry; **dry colour:** 2.5YR3/6; **moist colour:** 2.5YR3/4; few fine faint black and red oxidised Fe and Mn oxide mottles; moderate medium subangular blocky ;soft, friable, non-sticky, non-plastic; many normal fine and very fine pores; many normal medium & coarse pores; very few angular coarse gravel fragments; water absorption 1 second(s); common normal roots; gradual smooth transition;	red apedal B horizon
B3	1000 – 1500	**Moisture status:** dry; **dry colour:** 2.5YR4/6; **moist colour:** 2.5YR3/4; few fine faint black and red oxidised Fe and Mn oxide mottles; moderate medium subangular blocky; soft, friable, non-sticky, non-plastic; very few normal fine and very fine pores; few normal medium and coarse pores; very few coarse angular gravel fragments; water absorption 1 second(s); few normal roots; transition not reached.	red apedal B horizon

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 4 Soil analyses for profile SCC04 (Pta - R4)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC	CEC	Base	P	Org C	N	pH
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum	soil	clay	sat				H_2O
	(mm)	(%)	(%)						(cmol$_c$ kg^{-1})							(%)	mg kg^{-1}			
A	300		15.8	19.3	28.0	4.6	5.0	29.8	5.51	1.49	0.25	0.05	7.30	9.13	31	79.9	4.4	10200	854	6.06
B1	600		17.7	17.7	23.3	4.5	5.5	33.1	6.11	1.04	0.12	0.08	7.35	9.46	29	77.7	4.0	3720	527	5.29
B2	1000		16.1	14.0	21.5	3.9	5.2	42.1	7.40	1.42	0.09	0.07	8.98	8.48	20	106.0	3.5	1880	388	5.70
B3	1500		15.3	16.2	23.7	2.8	7.5	35.3	5.57	1.12	0.09	0.06	6.84	9.13	26	74.9	3.6	2320	457	5.77

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
A	8.1	0.1	5.6	1.7	0.4	0.3	0.0	79.2	0.6	0.1	5.6	101.8
B1	9.1	0.1	5.7	1.6	0.2	0.3	0.0	78.7	0.7	0.1	5.4	102.0
B2	10.0	0.2	6.6	1.6	0.2	0.3	0.0	76.4	0.7	0.1	5.7	101.7
B3	9.5	0.1	5.8	1.7	0.6	0.3	0.0	76.8	0.7	0.1	5.4	101.0

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
A	7	126	102	16	47	16	9	4	93	25	15	243	9	7	560	12	5	<2
B1	8	139	111	18	49	18	8	3	93	25	18	275	10	<6	562	15	7	<2
B2	11	143	114	18	53	19	<4	<1	91	22	18	251	11	<6	580	15	6	<2
B3	10	138	109	19	48	18	8	2	94	25	18	259	10	<6	604	14	6	<2

Horizon	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
	50	22		29					29	20					
	51	22		18			20	20	20						
	52	23		19			20		20			17			
	53	20		19			19		21	15				7	

Profile No: SCC05 (LTX P1 Danie)
Latitude & Longitude: 26°10'40"S; 25°50'31"E
Surface stoniness: none
Elevation: 1443 m
Terrain unit: crest
Slope: 1%
Slope shape: straight
Aspect: level
Micro relief: none
Parent material solum: binary aeolian
Underlying material: limestone
Geological Group: Quaternary

Soil form: Molopo
Soil family: 1100
Surface rockiness: none
Occurrence of flooding: none
Wind erosion: slight
Water erosion: none
Vegetation / Land use: agronomic cash crops
Water table: none
Described by: CvH / EL
Date described: July 2016
Weathering of underlying material: strong physical; strong chemical
Alteration of underlying material: calcified

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 300	**Moisture status:** dry; **dry colour:** 5YR4/3; **moist colour:** 5YR3/2; weak, fine, crumb; friable; few normal fine and very fine pores; few normal medium and coarse pores; few normal roots; gradual smooth transition;	orthic A horizon
B1	300 – 600	**Moisture status:** dry; **dry colour:** 5YR5/4; **moist colour:** 5YR4/3; weak medium subangular blocky; slightly firm; very few normal fine and very fine pores; very few normal medium and coarse pores; water absorption 1 second(s); few normal roots; gradual smooth transition;	yellow-brown apedal B horizon
B2	600 – 700	**Moisture status:** dry; **dry colour:** 5YR5/4; **moist colour:** 5YR4/4; weak medium subangular blocky; firm; few many normal fine and very fine pores; few normal medium & coarse fragments; water absorption 1 second(s); few normal roots; gradual smooth transition;	yellow-brown apedal B horizon
C	700+	**Moisture status:** dry; **dry colour:** 5YR7/3; **moist colour:** 5YR6/2; free lime; many angular coarse gravel fragments; water absorption 1 second(s), few normal roots;	soft carbonate horizon

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 5 Soil analyses for profile SCC05 (LTX P1 Danie)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						(cmol$_c$ kg^{-1})							(%)	mg kg^{-1}			
A	300		2.0	2.9	67.5	0.0	7.8	24.5	8.98	0.94	0.25	0.10	10.28	12.39	50	82.9	22.4	4640	563	5.77
B1	600		3.2	3.3	65.7	0.0	8.7	16.5	10.63	0.66	0.17	0.09	11.55	12.07	73	95.7	5.0	4540	558	6.42
B2	700		3.5	3.5	59.3	0.0	8.9	26.7	13.82	0.66	0.17	0.13	14.78	13.80	52	107.1	4.3	5260	599	6.39
C	1000		12.5	5.8	32.0	0.0	22.6	27.1	63.00	0.66	0.13	0.10	63.88	13.04	48	489.8	0.4	61200	506	7.71

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
A	4.6	0.3	4.2	0.5	0.5	0.0	0.0	87.3	0.3	0.1	3.8	101.5
B1	4.9	0.3	4.0	0.4	0.2	0.0	0.0	87.0	0.3	0.1	4.3	101.5
B2	5.8	0.3	5.4	0.4	0.2	0.0	0.0	83.7	0.3	0.0	5.2	101.6
C	3.9	25.4	3.1	0.3	0.6	0.0	0.0	43.1	0.2	0.0	25.3	102.0

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
A	3	72	118	11	34	22	<4	3	34	11	10	266	4	<6	241	8	3	<2
B1	4	73	122	10	33	21	6	11	32	9	10	305	4	<6	206	9	4	<2
B2	9	87	136	10	42	20	9	16	35	9	15	279	4	<6	249	8	5	<2
C	52	59	102	6	32	13	5	15	20	12	13	143	2	<6	134	6	<2	<2

Horizon	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
A	24	20	25				20						10		
B1	20	15		5	19	16	17						9		
B2	29	31					27						13		
C	18			22	26		17	17							

Profile No: SCC06 (LTX P2 Nico)
Latitude & Longitude: 26°19'37.6"S; 25°48'00.4"E
Surface stoniness: none
Elevation: 1420 m
Terrain unit: crest
Slope: 1%
Slope shape: straight
Aspect: level
Micro relief: none
Parent material solum: binary aeolian
Underlying material: andesite
Geological Group: Platberg

Soil form: Avalon
Soil family: 2200
Surface rockiness: none
Occurrence of flooding: none
Wind erosion: slight
Water erosion: none
Vegetation / Land use: agronomic cash crops
Water table: none
Described by: CvH / EL
Date described: July 2016
Weathering of underlying material: strong physical; strong chemical
Alteration of underlying material: ferruginised

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 300	**Moisture status:** moist; **dry colour:** 5YR5/6; **moist colour:** 10YR5/3; weak fine; loose; few normal fine and very fine pores; few normal medium and coarse pores; water absorption 1 second(s); few normal roots; gradual smooth transition;	orthic A horizon
B1	300 – 600	**Moisture status:** moist; **dry colour:** 5YR6/8; **moist colour:** 7.5YR5/8; weak medium subangular blocky; slightly; few normal fine and very fine pores; few normal medium and coarse pores; water absorption 1 second(s); few normal roots; gradual smooth transition;	yellow-brown apedal B horizon
B2	600 – 900	**Moisture status:** moist; **dry colour:** 5YR6/4; **moist colour:** 7.5YR4/6; common fine faint yellow, brown oxidised Fe oxide; weak medium subangular blocky; firm; few normal fine and very fine pores; few normal medium & coarse pores; water absorption 1 second(s); few normal roots; gradual smooth transition;	yellow-brown apedal B horizon
B3	900 – 1500	**Moisture status:** moist; **dry colour:** 5YR6/6; **moist colour:** 2.5YR6/1; common medium prominent grey reduced Fe oxide and common medium prominent black oxidised Fe oxide; weak medium subangular blocky; very firm; common normal fine and very fine pores; few normal medium and coarse pores; very few fine sesquioxide concretions/nodules; water absorption 1 second(s); few normal roots; transition not reached.	soft plinthic B horizon

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 6 Soil analyses for profile SCC06 (LTX P2 Nico)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						($cmol_c\ kg^{-1}$)							(%)	mg kg^{-1}			
A	300		3.3	28.0	53.8	0.0	0.0	16.6	4.57	1.01	0.39	0.04	6.02	9.78	59	61.5	122.1	4260	663	6.02
B1	600		2.7	2.8	54.0	4.2	8.0	23.3	6.78	2.50	0.27	0.05	9.59	10.98	47	87.4	11.1	4760	776	6.18
B2	900		4.0	2.6	50.4	3.1	8.2	28.3	6.17	3.80	0.20	0.06	10.24	12.61	45	81.2	6.5	3820	652	6.01
B3	1500		5.4	3.2	44.1	3.0	8.3	35.1	9.09	5.62	0.23	0.09	15.03	18.70	53	80.4	3.9	1770	363	6.04
B4	1800		4.3	2.4	43.2	2.0	8.9	35.0	8.41	5.45	0.20	0.05	14.12	17.28	49	81.7	4.8	2640	450	6.11

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
A	4.1	0.1	3.4	0.4	0.3	0.0	0.0	90.1	0.3	0.1	3.5	102.4
B1	8.0	0.2	4.8	0.5	0.2	0.0	0.0	82.3	0.4	0.1	6.4	102.8
B2	8.6	0.2	5.2	0.5	0.3	0.0	0.0	80.1	0.4	0.1	6.8	102.2
B3	9.7	0.2	6.1	0.6	0.8	0.1	0.0	76.3	0.4	0.1	7.9	102.2
B4	10.1	0.2	5.6	0.6	0.4	0.0	0.0	77.0	0.4	0.1	8.2	102.6

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
A	5	69	121	12	35	22	6	3	29	12	10	309	3	<6	232	7	<2	<2
B1	9	99	161	18	51	24	7	6	51	13	12	285	5	<6	329	9	3	<2
B2	8	102	214	16	54	26	<4	6	51	13	11	269	5	10	383	9	3	<2
B3	9	112	203	31	110	26	11	3	53	16	18	267	5	<6	506	11	6	<2
B4	10	108	203	23	80	28	6	5	56	15	14	270	5	<6	432	10	5	<2

Horizon	Mineralogy of the clay fraction (% m/m)													
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
A	24	30		25				23	23						
B1	25	29	23				24	24							
B2	26	22	20	19			20	20							
B3	27	29		22				26	23						
B4	28	28	22				25	25							

Profile No: SCC07 (LTX P3 Hansen Geel)
Latitude & Longitude: 26°24'59"S; 26°09'32"E
Surface stoniness: none
Elevation: 1506 m
Terrain unit: upper midslope
Slope: 1%
Slope shape: convex
Aspect: level
Micro relief: none
Parent material solum: binary aeolian
Underlying material: granite
Geological Group: Platberg

Soil form: Avalon
Soil family: 2200
Surface rockiness: none
Occurrence of flooding: none
Wind erosion: slight
Water erosion: none
Vegetation / Land use: agronomic cash crops
Water table: none
Described by: CvH / EL
Date described: June 2016
Weathering of underlying material: strong physical; strong chemical
Alteration of underlying material: ferruginised

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 300	**Moisture status:** dry; **dry colour:** 7.5YR6/4; **moist colour:** 7.5YR4/4; weak fine crumb; slightly firm; few normal fine and very fine pores; few normal medium and coarse pores; water absorption 1 second(s); few normal roots; gradual smooth transition;	orthic A horizon
B1	300 – 700	**Moisture status:** dry; **dry colour:** 7.5YR7/8; **moist colour:** 7.5YR5/6; few medium distinct yellow oxidised Fe oxide mottles; weak medium subangular blocky; soft, friable, slightly sticky; few normal fine and very fine pores; few normal medium and coarse pores; very few coarse angular fragments; water absorption 1 second(s); few normal roots; gradual smooth transition;	yellow brown apedal B horizon
B2	700 – 1200	**Moisture status:** dry; **dry colour:** 7.5YR7/8; **moist colour:** 7.5YR5/6; common medium distinct yellow, olive, brown oxidised Fe oxide mottles, common medium prominent yellow, brown, red oxidised iron oxide mottles; weak fine subangular blocky; slightly firm; few normal fine and very fine pores; few normal medium & coarse pores; very few fine sesquioxide concretions/nodules; water absorption 1 second(s); few normal roots; gradual smooth transition;	soft plinthic B horizon
B3	1200 – 1700	**Moisture status:** dry; **dry colour:** 7.5YR7/8; **moist colour:** 7.5YR5/6; many medium distinct yellow, red, black oxidised Fe oxide mottles; many medium prominent yellow, brown, red oxidised Fe oxide mottles; weak medium, subangular blocky; firm; few very normal fine and fine pores; few normal medium and coarse pores; few fine sesquioxide concretions/nodules; few normal roots; clear smooth transition;	hard plinthic B horizon
B4	1700 – 2000	**Moisture status:** dry; **dry colour:** 5YR7/4; **moist colour:** 5YR5/3; many medium distinct yellow, red, brown oxidised Fe oxide mottles; many medium prominent yellow, brown, red oxidised Fe oxide mottles; weak medium subangular blocky; very firm; few normal very fine and fine pores; few medium and coarse pores; common fine sesquioxide concretions/nodules; water absorption 1 second(s); few normal roots; transition not reached.	hard plinthic B horizon

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 7 Soil analyses for profile SCC06 (Hansen Geel)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						($cmol_c$ kg^{-1})							(%)	mg kg^{-1}			
A	300		9.5	6.2	55.5	5.2	8.5	12.2	4.04	1.06	0.28	0.04	5.42	7.83	64	69.2	83.6	4100	658	6.06
B1	700		8.7	5.0	47.9	5.1	10.5	22.1	4.36	1.27	0.12	0.05	5.81	9.35	42	62.1	6.5	3390	600	5.92
B2	1200		11.7	4.3	40.7	13.6	9.1	23.9	3.08	3.47	0.11	0.06	6.72	9.89	41	68.0	5.0	3200	642	5.94
B3	1700		12.7	4.6	40.9	5.5	9.9	26.1	2.84	3.80	0.13	0.06	6.83	8.91	34	76.6	5.1	2930	605	5.87
B4	2000		18.5	6.2	44.5	8.5	10.9	13.4	2.37	2.46	0.13	0.06	5.02	7.07	53	71.1	3.5	1460	375	5.87

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
A	4.4	0.1	3.5	0.7	0.4	0.0	0.0	88.1	0.3	0.1	3.2	101.0
B1	7.4	0.1	4.8	0.7	0.2	0.0	0.0	83.4	0.4	0.1	5.2	102.3
B2	8.7	0.1	5.9	0.6	0.2	0.0	0.0	78.2	0.4	0.1	6.3	100.7
B3	9.1	0.1	6.2	0.7	0.7	0.1	0.0	78.4	0.5	0.1	6.5	102.2
B4	6.1	0.1	6.9	0.8	0.7	0.3	0.0	81.5	0.4	0.1	4.5	101.3

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
A	6	78	154	8	33	22	6	3	40	17	10	329	4	<6	271	8	3	<2
B1	7	98	165	11	50	22	6	5	49	18	10	310	5	<6	312	7	3	<2
B2	11	102	172	19	67	24	6	5	48	14	11	298	5	<6	340	8	6	<2
B3	11	121	198	36	88	24	6	7	51	15	14	328	6	<6	441	14	4	<2
B4	8	144	238	95	100	15	12	3	43	17	21	382	6	<6	1404	29	3	<2

Horizon	Mineralogy of the clay fraction (% m/m)													
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
A	24		22				22	22					9		
B1	25		22				23	22					8		
B2	33	34					33								
B3	25	27	24				24								
B4	28	21	20				21						10		

Profile No: SCC08 (LTX P4 Hansen Rooi)
Latitude & Longitude: 26°25'13"S; 26°09'60"E
Surface stoniness: none
Elevation: 1507 m
Terrain unit: upper midslope
Slope: 1%
Slope shape: convex
Aspect: level
Micro relief: none
Parent material solum: binary aeolian
Underlying material: granite
Geological Group: Platberg

Soil form: Lichtenburg (Hutton)
Soil family: 1100
Surface rockiness: none
Occurrence of flooding: none
Wind erosion: slight
Water erosion: none
Vegetation / Land use: agronomic cash crops
Water table: none
Described by: CvH / EL
Date described: June 2016
Weathering of underlying material: strong physical; strong chemical
Alteration of underlying material: ferruginised

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 300	**Moisture status:** dry; **dry colour:** 2.5YR4/6; **moist colour:** 2.5YR3/4; weak medium subangular blocky; few normal fine and very fine pores; few normal medium and coarse pores; very few coarse fragments; water absorption 1 second(s); few normal roots; clear smooth transition;	orthic A horizon
B1	300 – 900	**Moisture status:** dry; **dry colour:** 2.5YR5/8; **moist colour:** 2.5YR4/6; weak medium subangular blocky; few normal fine and very fine pores; few normal medium and coarse pores; very few coarse angular fragments; water absorption 1 second(s); few normal roots; gradual smooth transition;	red apedal B horizon
B2	900 – 1300	**Moisture status:** dry; **dry colour:** 2.5YR5/8; **moist colour:** 2.5YR4/4; few fine faint yellow, brown, red mottles; weak medium subangular blocky; few normal fine and very fine pores; few normal medium and coarse pores; very few medium sesquioxide concretions/nodules; water absorption 1 second(s); few normal roots; gradual smooth transition;	red apedal horizon
B3	1300 – 1800	**Moisture status:** dry; **dry colour:** 2.5YR5/8; **moist colour:** 2.5YR4/6; common coarse prominent yellow, brown, red mottles; weak medium subangular blocky; few normal fine and very fine pores; few normal medium and coarse pores; pisolithtic pan, strong, continuous Fe and Mn oxides; common medium sesquioxide concretions/nodules; water absorption 1 second(s); few normal roots; transition not reached.	hard plinthic B horizon

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 8 Soil analyses for profile SCC08 (Hansen Rooi)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						($cmol_c\ kg^{-1}$)							(%)	mg kg^{-1}			
A	300		16.2	7.4	48.7	8.8	5.9	12.5	3.58	1.01	0.19	0.05	4.83	7.61	61	63.5	116.7	2340	356	5.76
B1	900		17.1	7.7	48.4	7.1	8.0	12.6	3.15	0.96	0.18	0.03	4.33	7.83	62	55.3	9.8	2080	398	6.05
B2	1300		19.3	7.4	46.8	6.2	8.9	12.0	3.44	1.01	0.10	0.03	4.58	7.07	59	64.8	7.7	2090	363	6.20
B3	1800		20.5	8.2	43.9	5.9	7.2	14.8	2.47	1.40	0.13	0.04	4.05	6.96	47	58.2	6.1	1880	317	6.02

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
A	4.5	0.1	3.2	1.0	0.2	0.0	0.1	89.9	0.3	0.2	2.5	102.0
B1	5.5	0.1	4.0	1.0	0.1	0.0	0.0	87.3	0.3	0.2	2.9	101.4
B2	5.3	0.1	3.9	1.1	0.3	0.0	0.0	86.7	0.3	0.2	3.2	101.0
B3	6.3	0.1	5.9	1.0	0.6	0.1	0.0	82.3	0.3	0.1	3.8	100.6

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
A	4	67	147	8	26	18	7	1	52	21	9	321	4	<6	268	9	3	<2
B1	4	77	122	8	30	15	6	2	57	21	10	331	5	<6	292	7	6	<2
B2	5	80	123	10	30	14	<4	2	56	22	10	293	5	<6	310	8	3	<2
B3	4	105	194	26	39	15	9	4	58	22	12	351	5	<6	496	25	5	<2

Horizon	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
A	25		20					20	16			19			
B1															
B2	18		19			20		19	15				9		
B3	24		19				16	21	13				8		

Profile No: SCC09 (V1 / Delport 1)
Latitude & Longitude: 26°53'01"S; 26°56'42"E
Surface stoniness: none
Elevation: 1305 m
Terrain unit: lower footslope
Slope: 2%
Slope shape: concave
Aspect: south-east
Micro relief: none
Parent material solum: single alluvium
Underlying material: sand
Geological Group: Quaternary

Soil form: Pinedene
Soil family: 1100
Surface rockiness: none
Occurrence of flooding: none
Wind erosion: none
Water erosion: none
Vegetation / Land use: Grassveld, open
Water table: 6000 mm
Described by: CvH / JD
Date described: June 2016
Weathering of underlying material: weak physical; weak chemical
Alteration of underlying material: generalised

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 400	**Moisture status:** dry; **dry colour:** 7.5YR6/4; **moist colour:** 7.5YR4/3; apedal single grain; loose; few normal fine and very fine pores; few normal medium and coarse pores; water absorption 1 second(s); few normal roots; diffuse smooth transition;	orthic A horizon
B1	400 – 800	**Moisture status:** dry; **dry colour:** 7.5YR6/6; **moist colour:** 7.5YR5/6; apedal single grain; loose; few normal fine and very fine pores; few normal medium and coarse pores; very few coarse angular fragments; water absorption 1 second(s); few normal roots; gradual smooth transition;	yellow brown apedal B horizon
B2	800 – 1500	**Moisture status:** dry; **dry colour:** 7.5YR6/8; **moist colour:** 7.5YR5/6; apedal single grain; loose; few normal fine and very fine pores; few normal medium & coarse fragments; very few angular coarse fragments; water absorption 1 second(s); few normal roots; clear smooth transition;	yellow brown apedal B horizon
B3	1500 – 3000	**Moisture status:** dry; **dry colour:** 7.5YR8/4; **moist colour:** 7.5YR7/4; apedal massive; loose; few normal fine and very fine pores; few normal medium and coarse pores; no slickensides; fine cracks; very many silica cutans; no coarse fragments; water absorption 1 second(s); few normal roots; transition not reached;	E horizon

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 9 Soil analyses for profile SCC09 (V1 / Delport 1)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						($cmol_c$ kg^{-1})							(%)	mg kg^{-1}			
A	400		19.1	55.9	23.9	0.5	0.7	0.2	2.40	0.50	0.13	0.03	3.06	4.78	2109	64.1	9.9	1800	299	5.85
B1	800		12.2	27.0	58.0	1.0	0.8	2.1	2.10	0.28	0.15	0.04	2.57	4.78	228	53.8	11.9	1350	235	5.70
B2	1500		14.0	39.1	38.9	8.7	0.0	3.5	2.19	0.48	0.08	0.04	2.79	3.91	112	71.4	12.0	904	179	5.13
B3	3000		11.6	47.9	38.4	0.7	0.4	1.1	1.96	0.55	0.07	0.05	2.63	3.70	326	71.1	13.3	679	109	5.14
lamellae	3000		12.6	42.5	42.0	0.8	0.5	2.4	2.00	0.58	0.09	0.04	2.71	3.80	158	71.2	13.1	682	159	5.35
matrix	3000		6.5	32.0	56.1	8.5	0.4	0.5	2.02	0.43	0.06	0.04	2.55	3.70	673	69.0	9.5	563	85	5.27

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
A	2.3	0.1	2.6	0.9	0.1	0.0	0.0	93.1	0.2	0.2	0.7	100.2
B1	2.5	0.1	2.2	0.9	0.2	0.0	0.0	94.6	0.2	0.2	0.8	101.7
B2	3.3	0.1	2.8	1.0	0.3	0.0	0.0	92.4	0.3	0.2	1.1	101.5
B3	2.6	0.1	2.3	1.0	0.1	0.0	0.0	94.2	0.2	0.3	0.6	101.3
lamellae	3.0	0.1	2.6	1.0	0.1	0.0	0.0	93.0	0.2	0.3	0.7	101.1
matrix	2.7	0.1	1.8	1.1	0.1	0.0	0.0	94.9	0.3	0.3	0.5	101.7

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
A	<2	38	49	8	18	4	<4	1	30	25	5	311	2	<6	263	7	4	<2
B1	<2	42	47	6	15	3	5	1	31	27	6	350	2	<6	273	7	<2	<2
B2	3	52	60	9	21	5	<4	<1	35	29	8	382	3	<6	308	9	4	<2
B3	3	36	47	7	16	4	<4	<1	30	30	7	300	2	<6	250	10	3	<2
lamellae	2	44	51	7	18	4	<4	<1	33	31	7	349	2	<6	293	9	4	<2
matrix	<2	47	55	6	13	3	5	<1	34	34	8	503	3	<6	318	7	4	<2

Horizon	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
A															
B1															
B2															
B3															
lamellae															
matrix															

Profile No: SCC10 (V2 / Delport 2)
Latitude & Longitude: 26°52'47"S; 26°56'59"E
Surface stoniness: none
Elevation: 1297 m
Terrain unit: valley bottom
Slope: 1%
Slope shape: concave
Aspect: north-east
Micro relief: none
Parent material solum: single alluvium
Underlying material: sand
Geological Group: Quaternary

Soil form: Sepane
Soil family: 2110
Surface rockiness: none
Occurrence of flooding: occasional
Wind erosion: none
Water erosion: none
Vegetation / Land use: Grassveld, open
Water table: none
Described by: CvH / JD
Date described: June 2016
Weathering of underlying material: moderate physical; moderate chemical
Alteration of underlying material: generalised

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 550	**Moisture status:** dry; **dry colour:** 7.5YR5/2; **moist colour:** 7.5YR3/3; weak fine crumb; hard, friable, common normal fine and very fine pores; common normal medium and coarse pores; water absorption 1 second(s); few normal roots; clear smooth transition;	orthic A horizon
B	550 – 1050	**Moisture status:** dry; **dry colour:** 10YR5/3; **moist colour:** 10YR4/2; common medium distinct grey and yellow oxidised iron oxide mottles; strong fine subangular blocky; hard, friable; common normal fine and very fine pores; common normal medium and coarse pores; water absorption 1 second(s); few normal roots; clear smooth transition;	pedocutanic B horizon
C	1050 – 1700	**Moisture status:** dry; **dry colour:** 10YR5/2; **moist colour:** 10YR3/2; common medium faint olive oxidised iron oxide mottles; strong fine subangular blocky ;hard, friable; common normal fine and very fine pores; common normal medium & coarse pores; water absorption 1 second(s); few normal roots; transition not reached;	Unconsolidated material with signs of wetness

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 10 Soil analyses for profile SCC10 (V2 / Delport 2)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						(cmol$_c$ kg^{-1})							(%)	mg kg^{-1}			
A	550		3.3	12.8	43.7	5.7	5.2	26.5	13.98	4.63	0.13	0.16	18.90	13.48	51	140.2	17.3	5040	578	5.96
B	1050		1.4	4.6	48.9	9.8	4.5	29.9	14.96	5.29	0.13	0.21	20.59	15.65	52	131.5	11.6	4480	419	6.34
C	1700		9.5	10.8	36.0	5.0	21.9	21.2	15.08	5.79	0.16	0.38	21.41	16.09	76	133.1	31.8	6120	509	6.64

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
A	6.5	0.8	3.7	1.2	0.7	0.0	0.0	83.7	0.5	0.8	3.9	102.0
B	6.7	0.8	4.2	1.1	0.6	0.0	0.0	84.7	0.5	0.7	4.1	103.5
C	6.5	0.9	3.9	1.2	0.6	0.0	0.0	84.8	0.5	0.8	4.1	103.4

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
A	6	107	134	13	34	25	4	4	47	70	16	416	5	<6	441	13	7	<2
B	5	105	145	15	38	24	<4	2	48	70	14	354	5	<6	432	10	4	<2
C	7	104	139	14	32	23	<4	4	49	74	15	396	5	<6	468	12	4	<2

Horizon	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
A	20	19	25		28								9		
B	28		29					23				20			
C	27		27					26				21			

Profile No: SCC11 (E1 / Eleazer Mine)
Latitude & Longitude: 26°40'03"S; 26°52'18"E
Surface stoniness: none
Elevation: 1386 m
Terrain unit: upper midslope
Slope: 2%
Slope shape: concave
Aspect: south-west
Micro relief: other mounds
Parent material solum: binary spoil
Underlying material: quartzite, conglomerate & shale
Geological Group: Transvaal supergroup

Soil form: Witbank
Soil family: 1000
Surface rockiness: none
Occurrence of flooding: none
Wind erosion: severe
Water erosion: severe
Vegetation / Land use: mine spoil
Water table: none
Described by: CvH / JK
Date described: June 2016
Weathering of underlying material: advanced physical; strong chemical
Alteration of underlying material: ferruginised

Layer	Depth (mm)	Description	Diagnostic horizons / material
1	0 – 750	**Moisture status:** dry; **dry colour:** 5YR7/1; **moist colour:** 5YR5/1; apedal single grain; very hard, friable; cementation stratified; water absorption 1 second(s); abrupt smooth transition;	Man-made soil deposit
2	750 – 1150	**Moisture status:** dry; **dry colour:** 5YR5/1; **moist colour:** 5YR5/1; apedal single grain; very hard, friable; water absorption 1 second(s); abrupt smooth transition;	Man-made soil deposit
3	1150 – 1550	**Moisture status:** dry; **dry colour:** 5YR7/1; **moist colour:** 5YR5/1; few fine prominent yellow and brown mottles; apedal single grain; very hard, friable; water absorption 1 second(s); abrupt smooth transition;	Man-made soil deposit
4	1550 – 1650	**Moisture status:** dry; **dry colour:** 5YR7/1; **moist colour:** 5YR5/1; few fine prominent yellow and brown mottles; apedal single grain; very hard, friable; water absorption 1 second(s); abrupt smooth transition;	Man-made soil deposit
5	1650 – 2000	**Moisture status:** dry; **dry colour:** G25/10B; **moist colour:** G27/5BG; apedal single grain; very hard, friable; water absorption 1 second(s); abrupt smooth transition;	Man-made soil deposit

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 11 Soil analyses for profile SCC11 (E1 / Eleazer Mine)

Layer	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						(cmol$_c$ kg^{-1})							(%)	mg kg^{-1}			
1	750		2.3	1.6	36.6	12.1	19.4	32.1	3.32	1.36	0.03	0.08	4.78	4.78	15	100.0	15.2	2310	108	3.35
2	1150		0.6	2.8	56.6	0.0	11.5	24.2	2.15	1.11	0.03	0.06	3.35	4.89	20	68.5	36.0	2790	145	3.31
3	1550		0.3	0.2	54.2	0.0	12.8	33.5	2.28	0.76	0.03	0.06	3.13	5.22	16	59.9	70.9	2440	81	3.34
4	1650		1.6	0.6	12.6	0.0	62.6	26.9	3.04	5.62	0.04	0.06	8.76	9.35	35	93.7	5.2	2790	97	3.01
5	2000		0.2	1.4	69.0	2.8	7.5	15.6	3.59	0.53	0.03	0.05	4.20	5.22	33	80.4	34.3	2680	152	3.29

Layer	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
1	8.5	0.1	5.5	3.2	1.6	0.0	0.0	78.6	0.4	0.1	4.3	102.4
2	8.0	0.1	4.9	3.1	1.5	0.0	0.0	80.0	0.4	0.0	4.6	102.5
3	7.4	0.1	5.3	2.9	1.1	0.0	0.0	81.1	0.4	0.0	4.4	102.9
4	11.4	0.2	5.9	4.2	1.8	0.0	0.0	68.3	0.5	0.1	9.2	101.5
5	7.8	0.1	5.0	3.2	1.2	0.0	0.0	80.3	0.4	0.0	3.9	101.9

Layer	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
1	12	100	394	19	67	98	32	<1	98	12	26	380	9	<6	332	28	19	18
2	10	86	359	19	67	120	27	<1	87	10	28	427	10	<6	320	25	20	17
3	10	87	409	15	56	87	32	<1	85	10	26	473	10	<6	323	25	18	17
4	12	119	452	41	121	281	38	<1	126	12	39	469	11	<6	423	43	29	32
5	7	89	411	19	62	93	24	<1	92	10	27	483	10	<6	331	21	20	17

Layer	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
1															
2															
3															
4															
5															

Profile No: SCC12 (E2 / Eleazer Mine)
Latitude & Longitude: 26°40'19"S; 26°52'30"E
Surface stoniness: none
Elevation: 1381 m
Terrain unit: upper footslope
Slope: 2%
Slope shape: concave
Aspect: west
Micro relief: none
Parent material solum: binary alluvium
Underlying material: dolomite & chert
Geological Group: Chuniespoort

Soil form: Witbank
Soil family: 1000
Surface rockiness: none
Occurrence of flooding: none
Wind erosion: severe
Water erosion: severe
Vegetation / Land use: mine spoil
Water table: none
Described by: CvH / JD
Date described: June 2016
Weathering of underlying material: advanced physical; strong chemical
Alteration of underlying material: ferruginised

Layer	Depth (mm)	Description	Diagnostic horizons / material
1	0 – 950	**Moisture status:** dry; **dry colour:** 5YR8/2; **moist colour:** 5YR5/4; few medium prominent red oxidised iron oxide mottles; apedal single grain; hard, friable, non-sticky, non-plastic; water absorption 1 second(s); abrupt smooth transition;	Man-made soil deposit
2	950 – 1500	**Moisture status:** dry; **dry colour:** 5YR8/2; **moist colour:** 5YR6/1; apedal single grain; hard, friable, non-sticky, non-plastic; water absorption 1 second(s);	Man-made soil deposit

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 12 Soil analyses for profile SCC12 (E2 / Eleazer Mine)

Layer	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						(cmol$_c$ kg^{-1})							(%)	mg kg^{-1}			
1	950		16.4	9.3	52.3	0.0	5.0	16.5	1.22	0.18	0.06	0.04	1.51	3.80	23	39.6	7.3	1660	174	3.61
2	1500		0.9	0.6	66.8	18.0	7.8	9.2	0.77	0.13	0.03	0.03	0.96	3.91	42	24.6	4.1	1310	77	3.34

Layer	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
1	1.7	0.0	3.3	0.5	0.1	0.0	0.0	95.8	0.1	0.0	0.7	102.3
2	2.2	0.0	2.9	0.8	0.3	0.0	0.0	94.3	0.1	0.1	0.7	101.3

Layer	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
1	<2	22	113	4	13	7	25	<1	17	9	4	105	<1	<6	80	12	3	3
2	<2	25	122	5	13	6	20	<1	22	10	5	102	1	<6	110	13	2	3

Layer	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
1															
2															

Profile No: SCC13 (Palmietkuil 062)
Latitude & Longitude: 27°01'44"S; 27°19'50"E
Surface stoniness: gravel
Elevation: 1456 m
Terrain unit: lower midslope
Slope: 3%
Slope shape: convex
Aspect: north-east
Micro relief: none
Parent material solum: single solid rock
Underlying material: granite & gneiss
Geological Group: Swazian era

Soil form: Katspruit
Soil family: 2000
Surface rockiness: none
Occurrence of flooding: none
Wind erosion: none
Water erosion: slight
Vegetation / Land use: agronomic cash crops
Water table: none
Described by: HBB
Date described: Nov 2015
Weathering of underlying material: moderate physical
Alteration of underlying material: generalised

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 200	**Moisture status:** moist; **dry colour:** 7.5YR5/8; **moist colour:** 7.5YR5/3; few fine distinct red and yellow reduced iron oxide mottles; weak fine subangular blocky; slightly hard, friable, non-sticky, non-plastic; common normal fine and very fine pores; common normal medium and angular coarse pores; fine cracks; very few mixed shape coarse gravel fragments; water absorption 5 second(s); few normal roots; clear wavy transition;	orthic A horizon
G1	200 – 400	**Moisture status:** moist; **dry colour:** 7.5YR4/2; **moist colour:** 7.5YR3/2; many medium distinct red and yellow reduced iron oxide mottles; weak medium subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; common normal fine and very fine pores; common normal medium and coarse pores; very few mixed shape coarse gravel fragments; water absorption 25 second(s); common normal roots; gradual wavy transition;	G horizon
G2	400 – 1200	**Moisture status:** moist; **dry colour:** 7.5YR5/3; **moist colour:** 7.5Y4/3; many medium distinct red and yellow reduced iron oxide mottles weak medium subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; common normal fine and very fine pores; common normal medium & coarse pores; very few mixed shape coarse gravel fragments; water absorption 25 second(s); few normal roots; gradual wavy transition.	G horizon

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 13 Soil analyses for profile SCC13 (Palmietkuil 062)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						($cmol_c$ kg^{-1})							(%)	mg kg^{-1}			
A	200		25.4	9.8	30.6	5.0	12.4	13.1	7.77	5.12	0.35	0.20	13.45	15.76	120	85.3	80.6	10400	1121	6.46
G1	400		20.4	16.5	25.9	5.2	13.3	22.2	8.30	7.60	0.21	1.27	17.39	19.24	87	90.4	9.4	9770	996	7.00
G2	600		16.0	7.0	22.1	4.8	9.2	44.1	14.16	12.73	0.23	2.26	29.37	23.15	53	126.9	4.9	7760	660	8.03
G2	800		17.2	5.3	16.6	3.9	13.3	42.1	41.40	19.17	0.22	3.83	64.62	85.87	204	75.3	3.0	21200	461	8.60
G2	1000		15.7	5.3	16.2	2.5	14.7	41.5	40.50	20.17	0.23	4.87	65.77	71.74	173	91.7	2.9	22900	365	8.74

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
A	6.4	0.5	5.3	0.9	0.4	0.1	0.1	82.3	0.5	0.2	5.9	102.4
G1	8.7	0.4	5.7	0.9	0.9	0.1	0.0	75.9	0.5	0.2	7.7	101.0
G2	10.2	0.8	5.9	0.8	0.7	0.1	0.0	73.3	0.5	0.3	9.1	101.8
G2	10.1	7.5	5.7	0.7	1.3	0.1	0.0	62.1	0.4	0.3	14.7	102.6
G2	9.9	7.9	5.8	0.7	1.4	0.1	0.0	59.9	0.4	0.3	14.9	101.2

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
A	9	110	184	18	44	32	7	11	33	39	12	279	4	<6	445	10	3	<2
G1	11	122	190	20	52	29	4	30	41	42	13	276	4	<6	478	10	3	<2
G2	11	121	216	17	56	32	4	23	41	45	14	247	5	<6	441	7	5	<2
G2	12	117	182	19	58	31	5	10	37	111	14	202	3	<6	1789	8	<2	<2
G2	12	116	186	21	56	29	6	7	34	91	15	199	3	<6	863	9	4	<2

Horizon	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
	34	26					28						12		
	32				37			31						19	
	21				22		19	19							
	25				29	23		23							
	18	17	20	5	24	16								16	

Profile No: SCC14 (Palmietkuil 079)
Latitude & Longitude: 27°01'49"S; 27°19'37"E
Surface stoniness: class 2 (2-10%) round and flat coarse gravel
Elevation: 1475 m
Terrain unit: lower midslope
Slope: 2%
Slope shape: convex
Aspect: north-east
Micro relief: none
Parent material solum: single solid rock
Underlying material: granite & gneiss
Geological Group: Swazian era

Soil form: Westleigh
Soil family: 2000
Surface rockiness: none
Occurrence of flooding: none
Wind erosion: none
Water erosion: slight
Vegetation / Land use: agronomic cash crops
Water table: none
Described by: HBB
Date described: Nov 2015
Weathering of underlying material: moderate physical; moderate chemical
Alteration of underlying material: generalised

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 200	**Moisture status:** moist; **dry colour:** 7.5YR5/4; **moist colour:** 7.5YR4/4;few fine faint red and yellow oxidised iron oxide mottles; weak fine subangular blocky; slightly hard, friable, non-sticky, non-plastic; common normal fine and very fine pores; common normal medium and coarse pores; fine cracks; very few mixed shape coarse gravel fragments; water absorption 5 second(s); few normal roots; clear wavy transition;	orthic A horizon
B1	200 – 300	**Moisture status:** moist; **dry colour:** 7.5YR5/4; **moist colour:** 7.5YR3/4; common fine distinct grey and yellow reduced iron oxide mottles; moderate fine subangular blocky; hard, friable, slightly sticky, slightly plastic; common normal fine and very fine pores; common normal medium and coarse pores; fine cracks; few mixed shape coarse gravel fragments; water absorption 25 second(s); few normal roots; gradual wavy transition;	soft plinthic B horizon
B2	300 – 800	**Moisture status:** moist; **dry colour:** 7.5YR4/6; **moist colour:** 7.5YR4/6; many medium prominent grey and yellow reduced iron oxide mottles; weak fine subangular blocky; slightly hard, friable, non-sticky, non-plastic; common normal fine and very fine pores; common normal medium & coarse fragments; few mixed shaped coarse gravel fragments; water absorption 25 second(s); gradual wavy transition;	soft plinthic B horizon
B3	800 – 1200	**Moisture status:** moist; **dry colour:** 7.5YR7/7; **moist colour:** 7.5YR5/6; common medium prominent grey and yellow reduced iron oxide mottles; apedal single grain; slightly hard, loose, non-sticky, non-plastic; common normal fine and very fine pores; common normal medium and coarse pores; fine cracks; very few mixed shape coarse fragments; water absorption 5 second(s); transition not reached.	unspecified material with signs of wetness

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 14 Soil analyses for profile SCC14 (Palmietkuil 079)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						($cmol_c$ kg^{-1})							(%)	mg kg^{-1}			
A	200		16.2	12.3	37.1	6.8	10.5	12.5	7.29	2.61	0.43	0.06	10.39	12.17	97	85.4	61.2	9120	830	6.62
B1	400		9.5	8.6	36.8	3.7	13.6	28.6	6.14	3.80	0.30	0.07	10.31	14.02	49	73.5	14.9	8390	747	6.60
B2	600		14.8	6.7	24.0	3.9	15.0	31.4	7.02	4.96	0.30	0.09	12.37	24.35	78	50.8	4.6	8550	867	6.45
B2	800		9.1	5.8	21.4	4.4	15.9	40.3	7.23	6.78	0.28	0.17	14.46	20.54	51	70.4	3.7	6610	673	6.33
B3	1000		30.0	7.8	21.1	8.1	19.4	18.2	15.04	11.74	0.35	0.30	27.43	25.11	138	109.3	4.7	2090	361	6.66
B3	1200		14.7	6.5	25.1	5.1	17.0	33.5	13.15	10.74	0.34	0.23	24.47	27.39	82	89.3	3.3	4460	595	6.68

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
A	6.2	0.6	5.8	0.8	0.8	0.1	0.1	82.3	0.6	0.2	5.3	102.8
B1	8.1	0.4	6.6	0.9	0.4	0.1	0.0	77.5	0.7	0.2	6.7	101.4
B2	14.6	0.3	10.2	0.8	0.6	0.2	0.0	62.9	0.6	0.1	11.7	102.0
B2	16.6	0.3	10.3	0.7	0.7	0.1	0.0	59.0	0.6	0.1	12.9	101.3
B3	17.7	3.5	11.3	0.8	2.9	0.1	0.1	51.2	0.9	0.7	11.3	100.4
B3	18.3	1.3	11.3	0.8	1.4	0.1	0.0	52.5	0.8	0.3	13.9	100.6

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
A	11	132	214	18	48	31	7	6	33	32	14	336	5	<6	456	9	4	<2
B1	13	155	273	39	79	33	9	10	46	28	15	299	5	<6	508	10	4	<2
B2	17	159	283	61	89	33	<4	12	45	25	16	262	5	<6	553	9	2	<2
B2	22	184	350	48	130	41	5	13	53	21	20	224	4	<6	518	10	<2	<2
B3	26	208	252	42	111	56	6	5	38	90	27	119	4	<6	729	5	<2	<2
B3	25	203	381	45	144	43	<4	10	43	41	24	158	4	<6	684	7	3	<2

Horizon	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
A	18				18	16	16	16							
B1	35	32					33								
B2	32	33					35								
B2	34	31					35								
B3	33	35					32								
B3	34	33					33								

Profile No: SCC15 (Palmietkuil 101)
Latitude & Longitude: 27°01'56"S; 27°19'24"E
Surface stoniness: class 3 (10-25%) angular stones and coarse stones
Elevation: 1488 m
Terrain unit: midslope
Slope: 3%
Slope shape: concave
Aspect: south
Micro relief: none
Parent material solum: single
Underlying material: granite & gneiss
Geological Group: Swazian era

Soil form: Rensburg
Soil family: 1200
Surface rockiness: class 1 (<2%)
Occurrence of flooding: none
Wind erosion: slight
Water erosion: slight
Vegetation / Land use: agronomic cash crops
Water table: none
Described by: HBB
Date described: Oct 2015
Weathering of underlying material: moderate physical; moderate chemical
Alteration of underlying material: generalised

Horizon	Depth (mm)	Description	Diagnostic horizons / material
A	0 – 450	**Moisture status:** dry; **dry colour:** 7.5YR5/2; **moist colour:** 7.5YR3/2; few fine distinct black geogenic mottles; strong medium granular; hard, firm, sticky, plastic; many normal fine and very fine pores; many normal medium and coarse pores; medium cracks; few slickensides; common clay cutans; water absorption 25 second(s); few normal roots; clear wavy transition;	vertic A horizon
B1	450 – 650	**Moisture status:** dry; **dry colour:** 7.5YR5/1; **moist colour:** 7.5YR4/1; common fine distinct grey and yellow reduced iron oxide mottles; strong medium granular; hard, firm, sticky, plastic; many normal fine and very fine pores; many normal medium and coarse pores; medium cracks; many slickensides; common clay cutans; very few coarse gravel fragments; water absorption 25 second(s); few normal roots; clear wavy transition;	unspecified material with signs of wetness
B2	650 – 1500	**Moisture status:** dry; **dry colour:** 7.5YR7/1; **moist colour:** 7.5YR6/1; common fine distinct grey and yellow reduced iron oxide mottles; strong fine granular; hard, firm, sticky, plastic; many normal fine and very fine pores; few slickensides; common clay cutans; common mixed shape stone and coarse stone fragments; water absorption second(s); few normal roots; transition not reached.	saprolite

WRB:

diagnostics:

Soil Taxonomy:

diagnostics:

Table 15 Soil analyses for profile SCC15 (Palmietkuil 101)

Horizon	Depth	Gravel	Texture of the fine earth						Exchangeable cations					CEC soil	CEC clay	Base sat	P	Org C	N	pH H_2O
			coSa	meSa	fiSa	coSi	fiSi	Cl	Ca	Mg	K	Na	Sum							
	(mm)	(%)	(%)						(cmol$_c$ kg^{-1})							(%)	mg kg^{-1}			
A1	250		5.0	5.2	23.1	1.5	4.1	60.3	20.20	7.77	0.66	0.63	29.26	33.91	56	86.3	72.1	10400	1021	6.62
A2	500		5.0	4.3	20.0	7.6	2.6	62.1	18.60	8.68	0.50	1.58	29.35	35.65	57	82.3	7.1	6850	692	7.04
B1	1000		3.0	3.7	17.0	1.7	3.3	70.8	21.55	11.74	0.51	3.33	37.13	35.98	51	103.2	8.0	6040	575	7.51
B2	1200		4.0	3.2	13.1	0.0	4.2	79.5	28.05	13.47	0.58	4.22	46.32	41.96	53	110.4	5.8	6000	394	7.89

Horizon	Major elements (%)											
	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	P_2O_5	SiO_2	TiO_2	Na_2O	LOI	Total
	(%)											
	9.9	0.6	5.3	0.8	0.7	0.1	0.1	72.0	0.5	0.1	12.3	102.4
	12.8	0.6	6.2	0.9	1.1	0.0	0.0	66.9	0.6	0.1	12.4	101.8
	12.8	0.6	6.2	0.9	0.9	0.0	0.0	67.0	0.6	0.2	12.9	102.2
	13.1	2.4	6.2	0.9	1.3	0.0	0.0	63.8	0.6	0.2	14.0	102.8

Horizon	Trace elements (ppm)																	
	Sc	V	Cr	Co	Ni	Zn	As	Br	Rb	Sr	Y	Zr	Nb	Ag	Ba	Pb	Th	U
	(mg kg^{-1})																	
	11	116	144	13	44	53	<4	4	64	45	16	272	7	<6	510	11	8	<2
	12	119	154	11	47	46	9	5	69	49	14	245	7	<6	502	12	7	<2
	11	132	170	15	54	49	5	6	77	62	17	220	7	<6	631	12	7	<2
	13	137	172	14	54	51	4	2	76	96	19	202	7	<6	893	12	5	<2

Horizon	Mineralogy of the clay fraction (% m/m)														
	Quartz	Kaolinite	Mica	Calcite	Smectite	Anatase	Goethite	Serpentine	Ilmenite	Pyroxene	Hematite	Plagioclase	K-feldspar	Apophyllite	Spinel
	26	21	23			20							10		
	24				26	21		20					10		
	20		26			23		21					10		
	25	22			29	24									

Field guide for an excursion to the

THE VREDEFORT STRUCTURE

Compiled by

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and
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University of the Free State

2010

Introduction

This introduction is taken for a large part verbatim from Bisschoff (1988), with a few alterations (mainly of terms: 'structure' instead of 'dome', for example) and additions by the authors. The descriptions of the stops are based on Bisschoff (1999) and Markgraaff and Bisschoff (1991). These additions are given in square brackets. All bold script text represents emphasis added by the authors.

The Vredefort structure (Figure 1), with its core of mainly Archaean granitic rocks and thick collar of sedimentary and igneous rocks, is one of more than a dozen domal structures in and around the rim of the Witwatersrand basin. In the formation of these structures all rocks up to, and including, the Transvaal Supergroup, were involved in the deformation of the basin. The Vredefort structure lies on a major lineament which is defined by the Great Dyke (Zimbabwe), the central part of the Bushveld Complex, the Pretoria-Johannesburg Dome, the Losberg intrusion, the Brandfort gravity anomaly, and the Trompsburg Complex. [These bodies are all of very different ages and the tectonic significance of this lineament is unclear. It is nearly 100% certain that the association of the Vredefort structure with the lineament is random.]

The southern part of the structure is covered by Karoo rocks, but gravity and borehole data prove that it is pear-shaped in plan. The collar rocks are overturned only in the continuously exposed northern half of the structure, whereas the formations in the southern half have normal outward dips. The granitic core of the structure has a diameter of 43 km along the north-eastern axis and about 55 km along the north-western axis. The structure is surrounded by a synclinorium (called the Potchefstroom synclinorium), the axis of which is regarded as the outer rim of the structure. The diameter of the structure is approximately 100 km along its north-eastern axis.

Another feature of the structure is the variation in dips of the overturned sedimentary rocks viewed from the core outwards. In the stratigraphically lower part of the collar, the overturning of the West Rand Group is less (100-110°) than the Central Rand Group formations (120-130°). Farther outwards in the Ventersdorp Supergroup and Transvaal Supergroup the overturning decreases again to a vertical position in the lower Transvaal strata, and reverts to normal dips (20-40°) in the Pretoria Group. The total thickness of the collar rocks which were involved in the deformation is about 19 km, taken from the unconformity between the Dominion Group and the Archaean granite to the top of the Magaliesberg quartzite, and includes a number of basic sills [and intrusive granite plugs]. The Roodekraal en Rietfontein complexes and the Lindequesdrift intrusion are emplaced along groups of major strike faults in the outer zone of the collar where the deformation was the most intense. There are also a number of major strike faults present in the Witwatersrand strata. The alkali granite plutons in the north-western sector are emplaced along some of these faults.

A crucial problem regarding the origin of the Vredefort Structure is the duration of the deformation processes. Did the deformation take place during a nearly instantaneous episode (a cryptoexplosion caused by gases from within the earth or by meteorite impact), one relatively short period of deformation (vertical and/or horizontal tectonic processes related to orogenesis and /or magmatism), or over an extended period (c. 500-600 Ma), in which one or more phases of deformation were active (diapirism)? Are the Vredefort Structure and the other domal structures referred to above genetically related or is the Vredefort Structure a unique structural entity? A reasonable conclusion can be arrived at only when the sequence of events in the history of the structure is firmly established.

More than 90 percent of the Archaean rocks of the core of the Vredefort Structure can be described as granitic gneisses and felsic granulites. The rest of the core is made up of a great variety of small bodies of metasediment, metabasite and meta-ultrabasite (basite = basic igneous rock). Two distinct meta-felsites can be identified in the central core: the one in contact with the Wits sedimentary rocks is in **amphibolite facies** and is referred to as the Outer Granite-Gneiss (OGG) or **Parys Granite** by various groups of researchers. It is a pink rock with quartz, orthoclase, plagioclase (An_{10}) and biotite as major minerals. It is mostly massive, but shows weak foliation in parts. The meta-felsite in the centre of the core is referred to as the Inlandsea Leucogranofels (ILG) or **Inlandsea Gneiss**. It consists largely of quartz and perthitic (i.e. K- and Na-rich) feldspar, with minor orthopyroxene. The ILG is in **granulite facies**, and the metamorphic grade increases towards the centre. Where the OGG and ILG meet, a broad zone (2-4 km) of charnokite is developed. The charnokite is much more orthopyroxene-rich that the ILG (>5%) and in addition contains significant amounts of water-rich minerals such as biotite and hornblende. The main feldspar is a plagioclase with composition An_{50}, indicating an enrichment in Ca, relative to the OGG, in the charnokitic zone.

On the basis of their petrology and relationships to the different events in the history of the Vredefort Structure, several other igneous rocks of different groups are distinguishable:

a. Epidiorites

These are basaltic to andesitic rocks which have undergone a "hydration metamorphism" in the production of a greenschist mineralogy. Some of these rocks were subsequently thermally metamorphosed in the hornblende hornfels facies and include the Dominion, Crown and Ventersdorp lavas as well as a number of sills and dykes which are intrusive into the Witwatersrand and Ventersdorp Supergroups.

b. Basic rocks

The rocks include the sills and dykes of dolerite, hyperite (gabbro-norite), norite and bronzitite (pyroxenite), and the Losberg complex. The basic intrusions are present in the Witwatersrand and Ventersdorp Supergroups, and in the Transvaal Supergroup and can be correlated with the mafic rocks of the Bushveld complex.

c. Dioritic and alkaline rocks.

Under this group are included the post-Transvaal complexes of Roodekraal and Rietfontein, the Schurwedraai and Baviaanskrans alkali granite plutons and associated mariupolite dykes. Dykes of alkali granite aplite in the north-eastern sector of the structure, and wehrlite intrusions on Koedoesfontein and Winddam also fall into this group.

d. The basic granophyre

This extraordinary rock type (named Vredefortite by Niggli) forms ring dykes in the Archaean granite and the Witwatersrand rocks close to the unconformity between them, and a few dykes in the Archaean granite up to about 10 km from the Dominion Group towards the center of the structure. *Today this intrusion is regarded as an impact melt* (italics added by M. Coetzee, NWU). The granophyre may be associated with the small outcrop of biotite-rich granite near the centre of the structure.

e. Post-Waterberg igneous rocks

These intrusions were emplaced after the formation of the structure was completed, and include the Annas Rust dolerite, and the Wonderfontein dyke.

f. Central ultramafite

This unusual rock has been interpreted by Tredoux et al. (1999) as upper mantle restite, based on geochemical evidence.]

Metamorphism

At least four main periods of metamorphism is recogniseable in the structure. The oldest is the pre-Witwatersrand metamorphism which is associated with the basement rocks and in which upper greenschist tot granulite facies were attained.

The three post-Witwatersrand metamorphic events include the low-grade (greenschist facies) regional metamorphism which has affected all formations up to the top of the Transvaal Supergroup, the thermal metamorphism which is restricted to the central part of the structure, and finally the development of the pseudotachylite (shock metamorphism).

Associated with the thermal metamorphism is the magmatism which led to the emplacement of the alkaline and dioritic complexes. The metamorphic aureole is roughly elliptical in plan and has its northernmost boundary near the contact between the Ventersdorp and Witwatersrand rocks and includes the granitic core and the greater part of the West Rand Subgroup adjacent to the core.

Pseudotachylite and shatter cones

Pseudotachylite and shattercones are present in all rocks, from the oldest basement rocks to the igneous rocks of Bushveld age – e.g. the dioritic and alkaline rocks, with the important exception of the basic granophyre. The pseudotachylite is absent or relatively rare in the granulitic rocks of the central part of the core. Pseudotachylite shows its peak development in the area at the base of the amphibolite facies of the core rocks (Figure 2) and in the collar rocks within the aureole of thermal metamorphism.

The shatter cones appear to be older than the pseudotachylite as some shatter cone surfaces have a thin veneer of pseudotachylite, and inclusions in the pseudotachylite may show shatter cone surfaces which do not cut the pseudotachylite.

In 1988, Prof Bisshoff wrote: “Taking into account the number of theories advanced to explain the origin of the Vredefort Structure, it is evident that researchers are confronted with a complex problem, consequently, firm adherence to any theory on the origin of this structure must be regarded as somewhat premature.” *Today the evidence supporting a meteorite impact origin is overwhelming.*

Age constraints

The age of the shock metamorphism, assumed to be the time of impact, has been established at 2.023 Ga (Table 1). The rocks affected by the impact, which are all listed in Table 1, cover almost 1.5 Ga of Earth’s history (from the Archaean to the Middle Proterozoic), or a third of geological time on Earth. An interesting aspect of the ages of the meta-felsites in the core is that, although there are indications that the Inland sea granite was reset partially at 3.1 Ga and again at ~2.8 Ga, these ages have not to date been recorded in the overlying Parys granite.

Selected viewing sites (Figure 1).

1. PILLOW LAVAS OF THE GREENLANDS FORMATION AT HATTINGSRUST 68

The greenstones of Greenlands Formation consist of chlorite amphibole schists and amphibolites that developed from basic lavas. On the farm Hattingsrust 68 pillow lava structures in komatiite were conserved in the amphibolite. Metasediments do occur but are subordinate and are represented by banded ironstone and chert. These rocks occur as small inclusions in the granite of the core of the Vredefort Structure. The metamorphic grade lies within the upper greenschist and lower amphibolite facies, and they are very similar to the pillowed komatiites in the Barberton granite-greenstone terrane.

The greenstones are cut by quartz veins and pegmatites, some of which are are spodumene-bearing. The quartz veins are from place to place gold-bearing. The first gold in the Vredefort structure was discovered at Blaauwbosch, in this area, where it was mined. Prospect trenches can be seen all over the area. These quartz veins and pegmatites are genetically related either to the Parys Granite or to the Archean granites normally associated with komatiites in greenstone belts.

2. THE INLANDSEA GNEISS AT SCHIETKOP 136

In this outcrop, the gneissic texture which develops in places in the Inlandsea gneiss can be seen. The presence of the orthopyroxene (probably derived from amphibole) indicates that the original granite was metamorphosed to the granulite facies. It has been postulated (M. Coetzee, NWU, pers. comm.) that the shape of Schietkop was caused by glacial pressure during Dwyka times - see if you can spot glacial drag marks.

Chemically, the Inlandsea gneiss is strongly depleted in upper crust compatible elements, such as K, Na, Si and the LIL trace elements, and enriched in more mantle compatible elements such as Mg, Ca and the HFS trace elements, relative to the Parys granite (Figure 3). This observation has prompted Hart and co-workers (1990) to postulate that the granite core is also tilted over at high dip angles, just like the sedimentary rocks in the collar, as shown in the cross section in Figure 4a. This model is referred to as **the 'crust-on-edge' theory**.

From this granite koppie an excellent panoramic view of the ring structure of the overturned collar of the Vredefort structure can be seen. The geographical center of the meteorite impact structure is more or less near the Inlandsche Zee (an ephemeral pan), which is situated in a south-south-western direction from the Schietkop trigonometrical beacon. The position is

3. THE BROODKOP SHEAR ZONE (DROOGKOP 304)

The south-eastern section of the Vredefort structure is covered by Karoo Group sedimentary rocks, but from geophysical evidence it is clear that the geology here is structurally significantly different to the north-west: Dips in the south are much less steep, and the metamorphic grade is low (greenschist facies as seem in the komatiites, as opposed to granulite facies in the adjacent gneisses. These 2 metamorphic zones are separated by a structural feature which strikes roughly SE-NW and has been termed the Southeast Boundary fault by Hart et al. (1990). Some workers, e.g. Lana et al. (2006) believe that this is an Archean (Dominion-age; 3.1 Ga) feature, but others like Hart et al. (2004) feel it is a primary feature related to the impact event; they suggest that crater formation proceeded to completion in the northern part of the impact area only, while a slab to the south detached itself and crashed back to its original, pre-impact, nearly horizontal position, thus truncating with crater approximately halfway. This geometry may be indicative of a low angle impact.

4. THE 'BETA' ROCKS AT THE INLANDSEA (KLIPKRAAL 49)

A small outcrop of ultrabasic rock at the shore of the Inlandsche Zee, indicated by the star on the map in Figure 1, has proved to a peridotite, very depleted in mantle incompatible trace elements such as the REE. Re-Os data for this rock implies an age of 3.5 Ga and the γ_{Os}, in other words the comparison of the Os initial ratio of the peridotite with the ideal CHUR mantle reservoir at time of impact, shows a value of less than 1, as shown in Figure 4b. Tredoux et al (1999) interpreted these data as indicating the presence of upper mantle material at the centre of the Vredefort structure: it would seem that the impact has tilted a ~40 km section of crust, plus some underlying mantle on its side. Walking from the rim, seen in the distance, towards this stop is therefore potentially equivalent to climbing down a 40 km hole into the Earth.

5. PARYS GRANITE / INLANDSEA GNEISS BOUNDARY AND CHARNOKITE AT SCHULPSPRUIT 540

The Parys granite (3.05 Ga) forms the outer zone of the granitic hub of the Vredefort Structure. This granite varies in composition from granitic to granodioritic and the texture varies from non-foliated (massive) to gneissic. Whereas the Inlandsea gneiss was metamorphosed to the granulite facies, the Parys granite is metamorphosed only to the amphibolite facies.

Hart et al (1990) has interpreted the Parys granite and Inlandsea gneiss as two separate crustal slabs, which were tectonically juxtaposed at ~2800 Ma, with the Parys granite slab eventually overriding the Inlandsea gneiss slab. This tectonic event reset many of the isotopic 'clocks' of the Inlandsea gneiss. The enrichment in water, and the spikes of many mobile trace elements, such as Zr and Ba (Figure 3), in the charnokite zone at the interface of the two slabs may represent a major dewatering event in the Inlandsea gneiss at 2.8 Ga, with the OGG acting as an impermeable seal which prevented the fluid phase from escaping. Evidence of further geochronological resetting at 2.5 Ga was interpreted by the authors above as an indication of a metasomatic event which injected fluid along the tectonic boundary between the two plates.

The model of Hart et al (ibid), especially for the 2.5 Ga event, is highly disputed by many other researchers (see Reimold and Gidson, 2001, for a discussion). One of the pieces of contrary evidence, pointed to by Reimold and Gibson (ibid), is the O isotope data presented by Le Grange et al (1999) which show that the $\delta(O^{18})$ values in the charnokite zone is the same as in the underlying Inlandsea gneiss (Figure 5): These authors feel that this means that no new fluid phase was introduced. Their argument is however a classic case of the 'absence of evidence' not being the same as the 'evidence of absence', because the interpretation of the O isotope data preferred by Reimold and Gibson (ibid) is not a unique interpretation of the data. If the intruding fluid was derived from a similar source as the ILG itself, it would have a similar isotope signature to the host rock and its presence will be isotopically 'invisible'. The origin of the charnokite zone remains poorly understood and is intensely contested.

6. THE PARYS MUSEUM

In the museum is a plaster model of a bird's-eye view of the Vredefort structure, i.e. what it would like like from an airplane. The geology is painted on the model, so that it gives one a good overview to link the stops we see during the trip.

6. SHATTER FANS IN QUARZITIC ROCKS OF THE HOSPITAL HILL FORMATION

Quartzite is a very brittle rock. It responds to shock metamorphism by forming characteristic features called shatter cones. Shatter cones were first linked to the propagation of shock waves in rocks when they were discovered in the walls of underground nuclear bomb testing chambers. When the rocks of the Witwatersrand Supergroup are reconstructed to their original horizontality, all the shatter cones point towards the centre of the structure, indicating that it is there that the shockwaves were initiated.

8. SCHURWEDRAAI ALKALI GRANITE AT KOEDOESLAAGTE 516 IQ

This pluton was emplaced along a strike fault where quartzites of the Jeppestown Formation were duplicated. The quartzites were forced apart by the magma, creating an elongated structure with a core of alkali granite. The granite is Na-rich, with albite as the major feldspar. The other feldspar is microcline, thus this is a subsolvus type of granite. The ferromagnesian components are clinopyroxene. The original magma appears to have been a syenite which assimilated quartz from the surrounding quartzites. Near the contact with argillaceous rocks, the peralkaline character is destroyed with the assimilation which produced a biotite-bearing rock. The granite cuts sills of norite belonging to the basic rocks of Bushveld age, but recent dating (Graham et al, 2005) confirmed an age of 2.05±0.01 Ga, making the granite coeval with the basic dykes, within error. Small faults in the country rock of do not displace the granite, indicating that they are younger. Pseudotachylite and shatter cones (some with a thin lining of pseudotachylite) are present in the granite. The intrusion of the granite caused intense thermal metamorphism leading to cordierite-andalusite in the argillaceous rocks of the Hospital Hill Subgroup and garnet hornfelses in the lower Government Formation.

9. THE HOSPITAL HILL FORMATION AT THE DONKERVLIET RIVER SECTION

This stop allows a side-on view of the overturned Hospital Hill quartzites. Ripple marks exposed in the outcrops next to the river can be used as a ‘way up’ criterion. It is clear that these layers are overturned (to 100-110^{o}), which is characteristic of an impact crater. The garnet hornfelses in the lower Government Formation, caused by the intrusion of the Schurwedraai granite, can be seen down river from the quartzite outcrops.

10. THE METAMORPHIC AUREOLE AROUND THE SCHURWEDRAAI GRANITE AT THE DONKERVLIET RECREATION CENTRE

The cordierite-andalusite aureole in the argillaceous rocks of the Hospital Hill Subgroup, caused at 2.05 Ga by the Schurwedraai granite, can be seen on and around a low hill on the grounds of the recreation centre.

11. PSEUDOTACHYLITE IN THE PARYS GRANITE AT THE LEEUWKOP GRANITE QUARRY ON KOPJESKRAAL 517 IQ

Pseudotachylite is a glassy to recrystallised, very fine-grained “mylonitic” rock that formed due to the Vredefort event. The pseudotachylitic veins contain inclusions of the country rock, and the chemical composition of the dark matrix of the veins is the same as the surrounding rocks. Thus, it is not the proper glassy basaltic rock, named tachylite. Note the rounded character of the inclusions.

The Archaean granitic rocks at this site are Parys granite with a larger “inclusion” of the Inlandsea Gneiss (light coloured granitic rock). Note the gneissic texture in these granitic rocks. The cross sections of the dark coloured pseudotachylite veins in the faces of the quarry give an interesting image of the random distribution of the pseudotachylitic veins. Also note the gravity settling of the inclusions in the large veins. Some of the outstanding features of the pseudotachylite are:

- The rounded nature of the inclusions in the pseudotachylite veins. These inclusions were mostly derived from the adjacent country rock. The inclusions can range in size from < 1 mm to > 2 m in diameter.
- The displacement of the country rock along the veins is small (usually < 0.5 m).
- The pseudotachylite is not associated with major faulting.
- There is no obvious geometrical pattern in the form, strike and dip of the veins.

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Table 1 Ages of the rock units exposed in the Vredefort structure (data from Coetzee, 2006 and Reimold and Gibson, 2001).

Rock type	**Method(s)**	**Age (Ga)**
CORE:		
ILG (Inlandsea Granite)	Sm-Nd, Rb-Sr, U-Pb	3.5 - 2.8
Ultramafics	Re-Os, Rb-Sr, U-Pb	3.5
OGG (Parys Granite)	Rb-Sr, U-Pb	3.05
Epidiorite sills	Rb-Sr, Ar-Ar	2.7
COLLAR:		
Wits Supergroup (mafic rocks)	U-Pb	2.8 - 2.7
Venterdorp Supergroup	U-Pb	2.6
Transvaal Supergroup	U-Pb	2.2 - 2.05
VREDEFORT EVENT	U-Pb	2.02

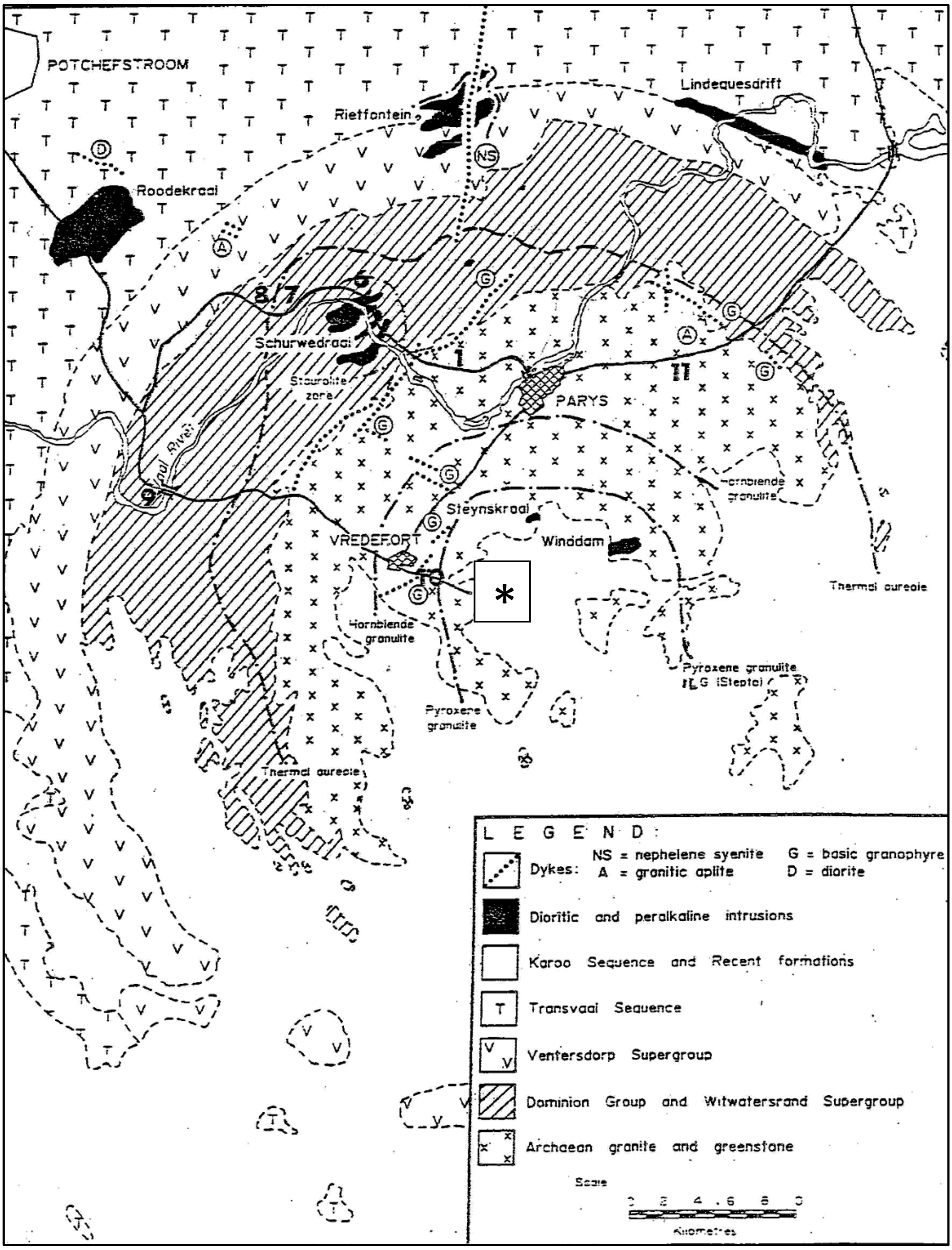

Figure 1 Geological map of the Vredefort Dome and selected viewing sites (modified after Bisschoff, 1988). The boxed star in the centre indicates the position of the Beta-1 borehole.

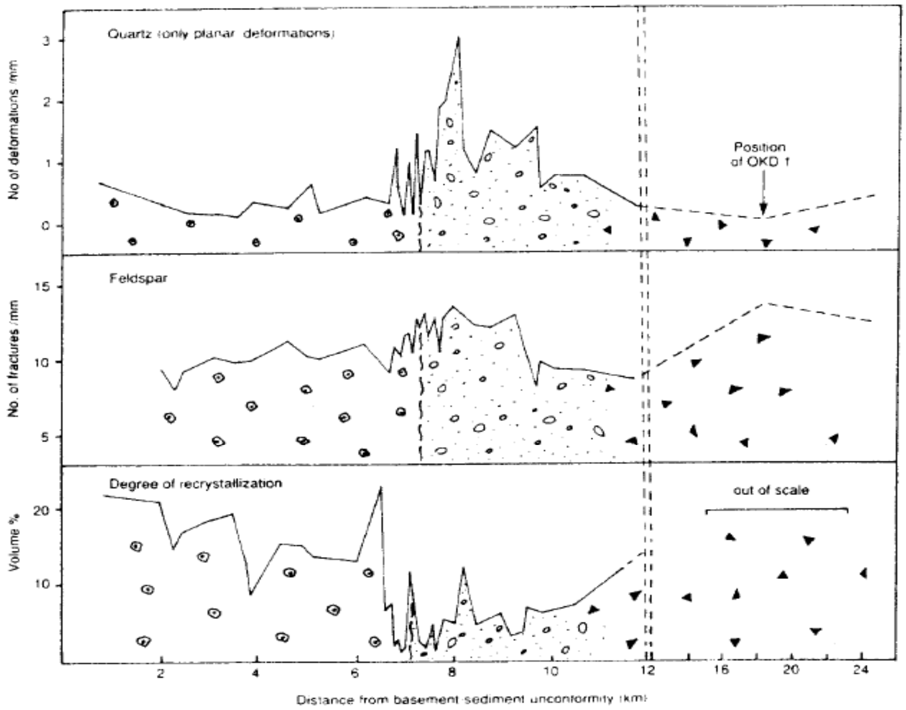

Figure 2 Distribution of shock features (Figure from Hart et al., 1991). The shaded area is the zone of highest density of shock metamorphism and coincides with the charnokites. The numbers indicate the sample analysed by Hart et al (ibid). The star in the centre indicates the Beta-1 borehole.

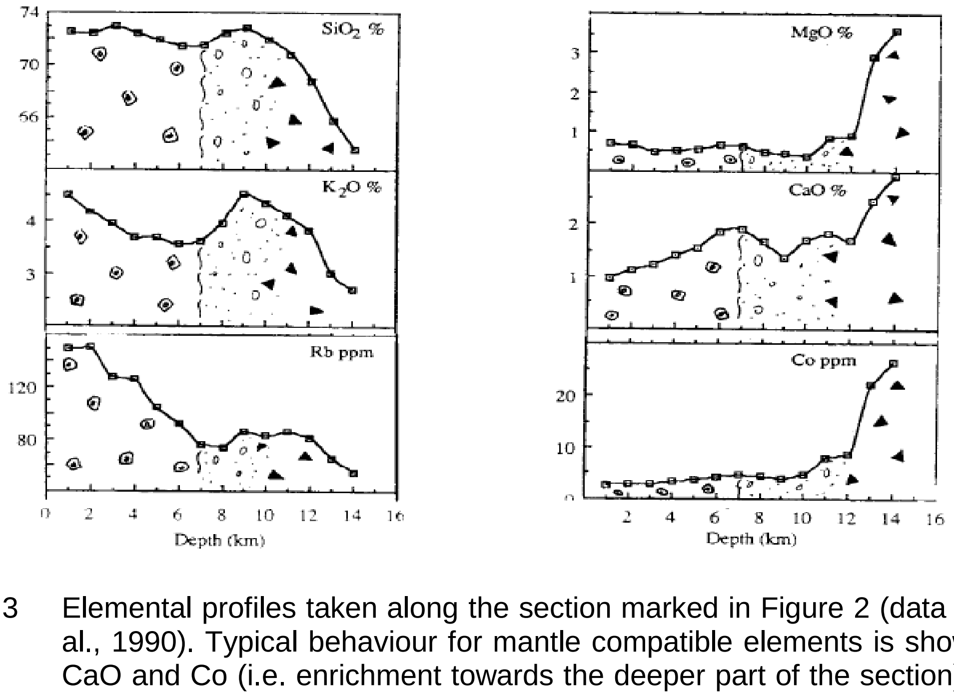

Figure 3 Elemental profiles taken along the section marked in Figure 2 (data from Hart et al., 1990). Typical behaviour for mantle compatible elements is shown by MgO, CaO and Co (i.e. enrichment towards the deeper part of the section) and that of crust compatible elements (enrichment towards to granite-sedimentary rock non-conformity) by SiO_2, Na_2O and Rb. Hart et al (ibid) used these data trends to argue that the granitic core of the structure is also tilted vertically, just like the overlying sediments.

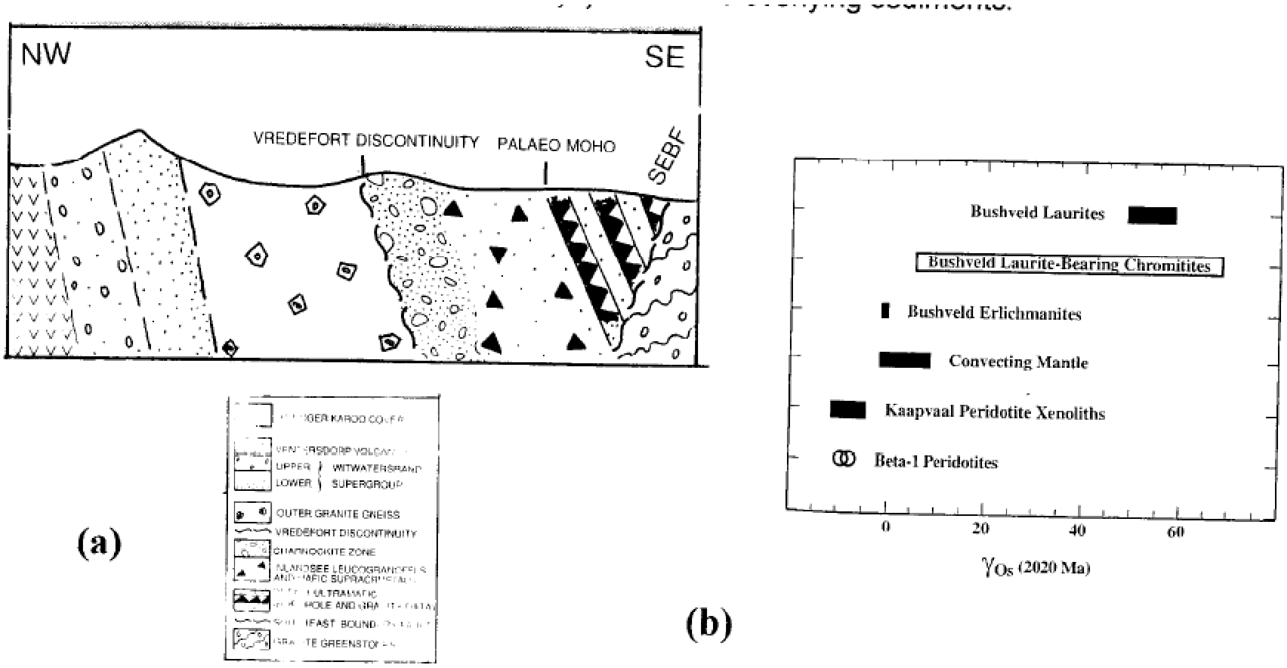

Figure 4 **(a)** Cross-section of the Vredefort structure, based on ‘crust-on’edge’ model of Hart et al (1990); and **(b)** Os isotopic data for the peridotite near the centre of the structure (for position of the bore hole in which the peridotite was sampled, see the star in the centre of the map shown in Figure 2).

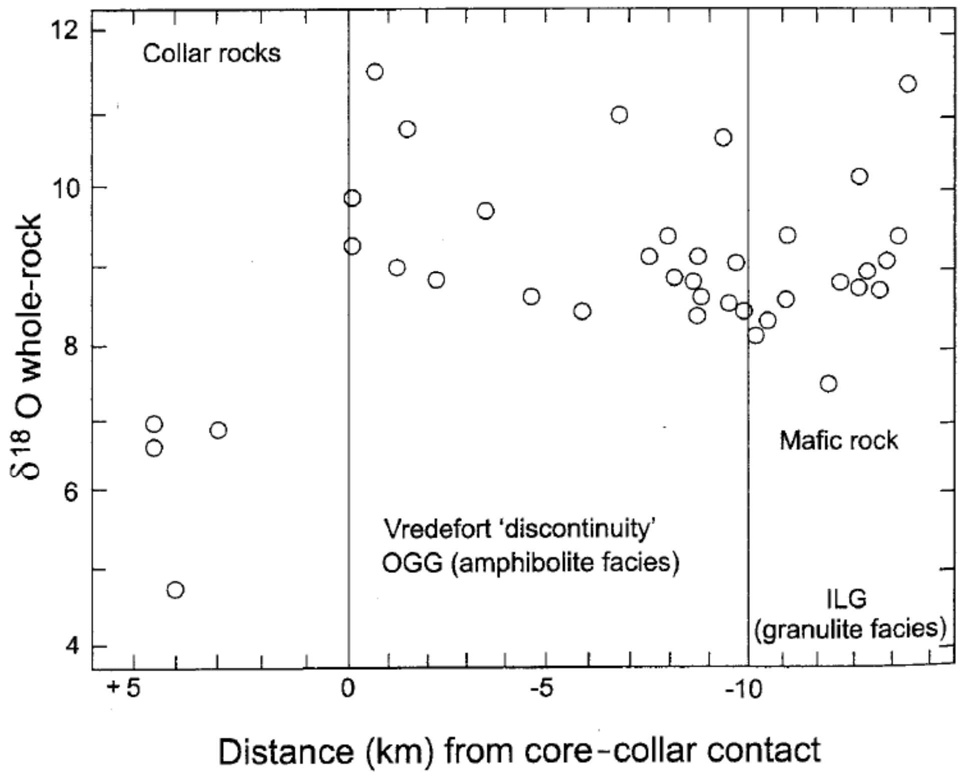

Figure 5 Oxygen isotopic data for the charnokite zone of La Grange et al (1999), as quoted in Reimold and Gibson (2001).