

CHAPTER 2

DATA

2.1 LITERATURE REVIEW

2.1.1 GENERAL GEOLOGY

The Economic Geology Research Institute of the University of the Witwatersrand in Johannesburg in 2001 produced a comprehensive bibliography entitled “The Vredefort impact structure and directly related subjects: an updated bibliography” (Reimold & Coney, 2001).

One of the earliest maps produced (judging from the portrayed simplistic structure of the Vredefort Dome) for the area is an undated map (Figure 5 in Appendix A) produced by WE Bleloch, currently on display at the Geological Records Section of the Anglo-American Head Office at 45 Main Street, Johannesburg. The map must have been produced following Stow’s recognition of the overturned strata, even though he attributed it to a volcanic centre (Nel, 1927).

A very detailed map (Appendix A, Figure 6) of the Vredefort Dome was produced by Louis T Nel over the period of 1923 to 1925 with the accompanying explanation of the map (Nel, 1927).

An electronic version of Bisschoff’s (1999a) map of the Vredefort Dome was used in this study and is to date the best detailed map of the area. The accompanying explanation of the map (1:50000) by Bisschoff (1999b) is a concise summary of the general geology of the area.

As far as the geological description is concerned, Nel (1927) mentioned that GW Stow made the first contribution to the geology of the area. Stow’s observations were documented in the 1878 report of the Geological Survey of the Orange Free State (Minnaar, 1989). Hall and Molengraaff released a memoir in 1925, after a visit to the Vredefort Dome, in which they mentioned that Bunkell, Draper, Gibson, Hatch, Higgs, Mellor, Penning, Penny, Robinson and Sawyer had all contributed to the geological knowledge of the area.

The enigma of the Vredefort Dome has attracted numerous researchers focusing on the geology and origin of the circular structure, being volcanic or extra-terrestrial. Among these researchers are Bisschoff (1969, 1973, 1984); Stepto (1979), Albat and Mayer

(1989), Antoine *et al.* (1990), Corner *et al.* (1990), Hart *et al.* (1981a, b, 1990a, b), Stepto (1990), Mayer (1992), Martini (1992), Hart *et al.* (1995), Tredoux *et al.* (1999), Brink *et al.* (2000a, b), Nicolaysen and Reimold (1999), Gibson and Reimold (2001), and Reimold and Gibson (2005), to name but a few.

2.1.2 GEOCONSERVATION

The geoconservation initiatives in South Africa seem sparse compared to Europe and the Far East. Despite the geological treasure of South Africa spanning geological time from >3500 Ma to recent times, very little has been done to conserve this heritage. In 1999 Reimold sent an invitation to the geological community of South Africa, as well as the whole of Africa to preserve our unique geological heritage and protect unique geological features from vandalism.

The Geological Society of South Africa's Geoconservation Committee is the current body providing a platform for the development of the geoconservation concept which is believed to be of critical importance. An inaugural workshop on geoparks, geological and mining conservation and tourism development in South Africa was held the 22nd of June 2007 by the Geological Society of South Africa's Geoconservation Committee at the Council for Geoscience, Pretoria (GSSA, 2007). The UNESCO network of Global Geoparks is very active in Europe, Australia and the Far East. The 4th International Geoparks Conference was presented in Malaysia, hosted by the Langkawi Geopark in April 2010 (UNESCO, 2010).

2.1.3 GEOTOURISM

Two books with the aim of introducing South Africa's geological treasures to amateurs are: "An introduction to South Africa's geological and mining heritage" by Viljoen and Reimold (1999), and "Geological Journeys" by Norman and Whitfield (2006). The first became a popular reference book, mainly to members of the mining community in South Africa. The latter serves as a traveller's guide to South Africa's rocks and landforms. Schutte (2009) produced a comprehensive overview of the current state of affairs relating to the sustainable development of geotourism in South Africa.

2.1.4 MINING

Very little information exists on the mining history of the VD. The historic mineral rights system which existed in South Africa in the previous century enforced secrecy between companies holding mineral rights in the area, mainly for gold. The result is that only limited statutory reporting provides figures and information. The main mining areas or mines around Rooderand and the Great Western mine were described in some detail with the lesser known activities escaping publicity.

The limited information, that is available, is contained in the early geological publications like those of Nel (1927), Kriel and Germishuys (1957), Borchers (1964), Whiteside *et al.* (1976), and Robb and Robb (1998), while Brink and Waanders (2011) wrote up a comprehensive, but regrettably, unpublished document of the history of activities relating to gold-mining per farm in the VD. A detailed report of what was accumulated during this study is given in the following Section.

2.2 VREDEFORT DOME GOLDFIELD: IDENTIFICATION AND DESCRIPTION OF GOLD-MINING ACTIVITIES

2.2.1 GOLD-MINING HISTORY

Exploration in the VDWHS must have been a daunting task even if the vegetation was less dense than today (J van der Merwe, personal communication: 15 November 2007). Prospectors must have traversed the mountains in great detail and followed on strike extensions of reefs with difficulty. It seems as if in no case had any conglomerates been seen on surface that escaped the prospectors hammer.

Robb and Robb (1998) refer to the Venterskroon Goldfield in the Vredefort Dome. Due to the wider distribution of mining activities in the VD, covering a much larger area than just that of the Venterskroon area, it is proposed that the so-called Venterskroon Goldfield should be enlarged and named the Vredefort Dome Goldfield (Figure 7). The location of the proposed Vredefort Dome Goldfield in relation to the other Goldfields of the Witwatersrand basin is shown in Figure 7.

According to De Jager (2005) the earliest recorded gold exploration activity in the Vredefort Dome area was in 1853. In the northern section of the Dome in the Rooderand area the Kimberley Reefs, locally known as the Amazon Reef, of the Turffontein Subgroup was extensively explored. Nel (1927), however, mentioned that

Figure 7

prospecting operations were first undertaken “round about the year 1888”. A Mr Marx, owner of the farm Lindequesfontein situated south of Reitzburg, applied on 10 September 1887 to the State to have his farm opened as public diggings for extraction of the Veldschoen Reef (Kriel & Germishuys, 1957). The first claims were issued on 1 December 1887 on this farm.

The climax of the mining activities around Schoemansdrif was the surveying work done to establish a mining town, which would have been called Bothasburg probably in close proximity to the current Reitzburg, west of Schoemansdrift. The position of Schoemansdrift is indicated on the map displaying the gold-bearing reef exposures which was prospected or mined in the Vredefort Dome World Heritage Site (Appendix B). The Lindequesfontein area later adopted the name Reitzburg in honour of President Reitz, the President of the Orange Free State, one of independent Republics of the time. The high price of mining machinery led to the establishment of various companies like Molteno Kie, Philippolis Kie, Neebe and Rörich, Devon Kie and Vredefort Kie.

From 1891, following the discovery of gold in the Witwatersrand, interest in the VD area increased due to the similarity of sedimentary units to those in the Johannesburg area (Minnaar, 1989). Gold was later also discovered in the Archaean schists on Blaauwboschpoort 13 near the Greenlands Station in the south-eastern section of the Dome (Nel, 1927).

Mining continued, interrupted by the Anglo-Boer war (1899-1903), until late in the 20th century. Several periods of mining activity can be derived from various references (Kriel & Germishuys, 1957; Robb & Robb, 1998; De Jager, 2005; Brink & Waanders, 2011). The first is the period pre-dating the Anglo-Boer War (1899-1903); the second, the years after the war up to 1911; the third, the resurgence of activities in 1930; and the last being the limited mining drive around the 1990s.

Several syndicates were formed to mine gold-bearing conglomerate bands or “banket” as it was known, with resulting mining activities in different localities in the region. The term ‘banket’ is named after a “sweet cake” made with almonds resembling the texture of the pebbles in the conglomerates. The term ‘reef’ was later introduced by sailors as the protruding quartz vein was likened to a coral reef standing out of the water (Handley, 2004). Some photographs of historic mining activities that typify mining conditions in the Vredefort Goldfield at the time are shown in Figure 8.

In this study, the names of the mining areas as mentioned by Robb and Robb (1998) are used, but where unnamed mining activities are described, the farm name is used.

Appendix C lists the coordinates of the prospecting trenches and mines identified during this study. The list contains both the mines for which a mine name exists and the unnamed mines which are listed under the farm name on which it occurs.



Figure 8 a-d. Historic mining photographs (courtesy Ben van Wyk, Extract Training Pty Ltd., photographer unknown). See text for more detailed description. Figure 8a shows some equipment, the wooden support and the poor initial safety standards where hard hats were optional. In Figure 8b a hand operated conveyance system running on tracks can be seen. An inclined stope and the use of carbide lamps are visible in Figure 8c. The use of mules to convey hoppers is seen in Figure 8d.

The suspension of operations which could not be pinpointed to a specific date was ascribed by Nel (1927) to careless management, too much attention being paid to share speculation in the first instance, and to the results being insufficiently encouraging. Kriel and Germishuys (1957) mentioned that a local Vredefort mine inspector, Mar. Robinson, reported even before the Anglo-Boer war that “*de riffen schyn zeer patchy te zyn*”, indicating that the decrease in mining activities were due to erratic occurrence of the reefs in the area.

Statements like the following in Nel (1927:113): “the reef is faulted at the 20-feet level and the continuation was never located”, support the idea of the structure also playing

havoc with mining entrepreneurs probably trying to resolve geological aspects by themselves, not realizing that the rocks were overturned.

2.2.2 GEOLOGY

The Vredefort Dome lies almost in the centre of the oval-shaped Witwatersrand Basin with dimensions 300 by 150 km. Even though the gold bearing reefs are minimally exposed at surface elsewhere, in the VD they and their hanging and footwall lithologies can be clearly seen and studied.

Stratigraphy

The lowermost quartzite of the Witwatersrand Supergroup lies concordant on rocks of the Dominion Group and discordant on rocks of the Swazium Erathem (Minnaar, 1989). The Dominion Group rocks occur between the basement gneiss and the Witwatersrand Supergroup rocks from the south-western to the northern sectors of the Vredefort Dome (Hart *et al.*, 1981a, b). No evidence of conglomerate preservation in the Dominion Group exists in the Vredefort Dome area even though this Group was extensively mined in the Hartbeesfontein area north-west of Klerksdorp, some 100km from the Vredefort Dome. The overlying amygdaloidal, andesitic Ventersdorp lava lies concordant on the Witwatersrand Supergroup (Bisschoff, 1999a, b). The stratigraphic subdivision according to SACS (1980) for the Klerksdorp and Central Rand Goldfields area is generally accepted for the Vredefort Dome area and was modified after Van Graan (1983) and Bisschoff (1999b) (Figure 9). The general lithology and thicknesses of the Witwatersrand units are given in the stratigraphic column depicted in Figure 9.

Sedimentology

According to work done by Robb and Robb (1998) the average thickness of the Witwatersrand Supergroup in the Vredefort Dome area is approximately 7,500 m. This succession was deposited between 3,074 and 2,714 Ma ago (Robb & Robb, 1998, after Armstrong *et al.*, 1991; Barton *et al.*, 1989; Robb *et al.*, 1990; 1992). The Central Rand Group is approximately 2,200 m and the West Rand Group 4,000 m thick. Minnaar (1989) calculated the composition of the Central Rand Group at 95 percentage sandstone and 5 percentage shale and the West Rand Group to contain 44 percentage sandstone and 56 percentage shale. Minnaar (1989) also noted that the Supergroup is

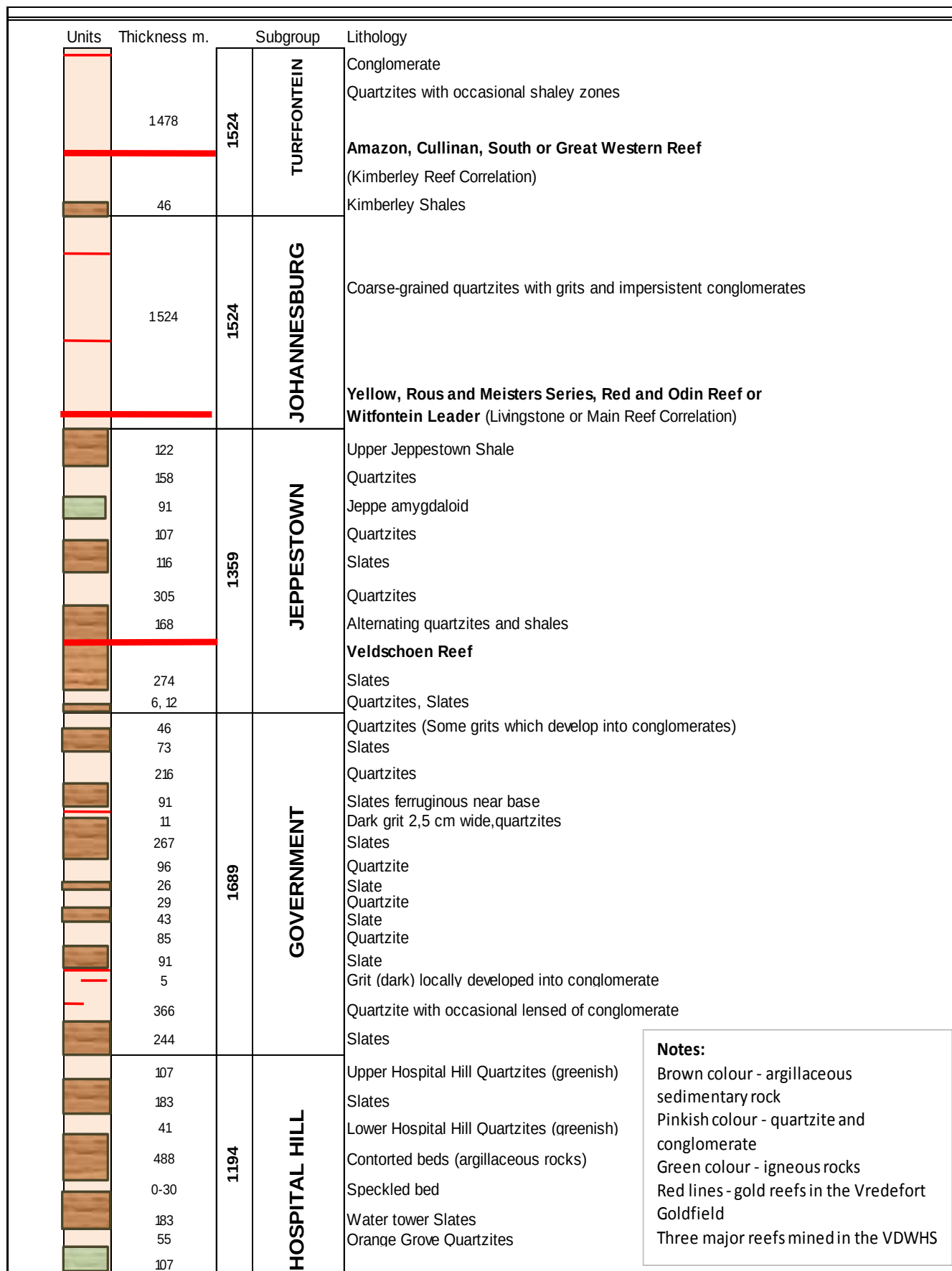


Figure 9. Stratigraphic column of the Witwatersrand Supergroup and the reefs of the Vredefort Dome Goldfield modified after van Graan (1983), and Bisschoff (1999b).

best-developed in the western part of the Vredefort Dome due to more rapid subsidence of the basin during Jeppestown and Central Rand times. The abundance and thickness of conglomerate bands increases towards the top of the Central Rand Group of the Witwatersrand Super group. Minnaar (1989) proposed a tidal flat complex model for the Hospital Hill Subgroup, a prograding delta for the Government and Jeppestown Subgroup, and a fan delta for the Central Rand Group in the Vredefort Dome.

Gold-bearing Reefs

The following three reef packages were mined in the Vredefort Dome Goldfield (Figures 9 and 10):

- The Amazon Reef, also known as the Cullinan, South, Rous, Jumbo or Great Western Reef(s) (local terminology), occurring in the Turffontein Subgroup of the upper Central Rand Group;
- The Meister Reefs, also known as the Odin, Main, Red Reefs, or Witfontein Leader (local terminology), occurring at the base of the Johannesburg Subgroup of the upper Central Rand Group;
- Veldschoen Reefs in the Jeppestown Subgroup of the lower West Rand Group.

Amazon Reefs (Cullinan/South/Rous/Jumbo or Great Western Reefs)

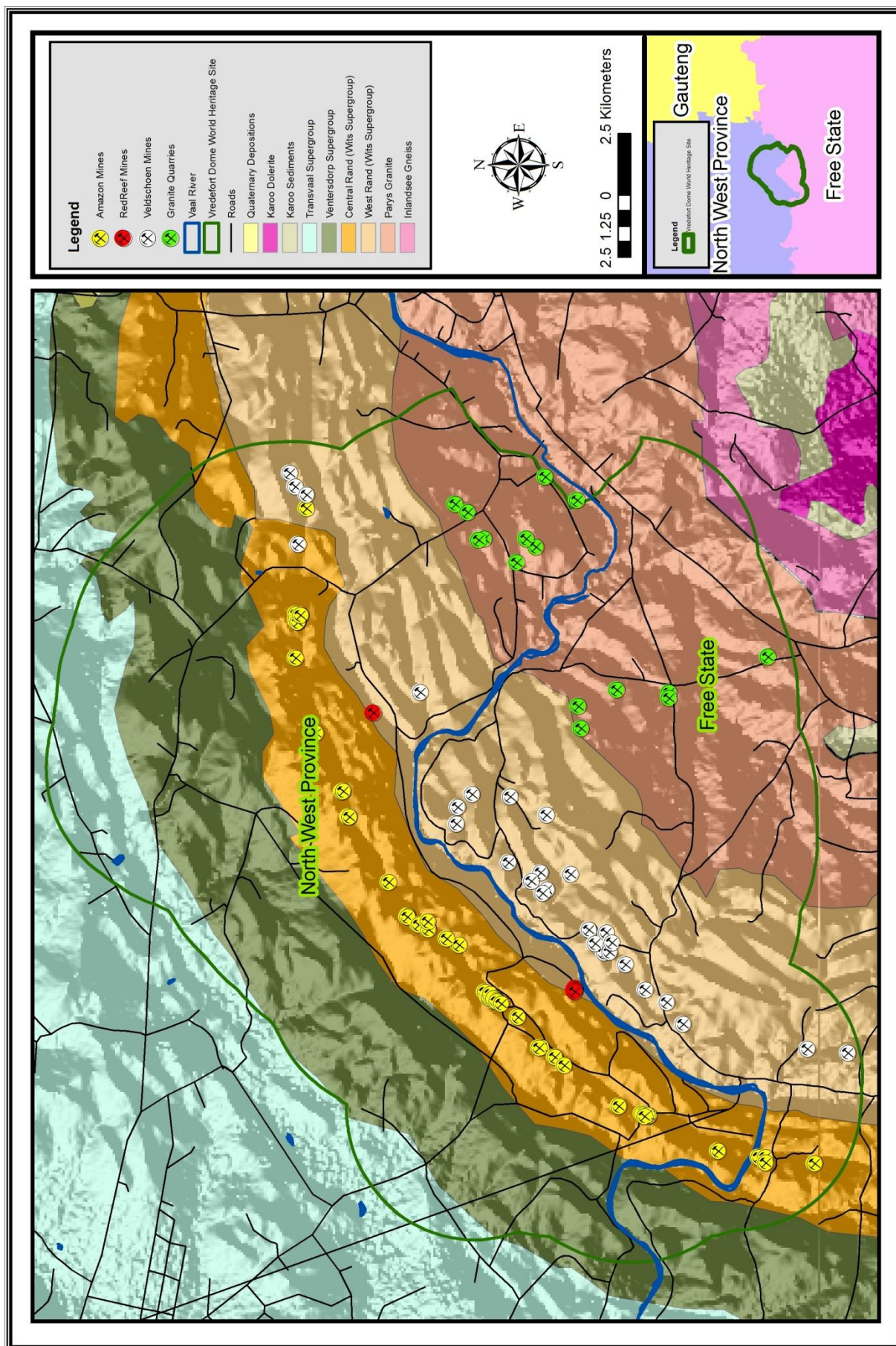
These reefs occur in the Turffontein Subgroup (Figure 9) where conglomerates are generally very abundant. These particular reefs are generally poorly sorted, oligomictic and proximal in nature. The pebbles are mainly vein quartz. The Vredefort Dome Goldfield does not, according to Robb and Robb (1998), appear to be a distal facies of either the Klerksdorp or Carletonville Goldfields.

Red Reefs (Meister/Odin/Main/ or Witfontein Leader)

The Meister Reef occurs at the base of the Johannesburg Subgroup and correlates to the Livingstone or Main Reef (Figures 9). These reefs are being mined in the West and Central Rand goldfields. These particular reefs are generally well sorted, oligomictic and distal in nature. The pebbles are also mainly vein quartz.

Veldschoen Reef

This reef occurs in the Jeppestown Subgroup (Figures 9). Van Graan (1983) mentioned that poor sorting and coarse pebble sizes characterize the Veldschoen Reef. Nel (1927)



mentioned that the Veldschoen Reef is very lenticular, fading into a single line of scattered pebbles or even a coarse or medium grained quartzite in places directly overlying the shales. Pebbles are mostly of quartz, quartzite, slate, and chert composition. These pebbles are generally well rounded, and pebble to matrix supported in a coarse matrix.

Structure

Robb and Robb (1998) mention that the Witwatersrand strata around the rim of the Vredefort Dome represent the most structurally disturbed portion of the entire Witwatersrand basin. The intensity of deformation is evident from the overturned strata observed at various localities but most prominent along the north-western collar of the structure. Faulting abounds as normal faults, bedding-parallel faults and thrusts with abundant mylonite and pseudotachylite.

The structural complexity played a detrimental role in the success of mining operations. In numerous on-reef developments observed throughout the study area, development went off reef due to structure. In hardly any case were development redirected to get back on reef. The intermittent and mainly unsuccessful exploration activities could also be linked to the structural complexities.

Incorrect geological interpretation is proposed as an alternative reason for the low grades encountered. From this investigation, mining seems to have been focused on the bottom of the reefs as the sampling results from the other Witwatersrand goldfields indicated bottom-loaded reefs (gold-mineralization grades are normally much higher in the stratigraphic base of the reefs). The problem in the Vredefort Dome is that the stratigraphy has been overturned (Figure 11) and uninformed miners were mining the stratigraphic top of the reef where lower gold grades are typically found!

Mine activities on the different gold-bearing reefs

The mining infrastructure on the different reefs will next be described in more detail. It is evident from the remains of mining infrastructure (buildings, platforms for equipment, etc.) that various independent small scale entrepreneurs were active in the area. The observed scale and variety of the remains of infrastructure assisted in the identification of a representative set of geotourism sites.

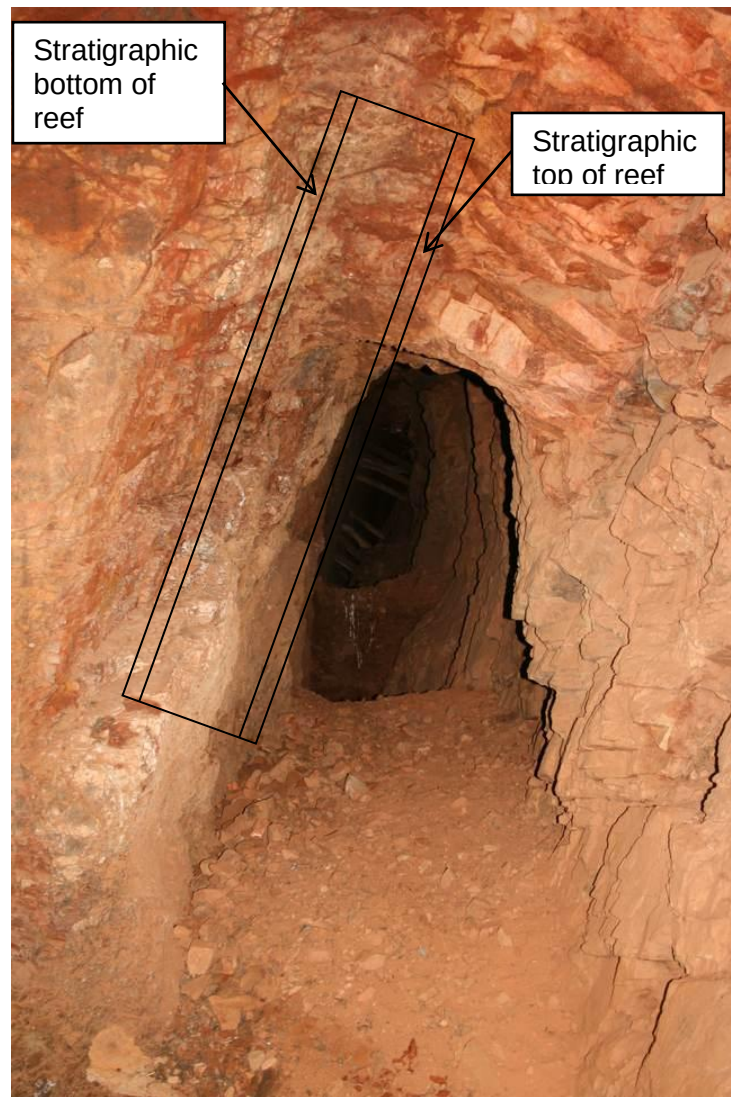


Figure 11. Picture taken at site N1 on the farm Nooitgedacht 89, indicating mining on the Veldschoen Reef. It is obvious that the mining was focused on the stratigraphic top of the reef that can easily be confused with the base of the reef due to the dip. Miners, none the wiser, did not realise that the reefs and strata had been overturned.

Mining of the Turffontein Subgroup (Amazon, Cullinan, Great Western, South, Rous and Jumbo Reefs)

A total of 65 mining sites were identified in these reefs and are indicated on a GIS map (Appendix B and Figure 10). Various small to medium size exploration trenches, as well as mines occur on each of the farms as indicated in Appendix B. These reefs were the most extensively explored and mined in the Vredefort Goldfield. The following mining areas were identified on these reefs:

- **Koedoesfontein 478IQ.** (Koedoesfontein 12 on Nel's 1923-5 map).

No literature reference could be found for this mine.

Classification

Mines and prospecting trenches exist.

Infrastructure

The mining infrastructure at this area consists of one walled adit, four winzes, two vent-holes and a large number of prospecting trenches of which one is approximately three meters deep and six meters long.

Beneficiation

No beneficiation activities were observed but the transportation of ore towards the Rooderand area seems obvious. The old mine route can be followed intermittently by observing tree growth and rock stacks alongside the road. In this area the old mine route is also currently used for a fire-control access road by local landowners.

Buildings

The adit has been partially closed with a brick wall. This enables the landowner to utilize the water that builds up in the mine for irrigation purposes. There is also a facility to tap water into fire fighter vehicles. The use of the mine water which is expected to be contaminated due to the presence of pyrite in the reef is of concern here.

Geotourism potential

No tourism activities are currently being undertaken within these mining excavations and none of the mining excavations are recommended for tourism potential according to the proposed criteria as discussed in Section 3.3.1.

The topography resulting from intense faulting in the area is remarkable, giving rise to a spring, the Enslin spruit. Although there is a concern regarding the safety aspect of the mine site, these types of geological factors resulting in specific landscape formation may also be highlighted as areas with geotourism potential.

- **Western portion of Buffelskloof 511IQ.** (Buffelskloof 24 on Nel's 1923-5map).

Classification

Adits were observed.

Infrastructure

A total of seven adits were identified on this farm.

Beneficiation

No sign of beneficiation activities was observed but the visible old mine road indicates transportation of ore towards Rooderand.

Buildings

Several ruins exist in close proximity to the excavations. Some of the claims near the mine entrances are still clearly legible as illustrated in Figure 12.

Geotourism potential

Mines were identified with potential to be made safe for tourists according to the proposed selection criteria. Some of these mines can be reached on foot from the Thabela Thabeng Resort on this farm and appears to be used as part of a hiking trail.

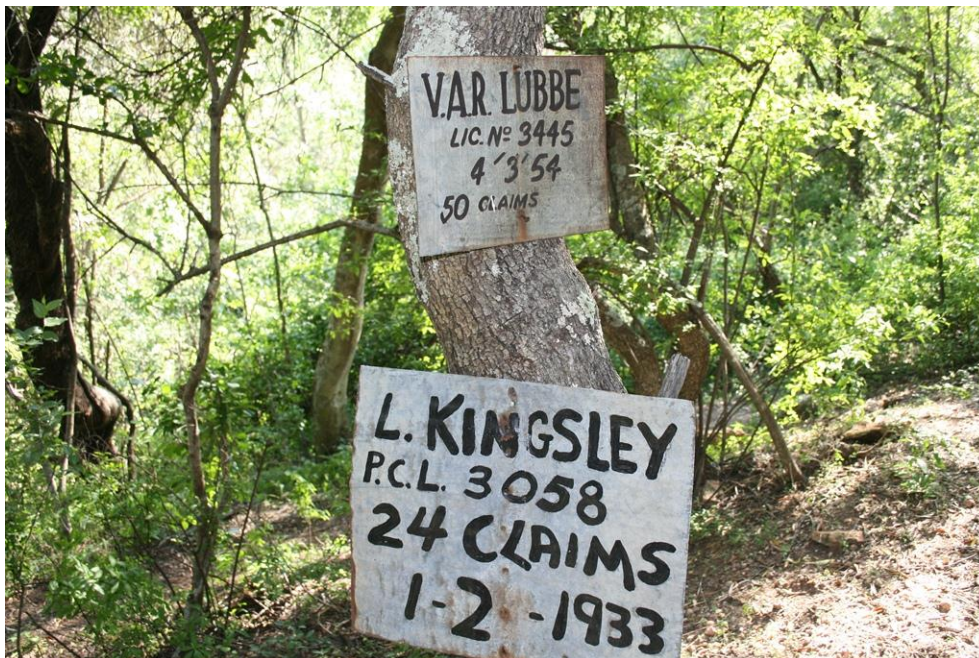


Figure 12. Claims near one of the mine entrances near the Thabela Thabeng resort at Buffelskloof 511IQ.

- **Eastern portion on Buffelskloof 511IQ.** (Buffelskloof 24 on Nel's 1923-5 map).

Classification

Adits were observed.

Infrastructure

Two adit entrances, B8 and B9 (Appendix C), occur on this farm.

Adit B8 is water filled and the dangerous overburden can be seen in Figure 13. This adit should be fenced in.

B9 is an open adit which appears to have a holing resulting in through ventilation in the mine. The adit hanging wall and overburden are unstable and were not fully accessed (Figure 14).



Figure 13. Adit, B8, with dangerous overburden and filled with water on the eastern portion of Buffelskloof 511IQ.



Figure 14. Adit, B9, on the eastern portion of Buffelskloof 511IQ with dangerous overhang at the entrance.

Beneficiation

No beneficiation ruins were observed here but it must be noted that the very dense vegetation is abundant and hindered observations.

Buildings

A stone building is present, currently hosting a borehole and it is not certain if the building is part of original ruins dating from the mining era.

Geotourism potential

Adit B9 was identified with geotourism potential.

These two adits, B8 and B9, occur in a densely overgrown valley (Figure 15) and give some idea of the desperateness and thoroughness of the fortune seekers of the time.

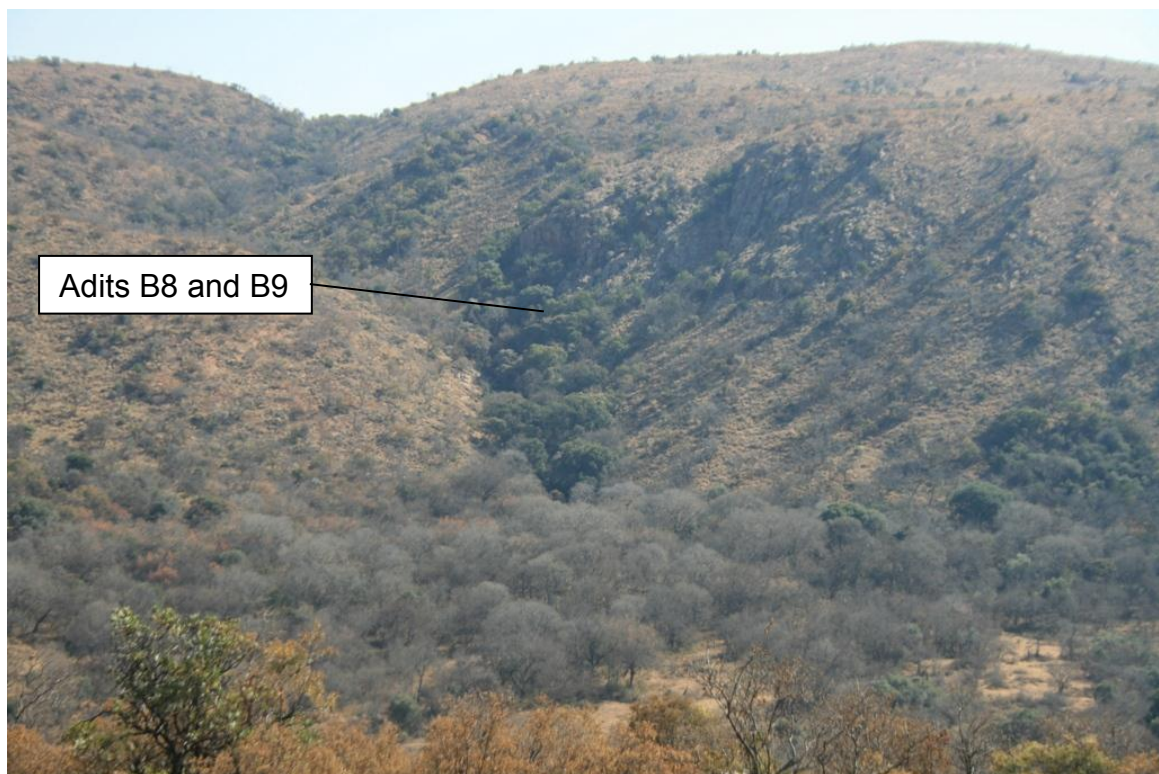


Figure 15. The valley on the eastern portion of Buffelskloof 511IQ in which the two adits (B8 and B9) occur.

A fresh exposure of the Amazon Reef that was mined on this farm is shown in Figure 16. The poor rounding of clasts, mainly milky quartz is evident. The dark matrix (due to sulphide mineralization) is visible and could indicate high gold values.



Figure 16. A fresh exposure of the Amazon Reef from Buffelskloof 511IQ. This sample consists of poorly rounded milky quartz pebbles in a dark fine-grained matrix.

Brink and Waanders (2011) mentioned that from September 1946 to March 1947 Eastern Transvaal Consolidated conducted exploration drilling for the Main Reef and South Reef on this farm. The results from the borehole core were the following: BFK1 returned 9.43g/t gold over 58.4 cm (531cm.g/t) at 105.1 m (Main Reef), BFK2 returned 0.86g/t gold over 48.3 cm (41cm.g/t) at 407.82m (Main Reef) and 9.77g/t gold over 73.7cm (720cm.g/t) at 421.51m for the South Reef.

- **Buffelskloof 483IQ** (Buffelskloof 44 on Nel's 1923-5map).

Classification

Adits and trench.

Infrastructure

A vertical pit, BK1, and three reef drives, BK2 and 4, occur on this farm (Appendix C).

Beneficiation

No remains of beneficiation activities were observed.

Buildings

No mine buildings were observed.

Geotourism potential

Two of the reef drives are unventilated and the fact that development is not holed resulting in through ventilation (dead ends), pose serious safety hazards. None of the

mines are fenced off and dangerous hanging wall conditions occur. The mines are all difficult to locate and the farm itself is not easily accessible from the road. Two of the reef drives are nevertheless identified as being potential tourism sites.

- **Rooderand 510 IQ** (Rooderand 26 on Nel's 1923-5map)

Classification

Several trenches and adits exist on this property.

Infrastructure

The full extent of mining development exists here from trenches, adits, reef drives to vent holes.

Beneficiation

Current beneficiation infrastructure exists in the form of sand dams, which are partially washed away. The possible beneficiation site and office activities are indicated by the occurrence of eucalyptus trees as the tendency in the past was to plant these trees for shade and mining support purposes close to the mining areas.

Buildings

Several stone building ruins and some cement structures are considered evidence of past mining activities.

Geotourism potential

Some of the ventilation holes, adits and reef drives were used for abseiling and mine tours in the past, these activities were however, ceased (Haggard, 2011, personal communication).

Of great concern here are the popularity, visibility and easy access to these mining infrastructures. Most of the development is visible from the road with noticeable waste rock and reef stockpiles due to colour contrasts of the waste material, ascribed to acid mine drainage and oxidation of the reefs, in relation to the surroundings (Figure 17). Unauthorized access to the sites is encouraged by a permanent stepladder over existing cattle fences even though warning signage is present.

Selected adits are recommended for tourism potential as indicated in Appendix C.



Figure 17. Mine workings, visible from the road (between Potchefstroom and Venterskroon) at Rooderand 510 IQ. The colour difference is due to weathering of pyrite present in the mined material.

Robb and Robb (1998) mentioned that gold grades were low in the Rooderand area, and that gold-mining activities were terminated on Rooderand 510IQ during and after the Anglo-Boer War (1899 to 1903). Nel (1927) reported that statements were made to Dr Mellor that the Amazon 'Series' (Reef) on Rooderand in places contained gold to an average value of 4 or 5 dwts (pennyweights, commonly called "weights" 1 dwts is equal to 1 ounce (oz)) to the ton (6.2 to 7.8 g/t).

During 1887 the government bought a portion of the farm Rooderand 510IQ to establish Venterskroon as a mining town. This followed the registration of mining leases on the farms Rooderand 510IQ and Buffelskloof 511IQ.

More recent mining activity includes drilling operations by ASTE in 1935 to explore the Amazon Reef, and in 1942 New Union Goldfields Limited acquired 33% of Rooderand Main Reef Mine shares (Brink & Waanders, 2011).

- **Nooitgedacht 508IQ** (Nooitgedacht 56 on Nel's 1923-5 map).

Classification

Mines and adits were observed.

Infrastructure

Seven workings with an extraction area were identified.

During current renovations to the old farmstead a furnace was found behind a more recently built wall, which was probably built to cover the furnace for aesthetic purposes (Figure 18). From the smell of strong chemicals and stains around the furnace it is possible that this is where the gold reef samples were analysed.

Extensive stoping was conducted at Nootgedacht 508IQ resulting in stopes open at surface (Figure 19). Some of these mining excavations were recently equipped with ladders to enable entrance into the old workings (Figure 20).

Porcupines were found breeding in one of the stopes.

Beneficiation

The Vaal River Company brought heavy machinery to mine six reefs on the farm Nootgedacht 508IQ (Nel, 1927). Nel (1927) reported 7,747 tons of “banket” being mined which yielded 855.160 ounces (24 kg) of fine gold in the period November 1909 to October 1911 when the mine closed down. Brink and Waanders (2011) mentioned 25kg gold from 5206 tons of ore at 4.83g/t. According to Brink and Waanders (2011) Central Mining Limited drilled boreholes J1 and J2 for Carbon Leader Reef on this farm in 1944 resulting in a maximum grade of 0.34g/t. The current property owner (GP Schoeman, 18 August 2010, personal communication) found evidence in the form of documentation indicating mining by the Amazon Mining Company from 1886 to 1910.

The old steam engine portrayed in Figure 21, was used for pumping water from the river. It is believed that this engine might have been used at the mine when the mine was operational.

Buildings

Remains of a sand dam, as well as a very impressive stone and cement foundation where a stamp mill was possibly hosted, were observed (Figure 22).

Geotourism potential

An adit is recommended for tourism activity following a proper safety and risk management plan.



Figure 18. What is left of a furnace that is believed to have been used in the assaying of the gold ore at Nooitgedacht 508IQ



Figure 19. Open stopes at Nooitgedacht 508IQ where the Amazon Reef was mined.



Figure 20. One of the stopes, K8, equipped with ladders at Nooitgedacht 508IQ.



Figure 21. The old steam engine believed to have been in operation at the Amazon mine, Nooitgedacht 508IQ (courtesy GP Schoeman).



Figure 22. The foundation for a stamp mill at Nooitgedacht 508IQ. Milled sand was found next to this structure, as well as concrete anchoring posts pointing to the foundation hosting the stamp mill.

- **The Great Western Mine at Elandslaagte 28**

This mine started mining in 1888 (Brink & Waanders, 2011). It is speculated that the mine was closed for an unspecified period, because Kriel and Germishuys (1957) mentioned that the Great Western mine started production in the nineteen thirties following renewed interest in the area. Borchers (1964, in Robb and Robb, 1998) reported that the mine sporadically produced until 1937 when it finally closed. A reef drive was developed along strike underneath the Vaal River from the Free State to the North West Province side. The mine was closed after intersection of a water fissure below the Vaal River and flooding of the mine.

During its lifespan 97.3 kg of gold was produced from 19,050 t of ore (Whiteside *et al.*, 1976). Brink and Waanders (2011) estimated a total production at 104 kg of gold from 2157 t of ore at 4.80g/t.

Nel (1927) mentioned that Molengraaff reported that the reef here consists of a basal conglomerate (1 metre thick), followed by overlying coarse pyritic sandstone.

Classification

Mines and trenches were observed.

Infrastructure

Of concern here is the tailings disposal facility (TDP), previously called slimes dam, which is eroding and depositing material into the Vaal River (see Section 3.3.2). The adit and shaft observed were not fenced off and the shaft particularly poses a threat to visitors due to the steep walls. Remains of the cement platform possibly used for the

stamp battery and cyanide leaching bins are visible (Figure 23). The whole area including the shaft with rock dump and slimes dam could be a tourism attraction if safety measures are implemented.



Figure 23. The remains of mining beneficiation infrastructure at the Great Western mine. The rectangular cement blocks in the foreground were part of the foundation of a stamp battery, whilst the rounded, cylindrical structures were the bases for cyanide leaching bins. Compare the photograph at the right (from Kriel & Germishuys, 1957) with the one taken in 2010 (fifty years later).

Beneficiation

In an undated report written by a mining engineer from London and Edinburgh, Henry Patterson, the prospecting work returned grades of 19 dwts to the ton (original document in possession of the current owner of the farm, Mr P Erasmus; also mentioned by Brink & Waanders, 2011). Patterson also mentioned that where the reef passes through the farm Kleinfontein 110, visible gold and a large nugget was found during prospecting efforts. Patterson recommended a 10 stamp battery to be erected between the base of the hill and the river with ore being conveyed with a tram system from all the reefs and cuttings to the battery. The workings were favourably mentioned in Patterson's letter to financiers and investors. Brink and Waanders (2011) date this report to around 1890, but on the available copy the date of 1924 was pencilled in.

Buildings

Various buildings exist from that period and are still in use by the property owner.

Geotourism potential

The mine is not at this stage being used for any tourism activities but some of the infrastructure could be made available for tourist attractions.

- **Tygerfontein 488IQ** (Tygerfontein 70 on Nel's 1923-5 map)

In the late 1990s the Randfontein Estates Gold-mining Corporation (REGM) acquired the prospecting rights to the Kimberley Reefs and prospected at various sites on this farm to identify potential surface mining sites, if any. This company was later sold and the prospecting initiatives ceased.

Classification

Mines and trenches exist.

Infrastructure

No infrastructure exists.

Beneficiation

No signs of beneficiation activities were observed and it is assumed that the ore from limited mining was treated at the adjoining farm Rooderand.

Buildings

No mining-related buildings exist on the farm.

Geotourism potential

The development observed on the farm Tygerfontein falls within the Suikerbos Nature Resort. The mines are on a hiking trail and it is recommended that proper investigations be done since this resort is often used by school camping groups (S Theron, 2010, personal communication). Access to the resort is controlled but the mine workings are all unfenced and no warning signs are present.

Mining of the Johannesburg Subgroup basal units (Yellow, Rous, Red, Meisters, Odin, and Main Reefs)

A total of 2 mining sites were identified in these reefs and are indicated on a GIS map (Appendix B and Figure 10).

According to Nel (1927) the Yellow (or Rous Series), and the Red Reef or Meisters Series (or Odin Reef) or Main Reef occur in the thick mass of quartzites between the Amazon Reefs and the top of the Kimberley slate (Figure 9). These reefs, also referred to as the Witfontein Reefs (Nel, 1927), were mined from the base of the Johannesburg Subgroup. According to Brink and Waanders (2011) the Meisters Series is the equivalent of the Main Reef, and the Rous' Series that of the Vaal Reef mined in the Klerksdorp Goldfield.

The reference to yellow or red in the name of the reef can be seen in the colour of the quartzites around the mines. The colours are attributed to the argillaceous material found in the quartzites and in some cases, as on Rooderand 510IQ, ferruginous shales display yellow and red oxidation colours (Figure 24).



Figure 24. Example of the red and yellow colours (weathering) observed in the reefs, quartzites, and ferruginous shales at Rooderand 510IQ.

These reefs are inconsistent and poorly-developed and very little is known about their economic value. Sampling results from 50 tons of the Odin Reef, a member of the Meisters Series, returned 12 dwts to the ton (18.7 g/t). However, this reef was displaced by faulting and could not be investigated further (Brink & Waanders 2011). Brink and Waanders (2011) mention that during the period from 1948 to 1950 drilling was conducted by Strathmore Exploration and Management Ltd on the Rous' Series, i.e. Vaal Reef. Only two mines, KL1 and RO1, were observed where this reef was mined (Figure 10 and Appendix B).

- **Koedoeslaagte 516IQ** (Koedoeslaagte 59 on Nel's 1923-5 map)

The reef mined at Koedoeslaagte was referred to as the Red Reef.

Although the mine, KL1, is visible from the road it is quite a distance from the road. The dense vegetation makes locating the adit very difficult. The hanging wall to the adit is very unsafe. This is due to the steep slope directly above the adit which consists of unconsolidated gravel and soil (Figure 25). Evidence of recent human occupation in and around the mine is of concern as it has a very good vantage point to the road. This concern is due to regular burglaries at dwellings in the area. The staff of the interim

management office of the VDWHS based in Venterskroon was informed of this. The waste rock dump's size indicates development in the region of 100 metres.



Figure 25. The adit, KL1, on the Red Reef at Koedoeslaagte 516IQ. Note the dangerous condition of the overhang.

Classification

A single mine adit was observed.

Infrastructure

No visible infrastructure exists.

Beneficiation

No beneficiation activities were observed.

Buildings

No buildings were observed.

Geotourism potential

The adit, KL 1 (Appendices B and C), was found with great difficulty and since access to this specific reef is very limited this adit should be limited to scientific access only since there are only two sites where this reef was mined and are accessible, keeping the unstable overburden in mind (Figure 25).

- **Rooderand 510IQ** (Rooderand 26 on Nel's 1923-5 map)

Classification

Mines and trenches were observed.

Infrastructure

Several mining activities, (RO 1-4) were concentrated on this farm's southern extent a mere 500 metres from the Vaal River (Appendix B). The Yellow Reef/Rous Series, and the Red Reef/Main Reef were accessed firstly through a decline in the quartzite hanging wall. The decline (RO1) dips at around 30° and is the only decline development on waste rock found in the VD as development were normally horizontal to intersect the reefs. The decline is only accessible down to 60 m as the rest is filled with water. No conglomerate was observed and it seems that the conglomerate is underneath the water level.

The reef mined could not be observed in outcrop but from the material found on the discard dump it appears to consist of small to medium-sized pebble, matrix supported conglomerate (Figure 26).



Figure 26. The Yellow Reef/Rous Series or Red Reef/Main Reef observed on the stockpile on Rooderand 510IQ. This reef is a small to medium size pebble matrix supported conglomerate.

Adit RO2 has through-ventilation and is in excess of 100 m deep. Top holing is through winzes RO3 and RO4. Both winzes are dipping at around 50° and very dangerous.

Discard dumps were observed (Figure 27). The mine adits are located high up against a steep hill with burned out coal and wood residues located at the foot of the hill directly below the mine adits. This could have been where a steam generator, like the one mentioned earlier, was located. The absence of any other beneficiation activities and the remoteness of these adits from the other mines north of the Vaal River raise questions around the locality of extraction facilities used. One could speculate that the reef was transported to the Nooitgedacht and Rebokkop mines and beneficiation plant almost directly across the river. The distance would be around 3 km. The closest other mines are more than 6 km away. Transportation across the river could have been done by using a cable system or by pontoon.



Figure 27. Reef is stacked high up against the hill between the mines on Rooderand 510IQ. The hat is for scale.

Brink and Waanders (2011) mentioned mining of the Main Reef along the Vaal River on this farm but no production figures are known.

Beneficiation

No beneficiation activities were observed.

Buildings

No buildings were observed.

Geotourism potential

All mining scars have been fenced in with rolls of security wire, but, already curious people have trashed the fences at each locality. The developments are recommended for scientific more than tourism interest as access to this specific reef is limited.

Mining of the Jeppestown Subgroup (Veldschoen Reef)

The Veldschoen Reef was stratigraphically the deepest reef to be mined from the Jeppestown Subgroup. A total of 30 mining excavations were documented on the Veldschoen Reef (Figure 10 and Appendix B).

Nel (1927) mentioned that the Free State Reefs Ltd. Company was mining the Veldschoen reefs on the farms Rebokkop 290 and Nooitgedacht 89 during October 1926. The general lenticular nature of the Veldschoen Reefs and the abundance of faulting were mentioned by Nel (1927) as the main reason for the discouraging gold grades obtained.

- **Aasvogelrand 249** (Aasvogelrand 293 on Nel' 1923-5 map)

Classification

Trenches were observed.

Infrastructure

Four trench and prospecting pit activities were found on this farm.

Beneficiation

No beneficiation activities were observed.

Buildings

No buildings were observed.

Geotourism potential

All trenches are less than two metres deep and are therefore not dangerous to tourists. If ever development progresses towards a resort or access to tourists, detailed investigations must be conducted and fencing and warning signposts considered. The sites are not visible from the road and difficult to locate.

- **Rebokkop 290**

Classification

A mine adit and a vertical shaft were observed.

Infrastructure

Brink and Waanders (2011) described the ore body as brecciated ferruginous mudstone which was mined at the base of the Veldschoen Reef associated with a shear zone. They also mentioned the recovery of 2.35 kg gold from 682 tons of ore at 3.45g/t from this mine.

A vertical shaft was sunk to allow extraction of ore from the adit level and possible levels below the current water table. Structural complexity seems to have been the main reason for closure of this mine despite it having a well-planned infrastructure. The reef drive at the first level is supported with post mining steel structures whilst the shaft below is filled with water (Figure 28).



Figure 28. Underground infrastructure covering a water filled shaft and leading to an unventilated end at Rebokkop 290.

Beneficiation

No beneficiation activities were observed but the remains of a road leading to the adjoining farm, Nooitgedacht 89, and the presence of beneficiation activities on this farm could indicate transportation of ore to the Nooitgedacht facility.

Buildings

No buildings were observed on this farm.

Geotourism potential

An adit with a fairly new gate is located close to the road. The proximity to the road and visibility allows easy access to passers-by resulting in measures by the property owner to close off the site to access without permission. This signage could lead to interested tourists entering the property to explore old workings and creates a very dangerous condition as visitors can fall into the vertical, water filled shaft. The drive on the other side of the shaft is a dead end with resultant poor ventilation and gas threats. Due to the poor ventilation and flooding this mine should not be used for tourism activities and the current measures to close it off and warn trespassers are commended.

- **The Colin Voi Mine at Nooitgedacht 89**

During its lifespan, 26.6 kg of gold was produced according to Whiteside *et al.* (1976). Brink and Waanders (2011) mentioned prospecting activities during 1926 and 1927, mining in 1934 and dump treatment with cyanide in 1935. They also mentioned production figures of 18.97 kg gold from 3540 tons of ore at 5.5g/t. S.A. Townships drilled the Veldschoen Reef here in 1937, referred to as borehole N1 (Brink & Waanders, 2011).

Classification:

A mine with shaft was observed.

Infrastructure

The mine consists of two stopes, a vertical shaft and an adit. The stopes are open to surface (Figure 29) and since it is unfenced it poses a safety hazard.

Beneficiation

A full beneficiation plant is presumed to have existed here, treating ore from the mines in the vicinity. Remains of a sand dam are visible and cement foundations with steel bolts can be seen. The presence of cement bowl shape structures similar to those observed at Great Western mine are assumed to have been the bases of cyanide leaching bins.

Buildings

No mining related buildings were observed.

Geotourism potential

The rock dump is visible from the road and with the entire infrastructure unfenced; this mine is considered to pose a health and safety hazard.



Figure 29. Slopes on Nooitgedacht 89 open to surface

Very limited information exists on the prospecting and mining history of the following properties and the available info is reported.

- **Welgevonden Mine on Eensgevonden 232**

Brink and Waanders (2011) mention small scale trenching in 1933 and again during the period from 1934 to 1937. No results are available.

- **Eerstegeluk 515**

This farm is situated between the farms Sunnyside and Libertas. Brink and Waanders (2011) reported that prospecting on this farm returned 8 dwts to the ton 12.44 g/t for the reef explored at this site (assumed to be the Veldschoen Reef).

- **Mimosa Grove 491**

S.A. Townships drilled the Veldschoen Reef here in 1937, namely borehole M1 (Brink & Waanders, 2011). Boreholes were also drilled on Renosterpoort 108: borehole R1; and

on Virginia 518: borehole V1, but with resulting low values. This farm is situated near Reitzburg.

General

It was observed at most mines where the reef and waste were separately dumped/stockpiled adjacent to the excavations, that the reef segmentation was coarser than that of the waste possibly due to blasting techniques (Figure 30). The question arises as to why the ore was never removed during the final mining days? Did the plants belong to different syndicates to the mines or were some of the mines toll treating for others? This could have led to the owners of the plants closing them and relocating to the Johannesburg goldfield before the final ore could be delivered for treatment? Or did all the mining activities come to an abrupt halt for some other reason?

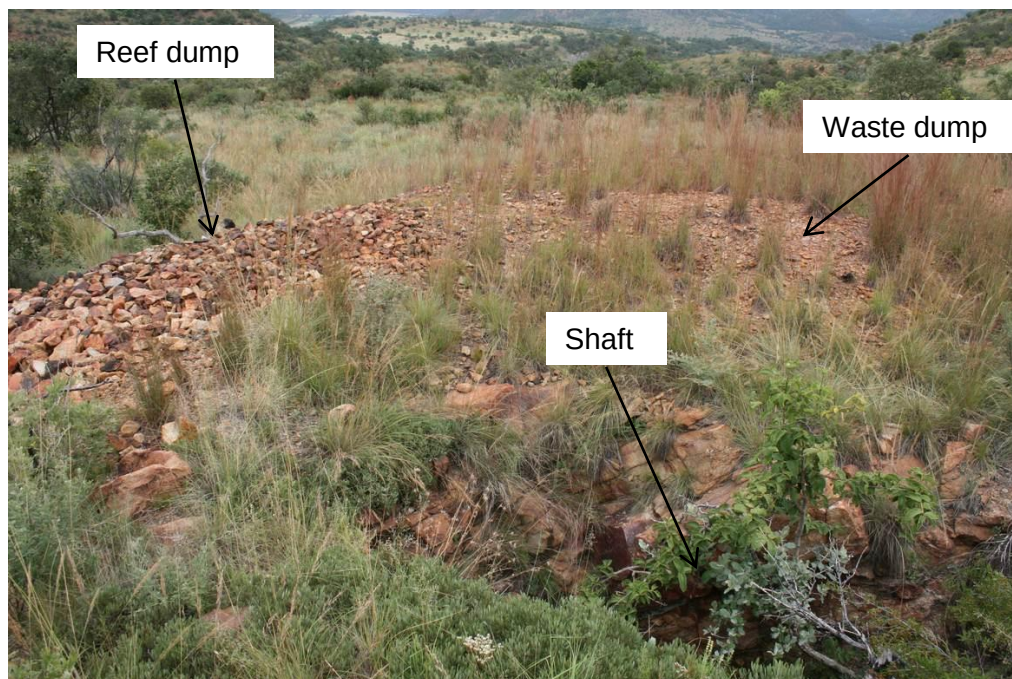


Figure 30. Separate reef stockpiles and waste dumps at mine BK3, Buffelskloof 483 IQ, where the Amazon Reef was mined. In this case there is the possibility that all mining activity was terminated before the ore was transported to a nearby plant.

Another unsolved mystery seems to be the complete absence of mining equipment and infrastructure excluding cement structures. The remoteness of the mines and abundance of other old farm implements in the area excludes the possibility of recent removal for scrap metal. Was mining equipment so scarce during those times of import that all equipment had to be taken with to enable future success in new endeavours?

Gold-mining outside the VDWHS

These mines were not surveyed since they fall outside the study area, but to compile a complete list of mining activities in the Vredefort Dome the mines are listed below.

- **Mayer's Mine on Lindekweesfontein 73.**

This mine is situated near Reitzburg. Brink and Waanders (2011) mentioned that the Veldschoen Reef was mined at this site between 1933 and 1935, and 0.092 kg gold was recovered from 523 tons of ore at 5.67g/t. According to Kriel and Germishuys (1957) an average grade for this reef was 16 dwts to the ton or 24.88 g/t.

- **Willie 905**

The only information on this site is that it was mined during 1933 (Brink & Waanders, 2011).

- **Procedeerfontein 100**

Brink and Waanders (2011) mentioned late unsuccessful prospecting operations on Procedeerfontein 100, northeast of Parys, from 1934 to 1953 by Transvaal-Orangia Main Reefs Ltd., on the Cullinan or Vaal Reef and the Veldschoen Reef.

Other mining activities

The mining of hematite for manufacturing of artefacts could be a possibility, referring to the iron artefacts found by Waanders *et al.* (2005). A source for hematite could be the Witwatersrand banded ironstones although no mining excavations were identified in the VDWHS as yet.

2.2.3 SITES OF INTEREST IN THE VICINITY OF MINES

These sites could be classified as culturally significant heritage sites.

Kraals

At most of the major mine sites three types of historic architecture is visible. The oldest, probably bearing no association with the later gold-mining activities, is the circular shelters. These features contain stacked rock walls normally not more than one meter in height, which withstood weathering through the ages (Figure 31). These were home to Sesotho or Setswana-speaking farmers from the 1500s to the 1700s. Most of the

villages were built in defensive positions on the crest of the hills, but it did not save them from destruction by the warriors of Mzilikazi (Reimold & Gibson, 2005).



Figure 31. Remains of stone kraals (Rooderand 518IQ) often seen on hills all over the VDWHS. These kraals are seen as Sesotho or Setswana dwellings and cattle kraals from the 1500s to the 1700s.

Mining infrastructures

The second type of historic infrastructure around old mines is mining offices, equipment and explosives stores or shelters. These structures were built with rock walls with or without mud plaster and were used mainly during the active mining times (Figure 32).



Figure 32. Stone-walled square buildings in the vicinity of gold-mines on Rooderand 518IQ.

Historic sites

The third historic infrastructure visible is lookout points close to mining areas. These are semi-circular rock-walled shelters and sniper or observer structures (Figure 33), probably dating from the Anglo-Boer War during the period 1899 to 1902.



Figure 33. Lookout shelters located close to mines on Koedoesfontein 478IQ close to QKF10.

2.3 GRANITE DIMENSION STONE QUARRIES: IDENTIFICATION AND DESCRIPTION

In defining the term dimension stone, Oosterhuis (1998:259) cited Thrush (1968):

... incorporating all naturally occurring rock material, cut, shaped, or selected for use in blocks, slabs, sheets or other construction units of specific shapes or sizes, and used for exterior or interior parts of buildings, foundations, kerbing, paving, flagging or for other architectural or engineering purposes.

When dimension stone is used as ornamental stone for decorative purposes the focus is usually on qualities such as uniform colour and/or texture (referring to grain size, shape and arrangement of the grains). Granite is notable for its quality to withstand weathering giving rise to a long-lasting polished finish even when exposed to harsh climatic conditions. The variety of colours, patterns and textures of granite, together with its ability to sustain a polished finish, renders granite a popular choice in ornamental stone. Dimension stone from different areas is marketed under specific trade names of which the following are different varieties of the so-called Parys Granite that was mined in the Vredefort Dome: “African Flame”, “African Juparana”, and “Transvaal Rosso” (Oosterhuis, 1998).

2.3.1 GENERAL GEOLOGY

The Archaean granite and granitic gneisses of the VD outcrop occur in the core of the Dome. The central part of the core is made up of the older Inlandsee leucogranofels (ILG), composed of leucogneiss and leucogranulite, and the outer part consisting of the

Outer Granite Gneiss (OGG), composed of younger granite and granitic gneiss (Figure 10, and Appendix D).

According to radiometric age determinations the ILG is dated at 3.5 Ga, and the OGG at 3.05 Ga (Stepto, 1990). The Archaean granitic assemblage is similar to those found elsewhere in the country except for the unusually high metamorphic granulite grade in the ILG core terrain (Hart *et al.*, 1981a, b).

Through the exposed quarry faces and three-dimensional blocks of granite intersected by pseudotachylite veins, mining contributed to the understanding of the formation of the impact cratering event. Pseudotachylitic breccia is molten material formed during impact and movement that flowed, carrying chunks of unmolten granite within the melt (Bisschoff, 1999b),

The sheer magnitude of the impact event becomes evident on observation of the enormously thick veins of pseudotachylitic breccia as illustrated in Figure 34. The basement granite exposed within the ring of hills (collar of the Vredefort Dome) is estimated to have been seven to ten kilometres beneath the surface when the impact occurred 2.023 Ga ago (Hart *et al.*, 1981a).



Figure 34. The spectacular, much photographed, quarry face at Leeukop quarry, Kopjeskraal 517, displaying thick veins of pseudotachylitic breccia (dark grey to black) containing large blocks of unmolten granite (pale pink and medium grey).

2.3.2 MINING HISTORY OF THE GRANITE QUARRIES

Granite mining commenced in the Vredefort Dome around 1890 and continued until 1998. One of the first granite miners and workers, Mr Mario Angelo Pedretti, immigrated to the area from Italy as granite sculptor. He initiated mining in the area of the current Parys waterworks and soon afterwards blocks were used to construct the Parys jail (Figure 35) in 1896 and the post office (Figure 36) (T van Rensburg, Head of Correctional Centre, Parys, personal communication, 12 February 2010). Parys Granite (trade name) became popular and was transported to Potchefstroom and the rest of the country where it was used to construct mainly government buildings. Further afield, the Receiver of Revenue building in Rissik Street, Johannesburg and also in the Voortrekker Monument in Pretoria were built or decorated with the Parys Granite. Parys Granite can be seen in the older areas of the O.R. Tambo International Airport.

According to Mr Mario Pedretti (son of the first mentioned Pedretti), the granite mining continued until the late nineteen-eighties when the focus moved to the Brits area where norites of the Bushveld Igneous Complex are mined. The decline in the mining of Parys Granite was also due to the environmental pressure applied by local population due to the noise and dust (Figure 37) made by the mining companies when they used a thermal lance (flame cutter) (Figure 38). This machine used a mixture of paraffin and diesel with oxygen to cut the granite and was used mainly to remove the outer weathered crust from the surfaces of outcrops to establish the quality of the stone and then to define the block that should be mined.



Figure 35. The first granite dimension stone mined around the area was used in the construction of the Parys jail in 1896.



Figure 36. Granite blocks used in the construction of the post office, Parys.



Figure 37. Cloud of fine particles created when a thermal lance cuts a slot into a granite block. This photograph was copied from the Techcorr website (Techcorr, 2012).



Figure 38. Thermal lance cutting a slot in granite. This photograph was copied from the Techcorr website (Techcorr, 2012).

The third reason for the demise of the industry around Parys was the unexpected appearance of the black pseudotachylite, which was not met with approval internationally. Today the pseudotachylitic breccia is regarded as one of the unique testimonies supporting the meteorite impact theory.

The granite from the OGG is similar to that mined at Leeukop (GQ3, Kopjeskraal 517, Appendix D). This rock was locally known as “African Juparana” (Oosterhuis, 1998) named, by Mr Pedretti (senior) (Mr Mario Pedretti (junior), personal communication, 20 February 2010), after a similar rock type found in Brazil.

Mining methods observed during fieldwork ranged from thermal lance cutting (Figure 39) to percussion drilling (Figure 40) and in one case (Kopjeskraal 517 GQ8, Appendix D) diamond wire cutting (Figure 41).

In some cases splitting of the blocks were done (Figure 42) by drilling a series of narrow holes a few inches apart with a pneumatic drill. Two half-cylinders of steel called ‘feathers’ were inserted into all the holes. A steel wedge-shaped ‘plug’ was then inserted. The plugs were then hit in succession with a hammer and a straight split in the granite block would result.



Figure 39 Thermal lance grooves clearly visible on a quarry face (GQ8, Kopjeskraal 517).



Figure 40. Markings left by percussion drilling holes, which are loaded with dynamite to crack the granite (GQ8, Kopjeskraal 517).

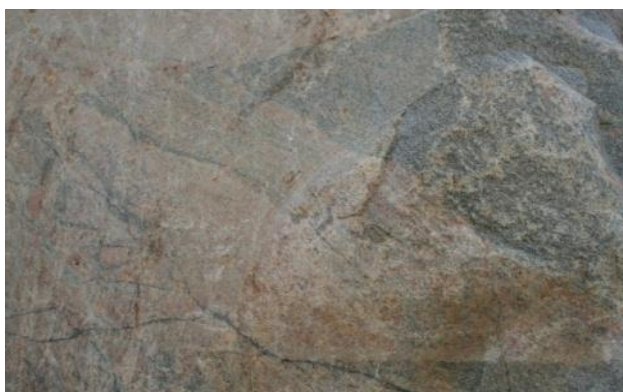


Figure 41. The flat surfaces of two dimension stone blocks from the quarry, GQ8, on Kopjeskraal 517 that were cut with diamond wire.

In some cases leftovers of ignition cord and jumper rods are still visible in the drill holes (Figure 43a and Figure 43b).

Due to the listing as a WHS, no further mining of the quarries are allowed. The last blocks of precious granite from these quarries are being transported to locations country wide and cut locally by the third generation Mr Angelo Pedretti. Blocks, unsuitable as ornamental stone, are left scattered around quarries amongst the rubble and mine dumps (Figure 44).



Figure 42. A historic photograph from Silver Grey Quarry, Creetown. Kirkcudbrightshire. Two quarrymen can be seen inserting the 'plug and feathers' into a large granite block. A recently separated block can be seen in the foreground. This photograph was copied from the Drystone garden website (Drystone, 2012)



a



b

Figure 43. (a) Ignition cord used to ignite dynamite candles, still dangling from drill holes at the GQ8 quarry on Kopjeskraal 157 and (b) jumper rods, used to do percussion drilling, still visible in some drill holes at the same quarry.



Figure 44. Scattered unused granite blocks around a quarry GQ12 photographed from a hot air balloon.

The Salvamento Quarry (GQ2) located close to the road on Kopjeskraal 517 displays a full sequence of the mining process. The various mining methods at this quarry are shown in Figure 45 with thermal lance cutting done in the main mining area (Figure 45(a)), followed by percussion drilling of the individual blocks of dimension stone (Figure 45(b)), and lastly blasted to dislodge the individual blocks (Figure 45(c) and (d)).

2.3.3 IDENTIFICATION AND DESCRIPTION OF THE GRANITE QUARRIES

A total of fifteen quarries were documented during this study and recorded in Appendices D and C.

GQ1 Pedretti Quarry at Kopjeskraal 517

This is a small quarry (GQ1), filled with water, and located close to Parys on the Kopjeskraal road. The eastern mining face displays excellent examples of soil-forming processes from the parent granitic bedrock (Figure 46). It is currently protected by an ordinary cattle fence along the road and access could be gained from the Vaal River side, and the tarred Kopjeskraal road.



Figure 45. In this photograph a full mining sequence from (a) thermal lance cutting, to (b) percussion drilling, and (c) blasting is displayed at the Salvamento Quarry. To the left of the quarry face block (d) just tipped over, while block (c) was lifted out of its original position by explosives.

Mining methods

Percussion drilling and thermal lance cutting mining methods were utilized here.

Geotourism potential:

This exposure will be valuable for educational purposes. This mine is close to the road and although not directly visible, it should be considered for tourism potential.



Figure 46. Weathering of OGG granite visible at GQ1 resulting in the formation of acidic soils and granitic boulders (Pedretti's quarry, Kopjeskraal 517).

GQ2 Salvamento Quarry, Kopjeskraal 517

The quarry walls display evidence of geovandalism where recent diamond drilling samples were taken, presumably for research, but later returned and cemented back in place (Figure 47a and b). At least this is the first known case where a mistake was acknowledged and an attempt made to correct it. Perhaps a lesson can be learned here by all geoscientists.

Another case of defacing a quarry faces by drill sampling can be observed at the Otavi Quarry on the R59 Parys-Sasolburg road. This Otavi Quarry is one of the famous historic excursion stops, which numerous overseas researchers have visited. The quarry is outside the proposed VDWHS, and, therefore, has not been included in this study.

Mining methods

At the Salvamento Quarry percussion drilling and thermal lance cutting mining methods were utilized. This mine has the largest concentration of unused blocks stacked east of the quarry. Dimension stone cutting experts rendered the blocks useless for current purposes due to excessive fracturing possibly caused by the mining process.



Figures 47a and b. Scientific researchers start to heed the concepts of conservation when the cores of diamond drilling were returned and cemented back in the quarry wall at Salvamento.

Geotourism potential

This is a prominent and well-known quarry that is currently regularly visited by tourists, researchers and student groups. The access gate is open and access to the mine is invited through the abundant dimension stone blocks scattered throughout the area. Of concern here are the vertical pit walls sometimes in excess of three meters high. Thermal lance cutting grooves up to 15 centimetres wide, also pose a safety risk. This mine is close to the road and should be considered for tourism potential.

GQ3 Leeukop/ Marlin Quarry, Kopjeskraal 517

Leeukop Quarry forms the topographic high in the Kopjeskraal area and hosts the most impressive pseudotachylitic breccia exposure on the southern wall of the quarry (Figure 48). The quarry is water-filled.

The quarry closed in 1998 due to problems with water, extraction of rock from the quarry and the destabilization of the steep quarry wall (Gibson, 2001). This was confirmed by a local resident, who was involved with the mine, mentioning the pit walls rendered extraction and conveyance with trucks impossible towards the end of the quarry life. This followed attempts to change the types of conveyor machinery (P. Kemp, personal communication, 15 March 2010).

Mining methods

Percussion drilling and thermal lance cutting mining methods were utilized here.

Geotourism potential

The risk profile is very high here as up to 50 meter vertical pit walls with unstable rock dumps exist. Erosion holes and channels exist on the northern rock dump. A tour

operator currently uses the quarry for abseiling. Access to the site is restricted by a locked gate and a notice. However, entry is gained through adjacent properties by tourist accommodation owners who do guided cycling trips through the quarry. This mine is close to the road and should be considered for tourism potential.



Figure 48. At Leeukop Quarry, the exfoliating granite pluton resembles a lion's head when viewed from the north. A very impressive pseudotachylitic breccia vein is exposed along the quarry face. This photograph illustrates how the quarrying contributed to the visualization of the three dimensional shape of these veins, something that would not have been possible on this scale without quarrying the Parys granites.

GQ4 Rietpoort 518

The Rietpoort Quarry has high vertical pit walls and is water-filled (Figure 49). This quarry has dangerous rock dumps with erosion holes. Attempts at construction of a road on the rock dump by capping of the rock dump are visible where soil was used as superficial cover. This has resulted in dangerously deep erosion holes forming in the dump along with unstable ground conditions. Unused blocks were used in the construction of a dam wall.



Figure 49. The Rietpoort Quarry, GQ4, with vertical walls and filled with water (Rietpoort 518).

Mining methods

Percussion drilled and thermal lance cutting grooves are visible.

Geotourism potential

It is recommended that an urgent risk assessment be done as there are currently tourism activities on this farm.

GQ5 and GQ6 at Rietpoort 518

Two quarries exist on Rietpoort 518. Quarry GQ5 is water-filled; while GQ6 is dry (no photograph available, see Appendix D).

Mining methods

Evidence of thermal lance cutting and percussion mining is seen.

Geotourism potential

Vertical pit walls are a danger in this quarry, but this quarry is not visible from the road. The quarries are located deep into private land and are currently not used for any tourism activities, but both would be suitable if made safe.

GQ8 at Kopjeskraal 517

This quarry is located right next to the road and is visible to passers-by. The site is cattle-fenced and not used as a visitor's attraction at the moment. Attempts were made

to fence in the individual quarry faces. Vertical pit walls exist in this water-filled quarry. A seven meter high rock dump exists.

Mining methods

Percussion drilling, thermal lance cutting and limited wire cutting mining methods were observed in this quarry.

Geotourism potential

If safety precautions are met this quarry can be used as a tourist attraction.

GQ7 at Rietpoort 518

The quarry is visible from the main Parys-Potchefstroom road and close to it. Access could not be arranged to this quarry. This appears to be a very small quarry in comparison to the rest.

GQ11 at Rensburgs Drift 432

This quarry was mined by Marlin Quarries operations (Mario Pedretti). Rehabilitation efforts resulted in the quarry face being partially filled in with rubble. This now poses a safety risk as erosion holes occur in this area (Figure 50). There are also two very high rubble rock dumps with steep slopes (Figure 51).

The granite is very coarse-grained. Of additional interest is a granophyre dyke situated close to the quarry and seen to cut the eastern face. This outcrop should be preserved for its academic and scientific value although weathered.

Mining methods

Percussion drilling and thermal lance cutting were used to mine this quarry.

Geotourism potential

As a result of the unsuccessful rehabilitation effort, infilling used resulted in unstable ground conditions rendering this quarry unsuitable for tourism.

GQ13 at Spitzkop 1060

The granite exposed in this quarry is very coarse-grained and positive weathering of quartz veins is visible in and around the quarry. A shear zone in the granite is exposed in the quarry face and should be preserved for its scientific value.



Figure 50. The quarry face at GQ11 (Rensburgs Drift 432) having been filled in with rubble.

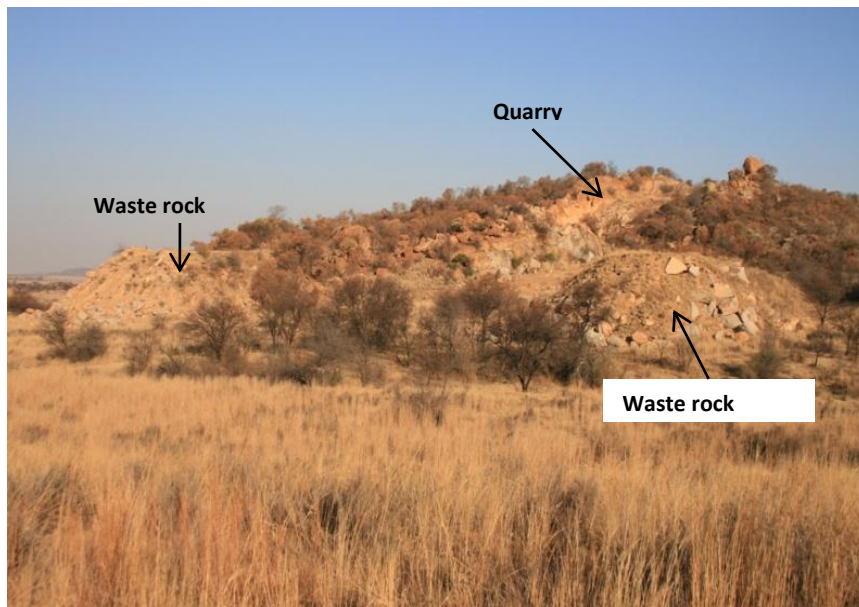


Figure 51. A distant view of the Rensburgs Drift Quarry, GQ11, with the two rock dumps.

A crane (pivot steel structure), previously used for lifting blocks out of the quarry and placing them directly on the transportation medium indicate the position of the quarry and can be seen from a distance (Figure 52a). The pivot structure is also seen on the photograph in Figure 52b taken while the quarry when still in operation. Steel cables are grouted into the granite to secure the structure.

The mining method at this quarry differs considerably from the rest observed in the area. The marking of the drill grid can still be observed and the steel pivot structure is still intact. The drill layout has been altered from a square grid to selective mining of blocks. This seems to have been done to exclude pseudotachylitic breccia and other structural features such as joints (Figure 53).

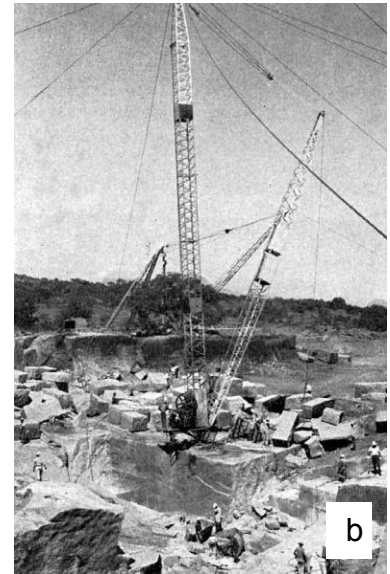


Figure 52. (a) The steel pivot structure at Spitzkop Quarry, GQ13, with the stabilizing cables still in place. (b) An old photograph of possibly the same quarry when in operation. This photograph was copied from the Marlin website (2012).

Mining methods

Percussion drilling and thermal lance cutting were used to mine this quarry.

Geotourism potential

This quarry has tourism potential mainly due to the remains of the mining infrastructure, as well as no water filling.

2.4 CLASSIFICATION OF MINING SITES: POTENTIAL FOR GEOTOURISM

Following the descriptions of the different mines and quarries, these mining activities are classified to enable the selection of sites that could be made safe and accessible to tourists and scientists. The rest of the sites should either be completely closed off due to hazardous conditions or at least fenced off to keep uninformed tourists out.

The following is a set of criteria that were chosen to identify mines, prospecting trenches and granite quarries with scientific, educational and tourism value:

- **Representative lithological units mined**

A representative set of the mined lithologies would make possible educational variety, and access to different reefs with immediate hanging and footwall lithologies available to scientists for observation.



Figure 53. The commonly used square grid implemented to quarry the granite blocks was modified (as can be seen from the percussion holes in the picture) to cut out unwanted structural features and/or to make use of an existing joint system to obtain solid blocks.

- **Representative mining methods used**

Different mining methods were used by different companies to extract the ore. This would benefit educational variety, as well as historic value.

- **Presence of gold extraction facilities**

The metallurgical beneficiation processes of the gold-mines is important for engineering educational purposes, and, further, of historic importance since very few extraction sites exists.

- **Safety**

The mines can be up to 123 years old with very limited human interference since closure. Access to most of the sites is unrestricted and the sites can pose the following risks:

- Toxic gases
- Drowning
- Falling into mine workings
- Getting lost
- Diseases transmitted by wild animals
- Danger from snakes and bees/wasps

Sites categorized to be of value to geoconservation must be in a state where making safe activities would be possible.

- **Accessibility**

Sites closer to road access and accessible on foot without climbing over rough terrain will be more suitable and less costly to turn into tourist attractions.

- **Provincial locality**

With limited river crossings sites on both sides of the river will be selected to facilitate easier access by school groups and visitors from the two provinces.

- **Representative lithological units**

Gold-mines

This refers to the lithological units of the Witwatersrand Supergroup which were mined in the case of the gold-mines. A representation of the three main conglomerate units (reefs), and variations thereof, mined in the VDWHS has to be selected for future reference.

Granite quarries

In the case of the granite quarries, all observed quarries occur in the OGG and none in the ILG. The difference in colour, viz. the whitish grey of the ILG versus the pinkish hues of the OGG, is the obvious reason why OGG, that is Parys Granite, was quarried. As the word “ornamental” implies, fashion in interior/exterior decorating also plays a role in the popularity of ornamental stone.

- **Representative mining methods**

Gold-mines

Although scattered pillar mining was the main gold-mining method employed, various stages of mining activities can be observed. This ranges from the initial exploration trenches, which strike perpendicular to the reefs, to areas where the complete mining infrastructures with reef drives, stopes and vertical shafts can be observed. The mining layout would typically consist of an adit with reef drives on each of the reefs intersected. These reef drives would then extend up to the side of a hill to provide free flow of air through the workplace (through ventilation) and a second escape. The stoping would extend up dip to surface or alternatively have raises or vent holes extending up to surface for ventilation. At some localities, expected to be the more modern mining layouts, a shaft has been sunk to facilitate extraction of ore from deeper levels. The

shaft infrastructure would then also be the conveyance for workers, material/equipment and ore to the surface.

Granite quarries

In the granite quarries, evidence of thermal lance cutting, percussion drilling and wire cutting were observed. The thermal lance cutting torches were also used extensively to clean granite outcrops in an attempt to locate the presence of pseudotachylite veins, as well as larger veins of pseudotachylitic breccia, to observe jointing patterns and to evaluate the general quality of the potential mining block.

- **Extraction facilities**

Gold-mines

Gold extraction equipment was expensive and very scarce as it had to be imported and transported to the VDWHS into uneven and remote terrain with ox wagons. It is assumed that this is the main reason for the establishment of only a few beneficiation sites. The uncertainty associated with the successfulness of the gold-mining activities also must have been a factor. A complete beneficiation plant would have existed of, amongst others, Jameson tables, mercury drums, stamp batteries and cyanide leaching bins. Remains of sites where these facilities remained are scarce and should be preserved as heritage.

Since 1887, nearly 50,000 tons of gold have been produced from mines of the Witwatersrand Basin (Viljoen and Reimold, 1999). That represented about 40 percentage of the total global gold production at that stage. At present the Witwatersrand Basin still contains about 45 percentage of the world's gold resources (Rob & Rob, 1998).

Historically, stamp mills were used to crush gold-bearing rock that was brought from the diggings. The ore was crushed into pieces smaller than 5 cm in size. The pieces were mixed with water and fed into an iron box located at the base of the stamp. The heavy stamps were attached to a camshaft at the top of the mill and were raised by power generated from an attached steam engine. The stamps dropped into the iron box where they crushed the gold ore. The stamp mills had to be ordered from overseas and transported by ox wagon from Cape Town, via Kimberley to the Vredefort Goldfield. The first stamp mills arrived in July 1886 and by 1894 2642 stamp mills were running day and night in the Johannesburg Goldfield (Handley, 2004).

Figure 54 displays photographs of a 10 stamp mill similar to those that would have been used on the Vredefort Goldfields. The stamp mill in the photograph went into operation at the Robinson mine at Langlaagte in Johannesburg in September 1886 (inscription on the mill – Figure 54). It is currently displayed in the Main Street Mining Mall in Johannesburg.

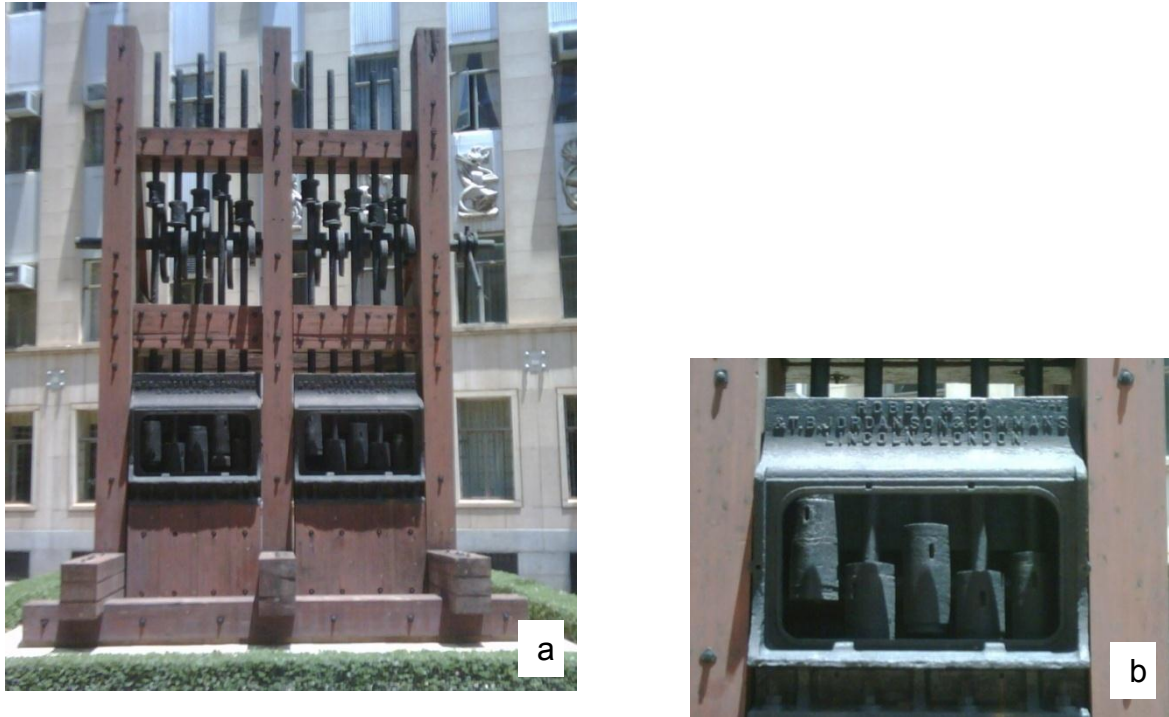


Figure 54. (a) A ten stamp mill used at the Robinson mine at Langlaagte in Johannesburg. It went into operation in September 1886. (b) The cast reads: "Robey & Co & MB Jordanson & Commans, Lincoln London".

Witwatersrand conglomerate gold was, during these times, mainly extracted from oxidized ore by passing crushed ore over mercury-coated copper plates with a 75 to 80% gold recovery.

The pulp discharged through the grates of the mortar box is allowed to flow over an inclined table, covered with a sheet of copper which has been amalgamated. The surface of the copper plate is scoured, then cleaned with a solution of potassium cyanide, and finally rubbed with mercury and a little sal ammoniac. The bright silvery surface is then capable of picking up tiny particles of gold in the pulp and retaining them in the form of a coating of amalgam. When a sufficient thickness has accumulated it is then scraped off, washed, mixed with mercury/quicksilver, washed with water, and finally squeezed through a canvas or chamois leather (Le Neve Foster, 1894).

In the case of unoxidized ore it was treated with a cyanide process. Foundations of the cyanide leaching bins are visible from the Great Western and Colin Voi Mines (Figures 55 and 56).



Figure 55. Cyanide bin foundations at the Great Western Mine, E1, Elandslaagte 28.



Figure 56. Similar cyanide bin foundations at the Colin Voi mine, N1 on the farm Nooitgedacht 89.

According to Sanders *et al.* (1994, in Robb & Robb, 1998), the official gold production from the Kimberley Elsburg Reefs in the Vredefort Goldfield amounts to 120 kilograms. From this study the total gold production totalled 158.95 to 167.95 kg. This Figure varies due to varying Figures published (Table 2). It is proposed that total gold production for the Vredefort goldfield in the VDWHS would have been in the region of 180 to 200 kg. This would include the myriad of small mines not quoted in the table or in previous literature and the fact that all production would not have been reported. Brink and Waanders (2011) also mentioned a fire which destroyed most of the early mining records (1912) in the Mining Commissioner's Office at Rooderand, Venterskroon.

Table 2: Summary of gold production from 1869 to 1937 in the Vredefort Dome goldfield (Brink & Waanders, 2011; Sanders *et al.*, 1994 in Robb & Robb, 1998.)

Reef	*Reference no.	Mine and/or farm	Time In Operation	Gold Production (kg)
Amazon	K1-K8	Nooitgedacht 508IQ	1909-1911	24.00-25.00
Amazon	E1	Elandslaagte 28. Great Western Mine	1888-1937	97.00-104.00
Amazon	R1-R24	Rooderand 26/510 IQ	Approx. 1869-1903	No information
Rous	B23	Buffelshoek	1889-1899	10.00
Veldschoen	BE1	Rebokkop 290	na	2.35
Veldschoen	N1	Colin Voi Mine / Nooitgedacht 89	na	26.60
Total kg gold produced				158.95-167.95

*Reference no. - see geological map in Appendix C.

na = not available

Granite quarries

Once the blocks have been excavated from the quarry they are lifted with a crane (pivot structure) (like that seen at GQ13, Spitzkop 1060) and loaded on lowbed trucks for delivery to the Parys railway station. These blocks were then railed to Durban for export. The blocks destined for the South African market were conveyed to Johannesburg where a Mr Paul Belfiore owned a masonry company which manufactured most of the tiles and blocks used in the construction industry (personal communication Mr Angelo Pedretti; 29 October 2012).

- **Safety**

Gold-mines

The mining method used in all the gold-mines is the conventional scattered pillar mining. The near vertical dip of the strata adds a very dangerous component to the abandoned sites. Stopes are open to surface resulting in approximately one metre-wide scars running along strike for tens of metres and extending down dip at 60° to vertical depths of up to 60 m. Shafts, ventilation holes and raises are openings from 2m x 2m to 4m x 4m wide. Shafts and ventilation holes are vertical whilst raises follow the reef plane, and, therefore, dip at anything from 60° to vertical (Figure 57). Some attempts to fence in excavations with rolls of barbed fence have failed as curious visitors have trampled the fences to ground level, resulting in easy access. Near vertical stopes display signs of collapse and rock falls (Figure 58). When entering mine workings through adits, the risk exists of falling down shafts, ore passes or into stopes (Figure 59).

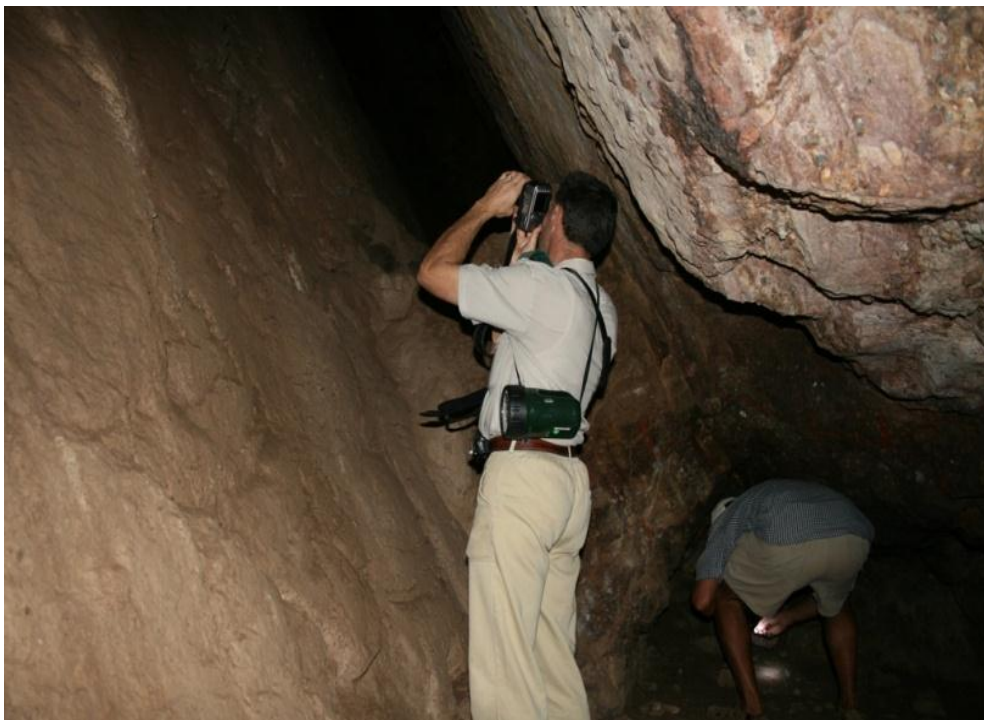


Figure 57. Near vertical stopes accessible from the side of the ridge at K3, Nooitgedacht 508 IQ.



Figure 58. The same stope as in Figure 57, showing signs of collapse and crumbling pillars.



Figure 59. An adit at R19, Rooderand 510 IQ where the stoping from the bottom level holed into the reef drive. The red flags were used in an attempt to warn visitors of the danger when walking past the site after abseiling down from a raise holed to surface (where sunlight enters to the left hand side of the picture).

The hanging wall conditions in most mines are suspect and proper inspection is recommended. Overburden which falls down adits and any near vertical excavation are also a problem (Figure 60).



Figure 60. An adit QB13 on Buffelskloof 511 IQ with bad overhang at the entrance.

Rock dumps are steep but a greater threat is represented by the sites where the rock dump has caved in and the risk exists of extensive failure (Figure 61).

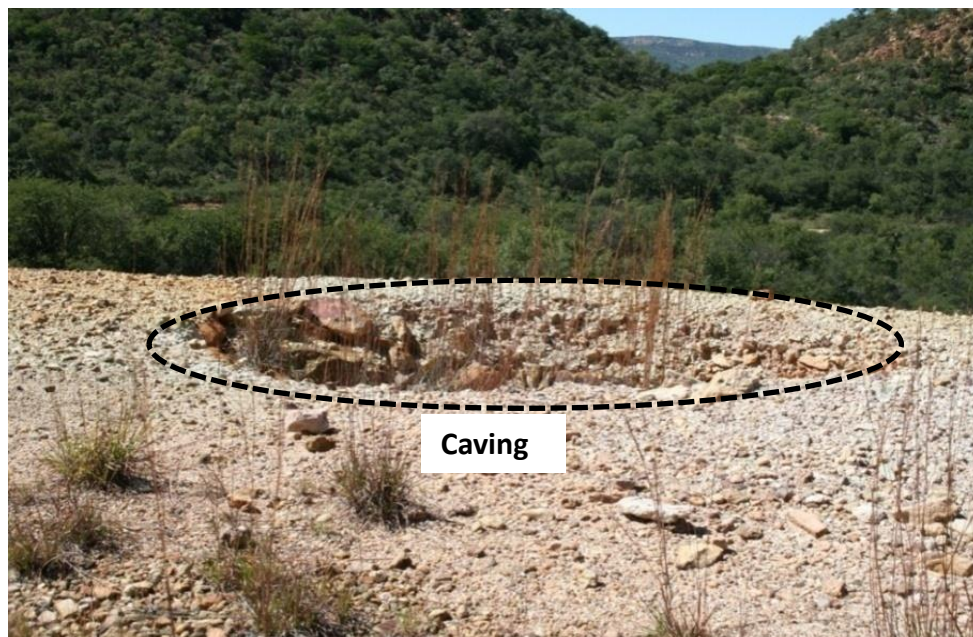


Figure 61. Rock dump, R15, on Rooderand 510IQ, displaying signs of caving.

Granite quarries

The granite quarries all feature high quarry walls (Figures 62 and 63) which are dangerous and sites identified as tourism areas should be made safe. Sites could be fenced off to prevent access and exposure to the risk of high walls and sinkholes. Further covering of rubble heaps and blocks are not recommended. It gives the false impression to uninformed visitors that the surface is safe to walk on.



Figure 62. High quarry wall (approximately 4m) in Salvamento Quarry GQ2, Kopjeskraal 517IQ



Figure 63. To the upper right of the group of people to the far right of the photograph unstable rock dumps and overburden at Leeukop Quarry GQ3 on Kopjeskraal 517IQ.

Since the end of mining, erosion and degradation have resulted in serious safety conditions in most quarries. The risk associated with unstable rock dumps and overburden is visible at Leeukop Granite Quarry (Figure 63).

Rocks dumps some with ramps, are usually unstable and often display serious caving that is often enhanced by water erosion (Figure 64). This is more dangerous than the gold-mines due to the size (often 3 to 4 cubic meters) of the dimension stone fragments comprising the waste dumps.

- **Accessibility**

Sites visible from the existing roads clearly pose larger safety risks as people exploring the area will be curious to investigate. Sites located in areas where tourists are currently



Figure 64. Caving observed at quarry GQ4, Rietpoort 518IQ

concentrated, like lodges and hiking trails, are classified as high risk due to existing uncontrolled movement of people at these sites.

On the other hand, sites with tourism potential should, preferably, be located close to existing roads where visiting the attractions can easily be facilitated, without building new access routes. In the case of the granite quarries, all are easily visible from existing roads due to their large rock dumps, all of which are attracting unwanted attention. Added value to some of the existing hiking trails would be access to some of the mining activities along these trails, but careful selection with safety in mind is of utmost importance due to accessibility during rescue operations should it be necessary.

- **Provincial locality**

Proposing sites representative of both provinces was thought to be important for especially educational purposes since access to the VDWHS from one province to the other there are only two river crossings available.

2.5 NATURAL SITES OR AESTHETICALLY SIGNIFICANT HERITAGE SITES

Various other sites are also linked to the mining industry in the VDWHS. They are therefore seen to be an integral part of the geoheritage of the area. Then the vast variety of biological life in the VDWHS, linked directly to the soil and underlying rock

formations, deserves mention in any discussion of the geoheritage of this area. Herewith some sites:

Vredefort

A historic view site of the Vredefort Dome (although serious misunderstandings also exist) just outside the town of Vredefort is at the coordinates 26° 59' 22.90" S, 27° 22' 26.64" E. This site was the original marketing attempt for the Vredefort Dome by a Town Clerk of Vredefort. It had a direction sign to the “dome”, and reference to the Vredefort Library where more information on the “meteorite” could be obtained (Figure 65). This site was taken by the uninformed as the site of the Vredefort “Dome”.



Figure 65. The site outside the town of Vredefort where the original “meteorite” or Vredefort “Dome” was to be found (photograph courtesy Prof AA Bisschoff).

An information centre as part of the World Heritage effort was built on the hill seen in the background of this photograph. The information centre is currently being equipped with the necessary displays pertaining to the meteorite impact structure and other relevant aspects.

Schoemansdrift

With the Schoeman family still living in the area, this historic river crossing bears testimony to human influences on nature. The remains of the old “drift” from

Schoemans"drift" can be seen in Figure 66 where the flow of the water is interrupted by rocks stacked on the sides of the old road in the riverbed. Also visible are the buildings and roads leading to the pontoon ferry which was used as conveyance in times of floods. Figure 67 shows the bridge in 2007 with the irrigation wall and some invader species.



Figure 66. Schoemansdrif around 1935, the drift and pontoon ferry crossings are visible on the right hand side of the photograph.



Figure 67. Schoemansdrif in 2007, with the irrigation dam wall seen on the left hand side of the bridge (note also the presence of the hyacinths and eucalyptus trees).

Steenkampsberg

Figure 68 shows the vertical to overturned strata of the Hospital Hill Subgroup of the Witwatersrand Supergroup clearly. The site provides an excellent lookout point which can aid in comprehending the magnitude of the impact event.



Figure 68. The view to the east from the lookout point at Steenkampsberg on the property of Thwane Bush Lodge

Kommandonek

Figure 69 shows the Kommandonek area with overturned Witwatersrand strata. This area is unique in that the Vaal River cuts perpendicularly across the Witwatersrand strata (Figure 70).

Biodiversity

The visitor to the VDWHS will be able to observe various botanical biomes when moving around between sites of geological interest. The close interdependence of geology, soil and plants makes mentioning of these unique biomes necessary. The grassland plant communities are of specific concern. These include the Carletonville Dolomite Grassland (CDG), Rand Highveld Grassland (RHG) and the Vredefort Dome Granitic Grassland (VDGG). The RHG and the VDGG are considered endangered and the CDG is considered vulnerable (De la Harpe, 2008).



Figure 69. Photograph showing the Kommandonek area with the overturned Witwatersrand strata.



Figure 70. The Vaal River cutting across the Witwatersrand quartzites. View from a hot-air balloon.

2.6 THE LEGISLATIVE SITUATION: SAFETY, ENVIRONMENT AND REHABILITATION OF SITES

There are several mines and quarries identified in the VDWHS. These mines are all defunct and the mining companies deregistered. Since none of the mines have been closed and rehabilitated, they are still subject to the laws applicable to mines in SA.

The Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA) is the primary act responsible for regulating mining activities in South Africa.

Mining will not be allowed in the VDWHS in terms of Section 48(1) (c) of the National Environmental Management: Protected Areas Act (NEM: PAA). A WHS is a protected area for purposes of this Act. The objectives of NEM: PAA are to provide, within the framework of national legislation, including the National Environmental Management Act (NEMA), for the declaration and management of protected areas; to provide for cooperative governance in the declaration and management of protected areas; to effect a national system of protected areas in South Africa as part of a strategy to manage and conserve its biodiversity; to provide for a representative network of protected areas on state land, private land and communal land; to promote sustainable utilisation of protected areas for the benefit of people, in a manner that would preserve the ecological character of such areas; and to promote participation of local communities in the management of protected areas (Kotze & De La Harpe, 2008).

There may, however, be extraordinary circumstances where mining activities are allowed, in which instance numerous provisions of the MPRDA will be applicable. These include: provisions on EIA and accompanying environmental management plans and programs; prospecting, reconnaissance and retention permits, mining rights, and permits and provisions relating to mine closure and rehabilitation.

Other acts which may also be applicable to mining activities include: the National Environmental Management Act 107 of 1998 (NEMA) (the principal act in South Africa that provides for cooperative environmental governance), the National Environmental Management: Biodiversity Act 10 of 2000, (NEM:BA)(concerning mining in national parks), the National Water Act 36 of 1998 (NWA)(a water use licence is required in terms of Section 21 before certain specified uses of water may commence), the Water Services Act 108 of 1997 (WSA)(applicable so far as water institutions are required to obtain permission from the relevant authorities before providing water services in a WHS), National Environmental Management: Air Quality Act 39 of 2004 (NEM:AQA)(the NEM:AQA provides for, among others, ambient and air quality standards, licensing of

certain activities, and EIAs, which may all be applicable to prospective applicants and authorities in WHS) and the Mine Health and Safety Act 29 of 1996 (MHSA) (Kotze & De La Harpe, 2008).

All the gold-mining activities, seen as historic workings, are all still classified as mines under the MHSA. This will be the case until the relevant mine is sealed, closed, rehabilitated and a closure certificate issued. The safety aspects relating to operating mines are therefore also applicable to these mines. This adds to the complication of having some mines open to the public. Regular entry inspections by a competent person will have to be done, among other legal requirements.

2.6.1 RISK RANKING

The Mine Health and Safety Act (South Africa, 1996) requires a risk assessment to be done on all activities which could impact on the safety and health of employees. It was therefore important that a risk assessment be done to highlight the risk factors associated with the sites and to rank the sites to assist in the selection of the most desired sites for tourist access.

A risk matrix was developed for use in the Vredefort Dome mining environment. This matrix assisted in identifying major areas of risk and was used to rank sites according to probability, exposure and severity of an undesired event occurring. The proposed risk matrix is intended to be used as a guide to enable the Vredefort Dome Management Authority and activity owners, with their personnel, to fulfil their moral and legal obligations of identifying and minimizing risk.

The Mines Health and Safety Act (South Africa, 1996) defines a risk as a condition in which the possibility of loss exists.

According to this act, risk is the degree of uncertainty with which an undesired event (accident, incident or near miss) is expected to occur, multiplied by the severity of the consequential loss for the event / occurrence;

i.e. $Risk = P \times E \times C$

where:

- P = the probability of an undesired event occurring;
- E = exposure or frequency is the number of times a person performs the task multiplied by the duration of the task in one year;
- C = the severity or consequential loss associated with the event.

This means that risks are:

- high when probability, exposure and severity of events are high, and, conversely,
- low when probability, exposure and severity are low.

The classification of the levels of severity associated with uncertainty, severity and consequential loss of events is given in Table 3.

Table 3: Levels of severity associated with uncertainty, severity and consequential loss of events (adapted from Greyling, 2010).

RISK MATRIX					
PROBABILITY		CONSEQUENCE		EXPOSURE	
Can it happen?	Value	What injury / damage could we expect?	Value	How often people are currently exposed to the hazard?	Value
Happens often	7	Catastrophic / Disaster / Multiple Fatalities / + R5 million	7	Continuously	7
Quite possible	6	Fatality / Severe Permanent Disability / R1 - R5 million	6	Frequently / Daily	6
Unusual - has happened here before	5	Very Serious Injury (ICU) / R500000 - R1 million	5	Often / Weekly	5
Remotely possible - happened elsewhere	4	Serious Injury (ICU) / R100000 - R500000	4	Occasionally / Monthly	4
Very unlikely but conceivable – has not happened yet	3	Disabling Injury / R1000 - R100000	3	Unusual / Yearly	3
Practically impossible - 1 in a million chance	2	Treat & Return Injury - Below R1000	2	Rare / Within 5 Years	2
Virtually impossible - full certainty	1	Near Miss Injury / Damage	1	Remote / Beyond 5 Years	1
RISK RATING = Probability X Consequence X Exposure					
0	LOW	100	101	MEDIUM	215
			216	HIGH	343

Potential hazards relating to the specific mining environment in the VDWHS with consequences are shown in Table 4.

All mining sites with tourism potential can now be risk-rated and ranked according to the defined set of criteria. This rating was done per farm and is presented in Appendix E and discussed in Section 3.3.1.

Table 4: The proposed mine excavation risk ranking (RR) form. C = consequence; E = exposure; P = probability.

No.	POTENTIAL HAZARDS	CONSEQUENCE	RISK RANKING			
			C	E	P	PR = (C*E*P)
1	Slipping and falling into mine workings	Possible fatalities, serious injuries				
2	Falling into overburden/Dump	Possible fatalities, serious injuries				
3	Hanging wall collapsing	Possible fatalities, serious injuries				
4	Getting lost underground	Possible fatalities, serious injuries				
5	Presence of gases in enclosed ends	Possible fatalities, serious injuries				
6	Wild animals and insects (leopards, warthogs, etc.; bees, wasps, etc.)	Possible fatalities, serious injuries				
7	Diseases (e.g. Histoplasmosis)	Possible fatalities, serious injuries				

2.6.2 SAFETY ASPECTS AND SELECTIVE CLOSURE

The greatest danger lies with mines close to public roads and specifically those visible from the roads. Visitors by car, motorbike or cycle or on foot can see these mines and are tempted to inspect them. Very few of the mines are fenced off and most are open with stopes, vent-holes and shafts gaping at the surface. Farm fences are normally in very poor condition and people interested in inspecting workings can easily gain access. Where sites are inside private game reserves or camps access control is therefore limited. However, sites situated within the terrain of camp sites or lodges are very high-risk due to concentration of people in the area.

Due to the immediate safety risk of tourists entering gold-mines and granite quarries, the results of this study were made available to the North West Provincial Government, Department of Agriculture, Environment and Conservation on the 15th of September 2010. The report included the details listed in Appendix C, and the proposal was made to contact landowners and discuss closure options with them.

The legal situation with regard to rehabilitation responsibility and closure certificates was discussed with the Department of Mineral Resources and is discussed in Sections 3.3.2 and 3.3.3.

2.6.3 ENVIRONMENTAL ASPECTS

According to Wells *et al.* (1992) in Robb and Robb (1998), the major environmental problems on the Witwatersrand gold-mines relate to the mining method, the nature of minerals present in the ore body and the management of solid waste mine-residue. Mine dewatering, the presence of pyrite and uraninite with the gold and the creation of slimes dams through ore processing are regarded as major environmental problems of the industry.

At one mine site, KF1 at Koedoesfontein 478IQ the adit entrance has been partially closed (Figure 71). The result is that rain and groundwater fill up the underground development forming a large reservoir of contaminated water due to acid rock drainage. The water has been used in the past to water a vegetable plot and is currently the source for water for cattle. It is also a very reliable source of fire fighting water high up in the mountains next to the fire-fighting road established in 2008 by the North West Department of Agriculture.



Figure 71. Mine adit KF1 at Koedoesfontein 478IQ partially closed for water extraction.

At other mines like Rooderand (RO1) the presence of plastic pipes indicates extraction of mine water (Figure 72)



Figure 72. Looking down the decline, RO1, on Rooderand 510IQ. Of general concern is the presence of the plastic water pipes indicating extraction of water in the not too distant past.

Tailings disposal facilities (slimes dams) are present in various localities where beneficiation took place. The erosion of tailings slimes into the Vaal River at Great Western mine (Figure 73) was clearly visible from the air.



Figure 73. The erosion of tailings slimes into the Vaal River at Great Western Mine, E1, Elandslaagte 28.

At Rooderand 510IQ (RO1) (Appendix C), the rock dump is not more than 300 m from the Vaal River (Figure 74) and probably produces AMD which could find its way to the river.



Figure 74. The rock dump on Rooderand 518IQ, RO1, with the Vaal River visible in the background.