

# **CHAPTER 1**

## **INTRODUCTION**

The exposure of rocks to the surface of the Earth presents an opportunity to learn more about the rocks, their origins, their content and the make-up of the Earth. Due to the enormous impact event around the Parys area a large part of the earth's succession has been exposed to the surface. The hunt for gold and dimension stone has further disturbed the surface outcrop. This human activity has, through the ages, left a history which together with its special geological heritage must be known and conserved for the future.

This study aims to identify the major mining scars left by both the gold and dimension stone industries in the listed Vredefort Dome World Heritage Site (VDWHS). It further strives to make a selection of representative sites available to future visitors and to identify remaining sites for rehabilitation and selective closure for safety reasons.

### **1.1 INTRODUCTION TO THE STUDY AREA**

The inner part of the Vredefort impact structure, the largest and oldest known meteorite impact structure on Earth, is known as the Vredefort Dome. The Vredefort Dome is situated approximately 150 kilometres south-west of Johannesburg, South Africa (Figure 1).

The study area is limited to the area of the structure listed as The Vredefort Dome World Heritage Site. The relationship between the inner part (Vredefort Dome) and the larger complex meteorite impact structure is illustrated in Figure 2.

The towns of Parys and Vredefort are situated on the granitic basement rocks of the central part of the Vredefort Dome, which is bounded by the mountainous rim consisting of up and overturned strata of the Witwatersrand Supergroup (Figure 3).

The regional geological map (Figure 4) illustrates the fact that the Vredefort Dome consists mainly of a central core of Archaean granitic rocks with surrounding strata of the Witwatersrand, Ventersdorp and Transvaal Supergroups, which were deformed to sub-vertical and overturned orientations after the meteorite impact. The younger Karoo Supergroup sediments and intrusives overlie the south-eastern Section of the Vredefort Dome (Figure 4). The most recent geological map of the Vredefort Dome and vicinity was compiled by Bisschoff (1999a).

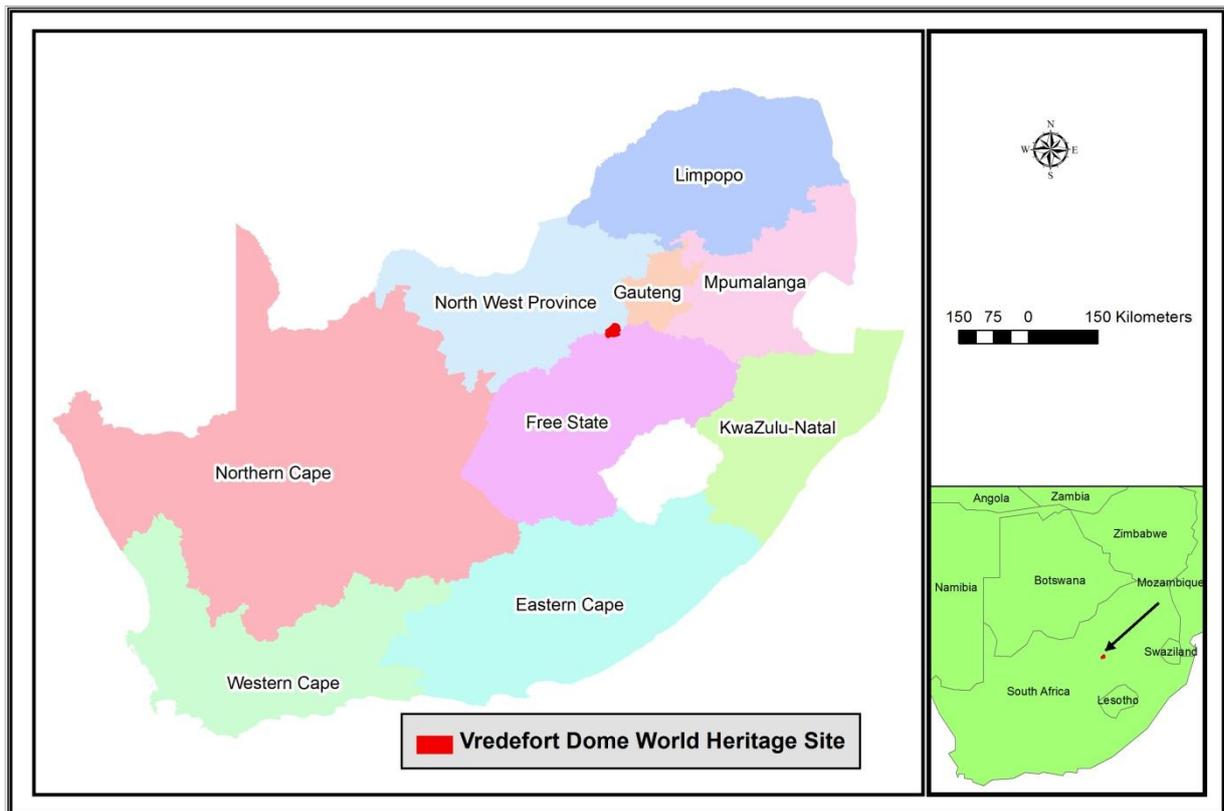


Figure 1. Locality map of the Vredefort Dome in South Africa (compiled by A Hattingh and JM Jansen van Rensburg)

The Vredefort Dome contains high quality and accessible geological outcrop sites displaying a variety of geological evidences of a meteorite impact structure. Following a comprehensive comparative analysis with other complex meteorite impact structures, Brink *et al.* (2005) demonstrated that it is the oldest, the largest and the only example on earth providing a full geological profile of an astrobleme below the crater floor. The impact is dated at  $2023 \pm 4$  Ma from zircon crystals found in pseudotachylite and granophyre (Kamo *et al.*, 1996).

Roughly a quarter of the Vredefort Dome's north-western Section ( $26^{\circ} 52'$  to  $26^{\circ} 56'S$  and  $27^{\circ} 11'$  to  $27^{\circ} 26'E$ ) (Figure 4) was listed as a proposed Natural World Heritage Site by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2005. The listing as a natural heritage site was promulgated to protect and conserve the unique geological assemblage resulting from the meteorite impact, including shock metamorphic textures and structures, typical rock types and geomorphological features (UNESCO, 2005).

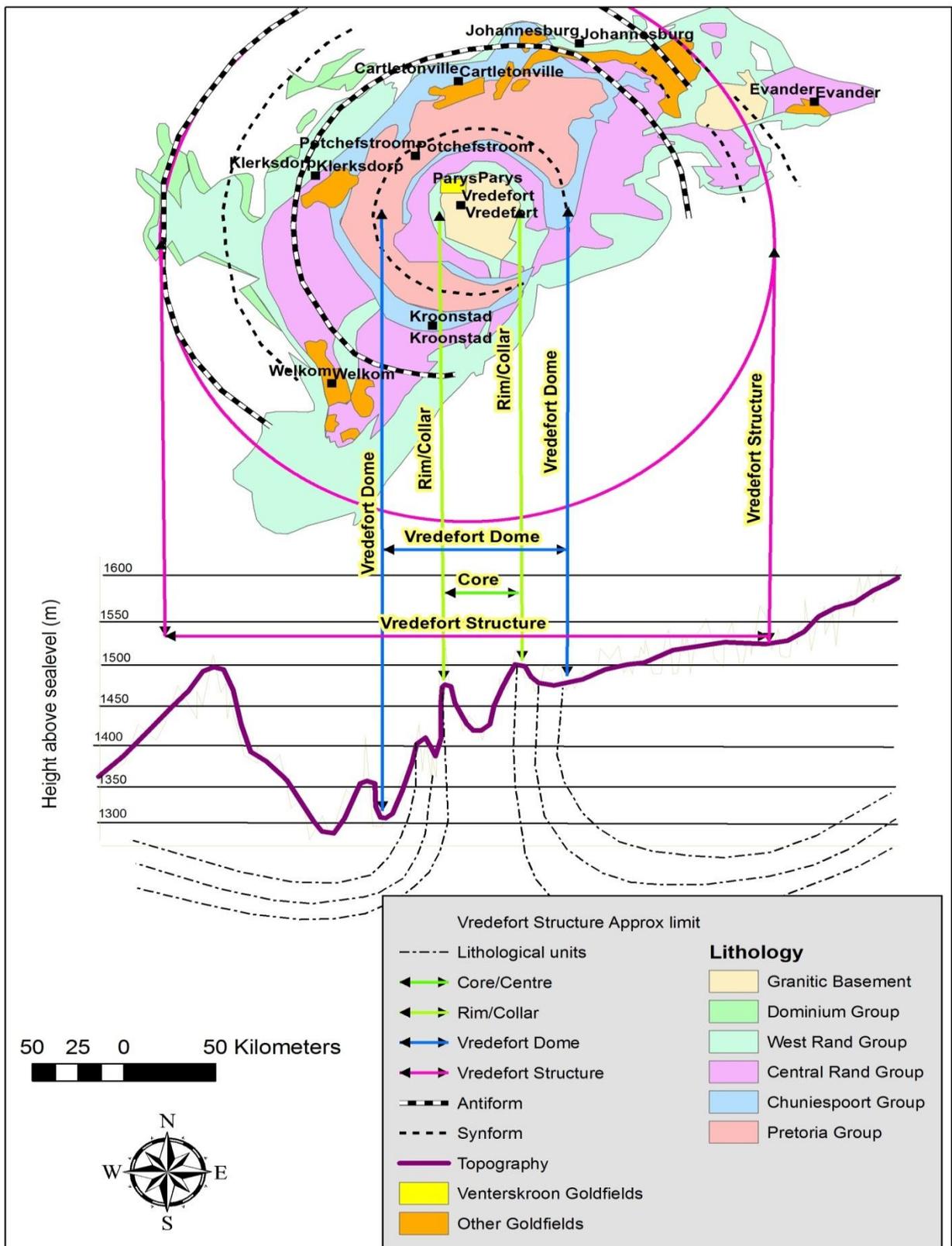


Figure 2. Simplified geological map showing the extent of the Vredefort meteorite impact structure (indicated by the pink circle), and the Vredefort Dome comprising the inner part of the impact structure (indicated by the synform) (after McCarthy, 1990, and Myers *et al.*, 1990). A diagrammatic section depicts the relationship between the larger Vredefort meteorite impact structure, Vredefort Dome with the rim/collar and the centre/core of the Vredefort Dome. (Not to scale. Compiled by A Hattingh and JM Jansen van Rensburg)

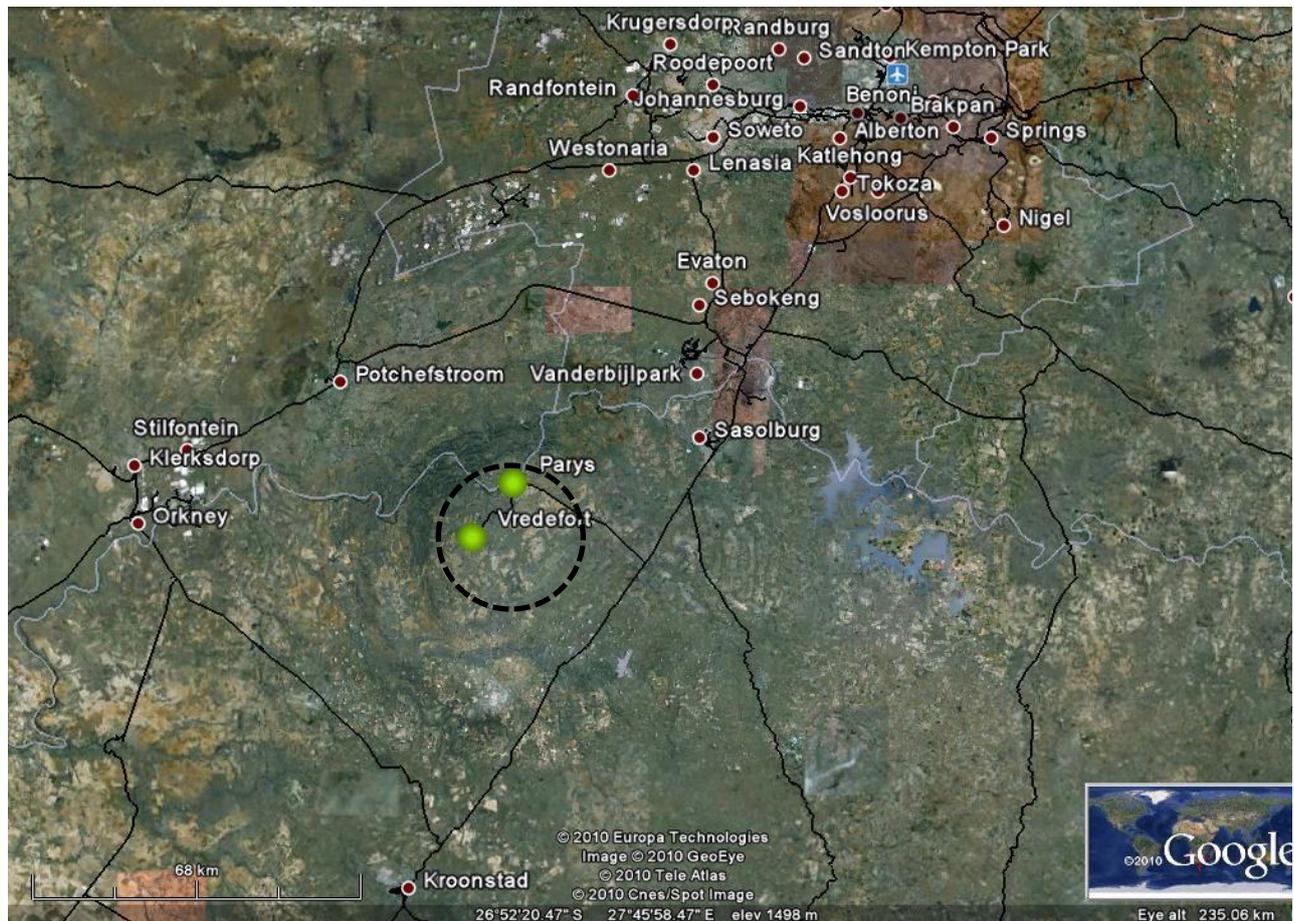


Figure 3. Google Earth image of the Vredefort Dome and vicinity indicating the towns of Parys and Vredefort. The core of the structure is indicated by a black circle.

The VDWHS straddles the Vaal River which forms the administrative boundary between the North West and Free State Provinces in the nomination area. It covers the following area: a core zone of 30,111 hectares (ha) which includes three nearby 1-ha outcrop satellite sites, namely the Stromatolite Basal Fault (Rooipoortje 435), Pseudotachylitic Breccia exposed in the Leeukop Quarry (Kopjeskraal 517), and the Chocolate Tablet Structure in chert (Walkraal 498), and a planned buffer zone of 14,422 ha (Figure 4). The altitude varies between 1,300 m and 1,692.7 m (UNESCO, 2005).

The VDWHS is predominantly privately owned. There are 149 farms in private ownership in the core area: 91 are located in the North West Province (18,857 ha) and 58 are in the Free State Province (11,251 ha). Six hundred hectares are owned by the State. Currently the site is managed by the Vredefort Dome Inter-provincial Task Team under the Vredefort Dome Steering Committee (UNESCO, 2005).

Figure 4

## 1.2 GEOCONSERVATION TERMINOLOGY

As the topic of geoconservation is relatively new in South Africa an explanation of terminology follows:

- **Geodiversity**

According to Gray (2008) the term “geodiversity” can be considered a shortened version of the phrase “geological and geomorphological diversity”. It has been defined as the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (land forms, processes) and soil features (Sharples, 2002). It includes their assemblages, relationships, properties, interpretations and systems. Geodiversity is the abiotic equivalent of biodiversity. The term was first used in 1993 in publications in Germany and Australia by Wiedenbein and Sharples (Gray, 2008).

- **Geoconservation**

Geological conservation involves the following actions: recognizing, protecting and managing sites and landscapes identified as important heritage for their geological (rocks, minerals, fossils), geomorphological (land form, processes) and soil features (Sharples, 2002; Burek and Prosser, 2008). It is the endeavour aimed at conserving geodiversity and geoheritage worthy of future generations. Burek and Prosser (2008) listed the steps that should be taken to conserve a geosite in Table 1 below.

- **Geosite**

Verpaelst (2004) describes a geosite as a site with remarkable geological or scientific significance, and states that the site’s geological character should meet several of the following selection criteria, namely:

- scientific value;
- geotourism appeal;
- educational value;
- historic significance;
- cultural, spiritual and social value;
- economic value;
- international significance;
- link with biodiversity;
- refuge for rare and threatened species;
- aesthetic quality;

- representativeness;
- stratigraphic landmark;
- palaeo-biodiversity;
- rare or unique character;
- precious character;
- vulnerability;
- quality or state of preservation;
- size; and
- accessibility.

Table 1: What is geoconservation? Geoconservation and the steps leading up to it (Burek & Prosser, 2008).

Activity relating to geological/geomorphological features, sites and specimens	Examples of activity	Comments
Initial awareness	Appreciation that geological/geomorphological features, process, sites and specimens exist	Not geoconservation – just awareness of natural environment or heritage / culture
Examination, description, scientific audit	Specimen collecting for curiosity, visiting and describing features, sites etc., geological mapping/survey.	Not geoconservation – collecting and scientific description. Classification and taxonomy start of scientific thinking.
Value/appreciation	Retaining specimens, telling others about features, sites etc., drawing and painting of features, sites etc.	Not geoconservation – but a subconscious state likely to result in support of conservation if a threat is perceived.
Awareness of threat/perceived threat.	Concern and desire to act	Not geoconservation – but likely to be followed by geoconservation
Unintentional or coincidental activity that leads to a geoconservation benefit	Conservation of valued woodland, including a geological feature that coincidentally benefits from conservation of the woodland.	Geoconservation? 'grey area' No intent here, likely area for debate
Conservation audit	An assessment of what is important to keep and where it is e.g. the GCR	Geoconservation action to identifying conservation priorities.
Protection through legal/policy means Management	Conservation legislation or National Park/ planning policy. Purchase of land or specimen, creation of reserve, securing of a site, enhancement of an exposure.	Geoconservation – to protect through law or practice Geoconservation - direct action to protect or manage
Awareness-raising of importance of feature	Interpretation, books, media, lobbying of politicians, education, involvement of local community.	Geoconservation – indirect action to build support for conservation
Development of a holistic approach of conservation showing the interdependence of all aspects of nature	Integrated landscape scale approaches, integrated biodiversity/geodiversity/landscape/archaeology/ conservation	Geoconservation – as part of a strategic, holistic and integrated approach to managing the natural environment

- **Geoheritage**

The Geological Society of America (GSA) defined geoheritage in a position statement draft on geoheritage (2011) as follows:

Geoheritage is a generic but descriptive term applied to sites or areas of geologic features with significant scientific, educational, cultural, or aesthetic value. Scientifically and educationally significant geoheritage sites include those with textbook geologic features and landscapes, distinctive rock or mineral types, unique or unusual fossils, or other geologic characteristics that are significant to education and research.

Culturally significant geoheritage sites are places where geological features or landscapes play a role in cultural or historical events. Aesthetically significant geoheritage sites include landscapes that are visually appealing because of their geologic features or processes. Many geoheritage sites can be tourist destinations (GSA, 2011).

According to Sharples (2002, in Gray, 2004) Geoheritage comprises a concrete example of what may be specifically identified as having conservation significance. Reimold (2006) mentioned in a summary of a lecture presented at the Geological Society of South Africa's Annual General Meeting in 2006 that South Africa's geological heritage spans geo-evolution of 3.5 billion years and have an enormous variety of outstanding natural heritage sites on display.

- **Geopark**

A Geopark (geological park) is defined in the UNESCO Geoparks International Network of Geoparks program (Geoparks Conference 2010) as follows:

A territory encompassing one or more sites of scientific importance, not only for geological reasons but also by virtue of its archaeological, ecological or cultural value.

It is also described as a territory with well-defined limits that has large enough surface area for it to serve local economic development. Thus, a geopark can be seen as an area that contains elements that may be particularly rare, scenic or geologically significant. These elements should be representative of the regional geological history, and of the events that have shaped this geological history (Verpaelst, 2004).

Eder and Petzak (2004) remark on the size and function of a geopark:

- In principle a geopark will represent a terrain which is of sufficient size to generate economic activity.
- A geopark would normally be of sufficient size to encompass a number of small sites (geosites), which taken together, illustrate important geological features.
- A geopark would comprise a number of geological-paleontological heritage sites of special scientific importance, rarity or beauty and so may not be solely of geological-paleontological significance. Archaeological, ecological, historic or cultural features could also be present, and should be regarded as important components of a geopark.
- The geoparks concept is designed to relate people to their geological-paleontological and geomorphological environment.
- A geopark also has to support education on (a) the environment, training and development of scientific research in the various disciplines of the Earth Sciences, (b) the enhancement of the natural environment, (c) sustainable developmental policies.

- **Geotourism**

Gray (2008, p 287) states that geotourism can be seen as the abiotic parallel to “ecotourism” and defined it as:

Tourism based on an area’s geological or geomorphological resources that attempt to minimize the impacts of this tourism through geoconservation management.

Dowling (2008, p 566) defines geotourism as follows:

Geotourism is sustainable tourism with a primary focus on experiencing the earth’s geological features in such a way that fosters environmental and cultural understanding, appreciation and conservation, and is locally beneficial.

### **1.3 GEOCONSERVATION OF THE VREDEFORT DOME**

The sequences of deformed and metamorphosed strata, together with the range of basic intrusions dating from Ventersdorp to Karoo age, and Archaean granitic rocks, which make up the Vredefort Dome, comprise an area of rich geodiversity and thus need to be conserved. It is believed that geoconservation of this area could be achieved

through creating an interest into the rich history and scientific aspects of the geological and mining heritage in the VDWHS.

An urgent effort should be made to conserve the variety of geological evidences of the Vredefort meteorite impact event against geovandalism, as well as the historico-cultural treasures (such as the rock art) and protect these sites against geovandalism. Signs of vandalism of Khoi-San Rock art occurring in the VDWHS at Daskop, where engravings (petroglyphs) appear on the Vredefort granophyre, were already observed. The granophyre represents the impact melt (Reimold & Gibson, 2005).

Going hand-in-hand with the mineral wealth of South Africa are the remnants of old civilizations' mining and smelting activities, such as Mapungubwe. Apart from recent mining activities in the Vredefort Dome, old Iron Age smelters were found at Thabela Thabeng (Waanders *et al.*, 2005). Such historic activities related to geology should be preserved.

According to Gray (2004), conservation allows natural processes to operate and natural changes to occur. Human intervention has in some cases destroyed the natural environment when an attempt was made to interfere through stopping natural processes. Change through human action in a site like the Vredefort Dome is inevitable, but can be limited if managed properly. This is the importance of conservation in geodiversity.

The earliest recorded gold exploration activity in the Vredefort Dome area was in 1853 when a prospecting application was made to the board of the then South African Republic ("*Volksraad*" of the "*Zuid-Afrikaansche Republiek*") for a portion of the north-western Section of the VDWHS where the Kimberley Reefs, locally known as the Amazon Reef, of the Turffontein Subgroup of the Witwatersrand Supergroup, was extensively explored (De Jager, 2005). Prospecting officially started in 1887 following a visit by the then President Jan Brand and was interrupted by the Anglo-Boer War from 1899 to 1903 (De Jager, 2005). The deceased local property owner Mr Johannes van der Merwe (personal communication: 15 November 2007), mentioned seeing gold pans being pushed by people in 1940 on the farm Rooderand 510 IQ. This was probably the last mining activity in the VDWHS.

## 1.4 THE LISTING OF THE VREDEFORT DOME AS A WORLD HERITAGE SITE

During the seven years since the listing of the VDWHS in July 2005 (UNESCO, 2005), a number of problems have stood out. The UNESCO listing of the VDWHS focused renewed attention on the area with an increased number of tourists exploring all the hidden treasures during weekends and holidays.

Gold-mining trenches and shafts are scattered throughout the ridges in the area along the Vaal River. Hikers on hiking trails traversing these ridges will encounter these unprotected hazardous trenches and shafts. The danger of the relics of gold-mining activity lies not only in unbarricaded openings and dangerously deep and steep excavations, but also in the up to 125 year-old unstabilized hanging and footwall conditions inside the mines.

Furthermore a major threat of degradation of sensitive outcrop by means of sample removal and vandalism exists. With increased tourism activities like hiking, bird watching, and abseiling, these overgrown mining and prospecting scars now pose a safety risk and also become a major threat to degradation through sample removal and vandalism.

Granite mining for dimension stone and export thereof had a delayed run but concluded around 1980 when the demand for the so-called commercial Parys Granite declined (Mario Pedretti, personal communication, 2 March 2008). The granite quarries are visible in the country side around the towns of Parys and Vredefort. Associated with the quarries are scattered, mainly low-grade granite blocks and fragments, some up to 40 tons in weight. Here too, thermal lance cutter grooves, destabilized and eroded rock dumps, ramps and pit walls up to 30 meters high, pose serious safety risks to visitors. Recent indiscrete sampling (geovandalism) in the walls of granite quarries, aids in the understanding of conservation of irreplaceable geological heritage resources.

Thus, the questions raised are:

- Will it be possible to make some of these mines safe for geotourism?
- Will it be possible to introduce geoconservation into the area to ensure that the sensitive outcrops are guarded against vandalism?
- Should a larger Vredefort Geopark be introduced to ensure the safekeeping of those valuable outcrops falling outside the proposed VDWHS?

## **1.5 RESEARCH AIMS AND OBJECTIVES**

### **1.5.1 RESEARCH AIMS**

The main aim is to explore ways in which to conserve geological sites associated with the past gold and granite mining in the VDWHS.

A second aim is to select suitable sites which could be prepared, equipped and made safe to enhance geotourism in the area.

The third aim is to recommend selective closure for the remaining sites due to the safety risk they pose.

### **1.5.2 RESEARCH OBJECTIVES**

- Identification of all mining excavations and general geological description of mines, prospecting trenches and granite quarries.
- Classification of sites according to a specific set of criteria to enable selection of sites with potential for geotourism.
- Identify the legislative situation with regard to safety and rehabilitation of sites.

## **1.6 RESEARCH METHODOLOGY**

A literature review of all mining activities in the VDWHS was followed by an identification and description of mining sites. Sites with potential for geotourism were then identified and lastly the legislative situation with regard to safety and rehabilitation of sites was investigated.

Seen in the light of geoconservation the first step in recognizing sites is addressed in this study by identification of gold-mining activities and granite quarries. This should then be followed by protection of these sites in the Vredefort Dome including safeguarding against unauthorized visitors and controlled access to representative sites identified in this study after making them safe. The management aspect should involve the Management Authority of the World Heritage Site ensuring regular monitoring of safety aspects and provision of emergency rescue facilities.

### **1.6.1 LITERATURE REVIEW**

A literature review covering the general geology of the Vredefort Dome; geoconservation and associated topics; geotourism; and mining activities was undertaken (see Section 2.1).

### **1.6.2 MINING EXCAVATIONS IN THE VDWHS: IDENTIFICATION AND DESCRIPTION**

Geological observations were difficult in most cases, due to the overgrown and oxidized nature of the gold-mining excavations and the danger of predators, snakes, bees and wasps. Bad hanging wall conditions and the fear of unknown box holes or shafts covered by debris were ever present. Due to the poor safety state of mines and the fact that most fieldwork was done alone, entry into the mines was limited. The result is a general description of the reefs and immediate hanging and footwall lithology from visible outcrops and mine excavations with a strong reference to existing literature.

The first task was to identify all the gold-mining excavations and granite quarries in the area bounded by the outer limit of the buffer zone of the listed VDWHS (Figure 4).

The following steps were taken.

#### ***Initial site investigation***

First, known sites were visited for both goldmines and granite quarries. Geographical positioning system (GPS) coordinates were recorded, the general geology described and photographs taken for archiving purposes that could also serve as a reference record. As far as possible the landowner and other people who are aware of a mining activity were questioned about the history of the relevant mine or mining activity.

It soon became clear that there are numerous small mines and exploration trenches associated with the gold-bearing reefs. It was not feasible to trek cross country in the hope of finding all possible mines and prospecting trenches.

#### ***Photographic mapping***

Therefore, secondly, with the aid of ArcGIS software, electronic aerial photographs and topographical maps were added to the electronic version of the latest geological map of the Vredefort Dome (Bisschoff, 1999a). The GPS coordinate points of the known sites were imported into the GIS.

As expected, in the case of the goldmines, the known sites coincided with certain lithological units of the geological map. This enabled correlation of certain lithological units with gold-mining activities. Immediately reef horizons became traceable between the larger known gold-mining areas. This was done by manipulating the fill and colour options of the relevant polygons in the GIS geological map. Undetected mining activities could now be identified by following these stratigraphic horizons along strike, looking at a superimposition of the aerial photographs and the geological map. The result was that disturbances in the surface landscape and differences in vegetation due to surface disturbance could be marked on the GIS.

In the case of the granite quarries it was easily identifiable on aerial photographs due to the larger size of the quarries.

### ***Field follow up as ground truthing***

Thirdly, follow up fieldwork then confirmed or rejected the potential mining excavations and associated activities. The method used resulted in the site identification as described in Chapter 2.

It should be noted here that access to some of the sites identified was a very difficult task. The decision was made to ensure as far as practically possible that the property owner was aware of the visit and gave permission before entering the land. With more than 99,5% of the land owned by private landowners this task alone was immense.

Personal communication with researchers and residents in the area provided valuable information in an attempt to put together the puzzle of the mining milieu in an area plagued by economic commodity price fluctuations, wars, poor infrastructure, complex geology and dangerous wild animals like lion, leopard and hippopotamus.

Geological descriptions of the reef and immediate footwall and hanging wall were only made where observations could be made without disturbance to the outcrop. This was necessary to ensure safety during the field work as most outcrops were severely weathered and it was evident that the search for fresh exposures could lead to collapse of ground. Disturbance of the outcrops would also have a negative impact on the geoconservation of a site. The geological descriptions were recorded in Excel spreadsheets linked to the GIS. Appendix C contains different spreadsheets, one each for the three gold-bearing reefs (namely the Amazon Reef, the Meister Reefs, and the Veldschoen Reef), and the granite quarries respectively. The sites were numbered, GPS coordinates given, classified according to the type of reef mined, the visibility of

the site from roads, tourism potential and accessibility. The sites were also described by referring to the type of mining development; the remaining infrastructure; the safety condition; the geology, including strike and dip of the reef; a general description; and finally, the property owner's name and contact details were recorded. The site numbers correlate to the numbers displayed on the GIS maps in appendices B and D for the gold-mines, and granite quarries, respectively.

### **1.6.3 CLASSIFICATION OF SITES WITH POTENTIAL FOR GEOTOURISM**

Due to the large amount of gold prospecting undertaken in the VDWHS it was decided to differentiate between prospecting trenches and mines. Then in the case of goldmines a differentiation was made into the various development methods used. This could include adits, reef drives, winzes, vent-holes, etc.

Firstly, the mining activities were classified into:

- a) prospecting trenches;
- b) mines with reference to the mining development used; and
- c) granite quarries.

Secondly, a set of criteria was developed to identify mines, prospecting trenches and granite quarries with scientific, educational, and tourism value (see Section 2.4). A matrix for risk analysis was then developed to identify and assess the risk associated with each of the sites that were identified as potential sites for geotourism (Section 2.6.1).

### **1.6.4 IDENTIFY THE LEGISLATIVE SITUATION WITH REGARD TO SAFETY AND REHABILITATION OF SITES**

The legislative requirements relating to the safety and rehabilitation of the gold-mines and granite quarries need to be taken into account. The following two acts are of relevance:

- Mines Health and Safety Act (MHSA) No. 29 of 1996 (South Africa, 1996); and
- Labour Relations Act (LRA) No. 66 of 1995 (South Africa, 1995).

In order to satisfy the requirements as stipulated in these acts, various mining risk management and assessment procedures were evaluated and a suitable risk management system and process for use in the relevant mining sites was then developed and applied to selected sites as discussed in Section 3.3.1.