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EVALUATING THE RATE OF ROCK ART DETERIORATION IN THE UKHAHLAMBA-DRAKENSBERG PARK, KWAZULU-NATAL

By

Tšepang Leuta

Submitted in fulfilment of the requirements for the degree of Masters of Geography
University of Pretoria
Pretoria

Supervisor: Professor K.I. Meiklejohn
Department of Geography, Geoinformatics and Meteorology

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DECLARATION

I, the undersigned hereby declare that this thesis submitted for the degree of Master of Arts in the Department of Geography, Geoinformatics and Meteorology at the University of Pretoria, is my own and original work, except where acknowledged. This work has not been submitted for a degree at any other tertiary academic institution.

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Tšepang Leuta

Student Number: 25192397

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ABSTRACT

One of the key reasons for the uKhahlamba-Drakensberg Park's status as a World Heritage Sites due is the abundance of rock art there. Unfortunately, through time, much of the rock art heritage in the Park is being lost through natural rock weathering processes, the decay of pigments and through the actions of people. The fragile art heritage is non-renewable and, therefore, requires specialized management.

In a case study, specific San paintings from Battle Cave study area were analysed using scanned and digital photographs with Geographic Information Systems software. Older images were compared with more recent ones and this was utilised to classify pigment colours and quantify the amount of deterioration that has taken place over time. Various methodologies were applied to classifying the images, and it was found that manual digitising provided the best means for quantifying the amount of deterioration.

A detailed analysis was undertaken of a feline painting at Battle Cave, as it had the best quality images that could be dated. Results showed that white pigment in the painting degraded more rapidly than the ochre colours. Visual analysis suggests that the damage to the figure is predominantly through pigment decay and through the granular disaggregation of the rock surface. Where pigments were applied to what were clearly weathered rock surfaces, the change was greatest over the 40-year intervening period between images analysed.

The methodology utilised in this study can be utilised to evaluate the rate of decay of rock art and is, therefore a useful tool for determining priorities with regard to the conservation of San paintings. In addition, the rate of deterioration is useful for evaluating and quantifying the contribution of rock weathering to landscape evolution.

"By prolonging life of material culture we derive greater pleasure from the objects and that by exercising conservation practices, we in a sense exercise humanity itself," *Haskovek (1991).*

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CHAPTER 1: INTRODUCTION

1.1. Rock Art and its Importance

South African rock art, which was predominantly left by the San people, is a priceless cultural heritage with significant scientific value; however, this legacy is also fragile. In addition to being narrative or historic, rock art is more often a scene of beauty remembered for its aesthetic qualities (Vinnicombe, 1972; Breedlove, 2002). It is important to also consider rock art as a historical source; whether it's primary intention was magical, religious, narrative, or simply a description of the San people's daily life and customs (Beltrán, 1982).

Early analysts believed the San paintings to have been made for merely aesthetic reasons (interpreting it as art for art's sake), or as a documentation of every day events (Whitley, 2001; Wright & Mazel, 2007). Only a few researchers acknowledged that the art might have great significance for the hunter-gatherer artists (Wright & Mazel, 2007). Today, thousands of paintings created by the San People have survived the physical elements, and are visible in rock shelters as a record of their ways of thinking, their spiritual beliefs, and their customs (Wright & Mazel, 2007). Despite the substantial undertaken and published, interpreting the paintings is an extremely difficult task (Wright & Mazel, 2007).

All rock art sites in South Africa are classified as national monuments and are therefore subject to protective legislation (SAHRA, 2000; Hall *et al.*, 2007a; KwaZulu-Natal Heritage Act, 2008). The National Heritage Resources Act protects all rock paintings done by indigenous people in South Africa (National Heritage Resources Act, 1999). When defining national heritage, the National Heritage Council Act (1999) includes, amongst others:

- places of cultural significance,
- historical settlements,
- landscapes and biophysical features of cultural significance, and
- archaeological and paleontological sites.

San rock paintings may not be destroyed, modified, excavated, removed from their original site, or exported without a permit from the South African Heritage Resources Agency or the relevant provincial authority (National Heritage Resources Act, 1999; KwaZulu-Natal Heritage Act, 2008). Anyone defacing the rock paintings or surfaces nearby, or removing them is, therefore, committing an offence and is liable for prosecution (National Heritage Resources Act, 1999; KwaZulu-Natal Heritage Act, 2008).

In addition to national and provincial legislation, the San art heritage in the uKhahlamba–Drakensberg Park is further protected by virtue of the area being declared a World Heritage Site in December 2000 by the United Nations Educational, Scientific and Cultural Organization (UNESCO) (Wright & Mazel, 2007). This was due to its scenic beauty, its high degree of biodiversity, and the exceptional cultural value of its heritage of San rock art. In rock art, not only do the San, but all South Africans have an African and World Heritage of great significance.

It is essential to emphasize that rock art is not casual decoration, but is part of the archaeological record and it has the potential to elucidate many parts of the artists' culture, since it can tell us about belief and ideology, myth and cosmography (Lee, 1986). It is further suggested that the art is also a monument to the San who today struggled to retain their rights and their land (Lee, 1986). Since it is part of the history of South Africa and an irreplaceable cultural resource, rock art deserves our efforts in its protection and preservation. Rock art sites are unique cultural resources that reflect prehistoric San belief systems that are important to South Africans as examples of the creative expressions of early inhabitants (Lee, 1986). To appreciate the art's importance, there is need to establish its history, which will help in valuing the depth of its meaning (Lee, 1986).

1.2. History

Human skeletal remains found at archaeological sites in the southern parts of the Western Cape province of South Africa, suggest that people of the same physical characteristics as the San have been living in this part of the continent for as long as 120,000 years (Deacon, 1994). There is, however, considerable uncertainty on this matter and whilst the origin and time of arrival of the San in southern Africa is not certain, they are thought to have lived here for centuries, and possibly millennia, perhaps as far back as 8 000 BP (Irwin *et al.*, 1980). Recent research suggests that paintings within the uKhahlamba-Drakensberg Park may be between 2 000 and 3 000 years old and, therefore, much older than was previously thought (Mazel & Watchman, 2003).

Rock art in the uKhahlamba-Drakensberg area is suggested to be the work of people in small societies, who temporarily live in a particular location (Willcox, 1956; Wright & Mazel, 2007). The prehistoric people who lived in the region apparently did not build permanent homes, or shelters. It is thought that the San had few material possessions and no permanent dwellings, but lived either in caves or they built small temporary and basic structures of sticks and reeds or grass (Willcox, 1956; Irwin *et al.,* 1980). The San chose rock shelters as living places, of which most had a sunny aspect, and were dry, although they sometimes had a waterfall at one end (Willcox, 1956). If no waterfall was present, the shelters chosen for living in were always near perennial water and usually had a far-reaching scenic view (Willcox, 1956).

The economic base of the San people, who were (and still are) indigenous to southern Africa, was variable and included hunting and gathering, agriculture, horticulture, pastoralism or a combination of these (Rosenfeld, 1988; Deacon, 1994). The San population was small, and comprised groups of probably from half a dozen to several dozen members, and they, therefore, had little significant impact on the vegetation or wildlife population of the area (Wright & Mazel, 2007). The normal social unit was the family or a group of two or three related families; the upper limit probably being the number who could be adequately fed by the killing of one antelope (Willcox, 1956).

The arrival of farming people about 1 500 years ago is suggested to have slowly reduced the number of indigenous San inhabitants; those who did not integrate into farming communities moved to higher mountain valleys (Coulson & Campbell, 2001). By 1850 the few remaining San had retreated to the higher mountain valleys where they were still known to be painting (Coulson & Campbell, 2001); this is given as the reason why much of the most recent San art is located in more rugged areas. The arrival of Europeans in the then Natal colony around the 1840's further changed the way of life of the San, and violent clashes resulted in their virtual extinction from what is now the uKhahlamba-Drakensberg Park (Willcox, 1956; UNEP, 2000; Anon, 2008). "Worse, during the seventeenth and early eighteenth centuries, the San communities were caught up in the increasing conflicts of the progressing colonial frontier and Sotho population increase, and they were all but eradicated" (Lewis-Williams, 2003:20). Some San fled to Lesotho where they were absorbed by intermarriage or died in further fighting (Lewis-Williams, 2003).

It is generally accepted that by 1871 the San hunter-gatherers, as a society, were no longer to be found in the Drakensberg area (UNEP, 2000). What they left behind is a remarkable and irreplaceable heritage of rock art. Today, the Drakensberg range is a major tourist destination in South Africa and one of the best-known adventure destinations in the world.

San rock art is said to have been influenced by agriculturalist values and to be religious in nature (Lewis-Williams & Dowson, 1992; Deacon, 1994; Vinnicombe, 1996; Lewis-Williams, 2003). To clarify this assertion, the way in which the art is painted, where it is placed, details of posture and composition, and the non-reality of many images are all related to the religious experiences of the artists (Deacon, 1994; Eastwood *et al.,* 1994). Many of the paintings indicate that San religion, like many other religions, is centred around the yearning for mystical power or inspiration, perhaps to enable people to cope better with the social and economic problems on a daily basis (Beltrán, 1982; Deacon, 1994). It is, therefore, apparent that art allows one an insight into the San's world view, and a peek into our own hunter-gatherer prehistory.

San rock art is almost certainly the earliest African form of human communication visible to us today and is possibly more graphic than any text (Coulson & Campbell, 2001). Although it may never be possible to fully deduce the meaning of all rock art, once the context in which it was painted, the intensity of its significance can be valued. Instances in which rock art production has been observed and documented provide an absolute date for the art and therefore subjects portrayed in rock art may permit an approximation of the maximum or minimum age for rock art creation (Lorblanchet, 1992). The representation of extinct fauna in art is one means by which minimum ages may be estimated, and equally, the appearance of "introduced" items or animals provides maximum ages (van Rijssen, 1987).

The age of images can play a role in the amount of deterioration and can be crucial in serving to discover pigments or sites that are at a high risk of rapid loss (Hall *et al*., 2007a). Once a painting is executed on the rock, it is immediately subject to chemical and physical weathering. Van Rijssen (1987) suggests that if the deterioration proceeds at a steady rate, the degree of weathering can be used as an indicator of absolute age. Rock art is undoubtedly one of South Africa's most important cultural treasures, as well as a unique historical record.

Substantial and significant debate on the age of paintings in the UKhahlamba-Drakensberg Park has taken place. It is not clear when rock painting commenced in the region (Lewis-Williams & Dowson, 1992; Coulson & Campbell, 2001), but it is suggested to have been as long as 10 000 BP or even older (Coulson & Campbell, 2001). Suggestions for dates range from approximately 30,000 years until a few hundred years ago (Solomon, 1998); other authors argue that the practice of rock painting in Southern Africa has a time depth of at least 26 000 years, but that the age of most surviving rock shelter paintings is probably less (Thackery, 1983; Rosenfeld, 1988).

Many paintings have vanished, but the earliest of those remaining date as far back as 4 000 BP (Coulson & Campbell, 2001). The most recent evidence presented by Mazel and Watchman (2003) suggests that the oldest paintings in the Drakensberg area date to at least 2000 to 3000 BP. Even then, it is acknowledged that the earliest paintings analysed (mainly from the Main Caves study site) do not represent the oldest San art in the area (Mazel and Watchman, 2003).

Rock painting is no longer practiced by the San (Solomon, 1998). As observers, we, therefore need to acknowledge that the paintings we see preserved on rock surfaces that are exposed to the Earth's atmosphere are probably rarely older than some 8 000 to 10 000 years old and that most are considerably younger, (Rosenfeld, 1988; Coulson & Campbell, 2001). It has even been suggested that believe that enclaves of San living in parts of the Drakensberg and Maluti mountains may have even been painting up to the end of the Nineteenth Century, and possibly into the early part of Twentieth Century (Solomon, 1998; Bassett, 2001). It is thought that the tradition of rock painting endured longer in parts of the KwaZulu–Natal Drakensberg than in other parts of the country.

By 1900 the San are said to have disappeared from the Drakensberg area and that painting ceased (Coulson & Campbell, 2001). Even though the San were still certainly painting in the Drakensberg mountains in the mid-nineteenth century (Wright & Mazel, 2007), it was only noted recently that some of their paintings of eland had deteriorated little since the day they were painted (Coulson & Campbell, 2001). Similar paintings in close proximity have already lost much of their colour, perhaps due to human interference, such as visitors sponging them with water for photography.

The uKhahlamba-Drakensberg paintings are well known for their subtle colours, fineness of line and detail (Solomon, 1998; Lewis-Williams, 2003). Shaded polychromes in the area are the most visually impressive art, where the painters have used fine detail and subtle blends and gradations of colour to produce remarkable visual effects (Solomon 1998). To explain the extreme fineness of their work especially in many polychromes, the San are suggested to have used pointed pieces of bone to draw outlines (Willcox, 1956). The brushes were made from the hairs of the tail or mane of the black wildebeest, tied to the end of a thin reed (Willcox, 1956). Additionally, the pots where the pigments were stored were the horns of small antelope (Willcox, 1956).

The colours used in San paintings, largely variants of red, including oranges, pinks and browns, were derived from ochre, or haematite (Solomon 1998). Yellow paint comprised yellow ochre, or limonite; black pigments were produced from manganese oxide and plain charcoal, and white pigment was made from clay (Solomon 1998). The white pigments have been said to preserve poorly and are the first to vanish (Solomon 1998). In contrast, in their recent study, Hall *et al*. (2007a) observed that both the ochre and the white pigment appeared to be well-preserved, where they are less exposed to direct solar radiation.

When manufacturing pigments, blood was added to some, particularly that of an eland, which was viewed as a creature of special significance for the San (Willcox, 1956; Lee & Woodhouse, 1970). This suggests that spiritual and symbolic components were included in the paints. Adding a liquid was necessary to change pigment into a paint that could be applied. Organic substances such as eggs, vegetable extracts and urine (support by high nitrogen contents in analyses) were also sometimes added as extenders, or to promote adhesion and binding (Willcox, 1956; Solomon 1998). Other suggestions for such media are milk and honey (Willcox, 1956).

From observations of San paintings, it is clear that the tiny particles of ochre bond well with the rock since their colour is exceptionally long-lasting. It is argued that exposure to radiation has implications on the pigment itself, and its ability to adhere to the rock surface (Hall *et al.,* 2007a; Hall *et al.,* 2007b). Neither the black nor the white and yellow colours bond as well with the rock as the red paint does, and one often finds that parts of an animal painted in red have lingered, while those painted in black, white or yellow have no trace left. This is particularly the case where people have been painted with white or yellow faces and all that remains is the top and back of the head. It was also observed that some of the paintings in the uKhahlamba-Drakensberg had been painted on a smoothed surface using a water-polished stone and covered with a clay-based ground (Hall *et al.*, 2007a). Despite their age and exposure, the paintings seem to have survived amazingly well, but are likely to decay faster due to anthropogenically induced detrimental effects (Hall *et al.,* 2007a).

For as long as rock art is in a state of reasonable preservation, it will remain captivate because it is communicates issues that deeply inspired the mind of the artist; in this case the San (Basset, 2001). The vitality and essence of San society no longer exists locally except in the visions from paintings that convey and interpret the San worldview (Bassett, 2001). Traditional ways of life, living in small bands, and travelling the landscape in search of animals to hunt and plant foods, have been much modified in modern times, but are an existing example of the oldest known economy (Solomon, 1998). Rock art in one form or another has been practised in many parts of the world where natural rock surfaces outcrop, hence the need to learn more about the natural settings over which the San created their art.

1.3. Study Aims and Objectives

Although little can be done to stem the deterioration of rock art caused by the natural environment, it can be managed in a way that minimizes potential damage. In order to evaluate weathering rates, it is possible to use digital images to estimate rates of damage. The aim of this project was, therefore, to quantify the external rate and amount of deterioration through a combination of visual technologies and accumulated observation. The rate of rock art deterioration was estimated, using Battle Cave and Main Caves as study sites to evaluate changes in the observed weathering.

In South Africa, the main focus of research has been the recording and interpretation of rock art, while there is little recorded documentation on the rates of rock art decay. To determine the rate of rock art deterioration, a crucial component is to know how it is being weathered.

In order to achieve the research aim the following research objectives were identified:

- Establishing the existing knowledge of the deterioration of rock art in South Africa;
- Investigating visually-evident weathering in San painted rocks through the study of photographs taken over the last four decades; and
- Establishing the potential for longer-term recording of rock art degradation.

The assumption was made that no single process of deterioration can be isolated, and that rock breakdown is due to co-dependent complex mechanisms, which are mechanical, chemical and biological.

1.4. Significance of the Study

Rock art research provides an insight into the minds of the San, the ways in which people organized their thoughts and beliefs in the Later Stone Age, and the role that religion played in their lives. The monitoring of deterioration of paintings is necessary to observe the effectiveness of past conservation work; to justify the importance of new or further conservation work; to possibly justify more drastic proposals such as the introduction of surface coatings or consolidants, and to correlate deterioration with other events such as bushfires, climatic events or salt accumulations where these are also monitored. This study will provide useful input into the scientific and environmental conservation activities within South Africa, and therefore emphasizes the need for developing effective policies and strategies for sustainable conservation and preservation of rock art.

1.5. Structure of the Dissertation

Chapter 1 provides a historical insight to the history, age and importance of South African rock art, through a literature review, which furthermore presents the specialized nature of threats to rock art sites from human and natural intervention. The Chapter also gives a generalized overview of description, rate and character of weathering, and basic conditions required for weathering to occur. Natural settings where rock art occurs are discussed as well, together with the importance of the properties of sandstones, which is the canvas for the paintings. Chapter 1 also presents the scope and research goals of the research.

Chapter 2 investigates the need to conserve the San rock art for future generations while Chapter 3 describes the setting of the study area by examining the geology and different physical characteristics within the study sites and a regional context in which rock art is developed. The methodology utilized to conduct the study is also presented in Chapter 3. Chapter 4 presents results and a summary discussion while chapter 5 outlines general recommendations for the management and conservation of rock art sites.

1.6. Causes of Rock Art Decay

There is a need to establish causes of rock art decay to evaluate the impact that degradation of rock-art sites may have on the loss of a heritage, while at the same time focussing studies of the natural landscape. Natural factors that cause the breakdown of rock, and consequently, the deterioration of rock art are controlled by the environment surrounding the rock and by the nature of the rock itself. Little can be done to arrest the natural rock weathering processes, but studies need to be carried out to investigate sources which might control or aggravate the processes even more.

It has long been acknowledged that rock weathering processes contribute towards the deterioration of rock art (Ollier, 1984; Rudner, 1989; Batchelor, 1990; Meiklejohn, 1997). In addition, humans also create changes and conditions which aggravate weathering. The major factors causing deterioration of paintings are the introduction of light, increased carbon dioxide, changes in humidity and, with fairly large numbers of people as in tourists, increases in temperature (especially in deep caves) (Rosenfeld, 1988).

People also introduce external organisms, including algae and higher plants which are able to establish themselves, particularly near light sources (Rosenfeld, 1988). Furthermore, biodegradable debris left behind by tourists creates luxurious feeding grounds for bacteria, fungi and other micro-organisms, and also, several species of algae, fungi and bacteria can establish themselves directly on the rock surfaces (Rosenfeld, 1988).

Factors that influence the deterioration of rock art in shelters and on open sites may operate in two ways (Rosenfeld, 1988):

- By causing the instability of the rock surface, which causes decay of painted art; and,
- By causing instability of the pigment layer on a rock surface which, therefore affects only rock paintings (Rosenfeld, 1988). Enhancing rock art by using either refined or non-distilled water, and rubbing cause more damage, in so doing affecting future scientific research and analysis.

An evaluation of the dynamics of the physical and chemical processes taking place at the rock surface must be established as a first step in any consideration of preservation of rock art sites.

1.7. The Natural Setting of Rock Art

In order to effectively study the rate of rock art decay, there is need to identify the lithologies onto which it has been created, and only then can it be determined which art is more prone to weathering. The connection between the rock art design and its setting is vital for its understanding, and particular interest ought to be devoted to it. The relationship between rock art and its surroundings should also be given consideration in preservation and conservation projects, which should involve the site as a whole, rather than just specific isolated, damaged, or endangered figures (Anati *et al.,* 1984).

Rock art is a term normally applied to paintings and engravings on natural rock surfaces. Paintings are found almost exclusively on vertical rock faces and almost always in protected positions, often in shallow or deep shelters of eroded sandstone and granite, but they also are sometimes seen on exposed cliffs and on the sides of boulders that are protected from elements (Coulson & Campbell, 2001). Globally, rock paintings are normally found on limestone and sandstone rocks and can also occur in the depths of caves where they have remained protected from the full intensity of environmental changes that affect surface rocks (Coulson & Campbell, 2001).

The four main settings in which paintings can be found in South Africa are under rock overhangs, in caves, on bare rock walls, or on secluded rocky outcrops or boulders (Meiklejohn, 1995). Of these, the most common location for paintings is under a rock overhang (Truswell, 1970; Irwin *et al.*, 1980; Bassett, 2001). Sandstone and quartzite are the most common surfaces on which San artists painted in South Africa (Bassett, 2001). These rocks weather more rapidly than most other lithologies. Because of faster rock disintegration, and their greater exposure to the outside environment, most, if not all, of the paintings still visible on cave walls in southern Africa are younger than European cave art (Rosenfeld, 1988).

It is estimated that 80 per cent of the rock art in South Africa is found as paintings in the Clarens Formation (Rudner, 1989; Batchelor, 1990). "The majority of the rock paintings in South Africa are not only on very porous and thus inferior sandstone (especially in Natal, Free State and northern Eastern Cape) and that most of the frescoes are exposed to the most harmful and disintegrating effects of wind and rain, but also, very many are on an extremely resistant silicified sandstone," Willcox (1956:66).

Where paintings occur on silicified sandstone and are at the same time exposed or partly exposed to harsh environmental elements, the rock and the paintings are not nearly as prone to disintegration as they could be if the rock were ordinary sandstone (Willcox, 1956). Very little of the sandstone in the uKhahlamba-Drakensberg is silicified and some (18%) has calcite as a cement (Eriksson, 1983). Contributing to the vulnerability of the art in the uKhahlamba-Drakensberg area is that under acidic conditions calcite is soluble and, therefore, given the presence of sufficient moisture, the weathering of sandstone by solution processes is likely to occur.

Many causes of rock art deterioration are complex interactions between the pigments, the rock and the surrounding environment and are, therefore, difficult to manage. Significantly, rock paintings are normally painted on surfaces that should at least have some degree of porosity, which makes them particularly prone to deterioration by natural rock weathering processes. As previously stated, this is especially so in the sandstones of KwaZulu-Natal. Lewis-Williams & Dowson (1989) contend that the Clarens Formation Sandstones are not as resistant to weathering as other lithologies found in southern Africa, such as granite. Nevertheless, they offer a good surface on which to paint.

Bedrock properties determine the vulnerability of the material to weathering processes and the ease with which weathered products can be removed (Viles, 1995). Rock structure is important since discontinuities and other places of intrinsic weakness are the areas that will be most prone to breakdown (Rosenfeld, 1988). In addition, structure influences rock strength and hence its resistance to certain physical weathering processes. Important rock properties include porosity, micro-porosity, permeability, saturation co-efficient, and water absorption capacity (Rosenfeld, 1988). These factors influence moisture movement and the ability of a rock to absorb moisture.

Some rock art sites were occupied and contain evidence of occupation by earlier societies, while others are not associated with archaeological deposits or traces of human presence (Solomon, 1998). Rock paintings occur primarily, but not entirely, in mountainous regions where there are abundant rock shelters (Lewis-Williams & Dowson, 1989). In some areas such as the uKhahlamba-Drakensberg, almost every inhabitable rock shelter has paintings or the remains of paintings. Because rock shelters are frequently shallow, paintings are often exposed to rain, and this has contributed to their poor state of preservation (Irwin *et al.*, 1980; Lewis-Williams & Dowson, 1989).

The degree of adhesion of a painting to the rock surface will depend on the nature of the rock, the nature of the pigment and its binder, and the method of application of the pigments (Batchelor, 1990; Loubser, 1991). Therefore, the more permeable the rock, and the finer the pigment particles, the greater is the penetration and adhesion of the paint. Dry pigments and those applied as a paste are easily peeled off and deteriorate rapidly, whereas those that are more fluid are able to infiltrate deeper into the rock making them more resilient (Loubser, 1991).

Since it has been established that most San paintings in southern Africa are commonly found on sandstones, particularly in the uKhahlamba-Drakensberg, it is vital to study properties of sandstones so as to establish what characteristics make them more prone to particular weathering processes, which consequently lead to rock art deterioration.

1.7.1. The Nature and Properties of Sandstones

Sandstones are estimated to occupy 15% of the world’s land surface and endure a variety of surface and sub-surface weathering processes that from time to time lead to deterioration and breakdown of the rock, but which also lead to a hardening and toughening of the external surface of the rock (Robinson & Williams, 1994).

Weathering processes are influenced by endogenetic and exogenetic factors, whereby endogenetic factors are related to the structure and composition of the rock itself, and exogenetic factors include climate and vegetation (Small and Clark, 1982; Viles, 1995). Rock structure and composition can only mean that texture is also important. It can therefore be deduced that fine-grained rocks may weather more quickly than coarse-grained rocks, which are noted to have fewer lines of weakness (Viles, 1995).

1.7.1.1. Rock Structure

Quartz-rich sandstones differ significantly in texture and composition; wide differences exist in grain size characteristics, density, strength and porosity, as well as in the kinds of minerals that are present, in addition to quartz, as either grains or cement (Robinson & Williams, 1994). In some sandstone, the grains have been well sorted and are all of similar size; other sandstones consist of poorly sorted grains of variable size (Robinson & Williams, 1994).

The grains can vary in form from very angular to perfectly spherical, and the size and shape of the sand grains determines how closely packed the grains can be (Robinson & Williams, 1994). In the case of the sandstones investigated in this study, the Clarens Formation is composed mainly of fine to very fine-grained sands which are said to be sub-angular with subordinate rounded and angular forms (Eriksson, 1983).

1.7.1.2. Rock Properties

Size and type of pores influence the permeability of the rock; for fluid movement within the rock, pores must be interconnected and of a size large enough to exceed capillary forces of the fluids (Wüst & Schluchter, 2000). The porosity of a rock, usually given as a percentage, is the ratio of the volume of the pores to the total volume of the rock, and pores in sediments are filled with interstitial fluids, for example, air, water, carbon dioxide and other gases or hydrocarbons (Wüst & Schluchter, 2000).

The quantity of cement in sandstone (if it is present) appears to be more important than its composition, because in sandstones where grains are linked together by cement precipitated from percolating solutions are much stronger than those in which clay and other fine detritus bonds the grains together (Robinson & Williams, 1994). The compressive strength of sandstones depends on their porosity, the amount and type of bonding material and the composition of grains (Bell, 1983). The total pore volume and pore sizes also affect the tensile strength of rock; in general, the greater the total pore volume and/or the pore size, the lower the tensile strength of the rock (Tamura & Suzuki, 1984; Yatsu, 1988).

In short, poorly cemented, porous sandstones have low strength, while dense, well-cemented sandstones have greater strength. The strength of sandstones is reduced considerably when the pores are saturated with water. The porosity and mineralogy of the Clarens Formation are such that moisture is a major influence on weathering processes (Batchelor, 1990). As the rock becomes more weathered, so porosity increases and micro-porosity decreases, thereby providing an environment that is even more susceptible to weathering (Rosenfeld, 1988; Meiklejohn, 1995).

Porosity and permeability have an important effect on the rate of weathering of the rock and hence of the paintings. The pore space is a channel through which water, one of the major reactants of weathering, permeates and transports the weathering products (Yatsu, 1988). Therefore, the surface area, where chemical reactions take place increases as porosity does (Yatsu, 1988).

Strength properties of many types of sandstone are similar to those of limestone of equivalent age, but are lower than most granites and other igneous rock (Robinson & Williams, 1994). Beds of quartz-rich sandstone are often underlain or succeeded by bands of weaker, clay-rich sandstone, shale or mudstone, along which weathering is often concentrated (Robinson & Williams, 1994). In studies on the deterioration of rock art by weathering of the Clarens Formation in the uKhahlamba-Drakensberg, it was acknowledged that weathering of the sandstone is an intricate set of interactions, rather than diverse individual processes (Meiklejohn, 1995, 1997; Hall, 1997).

1.7.1.3. *The Rate and Character of Weathering*

The rate at which rocks and minerals break down (weathering rate) may be defined more precisely as a measured deterioration in an earth material during a specified time period (Bland & Rolls, 1998). Underlying the basalt, which comprises the top of the Drakensberg escarpment, is a deep bed of sandstone (Willcox, 1956, 1963). Wherever this bed is exposed, it weathers in a strange way to form overhang on rock shelters though a few of the rock shelters are deep enough to deserve to be called caves (Willcox, 1956). Field observations suggest that the caves (or shelters) result from the enhanced weathering of alluvial sandstones, which are less resistant than overlying aeolian deposited sandstone.

Sandstone weathering encompasses several different stages, not all of which are associated with debris release and surface retreat, and over time the duration of each of these stages can be extremely variable (Warke *et al.,* 2006). Further complications regarding the weathering and breakdown of sandstone arise from the fact that debris release may not necessarily be coordinated with a specific weathering occurrence, but arise sometime later in response to the increasing effects of weathering; with a resultant decrease in material strength (Warke *et al.,* 2006). Some sandstone weathering events may owe their instigation and consequent development to environmental conditions that differ from those of the present, and for this reason to weathering processes that may have been more effective in the past (Warke *et al.,* 2006).

Even though San art is painted on porous surfaces and has adhered to the rock, the rate and degree of deterioration of the San paintings is cause for concern. It is contended that chemical processes are more important than purely physical ones in the weathering of sandstones in the study area (Meiklejohn, 1995). In the UKhahlamba-Drakensberg Park this disintegration was first detected in the late nineteenth century (Meiklejohn, 1995). At that time there was no method of conservation known and recording could only be done by copying the paintings onto paper (van Rijssen, 1987). The major cause of rock painting deterioration has been argued to be weathering of the rock surface rather than alteration of the paintings themselves, through a variety of mechanisms, some natural (van Rijssen, 1987).

It is argued that weathering rates may be uniform (or linear) over time; however, commonly the rate varies with time and is non-linear (Bland & Rolls, 1998). Rate refers ideally to the amount of change per unit time, although in practice it refers to generalized change, and, its calculation requires knowledge of the time period during which alteration has taken place, as a result it is rarely achieved outside the laboratory (Bland & Rolls, 1998). Furthermore, where a rapid rate is supported by a suitable ambient environment, there may be a high degree of weathering, but slow rates may achieve a similar end product if sufficient time is available. The controlling factors fall into two categories: intrinsic and extrinsic.

Temporal and spatial dissimilarities in sandstone weathering responses are attributed to fundamental controls that include the properties of parent material such as porosity, permeability characteristics and mineralogical composition (Warke *et al.,* 2005). Extrinsic factors contributing to weathering include micro-environmental conditions, fluid chemistry and hydrodynamics, amongst others (Bland & Rolls, 1998; Warke *et al.,* 2005).

1.7.2. Intrinsic Factors

1.7.2.1. Pores and Fractures, and Mineralogy

Pores and fractures channel the entry of weathering fluids and so control the intensity of weathering. They operate at the scale of a rock outcrop, where the pattern and intensity of weathering is typically a function of fracture (joint, bedding plane or fault), and density, and also at the mineral scale, where alteration follows cracks, fissures and other surfaces of weakness (Bland & Rolls, 1998). Different minerals might be expected to show differing responses to weathering processes, and, several attempts have been made to arrange minerals in the order of their stability (Bland & Rolls, 1998).

In the Clarens Formation of the uKhahlamba-Drakensberg, porosity is increased by an enlargement of the existing pores during the process of weathering (Meiklejohn, 1995). In a nutshell, it can be argued that during rock weathering in the Clarens Formation, the already existing pores are enlarged, instead of new ones being formed. Furthermore, as the pores get enlarged, moisture movement is enhanced. It is highly probable that the most weathered rock and the largest pores are found near the rock surface, and as a result this would ease moisture absorption, diffusion and transport taking place in the outer surface layer of the rock (Meiklejohn, 1995). Weathering processes that depend on moisture and changes in moisture are, therefore, likely to take place at, or very close to the rock surface.

1.7.3. Extrinsic (Environmental) Factors

Usually, the extrinsic factors that affect rock weathering include climatic, vegetational and geomorphological controls. However, these act indirectly, and it may be more rational to replace them with those factors that impact instantly on weathering intensity and rate (Bland & Rolls, 1998). These include temperature, the chemistry of weathering solutions and hydrodynamics.

1.7.3.1. Temperature

Rates of chemical and mechanical weathering are a function of temperature and rainfall (humidity) conditions (Huggett, 2003). Therefore, the intensity of chemical weathering depends on the availability of moisture and high air temperatures. Also, chemical weathering is minimal in dry regions, because water is in short supply, and in cold regions, where temperatures are low and water may also be scarce because it is frozen for much of the year. Mechanical weathering on the other hand, depends upon the presence of water and is (incorrectly) argued to be very effective where repeated freezing and thawing occurs, and is therefore minimal where temperatures are high enough to rule out freezing and where it is so cold that water seldom thaws (Huggett, 2003).

The main significance of temperature is its control on reaction rate. Ollier (1984) gives an example that generally, for every 10°C increase in temperature, the rate of a chemical reaction increases by a factor of two. A rise in temperature may cause a weathering process to take place different to that operating at a lower temperature. For that reason there is need to monitor rock temperature, since rock temperature and not air temperature controls rock weathering processes, as is the case within Battle Cave and Main Caves study sites (Meiklejohn, 1995).

1.7.3.2. Chemistry of weathering solutions

The effectiveness of weathering solutions is greatly influenced by their pH, as well as by temperature. The pH of rainfall is normally in the range 5.5 – 6.2, while that of pure water is 7 (Bland & Rolls, 1998). Rainwater has a lower pH (more acidic) owing to the presence of dissolved carbon dioxide, which is an acidic gas, and its pH may be affected locally by factors such as the presence of dust or aerosols from the sea (Bland & Rolls, 1998). Human activities also provide significant contaminants (Bland & Rolls, 1998; Pope *et al.*, 2001). The existence of calcite is essential in understanding the nature of chemical weathering of the Clarens Formation since the recorded pH of rain water in Giant’s Castle is often around 5 and may contribute to the formation of the precipitate (Meiklejohn, 1995).

1.7.3.3. Hydrodynamics

What is understood is that for weathering to take place, water must be mobile in rock. Hydrodynamics is the study of the nature and rate of water movement, especially through rock and regolith (Bland & Rolls, 1998). In solid rock, water will make use of existing courses at all scales, meaning, at the smallest level, that of an individual mineral, water enters fractures and cleavage planes, and varying styles and degrees of alteration will develop, determined by the patterns of weakness, temperature, and chemical characteristics of the water (Bland & Rolls, 1998). At a larger scale, that of joints, bedding planes and faults, the degree of weathering will be strongly affected by the density and pattern of these fractures (Bland & Rolls, 1998).

The physical environment plays an important part in determining whether rock art degrades quickly or slowly, and has a marked effect on the chemical reactions set up in the base rock, in the pigments and at the interface between the pigment layers and the base rock (van Rijssen, 1987). Weathering can be defined in simple terms as the disintegration or decay of rocks, physical weathering as the breakdown of the rock into fragments by entirely mechanical processes, and chemical weathering as the decomposition of rock minerals by agents such as water, oxygen, carbon dioxide and organic acids (Small & Clark, 1982). It is, therefore, argued that in reality, the distinction between physical and chemical weathering is somewhat subjective, as in most situations they not only act together but they can reinforce each other (Small & Clark, 1982).

The action of weathering in the destruction of rocks is dependent on the removal of the weathered layer by various means of transport, especially water, wind, ice and mass wasting (Buckle, 1978). If the weathered rock is not removed it may act as a protective layer to the underlying rock. It can therefore be understood that weathering itself involves no movement of material, but as a process it is dependent upon the movement of material by external agents (Buckle, 1978).

Many rock shelters contain large masses of rock that have fallen away and where paintings are found; but individual paintings could escape this fate for centuries, probably for millennia, because the rate of weathering is not uniform (Willcox, 1963). In reality this shows that rock weathering operated at many different scales. Apart from certain chemical processes, rock weathering does not take place in a stable environment, and even to a very small degree, changes in the environment are necessary before any breakdown is possible. As already stated, rock weathering is a chain of inter-reliant processes with a range of variables interacting to control the rate and type of weathering process. These controls include the properties of the bedrock, climatic and micro-climatic conditions, the length of time available for weathering, and the removal of the weathered product (Robinson & Williams, 1994).

The rapidity of responses to weather conditions is a measure of stone sensitivity, a property that changes over time and may also be referred to as a measure of durability (Warke *et al.,* 2005). It is further argued that, sandstone may respond to a relatively minor or low magnitude weathering event through rapid breakdown if its sensitivity to external events has been previously intensified by an accumulation of internal structural and mineralogical weaknesses achieved through long-term weathering exposure. Again, short-term exposure to an extreme event may result in catastrophic breakdown and resultant heightened sensitivity to future weathering activity (Warke *et al.*, 2005). The temporal decay dynamics of sandstone can, therefore, be extremely complicated to predict in all but the most general of terms (Warke *et al.*, 2005).

The rate of weathering can be difficult to estimate. San paintings have been said to be vanishing fast for a while, and, it was (incorrectly) estimated that only a few will be left intact on the Drakensberg area in a hundred years (King, 1942). A great many of these, however, are painted upon the rather friable ‘cave sandstone’, which is said to be weathering at an unusually high rate (King, 1942). The yellow coloured, fine-grained and fairly smooth rock that provided a good canvas on which to paint on was termed "Cave Sandstone" due to its weathering into rock shelters (Willcox, 1956). Today many paintings are not in their original state as colours have faded, some have completely disappeared, leaving an image with exposed patches of rock where several colours were once visible (Coulson & Campbell, 2001).

Over much of Africa, the weathered layer is often very thick due to the fast rate of chemical weathering in areas of high temperature and humidity, and some of the main factors that affect the rate and character of weathering are rock type, climate, organism, topography, and the age of the weathered surface (King, 1942); these are discussed individually below.

a) Nature of Rock or Rock Composition

Some rocks have their own irregularities, minute cracks that allow the rest of the rock to disintegrate, or a habit of absorbing moisture, which leaves them particularly vulnerable to the ambient weather (King, 1942). Also, mineral composition of rocks is very uneven, as a result the nature and rate of weathering differs from rock to rock. This only means that not only do rocks differ in their relative hardness, but they also vary in resistance to weathering processes.

b) Climate

Variations in weather (and, therefore, also climate) cause differences in the rate and type of weathering, and the main climatic controls are temperature and humidity (Buckle, 1978). Two facts of primary importance in connection with climate are:

- That the intensity of chemical reaction is doubled for every rise of 10°C in temperature; and,
- That water is either fundamental or of great assistance to most chemical decomposition. For this reason it is reasonable to infer that chemical weathering will be greatly favoured in moist, hot climates (King, 1942).

c) Plants and Animals

Rock surfaces are affected by bacteria, fungi, algae, lichen, mosses and higher plants and also by some micro-fauna, notably some termites, insects, birds and bats (Rosenfeld, 1988; Viles, 1995). The movement of animals and insects in the ground, such as rodents and termites, encourages weathering, by loosening and mixing partially weathered rock, increasing the access of oxygen and water to mineral particles, and carrying organic matter down from the surface (Buckle, 1978). Troops of baboons constantly turn over stones in the search for lizards and scorpions, and may, therefore, expose new surfaces to weathering and result in the subsequent decay of the rock art.

Larger animals also cause damage to rock art in shelters mainly by rubbing or stirring up dust. The accumulation of excreta in deposits may enrich rising groundwater in organic compounds, including urea, with possible resultant salt infestation of the rock (Rosenfeld, 1988). Urine and excreta from birds (Fig. 1.1) may affect the paintings; however, Woodhouse (1991) argues that such damage is limited to very few sites.

Figure 1.1: Excreta from pigeons and swifts in the Main Caves Study Site (Photographs: T.C. Leuta)

Lichens, fungi, algae and bacteria cause the breakdown of rock physically by producing acids from their hyphae which aid weathering by solution and by chemical alteration of minerals (Ollier, 1984; Batchelor, 1990; Viles, 1995). Algae and lichens are able to derive their nutrients directly from the mineral rock and the atmosphere without the intermediary of organic products in soils, are pioneer colonisers of rock (Viles, 1995). Fungi, which require small amounts of organic substances found in dust, will grow provided conditions are moist. All three require a brief period of high humidity and free water to begin growth. In addition, algae and lichens require some light (Viles, 1995), but all are able to endure long-lasting periods of drought.

Larger biological species such as trees and other plants also act as driving forces to weathering by the action of their roots, which grow underground and open up joints (King, 1942; Ollier, 1984; Batchelor, 1990; Bednarik, 2003); they widen cracks in rocks thereby potentially damaging the rock on which the paintings were created. Plant roots can also have corrosive effects on rock, especially through the organic carbon dioxide exhaled by the micro-organisms living on the root surfaces (Bednarik, 2003).

d) Topography

Steep slopes favour the rapid removal of the products of weathering and the exposure of bare rock surfaces. Temperature cycles are therefore (incorrectly) argued to aid frost wedging as water drains more rapidly from steep slopes, whereas its scarcity tends to minimize chemical reaction (King, 1942). However, the existence of freeze-thaw weathering as an agent of rock art deterioration in the UKhahlamba-Drakensberg Park is questioned (Meiklejohn, 1995, 1997; Hall, 1997; Sumner & Nel, 2006).

e) Age

Time is a further factor that makes it difficult to understand the direct climatic impact on weathering. Below is a summary of the processes relating to the weathering of the Clarens Formation and thus the deterioration of rock art in the study area as adapted from Meiklejohn (1995):

- The most important environmental control on the weathering process is the rock moisture regime.
- Rock weathering processes are highly influenced by the mineralogy, rock structure, rock properties and in particular the rock moisture and thermal regimes.
- Thermal stress fatigue, salt crystallization, hydration and dehydration of rock minerals, clay minerals and precipitated salts, solution, hydrolysis and chemical alteration, are the principal rock weathering mechanisms.
- The rock weathering process results in granular disintegration and the enlargement of pores and bedding planes.
- Short-term changes affect the rock surface and the area underneath the rock surface, and it is these that cause more damage and deterioration of rock art.

It would be incorrect to either generalize or dogmatize on the rate at which paintings disintegrate and disappear (Hoerlé, 2005), since there are paintings on the cave sandstone that will survive longer than the finest quartzite or the most fine-grained granite (Willcox, 1956). One can therefore deduce that the weathering rate is difficult to estimate. Many paintings appear to be fading fast and it has been estimated that only a few will be left undamaged because a great many of these were executed upon the cave sandstone, which seems to be weathering at an abnormally high rate. There is therefore need to discuss the major causes to such disintegration.

1.8. Specific influences on rock weathering

It is clear from the above discussion that rock weathering and the environmental controls on rock weathering are fundamental to the deterioration of rock art. Following is a discussion on the major environmental controls on rock weathering and how they influence specific rock weathering processes.

1.8.1. Moisture

Among a variety of factors influencing the rates and mechanisms of rock weathering, the microclimate of a shelter is crucial (Hoerlé and Salomon, 1998). Despite the interdependence of the weathering mechanisms (Aberg *et al.*, 1999), two major environmental controls on rock weathering, can be identified, namely temperature and moisture (Batchelor, 1990; Meiklejohn, 1995). It is argued that, of the two, moisture is more crucial than rock temperature in controlling the rock weathering causing deterioration of rock (Batchelor, 1990; Loubser, 1991; Lewis-Williams & Dowson, 1992; Meiklejohn, 1995) and subsequently the art created on it.

Moisture reaches the rock surface from various sources and through different courses, and is, therefore, the major factor that affects weathering processes. Water moves to the surface irrespective of the evaporative conditions and this may result in an active flow of excess moisture over the rock surface (Batchelor, 1990; Bednarik, 1994a). Internally, moisture moves through the pores to the rock surface by capillary action and, therefore, tends to be controlled more directly by ambient temperature and humidity conditions than by actual precipitation (Lewis-Williams, 2000).

Where the water runs down the rock surface and over the paintings (Fig. 1.2), destruction is at its greatest (Bednarik, 2003). It is further argued that where surface run-off occurs regularly, the establishment of mosses, fungi and lichens may be an unfavourable result. Running water dissolves soluble pigments, causing paintings to fade, and can also deposit minerals on the surface that may cover the art (Batchelor, 1990). This water can both dissolve minerals and precipitate salts on or near the surface (Rosenfeld, 1988; Batchelor, 1990).

Figure 1.2: Water flow over painted surfaces at Main Caves study site. (Photographs: T.C. Leuta)

The presence of precipitates, like those on the face where the "Battle" in Battle Cave study site is painted, suggests that moisture is drained by joint and bedding planes in the sandstone that hold most of the moisture coming through from the hillside (Lewis-Williams & Dowson (1989). Although most rock art in the Clarens Formation is located under overhangs, some is, nevertheless, exposed directly to rain and running water (Lewis-Williams & Dowson, 1992; Hoerlé and Salomon, 2004; Hoerlé, 2005, 2006; Hall *et al*., 2007a).

Rainwater is never pure water as it acquires numerous ions before it reaches the ground, many of which assist it in dissolving minerals. In addition, organic acids may also be present in rainwater (Bednarik, 2003). Most sheltered sites in the UKhahlamba-Drakensberg Park are not protected from the mist, which comes in contact with the rock surfaces (Meiklejohn, 1995).

When erosion removes surface material, the confining pressure on the underlying rocks is eased (Huggett, 2003). Furthermore, the lower pressure enables mineral grains to move further apart, creating voids, and therefore causing the rock to expand or dilate. Consequently, the dilation produces large or small cracks, and incipient joints present lines of weakness along which individual crystals or particles may disintegrate and exfoliation may occur (Huggett, 2003). Exfoliation is spalling of rock sheets from the main rock body (Huggett, 2003).

In many cultural environments, exposed rock surfaces experience cycles of wetting and drying when, for example, short rain events are followed by periods of evaporation.

Cycles of wetting and drying tend to give rise to expansion and contraction, with cracking and flaking of rock (Ollier, 1984; Yatsu, 1988; Loubser, 1991; Hoerlé, 2005). Similarly, summers in the uKhahlamba-Drakensberg experience frequent thunderstorms which can also produce rapid dissimilarities in temperature and moisture presenting an environment conducive for flaking (Meiklejohn, 1995). Temperature and moisture therefore have the most direct effect on rock weathering and thus the San rock art.

1.8.2. Temperature Changes

Climate determines the availability of water, ambient atmospheric temperatures, and ranges of temperature (annual and diurnal) within an area (Small & Clark, 1982). Additionally, weathering may be most active underneath rock shelters where neither the rate of temperature changes nor temperature ranges are great (Meiklejohn, 1997).

The Clarens Formation is prone to weathering, thus resulting in the deterioration of rock art painted on it (Willcox, 1956; Batchelor, 1990). The paintings can be found within rock shelters, where many are exposed to direct solar radiation for varying periods (Hall *et al*., 2007b). Many rock surfaces in the UKhahlamba-Drakensberg Park are exposed to direct sunlight for some part of the day, which apart from affecting the paintings, pigments may also cause thermal stresses within the rock (van Rijssen, 1987; Batchelor, 1990; Meiklejohn, 1995).

As previously mentioned, physical weathering results in the breaking down of rock into successively smaller fragments and particles and the main processes involve temperature changes. Large daily temperature ranges result in varying expansion and contraction of minerals, which therefore cause pressure in the rock. In the long run, this leads to fracturing of the rock. Moreover, since rocks are very poor conductors of heat, no heat from the outer part of the rock is transmitted to the interior, so the exterior thus expands more than the interior, which leads to strains and subsequent fracturing within the rock (Buckle, 1978). However, for such fracturing to occur, the rock must first be weakened by chemical weathering. Chemical weathering operates to some extent in all parts of the world, but is most active in regions of high temperature and high humidity where chemical reactions are said to occur very rapidly (Buckle, 1978).

Generally, rock surfaces are exposed to two main sources of heat: the sun, through solar radiation, and natural fire, and either source may raise the surface temperature, which then falls when the heat source is cut off (Bland & Rolls, 1998). This behaviour introduces the importance of temperature range, which is the difference between the maximum and minimum temperatures over a specified period of time, usually 24 hours, and the rate of temperature change which is the amount by which temperature changes during a specific period of time (Bland & Rolls, 1998). A surface layer of rock expands when heated by the sun's rays (insolation is exposure to the sun), and then contracts when the heat source is temporarily cut off. Breakage occurs when the strain due to expansion and contraction exceeds the rock's elastic limit (Bland & Rolls, 1998).

1.8.2.1. Insolation Weathering

Intense insolation may result in both large temperature changes occurring on the rock surface and similar temperature differences between the rock surface and its interior (Zhu, 2003). Rocks are thought to receive intense solar insolation in high-altitudinal areas, and this therefore causes them to experience rapid temperature changes (Whalley *et al*., 1984).

Insolation weathering is the consequence of alternating warming and cooling of rock surfaces under the direct influence of solar heating (Selby, 1985). Thermal differences (discussed above) can produce thermal fatigue in rocks and their eventual breakdown (Hall & Hall, 1991). The nature of solar heating is influenced by a number of external factors, including latitude, altitude, aspect (orientation of the rock surface), time of year, nature of cloud cover, rainfall, wind speed and air temperature (Ollier, 1984). Insolation heating stimulates faster temperature variations on the rock surface than in the interior (Zhu, 2003); this is more closely related to rock mineral composition than to pore size and pore density, and therefore implies that rapid temperature variations may lead to the constant expanding and contraction of the rock minerals (Zhu, 2003).

Temperature fluctuations may be short term, and involve rapid change. Insolation or solar radiation is capable of breaking up some rock types through thermal expansion and contraction, particularly in arid or semi-arid regions experiencing significant diurnal temperature variations (Bednarik, 2003), and subsequently lead to the decay of paintings occurring on such rocks. Bushfires are infrequent events, but when they occur, they raise rock surface temperatures to high values over short periods of time. Knowledge of the surface temperature does not tell us about temperatures within the rock. To understand this, there is need to study a number of physical properties and how they affect the reaction of a rock to surface heating or cooling.

The rock temperature itself depends on the air temperature, direct solar radiation, air and rock moisture conditions, thermal conductivity, albedo and mineral composition (Ollier, 1984; Meiklejohn, 1995). Some of these important properties are discussed below (Bland & Rolls, 1998).

1.8.2.2. Albedo

Albedo is defined as the amount of reflected solar radiation falling on a surface, and is expressed as a percentage of total solar radiation (Bland & Rolls, 1998). When an object reflects most of the light that hits it, it looks bright and it therefore has a high albedo. When an object absorbs most of the light that hits it, it looks dark. Dark rocks absorb heat faster than light ones, and therefore have low albedos (Ollier, 1984). Albedo is important because it is a measure of a rock's ability to absorb heat and consequently raise its temperature. The passage of this heat through a rock is affected by its thermal conductivity (Bland & Rolls, 1998).

In their recent study, (Hall *et al*., 2007b) show the same results as in their previous study (Hall *et al.,* 2005), whereby white pigment temperatures under certain circumstances were hotter than darker colours. It is, therefore, argued that when surfaces are close to or lower than air temperature, then the albedo-controlled response is that the darker surface will be hotter than the light-coloured. However, when the rock surface becomes hotter than the air, the lighter colour can become hotter than the dark (Hall *et al*., 2007b).

1.8.2.3. Thermal Conductivity

When the temperature of a surface is raised, heat is normally conducted to the sub-surface (Bland & Rolls, 1998). Thermal conductivity is defined as a measure of the rate at which heat is transmitted through a substance (Bland & Rolls, 1998). Rocks have a low thermal conductivity, and an important outcome of a low thermal conductivity is a marked temperature gradient (Bland & Rolls, 1998; Huggett, 2003). It is further acknowledged that the temperature gradient may be much steeper in the outer few millimetres of a rock, and that the presence of a temperature gradient means that variations in surface temperature will not necessarily have an effect on the temperature at a certain depth.

Pigment albedo may influence resulting temperatures and hence impact directly on weathering of the art itself in addition to the rock on which the art was created (Hall, 2007; Hall *et al*., 2007b). In their recent studies, Arocena and Hall (2004), Hall *et al*. (*2005*) and Hall (2006) have shown that under certain conditions lighter coloured materials can attain temperatures equal to or higher than the darker materials despite the influence of albedo on warming by direct radiation (Hall *et al*., 2007b).

Additionally, in rocks composed of crystals of different colours, the darker crystals warm up faster and cool down more slowly than the lighter crystals (Huggett, 2003). As a result, all these thermal stresses may cause rock disintegration and the formation of rock flakes, shells and huge sheets. It can also be argued that recurring heating and cooling causes a fatigue effect that enhances this thermal weathering.

1.8.2.4. Coefficient of Thermal Expansion

When a solid is heated, it expands and when cooled it contracts. Solids vary in their reaction to temperature change, and an indicator of the degree to which they respond to an increase in temperature is their coefficient of thermal expansion (Bland & Rolls, 1998). Also, when insolation occurs, surface layers are likely to expand, thus setting up tensile stress. When insolation ceases, surface layers contract (especially when the air temperature is low) and, as a result, compressive stress is developed (Bland & Rolls, 1998). Therefore, for breakage to finally occur the elastic limit must be exceeded.

1.8.2.5. Frost Weathering

Cryoclasty is one of the temperature-controlled weathering mechanisms most widely referred to in the literature of cold or mountainous environments, and this mechanism is dependent on the availability of water within the rock, and low temperatures enough for ice to form and cause damage (Hoerlé, 2006). The temperature at which ice is formed is known to decrease below zero with a decrease in pore size, a decrease in water content (because water tends to be retained in smaller pores where it is more difficult to freeze) and with an increase in dissolved salt content (Matsuoka, 1994). The behaviour of water at temperatures around the freezing point gives rise to an effective process of rock breakdown (Hall, 1997; Hoerlé, 2006) and hence the process of frost weathering.

Frost weathering is the process of rock disintegration that takes place when water freezes and so expands within rock, and for a definitive answer about the likelihood of frost damage, data on rock moisture is needed (Ollier, 1984). Frost action is one of the most vital physical weathering processes (Selby, 1985) since it is dependent on:

- The existence of pores and cracks in the rocks;
- The existence of water, with saturation and nearly pure water providing the most favourable conditions for the process; and,
- A temperature regime in which crack and pore temperatures fall through the range of about –2° to –7°C and hold that temperature for same hours in which freezing can be completed.

Water occupying the pores within a rock body expands upon freezing by nine per cent, this expansion is suggested to build up pressure in the pores and result in fissures, causing the physical breakdown of rocks (Huggett, 2003). Frost weathering breaks off small grains, and large boulders which, then end up being split into smaller pieces. The temperature at which freezing occurs can vary substantially, even for the same site (Hall, 2006). And, contrary to popular belief, there is no singular value of temperatures within which freezing of water will take place in rock (Hall, 2006). Substantial doubt exists as to the actual freeze-thaw mechanisms and whether the mechanism is actually active at all (Hall, 2006).

With respect to cryogenic weathering, freeze-thaw and frost action are commonly stressed (Zhu, 2003). It has been acknowledged that freeze-thaw weathering is controlled by several factors such as rock albedo, rock temperature regime, rock moisture content, rock moisture chemistry, rock properties, and rock strength (Hall, 1991, 1992, 1997; Meiklejohn, 1995). Salt content is also a possible agent that hinders the freeze-thaw process (Zhu, 2003).

Further, during winter months, when rock temperatures are at their coldest, rock moisture contents are at their lowest, especially at the exposed Battle Cave site, and are insufficient for cryogenic weathering to be active (Meiklejohn, 1995). The fact that freeze-thaw weathering does not currently occur at the study sites in the UKhahlamba-Drakensberg Park, does not rule out the fact that this process may have been active in the past (Meiklejohn, 1995).

As already argued by Meiklejohn (1995), due to being exposed to direct radiation, the Battle Cave study site experiences not only the warmest, but also the coldest rock temperatures of any known rock art sites in the study area. In their studies, Meiklejohn (1995) and Hall *et al.* (2002), found that Battle Cave does not, however, experience temperatures cold enough for freeze-thaw weathering to occur, hence the conclusion that it is unlikely that many, if any, other sites will experience this process.

In winter, moisture is scarcer but rainfall does occur occasionally in the uKhahlamba-Drakensberg, and minimum temperatures for air and rock types frequently drop below 0°C (Tyson *et al.*, 1976; Sumner & Nel (2006). Though there is potential for frost action if favourable temperatures coincide (sub-zero temperatures between May and September do occur), no frost action in areas adjacent to the study area has been recorded (Sumner & Nel, 2006). Therefore, it is highly subjective to presume freeze-thaw weathering just because conditions may be conducive at this altitude (Hall, 1997; Sumner & Nel, 2006).

There is clearly a need to re-evaluate cold region weathering processes and not simply suppose freeze-thaw, particularly without any evidence to support the contention. Freezing conditions are not adequate evidence of frost weathering (Hall, 1995; Sumner & Nel, 2006). With increased data acquisition, it is possible to establish that processes other than freeze-thaw are often responsible for rock weathering and that even where that process does dominate, it could be coalesced with other processes such that the breakdown and landforms are the product of process combinations, not a singular entity (Hall, 1997).

It has been argued that temperature changes on their own may not be sufficient to cause the weathering of the Clarens Formation sandstone in the protected shelters (Meiklejohn, 1995). It is thus possible that moisture changes rather than temperature changes, or even a combination of the two may be the major reason for rock weathering and rock art decay in the UKhahlamba-Drakensberg Park. Meiklejohn (1995) shows that although the temperatures in the study area can at times drop below zero in winter, the possibility of frost is restricted by the aridity of the climate in that season, hence the need to study the impact of wind on weathering processes.

1.8.3. Wind

Wind-blown particles can themselves be identified as agents of rock art deterioration. These particles act as abrasives that can cause considerable damage to paintings (Batchelor, 1990). In addition, wind can affect weathering processes by evaporating moisture from the rock surface; it could indirectly affected rock weathering in that it may aid evaporation of moisture at the Main Caves study site at the rock surface thereby enhancing weathering processes associated with the drying of rocks (Meiklejohn, 1995). Since Battle Cave is more exposed, it is more likely to experience greater wind speeds than the Main Caves; for this reason, wind may increase evaporation at the rock surface and, in so doing contributing towards the lower rock surface moisture contents observed at Battle Cave (Meiklejohn, 1995). Further to the purely physical effects of wind-induced moisture evaporation discussed above it potentially causing the precipitation of salts and consequently weathering due to crystallization pressures (Batchelor, 1990). A further reduction of the water content can have two consequences:

- The salt may crystallize, but this is a very slow process and has to take place around foreign particles such as dust;
- Alternatively solution is maintained, in which case, it is said to be supersaturated (Ollier, 1984). Therefore, crystallization is postponed, but when it occurs it is very rapid.

If a solution is cooled, the effect will depend on the concentration (Ollier, 1984). In addition, if the solution is far from saturation, then no crystallization will take place and if it is near saturation, then crystallization may take place (Ollier, 1984). It is therefore significant to discuss the effect salt weathering has on the rock and consequently on San paintings.

1.8.4. Salt Weathering

A few centimetres behind the walls of rock shelters, the rock may be saturated with water that contains a high concentration of minerals and salts (Batchelor, 1990; Lewis-Williams, 2000). As it evaporates, it deposits these substances on the paintings. At the same time the water dissolves the minerals strengthening the tiny particles of sand that make up the sandstone on which so many of the paintings have been created. The particles drop down and the paintings fade. This is particularly so as most of the salts are commonly found mixed with the paint or deposited between paints and the rock surface (Batchelor, 1990; Loubser, 1991). Because some of the pigments used by the San soaked into the rock, this process can continue for a while without much noticeable effect on the painting, but, when the critical depth is reached, the paintings fade away rapidly (Lewis-Williams, 2000).

Weathering processes that take place near or at the rock surface are the most detrimental to rock art since they occur at the boundary between the paintings and the rock or within the pigments themselves (Meiklejohn, 1995). Moreover, weathering processes that are possibly to be active at this border consist of salt crystallization, hydration/dehydration of both minerals and precipitates, hydration/dehydration of clay minerals, solution processes, and hydrolysis. These processes are enhanced on by changes in humidity, hence the changes in atmospheric moisture resulting in certain weathering processes being active (Meiklejohn, 1995). Further, moisture may weaken rocks such that saturation may reduce the dry compressive strength of sandstone by up to sixty per cent (Bell, 1983; Meiklejohn, 1995).

Salt-based weathering mechanisms are known for causing or assisting the flaking process (Robinson & Williams, 1994; Hoerlé, 2005). These mechanisms contribute to weathering in a variety of ways; salts exert physical pressure by (Ollier, 1984; Bland & Rolls, 1998; Pope *et al*., 2001; Huggett, 2003):

- Thermal expansion: For weathering to occur, the thermal expansion coefficient of salt should exceed that of the surrounding rock. This sets up tensile stress, to which rocks have least resistance.
- Hydration: When salts hydrate, there may be a significant increase in volume. Therefore, the greater the degree of hydration, the greater the pressure generated.
- Crystallization pressure, which is brought about by increasing the concentration of a solution at a constant temperature, usually by evaporation; and by lowering the temperature of a solution that is close to being saturated.

Salt crystallization is linked to wetting-drying cycles being the main agent for granular disintegration and flakes (Ollier, 1984; Benito *et al*., 1993), and hydration acts concurrently on salt growth (Fahey, 1986). Disintegration rates by salt weathering are accelerated where a large diurnal range of temperature and very low relative humidity exists

(Benito *et al*., 1993). In addition, it has been experimentally demonstrated in laboratory experiments salts dissolved in the water increase the efficiency of the freeze-thaw cycles (Williams and Robinson, 1981; McGreevy, 1982; Benito *et al*., 1993).

Salts formed from reactions between acids and bases can cause rock breakdown, and this is because of the pressure they exert, either when they crystallize from solution or when, in the crystal form, they expand on heating or hydration (Ollier, 1984; Pope *et al.,* 2001). For salts to be effective weathering agents, they need to enter rock pores, naturally in solution (Ollier, 1984; Benito *et al*., 1993). When salt crystals formed within pores are heated, or saturated with water, they expand and exert pressure against the confining pore walls; this produces thermal stress or hydration stress, respectively, both of which contribute to salt weathering (Ollier, 1984). The crystallisation of salts exerts sufficient pressure to disrupt the cohesion of rock grains. Sub-surface crystallisation causes the breakdown of protective layers, therefore resulting in destruction of pigments.

1.8.5. Pigment Properties

In addition to rock weathering processes, the pigments of paintings most exposed to solar radiation have faded at Battle Cave study site, while those painted in more sheltered locations are in good condition of preservation (Meiklejohn, 1995). On the other hand, it is indicated that at the Main Caves study site, there is less evidence of pigment declining due to ultra-violet radiation, and that most of the deterioration of the rock art is due to rock weathering processes.

Paintings are, in general, more vulnerable to weathering than engravings. The paint might be a cause of its own degradation. To address this issue, the exact composition of the paint should be determined to assess its potential chemical reactivity and physical properties, especially its hydration susceptibility and permeability (Hoerlé, 2005). In addition to factors that affect the rock support, the resilience of paintings depends on the properties of the pigment and the bonding of the pigment to the rock (Rosenfeld, 1988). For example, it has been indicated that paintings which were produced using a thin penetrating pigment, outlast those created by paste. The paste peels off whereas a liquid pigment easily penetrates into rock, especially if the rock is porous.

The wetting of paintings, in an attempt to make them clearer (*e.g.* during photography) is a major factor contributing to their destruction. As previously mentioned, alternating wetting and drying causes flaking, and unless some pigment penetrates into the rock pores, this may ultimately remove all traces of a painting (Ollier, 1984; Rosenfeld, 1988). However, the infiltration of pigment into pits and hollows of the surface also leaves a faded figure (Bednarik, 1994a).

Moisture is undeniably the major cause of the decay of paintings and pigments, and many factors are involved in the process of degradation of the pigment itself as well as of the base rock or pigment bond, both of which result in the loss of the painted image (van Rijssen, 1987). It must be emphasized that the factors that influence the weathering of sandstone, and hence the deterioration of rock art, cannot be isolated as each is part of the environment in which this deterioration takes place.

Arocena *et al*. (2008) and Hall *et al*. (2007a, 2007b) reported that the discrepancies in the thermal responses of pigments in San rock art were due to the thermal properties of minerals in the pigment. And that clearing protective vegetation cover such as trees for better tourist viewing of rock art is an example of change in the surrounding environment that can introduce significant differences in the thermal responses of the pigments as they get direct exposure from solar radiation. It is argued that these thermal stresses can eventually lead to the formation of cracks in the pigments.

In the same way, where the paintings have been created on top of a clay-based ground, the clays slow down water infiltration from the rock to the pigments such that any cracking may facilitate water movement from the rock to the air (Arocena *et al*., 2008). The cracking may be a response to the enhanced thermal fluctuations resulting from the removal of vegetation that acted as a shield (Arocena *et al*., 2008). It is, therefore, clear that pigments alter the surface’s albedo, porosity, chemistry, and thermal properties (Hall *et al*., 2007b).

Having discussed the natural causes of rock art deterioration, following are the human-induced causes which can ultimately be avoided through the understanding and appreciation of the significance of San rock art in South Africa.

1.8.6. Human-Induced Causes

Factors that influence the deterioration of rock art can be of human/animal or of natural origin. Every visitor to a rock art site produces a series of variations in the interior microclimate of the cave or shelter due to his own metabolism, and these variations are produced by the emission of heat through radiation through the skin, and by the production of carbon dioxide through respiration (Hoyos *et al.*, 1998). The impact of tourism, though not insignificant, is less prevalent in shelters (due to being in the open) than in caves. The atmospheric changes caused by the presence of humans, which are so essential to cave art preservation, are less severe in open rock art shelters and in comparison are easier to control.

Since rock art occurs on natural outcrops, it is subject to the normal geological processes of weathering (Rosenfeld, 1988). These processes can be severely modified by man-induced changes in the environment. Additionally, the disruptive consequence of industrial development is evident, but atmospheric pollution, bringing new products in dust and increased acidity of rainwater may be less easily noticeable and may extend well outside the areas of actual development. The most visible example of human impact weathering, dominating the stone conservation literature is the weathering caused by atmospheric pollution, obvious at local to regional scales (Aberg *et al.,* 1999; Bertilsson, 2002).

Development, settlement, and a system of roads increase the accessibility of rock art sites to visitors, where even the most responsible tourist or scientist impinges on, even if only briefly, the natural environment of a rock art site (Rosenfeld, 1988). The original artists also impacted on their environment, but the nature and degree of human-induced environmental alteration is extremely increased under the impact of industrial societies (Rosenfeld, 1988). This, combined with the natural deteriorating forces on the rock, has aggravated rock art deterioration problems. It is worth noting that such destruction is not highly significant in the study area due to its remoteness.

Taking samples of rock art for direct dating is also problematic since the sampling procedure damages the art to a certain degree. Furthermore, it is not always possible to be certain in the field when sufficient organic material for dating purposes has been gathered. Therefore, archaeologists are in a difficult position when collecting samples or material has to be dated. There is the need to decrease sample sizes in order to protect the art against the futility of collecting a sample which is too small to contain reasonable organic material for dating (Hoerlé & Salomon, 1998). This highlights the need for sampling to be carried out only with skilled technical assistance.

Another important issue related to human-induced causes of rock art decay is the various heritage conservation and management activities performed around the world. Even though all such actions arise from positive initiatives, they may have negative results. One obvious risk is posed by increasing cultural tourism (Bertilsson, 2002). It is argued that when carefully planned and controlled, cultural tourism encourages education about and protection of rock art. On the other hand, uncontrollable and unconstructively executed tourism can contribute to rapid and severe deterioration of panels and sites (Bertilsson, 2002). In this sense, the management of sites to the general public can often become a critical matter.

The most offensive action of human beings on San rock paintings is vandalism. Vandalism of San rock art goes as far back as 1893, when farmers had damaged the paintings by creating crude charcoal imitations, scribbling over them, trying to remove them, and lighting fires in rock shelters (Wright & Mazel, 2007). It was shown that in 1897, rinderpest guards and policemen used the Main Caves paintings for target practice. Since then, vandalism has incorporated delineating paintings with pencil, scratching them, chiselling, throwing stones at them, and coating them with varnish (Wright & Mazel, 2007). Moreover, some cases indicate the removal of paint for medicinal purposes.

1.9. Summary

The rock art heritage is still at risk. Although new sites are discovered continuously, just as many or more are constantly endangered or destroyed. Once a site is lost we also lose the memory of its creators, the unknown people without writing - the loss is forever and the rock art can never be replaced.

Though not much can be done to stop the natural processes of weathering that will eventually destroy the paintings, something can be done to prevent the much more immediate destruction being caused by people. Once damage resulting from human activity has been prevented or reduced to a minimum, the art is mostly susceptible to natural weathering of the rock surfaces where images occur (Hoerlé & Salomon, 1998). To protect the art successfully, we need to be proactive about conservation policies.

Appropriate preservative measures must be put in place, especially since the wrong measures may intensify weathering processes. To do this, we need to understand how weathering affects individual rock art sites. The shortfall in our understanding has severe implications for how rock art sites are interpreted, conserved and managed. A scientific analysis of the weathering processes, whether natural and/or human-induced and the factors affecting them at a given site, is therefore necessary before any conservation intervention.

CHAPTER 2: CONSERVATION AND PRESERVATION OF ROCK ART

2.1. The History of Rock Art Conservation in South Africa

The uKhahlamba-Drakensberg is acknowledged as one of the World's best known rock art regions since it contains a high concentration of rock. Not only are the paintings well preserved, but they are also of outstanding quality. Interest in recording and conserving rock paintings in South Africa began in the mid 19th century after realizing that the artists were no longer actively painting and that the paintings were vulnerable to damage (Deacon, 1993).

Recording of rock paintings in the uKhahlamba-Drakensberg began in the Giant's Castle area in 1876 and the first coordinated effort to record rock paintings in the area took place in 1910 (Wright & Mazel, 2007). Additionally, due to growing concerns in government circles about the damage which was being done to the paintings through human actions as well as natural causes, all rock paintings within a particular area of the southern uKhahlamba-Drakensberg were to be found. The first recording of large numbers of paintings, totalling 1041 images in 37 sites was produced, and recommendations for the physical removal of some 20 groups of paintings to the Natal Museum in Pietermaritzburg were proposed (Deacon, 1993). However, there was little common interest in San rock art, and over the next 40 years practically no recording work was done (Wright & Mazel, 2007).

From 1979 to 1981, an extensive rock art survey covering the uKhahlamba-Drakensberg was undertaken (Wright & Mazel, 2007). At the end of this survey, the number of painted sites in the uKhahlamba-Drakensberg was understood to be 500. Later discoveries have increased the number of known painted sites to around 600, and these sites hold between 35 000 and 40 000 individual images, which have been documented by means of written descriptions, photography, and tracings (Wright & Mazel, 2007).

Official concern in Natal about the preservation of paintings in the uKhahlamba-Drakensberg dates as far back as the early 1900's; important advances were made towards understanding and recording San rock art in the mid-1970s (Deacon, 1993). The first heritage legislation in South Africa passed by government was the Bushman Relics Protection Act in 1911 after discovering that a European collector was on his way to acquire artefacts for overseas museums (Wright & Mazel, 2007). This legislation banned the damage or destruction of the paintings and therefore rock art is still protected in terms of the National Monuments Act (Deacon 1993; Wright & Mazel, 2007), and the Kwazulu-Natal Heritage Act No. 4 of 2008.

In a quest to find ways of preserving San rock art, a joint project of the National Building Research Institute of the CSIR and the National Monuments Council was launched in the 1970s, but the results were uncertain (Deacon, 1993). Further initiatives show the development of new products, surface coatings and silicone preparations which were applied to unpainted rocks and to rock paintings at three sites in Natal in the 1950s' to test their capability to slow down natural and human damage. Unfortunately, the cost of materials prevented extensive application and follow-up studies were not completed (Rudner, 1989). Also, in 1974, a programme at a cost of R100, 000 was supported by the NBRI of the CSIR and the National Monuments Council (NMC), over eight years, to study methods for preserving and protecting rock paintings (Deacon, 1993).

However, not all rock shelters inhabited by the hunter-gatherers and farmers were painted (Wright & Mazel, 2007). Sites that are not endangered by humans may be at the risk from natural processes that can also damage or destroy rock art. No rock art site will last forever or remain always in a state of exceptional preservation (Swadley, 2002); hence, the need to find ways to slow the rate at which it is decaying.

2.2. The Purpose of Conservation

The importance of prehistoric rock art as a substantial part of the cultural heritage of South Africa is progressively being acknowledged by academic and national heritage management bodies. Conservation has as one of its purposes the preservation of cultural property for study and research by scholars whose work expands our understanding of humanity's development (Levin, 1991). In reality, objects preserved collectively can help express the essence of a culture (Levin, 1991). Conservation also has the function of preserving the world's material culture for future generations. In practice, that has often meant managing the cultural heritage by sheltering it from public contact (Levin, 1991).

The process of conservation in recent times emphasises the repair of damage arising from numerous causes, but also, importantly, includes preventive measures to minimize the rate and degree of such occurrences. Good conservation means that rock art is handled carefully and delicately, taking into account the reactivity of materials and fragility structures (Stolow, 1979). Furthermore, conservation practice recognises that the effects of environmental factors are minimized by setting up proper control measures (Beltrán, 1982).

2.3. Preservation

The technical, scientific, and management requirements of site preservation can be more complex than those for objects in museums. While museum collections are usually assured security and care within an environment where humidity, temperature, and light levels can be controlled, outdoor sites are exposed to destructive natural forces and often are not secure from vandalism.

Preservation of San art requires the input of many disciplines, meaning all key players must be involved in the design of a management policy and associated strategies. A blending of expertise of for example, archaeologists, site managers, conservators, scientists, tourism planners, engineers, and geologists, is necessary to devise an overall preservation strategy that can be developed into a master plan for a site (Whitley, 2001). The goal must be a holistic approach that can spot all threats and create countermeasures, as well as a management plan with methods to ensure implementation (Deacon & Agnew, 2006). Most importantly, a crucial part of the planning process must be consideration of the views and cultural and economic needs of the local population.

It is crucial to stop or at the very least minimize rock weathering processes in order to preserve the rock art (Meiklejohn, 1995). If the controls on the deterioration are environmental, very few measures can be undertaken to prevent rock weathering processes in the absence of any chemical applications that may preserve rock art (Meiklejohn, 1995). Two major methods that can be used to preserve rock art in the original are: altering the environment in which the rock art is found and applying preservations to the rock surface (Meiklejohn, 1995). However, with only limited research into chemical applications that may preserve rock art, not much can be done to stop weathering processes because controls on rock deterioration are environmental (Meiklejohn, 1995). While conservation of rock art may entail a few measures that slow weathering processes, they will not ultimately guarantee the ultimate preservation of this precious legacy (Meiklejohn, 1995). There are no effective conservation methods to ensure the painting’s everlasting survival, and once the art has been destroyed, the record made of it will be all that remains (Bednarik, 1994a).

2.4. Conservation

Conservation should not be confused with restoration, where existing materials are modified or new materials added, or both. The aim of conservators is, instead, to reduce the rate of decay of painted surfaces and their rock support, to manage and protect the sites where these occur, and to educate the public and researchers about their significance and value. Acceptable conservation, in a broad sense then, is to slow rather than hasten the rate of decay.

There is no single right way to manage rock art sites, because each site is unique, but also because conservation is a relative concept that changes through time (Loubser, 2001). Further, appropriate management practice, as understood by current conservators internationally, is to slow the rate of decay and preserve the integrity of a place for future generations to enjoy, study, and preserve (Loubser, 2001). Therefore visitation, research, and conservation should proceed in such a manner that there is minimum impact done to a site.

Most of the paintings in the study area are found in the shallow caves at the base of the yellow cave sandstone cliffs, though a few occur on isolated boulders or rocks (Willcox, 1956; Truswell, 1970). To show their uniqueness, their conservation therefore varies greatly from one site to another depending on factors such as exposure to the elements, internal pressures in the rock, and past and continuing damage by man (Irwin *et al.,* 1980).

With few exceptions, decay of the rock substrate and linked art is seen as destroying the momentous values of a place, be it spiritual, archaeological, or aesthetic (Loubser, 2001). If at all possible, proper conservation and management actions, which include recording, analysis, treatment, and interpretation, should not detract from any of these values; in practice it is extremely difficult to preserve every single value for the future, and, therefore, efforts to save some values usually compromise the integrity of others (Loubser, 2001).

2.4.1. Managing Rock Art Sites and Collections

A comprehensive national and international approach to preventive care of collections involves education, research, and outreach (Levin, 1991). Further, incorporating conservation studies into the formal education of art historians and offering training in preventive conservation technologies to conservators are essential. In addition, with increasing rock art tourism, special efforts should be made to join forces with tour operators and guides, as well as with local populations, who are better able than anyone to preserve the art and become custodians and curators of the sites. The cultural value of the rock art sites is protected by linking preservation of the sites to a community's economic wealth (Clottes, 2006).

Levin (1991) explains that while none of the problems related to the management of sites, both in archaeological and urban settings, lend themselves to simple solutions, the necessity for protective measures is clear. As a result, no site can be preserved without the support of the surrounding community. It is, therefore, crucial, that creating a local constituency for site conservation and preservation means making that community part of the site management process. Accordingly, training is a solution for involving people, both for professionals whose skills require improvement and for the local population. Workshops for those directly engaged in rock art management and conservation are another practical step to be promoted (Clottes, 2006).

Rock art sites are highly susceptible to environmental and human damage as they are often located in environments where ambient conditions are difficult to control. Many significant sites are located in developing nations which often lack the expertise and financial ability to preserve their historical riches (Levin, 1991). Further, these nations are frequently overshadowed by issues of health, education, poverty, economic development, and overpopulation, and cannot dedicate much energy and resources to the conservation of their cultural resources.

It is clear that rock art is deteriorating rapidly due to natural weathering processes and thoughtless human activities, hence the need for long lasting effective and efficient conservation and preservation techniques. Preservation and conservation of rock art is a delicate matter that should be undertaken at a highly professional level. Because of natural factors and intentional human vandalism, as well as the variety of agents of deterioration, each requires specific study. In order to develop an efficient network of preservation and conservation services, national governments and international bodies should perhaps encourage exchanges of experts, information, and services.

For conservation purposes, the most vulnerable or badly damaged sites have and are being closed or covered up, but others are being protected in more visitor-friendly ways; for example, with walkways or viewing platforms (Bahn, 1998; Deacon, 2006). It is further proposed that installation of boardwalks (*e.g.* Fig. 2.1) could also be used to control and educate visitors at sites more particularly in the absence of trained guides. Although this would not be practical at all sites, boardwalks are fine examples of how protective and educational facilities may be combined in the field: the walking surface reduces dust, the attached handrails keep visitors at a suitable distance which prohibits them from touching the painted surfaces and the information or interpretative panels inform and educate people.

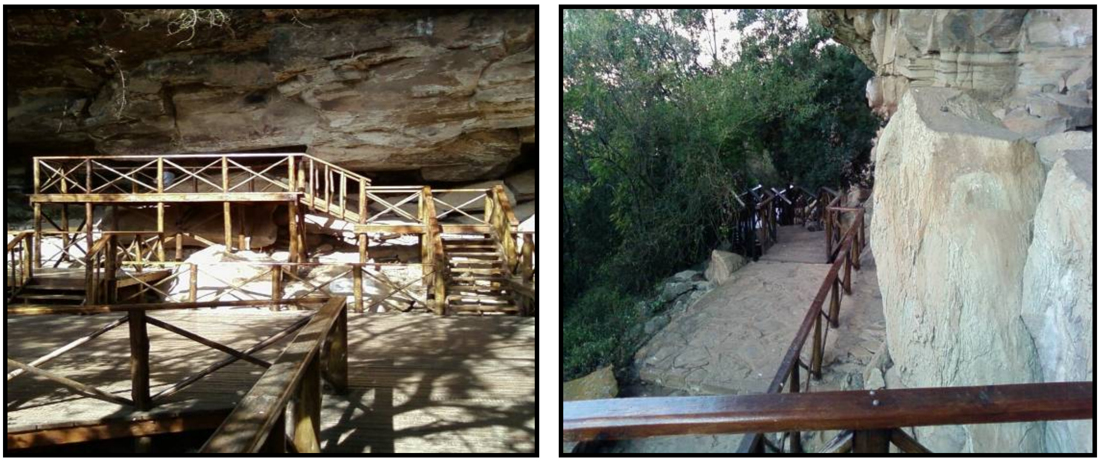

Figure 2.1: Boardwalks with viewing platforms installed at the Main Caves study site to reduce the risk of dust, rubbing and touching of paintings (Photographs: T.C. Leuta).

Interpretive panels can present several functions. They can provide visitors with an overall impression of the significance and heritage of a site and introduce the concept of protecting cultural resources. Interpretive panels may also offer information on visitor etiquette, points of interest, flora, fauna, geology, and trail statistics such as length, time needed and hiker information (Swadley, 2002).

A well maintained, clearly marked trail is important for preserving the natural environment and establishing a managed presence along routes leading to rock art sites. It is always a good idea to include a visitor register at the start or end of the trail (Swadley, 2002). This would give a little formality to the entrance and is a visual focal point to mark the beginning of a trail. Visitor registers are useful to enforcement officers and can also include visitor feedback information. Parking areas form the visitor's first impression of whether an area is neglected or well managed (Swadley, 2002). Additionally, the impression managers need to make on the visitor is that the site is well maintained and is regularly checked by agency staff. Also, it is shown that weeds growing in the parking area, overflowing trash cans, or similar signs of neglect imply that the area is not actively managed and there is an unlikely chance that visitors will bump into agency personnel. Unfortunately, this is all the permission a vandal needs to deface a site (Swadley, 2002).

Vandalism of rock art sites is a growing international problem. Whatever methods one country may be considering in response to this problem have probably been tried elsewhere. It is well worth the effort to seek advice and assistance from experienced individuals and organizations; such advice can probably save one considerable time and expense. Other than human-induced problems which can be eradicated, the problem of natural forces need to be considered and taken care of, hence the need to reduce the impact moisture has on paintings.

2.4.2. The Control of Moisture

For effective rock art preservation, there is need to protect the rock against moisture related processes, either by protecting the rock itself or by altering the environment so that moisture and temperature changes are kept to a minimum (Meiklejohn, 1995). Of the various types of moisture affecting the survival of rock art, surface run-off is the easiest to address, and also the first that can be dealt with (Bednarik, 2003).

The monitoring of rock moisture content is a necessity and in its absence some indirect supervision is necessary (Hall, 1997). Moisture and temperature go hand in hand in helping to determine and examine weathering processes (Hall, 1997). An analysis of the moisture distribution and chemical composition will allow the determination of the origin of the water, the nature of the species in solution (and their relation to the observed deposits) and their potential influence to the paint and/or the rock.

The interdependence of many forms of moisture (*e.g.* capillary water requires a source such as an aquifer) is crucial in understanding the hydrological regime of a site, which in turn is essential in any remedial work (Bednarik, 2003). If water runoff appears to be the main source of damage, it must be diverted from the paintings; this could be achieved through short-term solutions such as installing drip-lines (Meiklejohn, 1995), and ridges or gutters (Lewis-Williams, 2000; Bednarik, 2003) on the ceilings of some shelters and caves to redirect the water path.

One of the most efficient methods for preventing further weathering of rock art sites is the construction of roofing in order to keep the rock surfaces dry, since the observed weathering reactions will almost cease if water is absent (Walderhaug, 1998). Vegetation can also be introduced to soak up surface run-off above a site, although when planting vegetation near rock art, the fire danger must always be taken into consideration (Bednarik, 2003). Weathering may also be delayed by covering the rock art sites with earth or other materials, but the effect of covering a rock art site will vary according to the type of rock and weathering reactions active at each individual site (Walderhaug, 1998). It is, therefore, important to determine which weathering processes are active before covering a specific rock art site.

While it is feasible, and often quite practicable, to control gravitational water, capillary moisture is virtually impossible to eradicate (Lambert, 1980). Rising in porous rock, usually from an aquifer, it is probably the main factor in the formation of sandstone shelters at the base of cliffs (Lambert, 1980). Moreover, moisture rises from the ground so the salt spalling it causes through wetting and drying cycles erodes the rock rapidly, but only above ground (Lambert, 1980). The erosion process continues after rock art has been located in the shelter, and other than preventing the aquifer from reaching the rock, one sees no realistic possibility of arresting the process. Since natural weathering cannot be halted, the need arises of documenting paintings so that when they have completely vanished, their record is what remains.

2.4.3. Recording of Rock Art

In terms of preservation, the content of the rock art records is often not enough, and in most cases it is missing and this clearly affects the potential use of these archives as tools for informing management and conservation practices (Hoerlé, 2005). Because recordings can be seen as being incomplete especially if only one technique is used, an effective recording should cover different techniques such as photography, drawing and tracing.

Since very little can be done about the deterioration caused by the environment, other than the careful recording and documentation of the paintings, suitable conservation measures (and research into efficient conservation measures) need to be adopted to avoid any further negative human destruction on the rock art (Deacon, 2006). Thus, because nature conservation and the conservation of rock art must be interrelated because rock art is a vital part of the environment, recording is an essential part of the study of a cultural heritage site. A multidisciplinary approach is best and should be used, and every case should be treated as unique (Irwin *et al*., 1980; Loubser, 2001; Swadley, 2002) and every element should be carefully studied.

While the publication of detailed descriptions of prehistoric art sites can increase the likelihood of human damage, in contrast, the lack of records can make it harder for researchers and public authorities to notice and take steps to prevent threats to the rock art. The nature and rate of decay of rock art are a source of great concern not only to researchers but to the nation as a whole. Although there has been a great deal written concerning the location, interpretation, restoration and archaeological significance of rock art in southern Africa, little has been accomplished in coping with the processes of deterioration or techniques for its preservation (Meiklejohn, 1995).

Sites that are not endangered by humans may be at risk from natural processes that can also damage or destroy the rock art. If several sites are in need of documentation, Swadley (2002) emphasizes the need to concentrate on sites that are most affected by depreciative visitor behaviour or other sources of natural degradation. Therefore, the rapid decay, exfoliation, and other types of deterioration of rock art in many parts of the world make it crucial to progress with exhaustive recording as rapidly and as reliably as possible (Swadley, 2002).

Although there is need for many recording methods so that recorders can choose methods which best suit their needs and capacities, Clegg (1991) agrees that some methods do much the same things as others, and some are better than others. A period of learning or experimenting with a particular method may therefore be needed before a practitioner becomes competent. The need for many different methods stems from the three main sources of variation (Clegg, 1991):

- Every individual picture is different and presents its own problems;
- Every recorder or recording situation has different resources of time, materials, equipment, money and skill; and,
- Different tasks or archaeological problems have different aims, which need suitable methods.

In deciding which techniques are to be applied in any particular case, the goal should be the best possible data recording and minimal resource destruction (Swartz, 2006). Photography is the most common, practical, and cost-effective way to record rock art, and is recommended as the primary recording technique. Good photographs are essential to rock art recording, and varied photographic techniques are stressed since they document and do not require physical contact (Whitley, 2001). Since photography is dependent on correct lighting conditions, an essential first step is to examine the rock art panels at different times of the day to record under different lighting conditions (Whitley, 2001).

The fact that managed rock art sites need to be photographed at least twice every year for future comparison since the photographs taken today will be the valued old photographs of the future (Swadley, 2002). In a few cases where the public cannot visit a site because of pollution or difficulty of access, full-size replicas can be produced (Bahn, 1998). Replicas make an increasing contribution to giving the public access to their heritage while lessening visitor pressure on the actual sites. It would be incorrect to assume that the rock surfaces at the studied sites were unaffected by weathering when the rock art was initially created. That is, most of the observed weathering may have occurred even before the rock art was executed, and the presence of the topmost weathered zone may have facilitated the artists' work.

Humans have been recognized as the worst enemy of rock art. The main outstanding problem is that of vandalism, and while some measures can be undertaken to protect sites with fences, for example, there is really no protection against the determined vandal (Bahn, 1998). Beltrán (1982) also raises a very important fact that some of the sites are isolated, hence the difficulty to guard all of them by wardens, or by fencing.

2.4.4. Public Access

Increasing tourism is a concern for all nations, whether developed or developing. Part of conservation's function is preserving cultural heritage so that it can be enjoyed by many, even though public access to sites sometimes has resulted in significant harm (Levin, 1991). An essential issue is whether the public should be excluded from historic places or, whether damage done by tourists should be accepted as the price that must be paid for allowing people to experience their cultural heritage (Levin, 1991). There would, thus, be need to establish what an appropriate level of usage is, and what level of destruction should be perceived as acceptable. On the other hand, we should ask ourselves if instead of opening all heritage sites with paintings, only a few should be made accessible to the demands of tourism.

In rock art conservation, the significance of sites is maintained by protecting the original material on the one hand, while encouraging controlled public access on the other. This approach can be carried out with the knowledge that public access invariably puts the rock art at greater risk from damage. On the other hand, such an approach raises the problem that people will only care about the conservation of heritage places if they are aware of them (Deacon & Agnew, 2006). In many countries the preferred option of protecting rock art is to avoid publicizing it, so that only those most interested will take the trouble to see it (Deacon & Agnew, 2006). One can view this option as an approach to reduce the risk of damage caused by human beings. However, the down side to it is that the general public is less likely to support public funding of rock art conservation if it remains uninformed of the art's importance.

There may be various ways to protect painted places from an increase in visitor pressure; these can include drastic measures such as closing places with rock art to visitors (Whitley, 2001). The caging of caves and shelters is often the only way to stop visitors from entering them and such can be visited only under supervision (Whitley, 2001). Caging usually occurs as a desperate attempt to prevent rapidly increasing number of visitors from damaging painted surfaces (Whitley, 2001). A number of considerably less drastic measures include the placing of 'psychological barriers', which may be low fences, artificial rock ledges or some strategically placed prickly bushes (Whitley, 2001). However, the effectiveness of such measures depends on local circumstances, particularly site topography.

Each site has its unique human, geological and environmental problems that change over time. Management programs are instituted whenever visitors know the locations of rock art sites or if sites can be easily found (Swadley, 2002). The nature of the program and associated management activities depends on specific site properties and on how well the sites are known and how easily they can be reached. Sites to be protected by anonymity should not be identified in literature, maps or otherwise be visibly marked, and also, side trails leading directly to those sites must be covered or diverted to other locations (Swadley, 2002).

Keeping sites a secret may not always work as it is almost impossible to keep the public away from sites (Deacon, 2006). To reach sites closed to the public, a determined visitor will climb under a signed fence, in which case not even armed guards will prevent him or her from visiting such a site (Whitley, 2001). Such a strategy only encourages more vandalism and site destruction especially by professional traffickers (Whitley, 2001). Isolation of the sites and the secrecy about their locations ensures that the looters' work will go undetected, and because the looters know how to find the sites anyway as they have an economic motivation to do so. In some cases visibility and visitation are, therefore, the best ways to prevent vandalism and looting, particularly the intentional and malicious kind (Whitley, 2001).

Adequate site management requires money, and keeping a site's location a secret concerns the way that funding is allocated and resource importance established (Whitley, 2001). It is argued that agency funding tends to be allocated based on demonstrable evidence of need (Whitley, 2001). This is often driven by public interest and demand, that is, resources used by the public such as parks and campgrounds receive funding (Whitley, 2001). This causes them to be seen as important, whereas resources whose only apparent worth is some abstract heritage value are perceived as less critical. Hidden sites may be acknowledged as important, but are not near the top of the priority list when funding is allocated. Rock art site management does require financial resources, especially with the increase in site tourism, but these resources can only be allocated for when shown in a practical rather than abstract way that the sites are important, and that the public cares about them.

In times of economic pressure, unknowledgeable tourism operators, communities, property owners, and managers are lured into considering ways of encouraging even the uninterested to visit the rock art sites, without first putting in place measures to protect the paintings (Deacon & Agnew, 2006). Even when the art itself escapes outright destruction, pressure can be strong to develop the surrounding area and thus change the context of the art drastically (Deacon & Agnew, 2006). Rock art is part of the landscape, which often plays a major role in its meaning (Anati *et al*., 1984). Even modern tourists sense this when they experience the art in its natural environment (Clottes, 2006), hence the need to bring awareness to the public about the importance of this heritage.

2.4.5. Education and Awareness

Education and knowledge are essential, including relentless educational efforts directed at the general public, along with pressure on governments and decision makers to provide and above all put in force legislation for the protection of the art. Public concern for rock art does not have a profile and there is therefore a need to fuel interest in the subject (Deacon, 1993). This can be done effectively where visitor education is a fundamental part of a management plan. In recent years, more and more people have become aware of the existence of rock art; this awareness could serve to enhance its value and facilitate its protection (Clottes, 2006).

The uKhahlamba-Drakensberg park, while being a favourite destination of many, is not viewed as a mass tourism area, and limitations are, thus, placed on the possible extent of development in the park (KwaZulu-Natal Department of Local Government and Traditional Affairs in the uKhahlamba-Drakensberg Development Management Area, 2004). Metropolitan areas are the major generators of wealth of the country and hence their ability to absorb an urbanizing population should be maximized. However, the fact that the wilderness is a vulnerable limited resource which requires special management. Therefore, greater attention needs to be devoted to landscape quality. For example, one of the projects undertaken is the grassland management programme, in which large areas of the park are burnt annually to improve and maintain quality grasslands.

As part of effectively and efficiently managing the park, regular guided tours are taken through the Main Caves daily for a small fee. This serves to educate visitors and to prohibit any kind of vandalism. The importance of this contact is not determined by productive value or even the economic value for tourism (KwaZulu-Natal Department of Local Government and Traditional Affairs, 2004). Rather, its importance lies in the opportunity for people to be part of the totality of the region in which they live.

Rock art usually survives in the original context in which it was created by human kind. The relationship between the rock art creation and its environment is therefore vital for its understanding, and special attention should be devoted to it. The relationship between rock art and its surroundings should be given consideration in conservation and preservation projects, which should involve the site as whole rather than just specific isolated, damaged, or endangered figures.

Increasing public awareness and understanding could be the means to rock art sustainability. This could be achieved through a range of research, dissemination, guidance, education, training and management programmes that are integrated into wider heritage and landscape promotion schemes (Clottes, 2006). At the same time, increasing tourism has created new threats. Too many sites remain unprotected and vulnerable to the ever-increasing numbers of visitors (Clottes, 2006). Under such circumstances, protecting rock art and its environment remains challenging. For example, it is difficult to prevent irresponsible tourists or locals from making graffiti, enhancing figures for photographs, and sometimes even removing artefacts from their surroundings.

Below are conditions that Swadley (2002) identifies, that seem to encourage visitors to vandalize sites, even if they come to the park with no such intention:

- Graffiti is already present
- Little or no evidence of facilities or other improvements exist
- Little or no interpretive or educational information is available
- The site is located close to parking or is directly accessed by vehicle
- The site is located in an isolated area where there is no sign of the presence of park or site staff or any other authority
- Facilities, structures or site components are in poor condition
- Trash or litter is present

It is only through adequate publicity and education that the value of this legacy will be realized by the public at large (Meiklejohn, 1995). In educating government officials, including tourism ministries, conservation organizations should remain up to date with the training of technical personnel and site managers regarding the benefits and dangers of site development. A nation's historical possessions can cultivate national pride and provide economic rewards as employment-generating attractions. Taken collectively, the above measures could advance preservation of rock art while raising the awareness of one of the most spectacular cultural achievements of humankind. A historic site is a heritage to be preserved, rather than a commodity to be exploited (Levin, 1991).

The real answer to the problem of conserving the rock art heritage is a long-term commitment to conveying the message to people of all ages, especially school children, that this is a fragile, priceless and irreplaceable resource, which needs to be treasured and preserved for future generations. At the same time, there is need to show respect for any indigenous peoples who still regard the art as sacred or highly significant (Bahn, 1998). Rock art is non-renewable and therefore requires specialized management.

Because there is no national body with sufficient staff to coordinate rock art research and conservation in South Africa, it is necessary to build up a sense of responsibility from a local or regional level (Deacon, 1993). There is also a need for expertise to develop and apply rock art conservation measures. Professional expertise can grow only if there is a market for these skills. The market can be stimulated by well-planned programmes of rock art sites protection and management (Deacon, 1993).

Research significance will of course change through time, and this highlights the need for minimal destruction during research. As this may not be always possible, Whitley (2001) provides an example of when a place is targeted for complete destruction by dam or road construction. This calls for the collection of representative samples and storing them for future research. If the necessary financial and logistical support can be assembled, then the entire panels can be removed for storage in museums. The removal would then be conducted under the auspices of a highly experienced rock quarry manager or stone mason. Removal is only an emergency measure and is not recommended because of various ethical, interpretive, and practical problems of having a rock outside its field context (Whitley, 2001).

Due to growing awareness, the future will bring yet more tourism pressures on sites, more theft of artefacts, and more destruction of sites. The listing of World Heritage Sites (cultural sites and monuments of the highest value) has been an important step in raising public awareness, but the list is very small when compared with the world's large number of sites (Deacon & Agnew, 2006). All things connect, and so it is with our natural environment and cultural heritage (Deacon & Agnew, 2006), hence an urgent need to find ways to create this link in the public mind and, through education, gain support to save for future generations the sites and monuments of humankind.

The main argument in this chapter is that the key to rock image conservation is the proper management, education, and involvement of people rather than in the constant hands-on repair of damage caused by people. Put another way, prevention by means of minimalist informative presentation is more desirable than the sophisticated intervention preservation (Whitley, 2001). Only time and critical analysis will tell if this is indeed an independent and effective model for conserving sites with rock paintings.

CHAPTER 3: GEOGRAPHIC SETTING AND RESEARCH METHODOLOGY

This chapter provides a physical background of the uKhahlamba-Drakensberg and gives a description of the region's physical characteristics that pertain to rock art deterioration and the threats to its future. The discussion begins with the description of the study sites, description of the region's geology, and its climate, temperature, humidity, and precipitation characteristics. The methodology used in evaluating the amount of decay of the San rock art in the collected data follows after this discussion.

3.1. Description of the Study Sites

The Drakensberg is southern Africa's most spectacular mountain chain, which covers an area of approximately 202 200km² (Ecoregions SA, 2005), and runs from the north-eastern parts of South Africa southwards to the border between Lesotho and the province of KwaZulu-Natal, and then extends into the Eastern Cape Province. The altitude of the mountain range is between 1400m and 3000m.a.s.l, while it is positioned between 100km and 300km from the Indian Ocean (Schulze, 1979). Giant's Castle is a peak on the escarpment, which marks the southern border of Giant's Castle Game Reserve, which extends about 25km northwards and is up to 14km wide (Irwin *et al.,* 1980).

The study focussed on two protected and fenced museums (Fig. 3.1) administered by the Ezimvelo KwaZulu-Natal Wildlife. Battle Cave (29°17'S. 29°31'E.) near the Injisuthi Rest Camp is at an altitude of 1700m to the north of Giant's Castle region of the uKhahlamba-Drakensberg Park, while the Main Caves (29°09'S. 29°25'E.) near the Main Rest Camp at Giant's Castle is at an altitude of 1800m. Although the sites are termed caves at times, it would be more appropriate to identify them as shelters due to being open to the sun, wind and rain (Hall *et al*., 2007a).

The Main Caves is situated entirely within the Clarens Formation sandstone and comprises two shelters, one east-facing and the other north-facing. On the other hand, Battle Cave is a shallow shelter with a north-facing aspect receiving more radiation than any other site within the Clarens Formation (Meiklejohn, 1995; Sumner & Nel, 2006; Hall *et al*., 2007b). These study sites were chosen for their accessibility and richness of paintings, as some paintings are exposed to direct solar radiation.

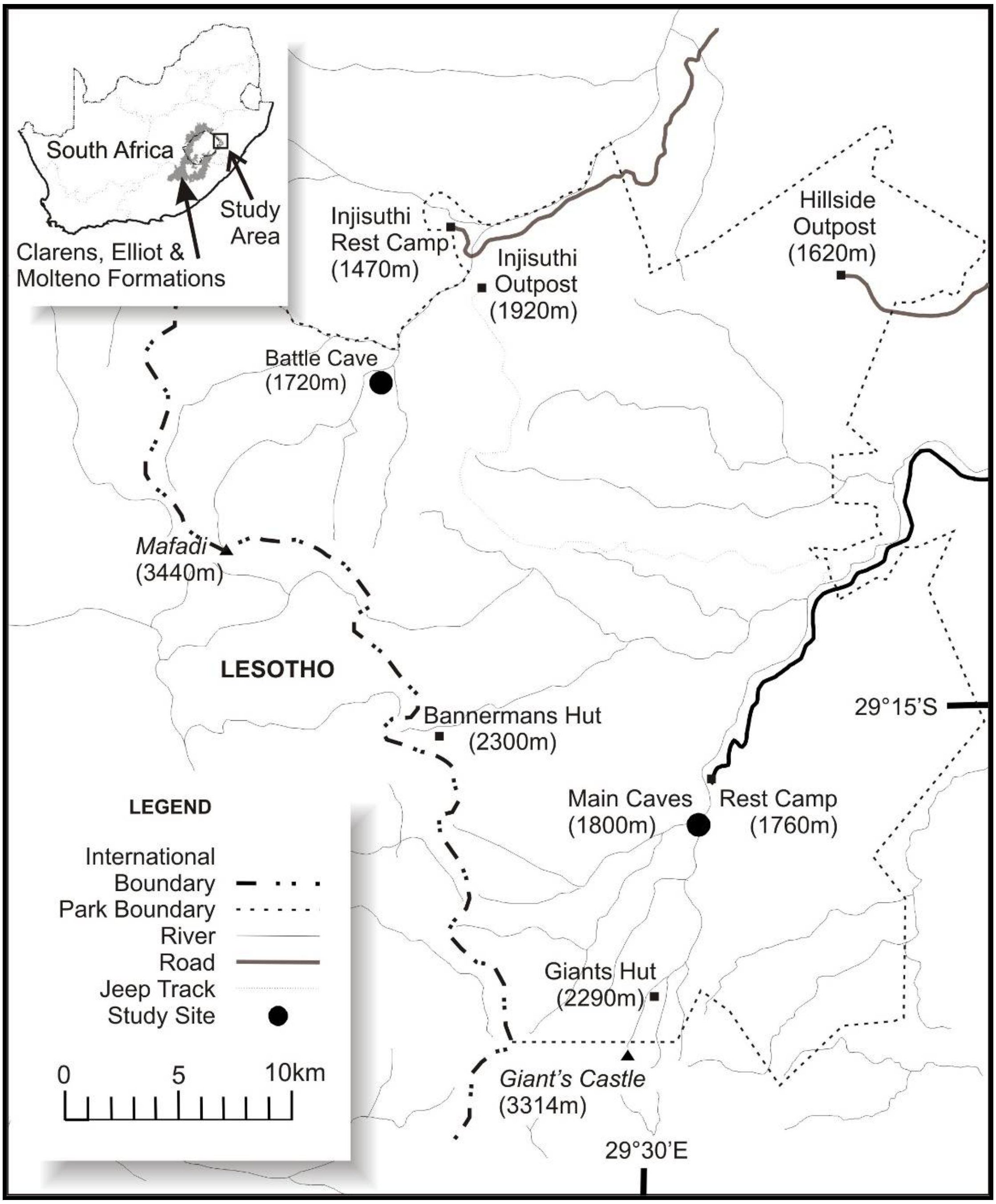

Figure 3.1: Location of the Study Sites in Giants Castle Game Reserve, uKhahlamba-Drakensberg Park (Meiklejohn, et al., 2009).

3.2. Geological background

As noted earlier, rock paintings at the study sites were observed to fade unevenly. To understand why certain paintings are better preserved than others, there is need to examine and understand the geology of the Drakensberg. Geology is concerned with the nature of rocks and minerals. The geology of the Drakensberg is relatively simple because the rocks lie more or less horizontally and are almost entirely igneous and sedimentary types (Irwin *et al.,* 1980).

The most unique physiographic characteristic of the Drakensberg foothills in KwaZulu-Natal is the high cliffs formed of cream to maroon, fine-grained sandstone which comprises what is known as the Clarens Formation (UNEP, 2000). All rock paintings in the UKhahlamba-Drakensberg Park are found on sandstone under protected shelters and on isolated boulders (Batchelor, 1990). Sandstone is a sedimentary rock that is a product of the weathering of igneous, sedimentary and metamorphic rocks (Loubser, 1991). It is normally a combination of weathered grains of quartz and the insoluble products of rock weathering (Loubser, 1991). Where water was present during the deposition of material that became sandstone evaporated soluble salts that have precipitated out also formed part of the medium of the sandstone (Loubser, 1991).

A high proportion of the Clarens Formation is an aeolian deposit, laid down by the wind, and one of the indicators of this is the cross-bedding, which is evident in many places in the study area (Truswell, 1970; Irwin *et al.,* 1980; Eriksson, 1983; Meiklejohn, 1995). The depositional environment of the aeolian sandstones was extremely arid with the existence of widespread sand dunes (Eriksson, 1983). Generally, the Clarens Formation is soft and crumbly, and the original name of the Formation, Cave Sandstone, took its name from the frequent occurrence of shallow overhangs and shelters on its face and particularly at its base (Truswell, 1970). It is in these overhangs that the San lived for thousands of years and where, today, their paintings can be found (Truswell, 1970).

At Battle Cave, aeolian deposits are less porous than the sediments at the Main Caves, and it is therefore more difficult for moisture to move through the rock at the former site (Meiklejohn, 1995). As a rock body is weathered, the movement of moisture through the rock becomes easier and greater (Meiklejohn, 1995). If weathering causes an increase in water movement through rock, this could result in further weathering, thus causing an increase in the rate of rock breakdown and hence rock art deterioration.

The scenery of the uKhahlamba-Drakensberg, as indeed most of South Africa, has been shaped and moulded primarily by flowing water (Irwin *et al.,* 1980). Rivers in the uKhahlamba-Drakensberg, most of which flow throughout the year, have their source in the high water-retaining capacity of the Basalt and Sandstone that mark the area's Geology (Irwin *et al.,* 1980).

Ice plays a role in that water, which alternately freezes and melts in cracks or behind boulders, expands and forces them wider apart each time (Irwin *et al.,* 1980). Eventually a slab or boulder will break off and fall by gravity. Initial observations in the uKhahlamba-Drakensberg indicate that this process may be more significant on the south-facing slopes which are cooler and remain snow covered for longer periods after a snowfall, and also in parts of the “Little Berg” where the south-facing slopes are visibly steeper and more broken (Irwin *et al.,* 1980). However, despite the evidence presented by Irwin *et al.* (1980), there is little evidence for the process or even the potential for freeze-thaw weathering (Meiklejohn, 1995, 1997; Hall, 1997; Hall *et al* 2003, 2007a). In fact the very presumption that freeze-thaw weathering actually takes place is questioned.

The suggestion by Irwin *et al.* (1980) that freeze-thaw happens at all should therefore be viewed with caution. It is, however, acknowledged that rock breakdown may be a result of solar heating. The differences between day and night temperatures, not only cause rocks to expand and contract but do so unevenly, and that, this, combined with chemical activity, causes the rocks to crack and pieces to flake off in curved parallel slabs (Irwin *et al.*, 1980). This exfoliation may occur on a small or large scale (Irwin *et al.*, 1980).

The Battle Cave study site is a shallow shelter with a north-facing aspect, and therefore receives considerably more radiation than other known sites within the Clarens Formation. Because the paintings at Battle Cave receive substantial direct insolation in winter and some art becomes more exposed, blocks upon which the art is painted fall from back walls onto shelter floors (Meiklejohn, 1995). Naturally, when a rock falls it has the potential of setting a great many other pieces in motion, hence the need to monitor the influence of solar radiation on rock temperatures (Smith, 1977; Kerr *et al.*, 1984; McGreevy, 1985; Jenkins & Smith, 1990; Meiklejohn, 1995 (3.3.1.1)).

3.3. Factors influencing rock and rock art weathering

3.3.1. Temperature and solar radiation

Climate is one of the major factors that shapes the environment, and therefore influences weathering rates, particularly temperature (Gore, 2005). Climate is usually regarded as the average daily weather pattern recorded over at least 30 years but it may change over the course of time. Weather is the day to day state of the atmosphere with which people are usually more concerned, for example, when in the uKhahlamba-

Drakensberg. The climate of the uKhahlamba-Drakensberg has remained more or less the same for the last 10 000 years, but near-glacial conditions used to exist in the region between 15 000 and 26 000 years ago, with average temperatures possibly 5°C lesser than today (Wright & Mazel, 2007).

3.3.1.1. Temperature

The surrounding environment directly influences rock-weathering processes, hence the necessity to monitor the local environmental conditions at rock art sites (Ollier, 1984; Meiklejohn, 1995). Temperature is a basic parameter of the physical environment, and as stated earlier, high temperatures influence weathering processes (Schulze, 1979). Other than altitude, latitude and distance from sea also exert geographical controls on temperature (Schulze, 1979).

Climatic data were obtained from automated stations of the South African Weather Service, and the closest stations to the study sites are Giant's Castle and Cathedral Peak. The data presented from the Giant’s Castle weather station represent monthly averages whilst those from Cathedral Peak are daily averages. Only a representative portion of the data is presented and these being those which are considered of importance to the weathering of the San rock art in the Clarens Formation of the UKhahlamba-Drakensberg Park. Furthermore, emphasis of the analysis is on the most recent data to establish the processes that are currently active.

The mean annual temperature of the UKhahlamba-Drakensberg Park is approximately 16°C, but varies considerably from a seasonal and diurnal perspective. The highest temperatures (ranging between 35° and 40°C) occur during summer on north-facing slopes at lower altitudes, while the lowest temperatures (down to about -13° to -20°C) occur during winter nights on the summit plateau (UNEP, 2000; Ecoregions SA, 2005; Hoerlé 2005; Wright & Mazel, 2007). The earliest data analysed is from 1993 and the latest in 2007. During the period 1993-2007 the maximum average daily temperature recorded was 25.7°C and the minimum 2°C at Giant’s Castle. Monthly maximum (Fig. 3.2) and minimum (Fig. 3.3) temperatures are also presented for Giants Castle for the years 1995, 2000, and 2006.

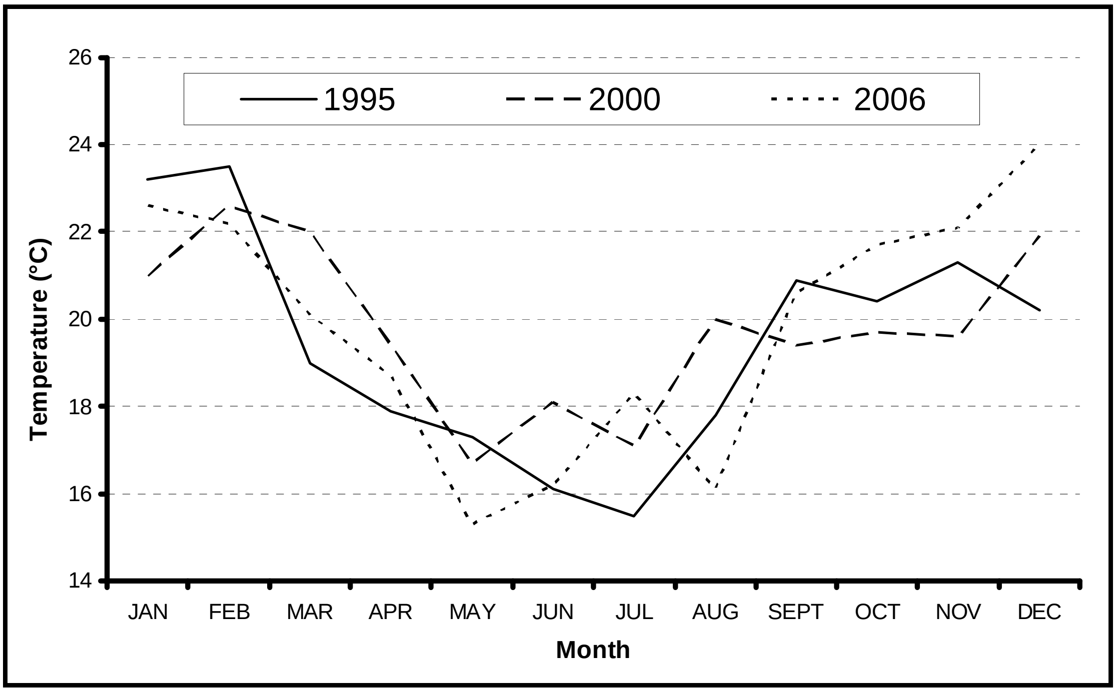

Figure 3.2: Average Monthly Maximum Air Temperatures for Giant's Castle (Data: South African Weather Services).

Air temperatures were greatest in summer and lowest in the winter months as observed in figures 3.2 and 3.3. San rock art sites are exposed to a variety of weathering processes that serve to deteriorate or destroy the paintings (Meiklejohn, 1995, 1997). In southern Africa, San rock art is located within shelters where it is exposed to considerable diurnal and seasonal temperature fluctuations as well as to the impact of solar radiation, wind, and rain (Hoerlé & Salomon, 2004; Hoerlé, 2005, 2006). However, air temperatures are not a surrogate for rock temperatures and thus any deductions from these data are misleading, hence the need to establish the influence sunshine and solar radiation have on rock temperatures (Hall, 1997).

Temperature changes on their own may not be sufficient to cause the weathering of the Clarens Formation sandstone in the protected shelters (Meiklejohn, 1995). Moisture changes, rather than temperature changes, or even a combination of the two, may be the major cause of rock weathering and rock art deterioration in the UKhahlamba-Drakensberg Park.

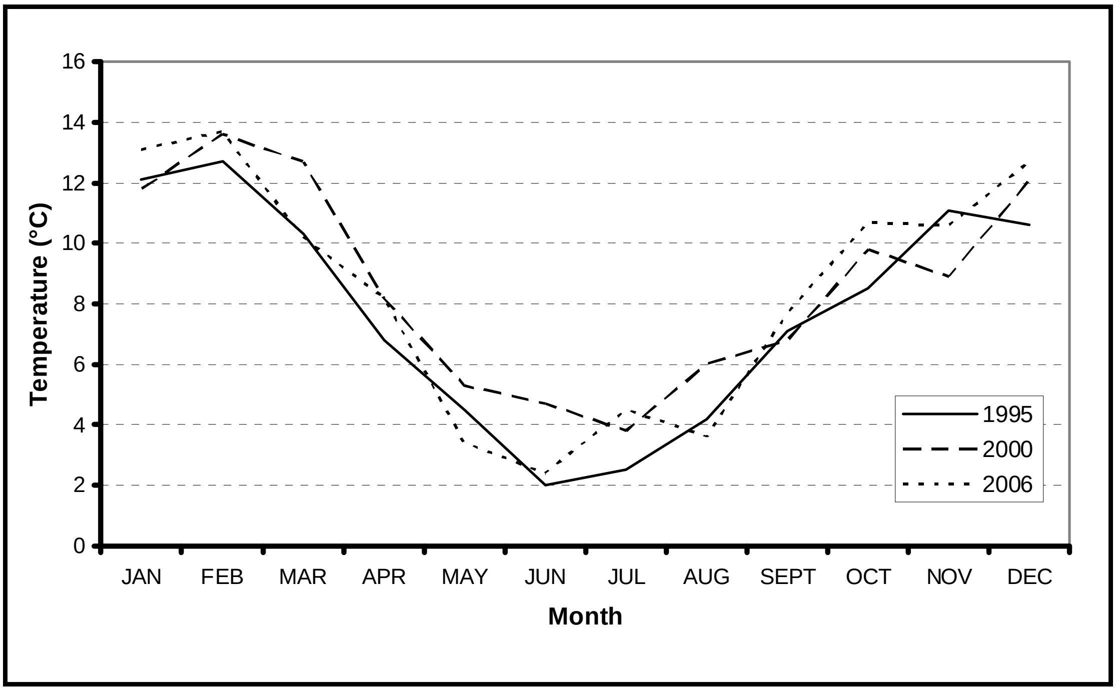

Figure 3.3: Average Monthly Minimum Air Temperatures for Giant's Castle (Data: South African Weather Services).

3.3.1.2. Solar Radiation

The effect of rock temperature is more significant on weathering processes than air temperature (Meiklejohn, 1995). Nonetheless, Meiklejohn (1995) argues that below rock shelters where little, if any, direct solar radiation is received, the surrounding air temperature will influence rock temperatures and must therefore be measured. The Drakensberg receives 70 to 80 percent of possible sunshine hours during winter and 50 to 60 percent during summer (Tyson *et al.,* 1976).

As previously indicated, due to its north-facing aspect, Battle Cave receives significantly more radiation than other known sites within the Clarens Formation (Meiklejohn, 1995; Sumner & Nel, 2006). Most north-facing rock faces within the Clarens Formation, where much of the known rock art is created, have slope angles more than 30°C, and as a result receive maximum direct incoming radiation during autumn (Tyson *et al.,* 1976; Meiklejohn, 1995). Diurnal changes in radiation receipts are as a result also greatest on steep north-facing slopes during equinoxes and therefore, weathering mechanisms that are temperature-dependent are possibly most active during this period (Meiklejohn, 1995).

The relationship between incoming radiation and relative rock moisture contents is inverse (Meiklejohn, 1995). It is shown that atmospheric moisture has a greater role in affecting the rock moisture contents than radiation in the moister environment of the Main Caves. Additionally, the small influence of radiation on rock moisture contents at the Main Caves may be due to the fact that only in winter does direct radiation fall onto the rock surface. However, the high radiation receipts at the exposed and dry environment of Battle Cave would cause evaporation of any rock moisture, thus intensifying the difference in rock moisture contents between the two study sites.

Mean monthly air temperatures for Cathedral Peak from 1959 to 1983, range between 6°C in July and 24°C in January (Figs. 3.4, 3.5, 3.6 and 3.7). Weather systems that bring precipitation and cause major temperature fluctuations are associated with the passage of an eastward moving upper air, wave system with sharp weather changes along a cold front (Tyson *et al.*, 1976). The most severe cold and heavy precipitation, in the form of rain and snow, which accompany these systems, occur most frequently in spring (Tyson *et al.*, 1976). Within the uKhahlamba-Drakensberg area, local winds are said to come about frequently and influence temperature fields by lowering valley floor temperatures, and in that way increasing frost hazards by night (Tyson *et al.*, 1976). Further, by day they ventilate and cool slopes and often trigger local thunderstorms in summer.

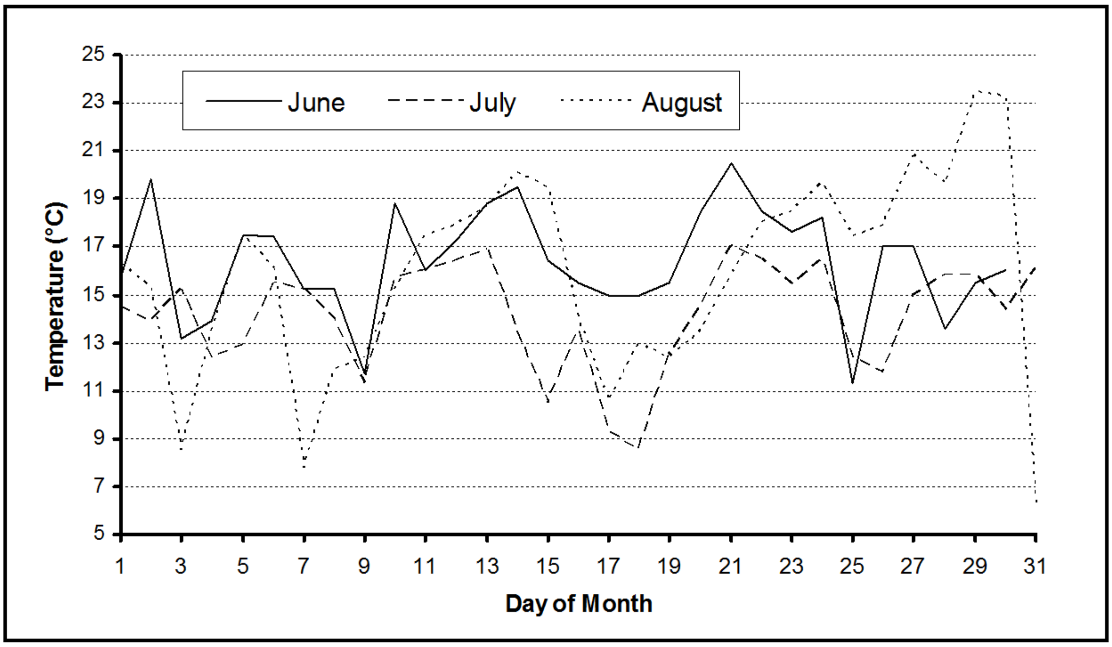

Figure 3.4: Daily Winter Maximum Temperatures for Cathedral Peak for 1959 (Data: South African Weather Services).

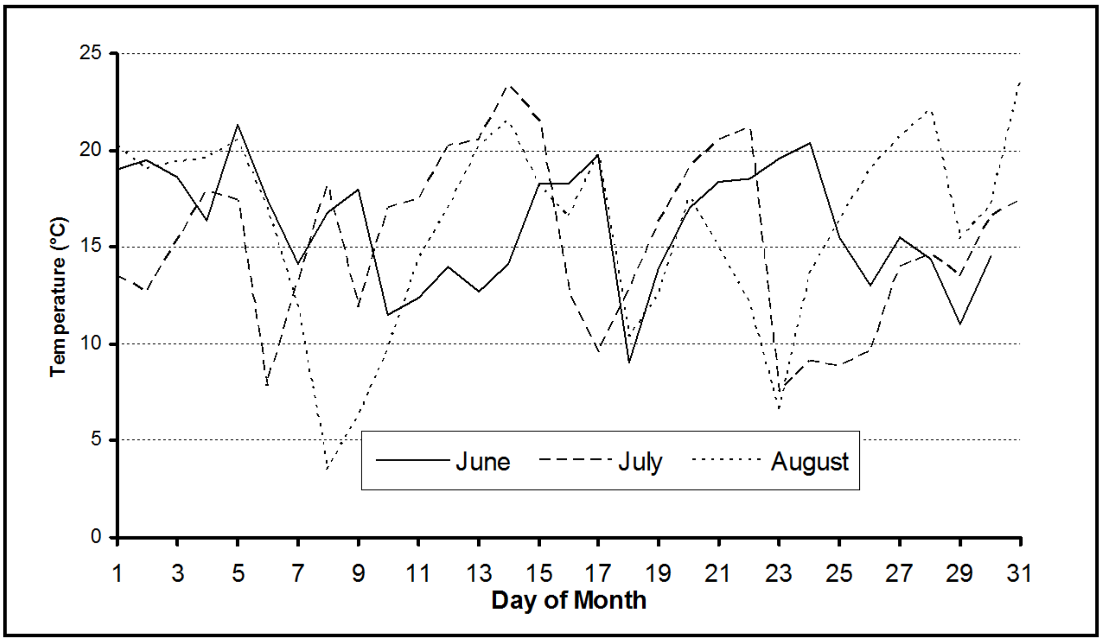

Figure 3.5: Average Daily Winter Maximum Air Temperatures for Cathedral Peak (Data: South African Weather Services).

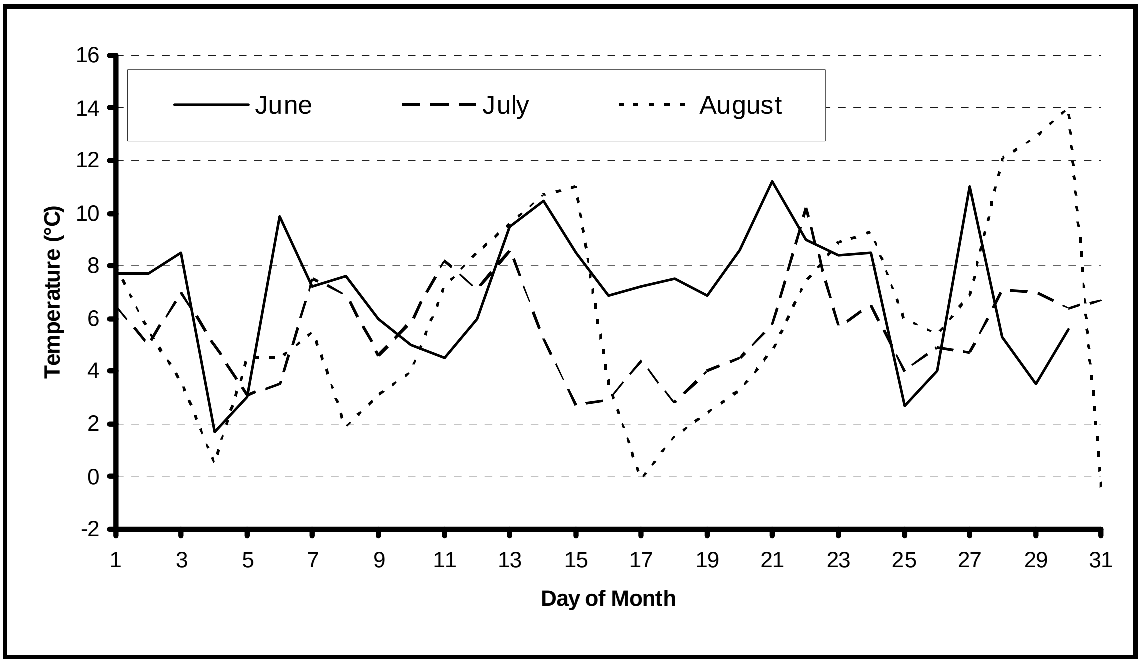

Figure 3.6: Daily Winter Minimum Air Temperatures for Cathedral Peak for 1959 (Data: South African Weather Services).

3.3.1.3. Frost

Conditions contributing to the occurrence of frost are a relatively poor conducting surface layer, absence of general winds, clear skies and dry air (Tyson *et al.*, 1976). Further, in winter when all these conditions prevail, and at lower altitudes when drainage of cold air from high plateau areas drains into the lower-lying valleys, frosts are of common occurrence in the High Drakensberg. However, the local topography has an influence on the distribution and intensity of frosts (Tyson *et al*., 1976; UNEP, 2000).

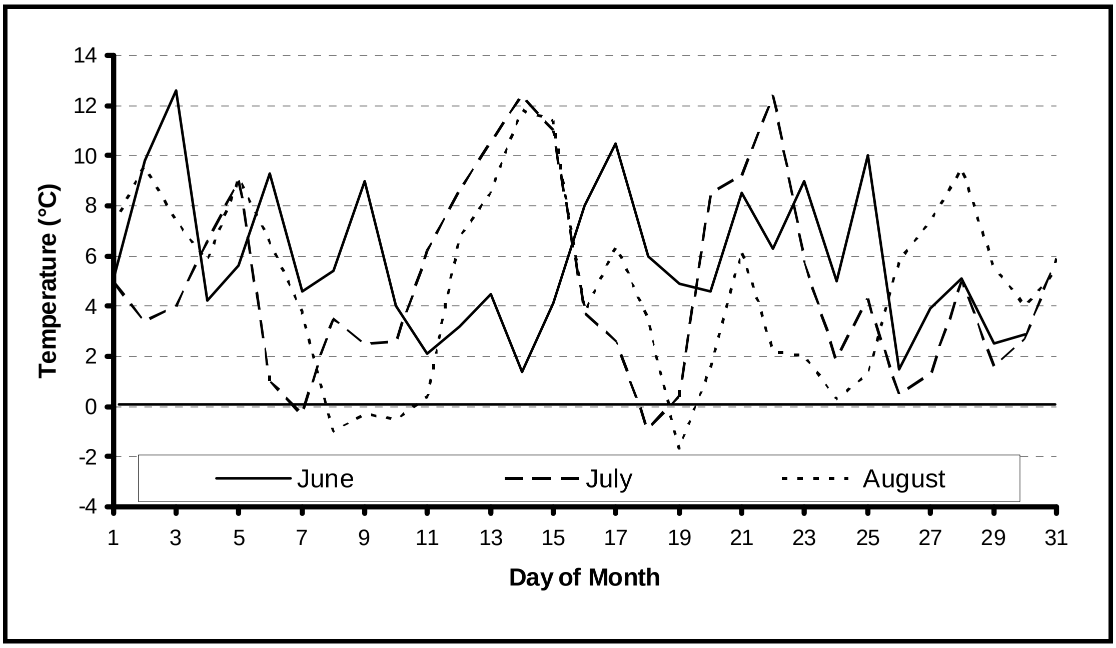

Figure 3.7: Daily Winter Minimum Air Temperatures for Cathedral Peak for 1983 (Data: South African Weather Services).

Conditions favourable for frost occur in winter with an annual duration of about 180 days at higher plateau elevations for example, in Lesotho (UNEP, 2000), to 60 days in the lower Bushmans and Tugela valleys at Estcourt and Colenso (Tyson *et al*., 1976). Temperatures below zero may occur now and then between May and September (Tyson *et al*.,, 1976). Evidently, this was the case in 1983 when temperatures dropped to -0.9 in July and -1.7 in August (Fig. 3.7), when all conditions conducive to frost action prevailed. Below the escarpment frosts can first be expected in May, whereas in the lower foothills and river basins frosts will not occur until June (Tyson *et al*., 1976). The last frosts of winter are experienced in October above the escarpment, in September immediately below it and in August further to the east at lower altitudes.Moisture is scarcer in winter but rainfall does occur occasionally in the uKhahlamba-Drakensberg; there is, therefore, the likelihood for frost to occur if favourable temperatures agree (Sumner & Nel, 2006). It is further observed that over the winter period, minimum temperatures for air and both rock types frequently drop below 0°C. Bednarik (1994a) generally accepts that the most favourable conditions for rock weathering are moist, warm climates; therefore, cold dry climates are said to be less favourable for weathering.

3.3.2. Humidity and Precipitation

It has been acknowledged that the role of moisture in most rock weathering processes is vital (Ollier, 1984; McGreevy & Whalley, 1985; Meiklejohn, 1995). The primary cause of moisture around the two study sites is precipitation in the form of rain and/or mist, while snow and hail contribute less to that moisture (Meiklejohn, 1995).

3.3.2.1. Humidity

Humidity data reflects the seasonality of the rainfall with summers being more humid than winters (Meiklejohn, 1995). The sheltered rock surfaces within the study sites are wetted by the condensation of atmospheric moisture and mist as well as seepage along joints within the sandstone. Additionally, seasonal variations in the quantity of moisture available to rock surfaces will influence the likely active weathering mechanisms. In this regard, the most active period for rock weathering by thermally controlled processes has been shown to be, during autumn, but it is then that atmospheric moisture conditions are dry thus restraining moisture-related mechanisms.

Rock moisture content has a strong relationship with atmospheric humidity such that changes in atmospheric humidity are accompanied by rapid changes in rock moisture content (Meiklejohn, 1995). Therefore, moisture-related weathering processes must be considered in any study examining the decay of rock art in this region given the geology of the Clarens Formation and the seasonal nature of the atmospheric moisture regime (Meiklejohn, 1995).

3.3.2.2. Precipitation

The uKhahlamba-Drakensberg is one of the best watered, least drought-prone areas of southern Africa (Tyson *et al*., 1976; UNEP, 2000). This is further acknowledged by Lewis-Williams & Dowson (1989) as it is confirmed that summers in the uKhahlamba-Drakensberg are warm and wet, and moisture-dependent mechanisms may then become predominant. The role of moisture in most weathering processes in the uKhahlamba-Drakensberg is therefore acknowledged to be significant (Ollier, 1984; Meiklejohn, 1995).

The rainfall measured at the Giant's Castle weather station obtained from the South African Weather Service (1959-2006) is the closest available approximation of the rainfall of the Injisuthi valley, which is located in the northern corner of the reserve. The rainfall regime in the uKhahlamba-Drakensberg is highly seasonal with the wet season accounting for around 70 to 80 percent of the annual total, while the winter months from May to August account for less than 10 percent (Tyson *et al*., 1976; Irwin *et al.,* 1980).

Both the oldest and the most recent rainfall data for the wet season available at the South African Weather Service from the Cathedral Peak and Giant's Castle stations were analysed. This was done with the aim of describing the study area's climate and to try and establish how much an impact precipitation has on the deterioration of the San paintings. The most recent rainfall data available for the wet season was from November 1983 to March 1984, whereas the oldest was from November 1959 to March 1960. The highest rainfall recordings in the wet season from 1959 to 1960 were in December, February and March (Fig. 3.8), while the highest rainfall from 1983 to 1984 was recorded in November, December and March, in no particular order (Fig. 3.9).

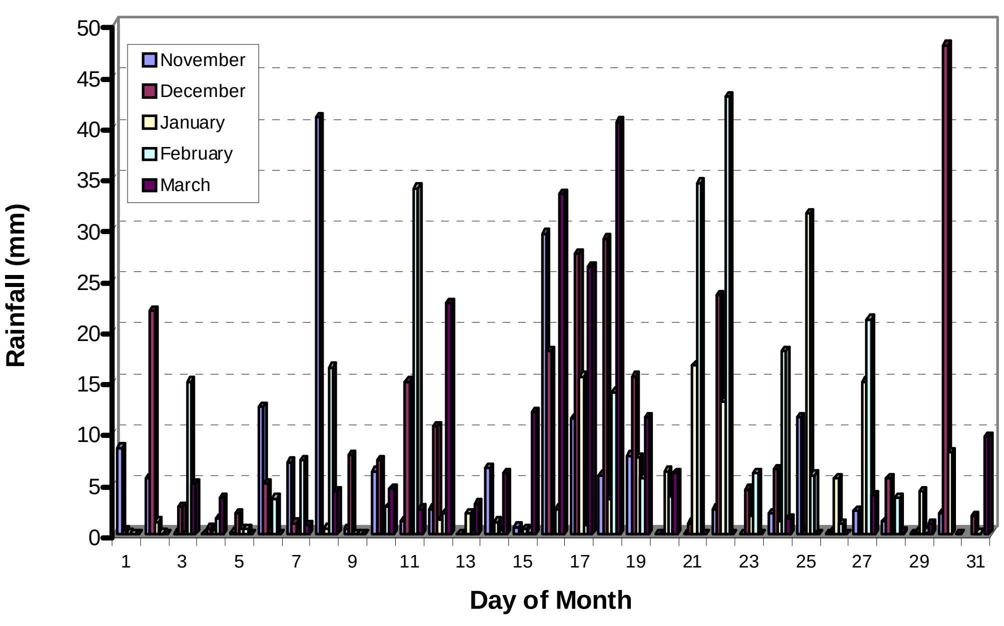

Figure 3.8: Average Daily Rainfall for Cathedral Peak for the Period 1959-1960 (Data: South African Weather Services).

As previously noted, the most influential potential weathering factor is moisture, which can occur at rock art sites in various forms: as moving or stationery surface deposits (lakes, rivers, waterholes), as surface run-off, as atmospheric precipitation, as gravitational water filtering through a rock mass, as capillary moisture rising in a porous rock mass, as interstitial moisture in equilibrium with relative atmospheric humidity, and in the form of air humidity (Bednarik, 2003.). An increase in moisture content will provide an environment, which is more conducive to weathering, and thus increase the rate of rock breakdown and consequently provoke pigment loss and further fading of the rock art.

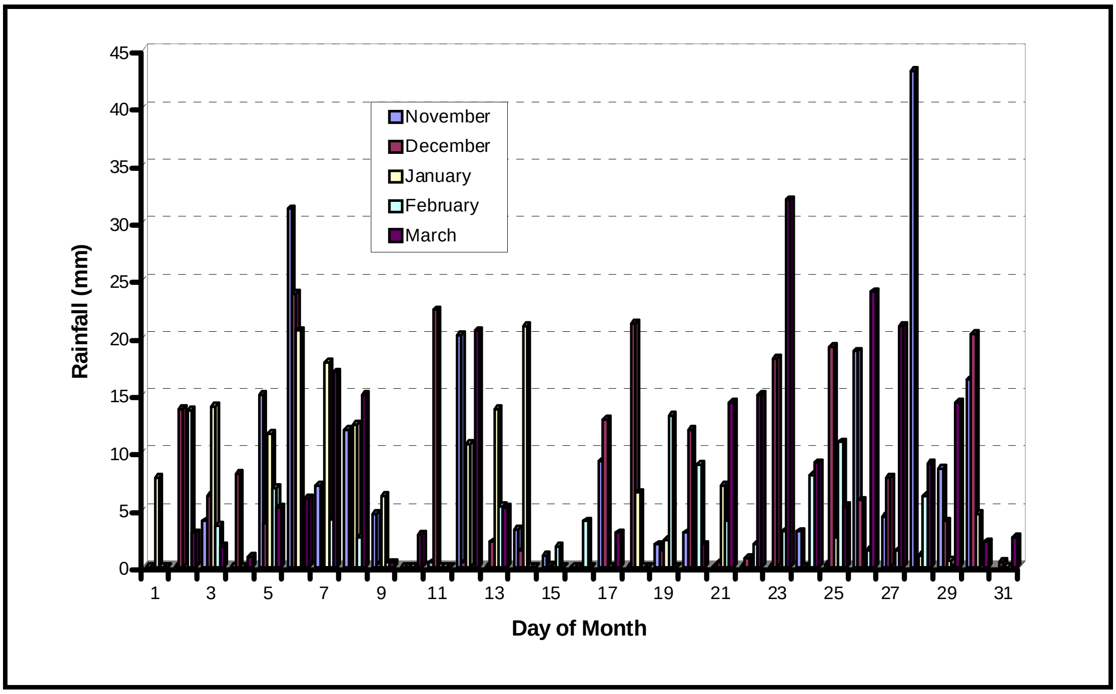

Figure 3.9: Average Daily Rainfall for Cathedral Peak for the Period 1983-1984 (Data: South African Weather Services).

The uKhahlamba-Drakensberg is occasionally prone to heavy winter snowfalls (Tyson *et al*., 1976); in addition to that, summer rainfalls may result in flooding in valleys and landslides on the mountain slopes. The annual rainfall is 450mm in the southwest; over 1000-1100mm in the northeast and highest altitudes (the High Drakensberg) often receive between 1800 and 1900 mm (UNEP, 2000; Wright & Mazel, 2007). The uKhahlamba-Drakensberg receives most rainfall during January and February and in this study, the wet season is defined as the five wettest months, which correspond to the months November to March. Precipitation in the form of rain, snow or frost is essential in aggravating weathering processes that have an influence on rock paintings.

As noted earlier, an increase in moisture content will provide an environment, which is more conducive to weathering, and thus increase the rate of rock breakdown. Highest vapour content of the atmosphere is observed in summer, the lowest in winter (Tyson *et al*., 1976) and this corresponds to the highest rainfall records (for example, Figs. 3.8, 3.9 and 3.10) for different years at both the Cathedral Peak and Giant's Castle weather stations.

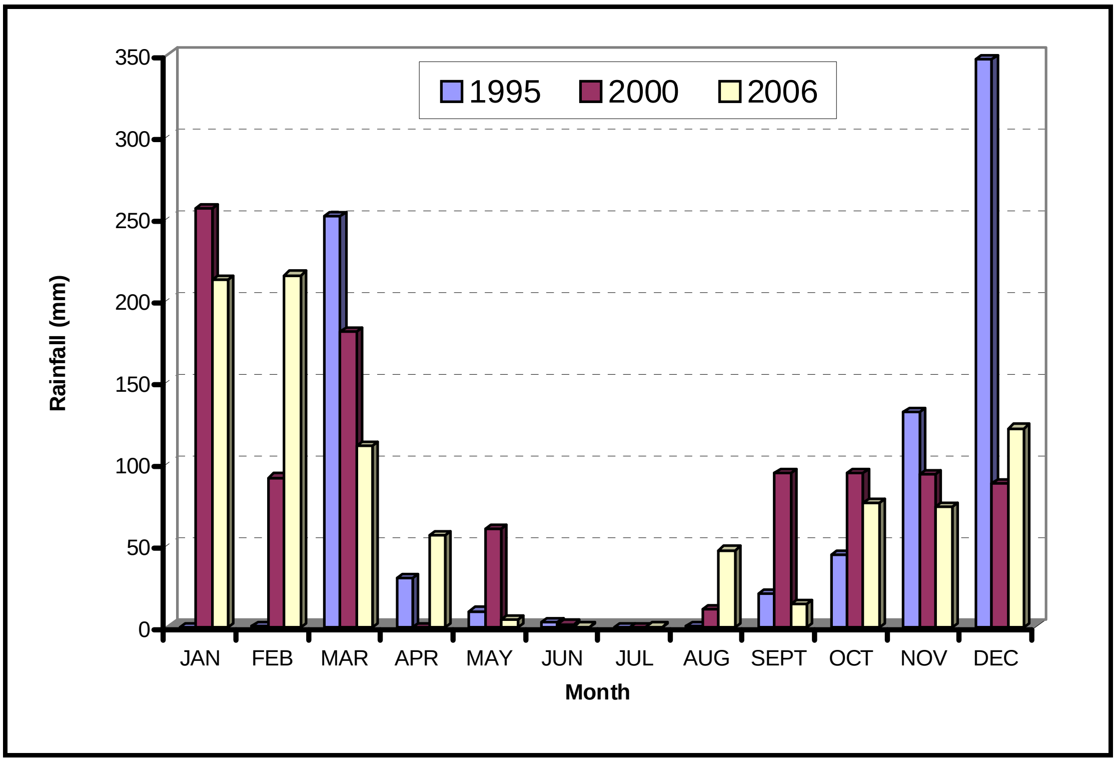

Figure 3.10: Average Monthly Rainfall for Giant's Castle (Data: South African Weather Services).

Moisture moving along joints and bedding planes during summer may have an effect on seasonal variations of rock moisture (Meiklejohn, 1995). Given that the rock art is painted on the rock surface and that the pigments are only likely to penetrate a short distance into the rock, it is processes acting at or close to the surface that are likely to be most destructive (Meiklejohn, 1995). The rock moisture changes affected by atmospheric humidity have the greatest impact at the rock surface and the area immediately below the rock surface, and are therefore the most destructive (Meiklejohn, 1995).

2000 was the wettest year analysed, followed by 2006 and then 1995 (Fig. 3.10). The mean monthly readings indicate July was the driest, followed by June and then

August, still confirming the results that moisture and humidity, major causes of rock weathering, reign in the summer months as compared to the winter season. The monthly average rainfall at Giant's Castle was 913mm (Fig. 3.10).

Wind may rock moisture and therefore influence rock weathering processes at the Main Caves study site by evaporating moisture from the rock surface (Meiklejohn, 1995). Because Battle Cave is more exposed to direct radiation, it is likely to experience greater wind speeds than the Main Caves. It is therefore possible that wind may be responsible for more evaporation at the rock surface and, hence contribute towards the lower rock surface moisture contents observed at battle Cave,

Palaeoclimatic evidence shows that the eastern part of Southern Africa, the uKhahlamba-Drakensberg included, was a lot wetter between 1 000 and 2 000 years ago than it is today (Partridge *et al.*, 1990; Hoerlé, 2005). The evidence also documents a warming between 5 000 and 8 000 years ago and then several relatively small temperature fluctuations during the last 5 000 years, but the difference is not more than 2°C from the present mean.

3.3.3. Thunderstorms and Hail

The climate of the uKhahlamba-Drakensberg is marked by dry winters and wet summers, with much of its rainfall coming in the form of summer thunderstorms (Wright & Mazel, 2007). Summer thunderstorms provide the major source of rainfall over Drakensberg escarpment (Tyson *et al*., 1976). A high, but undetermined proportion of around 70 to 80 per cent of the rain falling during summer months is directly as a result of orographic effects and associated thunderstorms (Irwin *et al.*, 1980). Storms occur in mid to late afternoons on approximately 100 days per annum (Tyson *et al*., 1976; Hoerlé, 2005) at the top of the escarpment while the area below, probably receives significantly more (Schulze, 1979).

Two types of thunderstorms occur mainly in the middle to late afternoons during the summer months: those associated with a moisture discontinuity and moving across the country from a generally westerly direction and those that develop along the eastern edge of the escarpment (Tyson *et al*., 1976; Irwin *et al.,* 1980; UNEP, 2000). It is further suggested that the former are often high above the ground while the latter are likely to surround one in mist at very short notice, which is frequently 5 to 10 minutes.

Hail is thought to be infrequent and of little ecological significance in the uKhahlamba-Drakensberg (King, 1947); it is recorded on about 8 days in the year (Tyson *et al*., 1976; Irwin *et al.,* 1980; UNEP, 2000). With increasing distance from the Drakensberg these figures drop (Tyson *et al*., 1976; Irwin *et al.,* 1980; UNEP, 2000). Whereas thunder is most often reported in December and January, hail is usually most frequent in November and December. The associated density of lightning ground-flash is quite high and can be responsible for the outbreak of veld fires (Schulze *et al.*, 1997; Hoerlé, 2005).

The following section is an outline of the methodology used in this study. The aim of the method used was to be able to calculate the amount of deterioration that has occurred on the San paintings in the UKhahlamba-Drakensberg Park over the period of about two decades.

3.4. Research Methodology

The aim of this section is to present the method undertaken in carrying out this study. This involves fieldwork, the literature consulted, and ways used in reaching the final stages in analyzing the data collected. Some of the methods will be dealt with under subtitles so as not to confuse steps embarked on. Some of the steps include data compilation, importing data to ArcView GIS, manually digitizing the images, creating, and converting themes to grids, storing grid themes, calculating the sums of values represented by all pixels and percentages of decayed areas on paintings and last but not least deriving charts from these calculations.

3.4.1. Fieldwork and Materials used

Visits to the rock art sites were taken, firstly for general acquaintance with the study sites, and secondly for collection of the most recent digital images, which were used in comparison with the old, scanned photographs. Both new and old published material was consulted and used in the literature and analysis of the study. Most of the literature compiled was obtained from studies undertaken in the very same study sites and was then used in the analysis in support of the results obtained.

Climatic data (from 1959 to 2006) obtained from automated stations of the South African Weather Service was also used in establishing those factors which have utmost impact on the deterioration of the San paintings in the UKhahlamba-Drakensberg Park. The closest weather stations to the study sites are Giant's Castle and Cathedral Peak. The data presented from the Giant's Castle weather station represented monthly averages whilst those from Cathedral Peak were daily averages. Only a representative portion of the data i presented. Furthermore, emphasis of the analysis is on the most recent data to establish the processes that are currently active.

3.4.2. Analysis of Photographs

The most common recording technique of rock imagery is photography as discussed in Chapter 2. Photography has obvious conservation advantages over other recording techniques; one being that during the recording process the camera does not touch or rub against the rock paintings. Unfortunately, paintings sometimes look faded and many photographers at times resort to artificial enhancement, such as wetting paintings as already stated. These actions not only have detrimental effects on the rock surface and pigment, but may jeopardize attempts to analyze and date possible residues contained by the imagery (Whitley, 2001).

Photography was utilised in this study due to its advantages, which included the availability of art to the researcher, the decrease in the danger of damaging the art and the provision of a more objective recording. The development of colour photography has overcome objections but other difficulties remain; the inaccessibility of the best paintings, the often poor light and the awkward positions in which they must be photographed (Willcox, 1956).

Recently, the effectiveness of photography for recording and analysis has been greatly enhanced by the development of computer-aided or digital image processing techniques (Clogg *et al.*, 2000). In the case of this study, the handling of images was also made easier by using digitization so that faint, normally hidden and damaged features could be identified. As the photographs utilised in the study were not taken in the same conditions (*e.g.* light, angle, film), the analysis concerns only general geometrical features.

Digital images from the Main Caves and Battle Cave study sites were utilized for comparison with old scanned photographs so as to calculate the degree of deterioration of the rock paintings. Comparing old photographs with recent images to determine their present state made an evaluation possible of the progression of the damage to the paintings. Any disturbed areas on the rock art as observed from the images were recorded. Photography has usually been employed only to support other techniques, often just to serve as illustration for a text. It has obvious advantages, however, not only because it implies an always helpful cut in fieldwork costs, but also because the art is more readily available to the researcher.

In addition, the use of photography greatly reduces the risk of damaging the art, and could be said to provide a more objective recording. The use of photography has nevertheless been limited mainly because of the problems entailed in its practical application (Clogg *et al.,* 2000). This is largely dependent on the skill of the photographer, both in the field where factors such as lighting, focus and exposure that greatly influence the results must be balanced, and in the darkroom (in the case of prints) where complex chemical processing techniques must be used to enhance the images and reveal hidden detail (Clogg *et al.*, 2000).

3.4.2.1. Automated and Supervised Classification of Images

Automated and supervised classification (see Lillesand *et al*., 2007) of images was tested using photographic and scanned images, which were classified using ERDAS IMAGINE® and ArcView® Image Analysis® software to differentiate between different coloured pigments and between paintings and the underlying rock surface.

3.4.2.2. Manual classification of Rock Art Images

Images from 1965 were obtained for San paintings in Giant’s Castle from the family records of K.I. Meiklejohn. The painting of a feline from Battle Cave was used as a case study as clear images were available from 1965 and this was again photographed in 2006, providing a 41-year period for comparative analysis.

The preparation of data and its analysis was undertaken using ESRI® software namely, ArcView®. The data compiled (both digital images and old scanned photographs) was exported to ArcView® and manually digitized. In ArcView® different themes were created for each image. The first theme was created for an outline of the painting found in the image. The second theme was produced for all the decayed areas found inside each painting. An example indicating of both themes can be viewed in Figure 3.11 below. These decayed areas were formed as polygons and an attribute table was created. The information entered into the attribute table corresponds to different colours that make up all polygons of decayed areas.

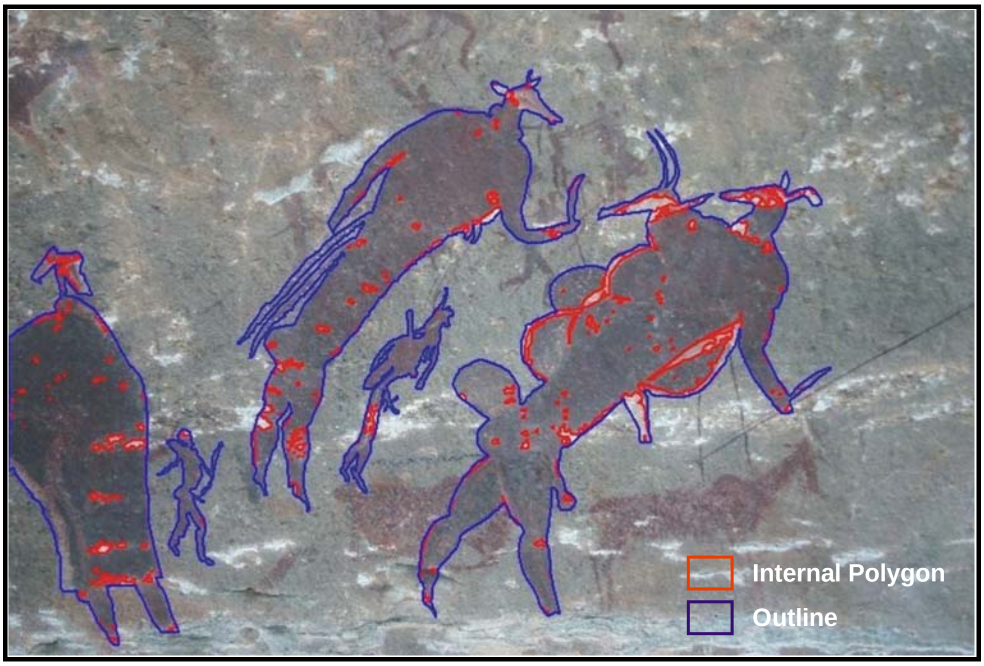

Figure 3.11: A digitized image from the Main Caves North Shelter showing the outline and internal polygons of decayed areas (Photograph: K.I. Meiklejohn).

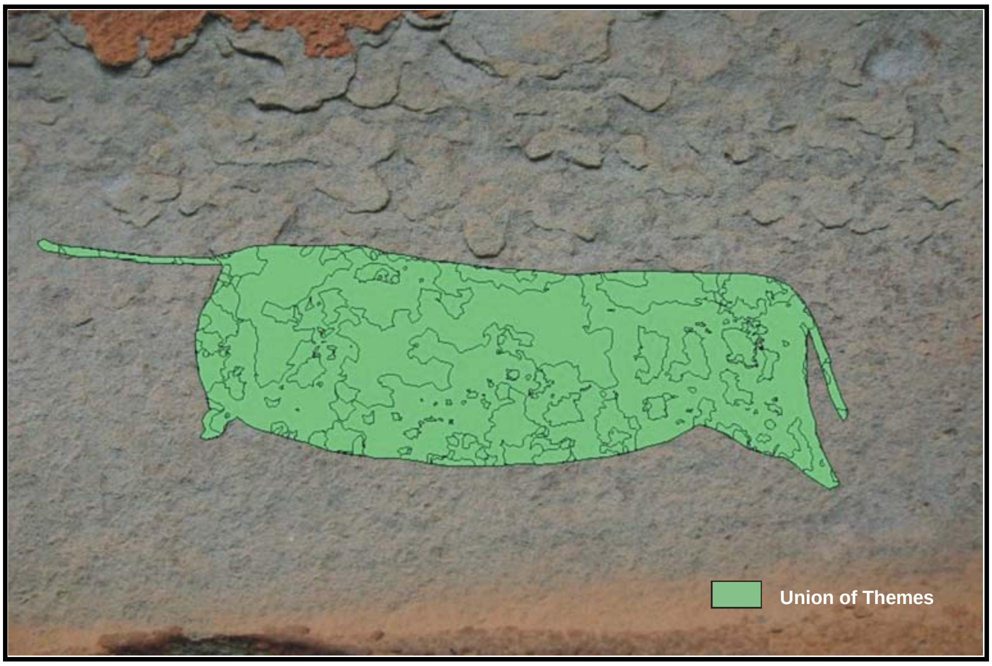

Figure 3.12: A union of the outline and polygon themes of a painting of an Eland from Battle Cave (Photograph: T.C. Leuta).

A third theme was created (Fig. 3.12) which was a union of the previously created themes. The Union process creates a new theme by combining two polygon themes. The output theme contains the combined polygons and attributes of both themes. Union is used to create a new theme that contains the spatial combination of information with attribute data (ESRI, 1999).

Because data does not always come exactly as needed, it is necessary to plan which data is appropriate and how it needs to be utilised. In this case, the data had to be converted from vector to raster. Then the following step was that of converting the feature themes (lines, polygons and the union of these two) to grid themes for easy analysis. The process of converting vector data, which is a series of points, lines and polygons, into raster data, which is a series of cells each with a discrete value is said to be essentially easier than the reverse process, which is converting data from raster format to vector format.

Themes, including feature and image themes, can be converted to grids. Vector to raster conversion is called rasterisation, while raster to vector conversion is called vectorisation (Fonte, 2006). In the vector data structure, the geographical space is considered continuous and therefore the geographical information is represented as points, lines and areas (Fonte, 2006). In the raster data structure, the geographical space is discrete and the primitives used to represent the geographical information are cells (pixels), usually square, (Fonte, 2006). Reasons for converting data from vector to raster format lie in the advantages indicated in Table 3.1 and Table 3.2.

Table 3.1: Advantages of analysing data in raster and vector formats (Buckley, 1998).

Raster Data	**Vector Data**
Simple structure and easy to overlay	Very high resolution works well with boundaries
Efficient storage for dense, heterogeneous data	Efficient storage of sparse data
Easy creation from image data	High spatial accuracy
Grid structure makes analysis easier	Explicit representation of linear features
Allows integration of imagery and GIS data	Requires less storage space
Modelling can be performed easily and rapidly	Easier for general public to understand

Raster data is made up of grid cells, with each cell having an assigned value. To understand how image processing works, it is first necessary to understand how digital images are represented in the computer. There are two spatial models for storing geographic data - the vector data model and the raster data model. Examples of the raster data model (Buckley, 1998):

- Information from satellite
- Scanned data
- Aerial photographs
- Other forms of image data where each pixel (grid cell) has a value.

Table 3.2: Disadvantages of analysing data in raster and vector formats (Buckley, 1998).

Raster Data	Vector Data
Must pre-define spatial resolution	Inefficient storage of dense data
Requires large amounts of storage space	Manipulations require sophisticated algorithms
Inefficient when data is sparse or homogeneous	Processing can require lots of computer time
Deals poorly with linear features	

Spatial Analyst allows the user to integrate vector and raster themes.

- Earth is treated as one continuous surface
- Each location is represented as a cell
- Cells are organized into a matrix of rows and columns called a grid
- Each grid contains cells that represent some kind of geographic phenomenon

The grid theme is the primary data source used by Spatial Analyst (ESRI, 2007). A cell is the basic spatial unit for a grid theme and therefore in the raster format, the area being studied is represented into cells or pixels. Cells or pixels are squares (equal height and width) and every cell can be uniquely identified by its row and column position. Also, each is assigned a value that may represent continuous or discrete values. Cells are assigned an integer, floating point, or NO DATA value that represents a measure of geographic phenomena; each pixel has a numerical value that represents the brightness of that pixel (ESRI, 2007).

Pixels with high values are bright, whereas those with low values are dim. Pixels in the raster form can be seen when part of the image is enlarged. By being composed of an array of pixels or points, digital images facilitate the measurement of features and allow direct comparison in a more accurate way (Clogg *et al.*, 2000). In relation to conservation methods for rock art, photography can therefore be employed to support other reliable and accurate recording techniques.

3.4.2.3. Storing Grid Themes

The workspace where grid datasets is stored was defined beforehand, and in this study ArcView created the INFO subdirectory and grid subdirectories. There is one INFO subdirectory and a subdirectory for each grid. INFO subdirectories contain several files that relate to each grid's theme table, and grid subdirectories contain several files that store geographic data (ESRI, 2007). Grid subdirectories store data files about each grid. Some grid data files have related INFO files; some do not (ESRI, 2007). If a grid is altered, ArcView automatically updates corresponding information.

Grid themes with integer values have a theme table, value attribute table that store the codes and categories, and in a floating point grid theme, each cell stores a value that represents a measure of geographic phenomena (ESRI, 2007). The table corresponding to the grid theme that was created from the union of outline and polygon themes was then updated with the colour classification which represents the area that has not deteriorated at all. This area of unaltered ochre pigment was termed "paint" in all images worked on. The other coloured pigments were "white" or "red, while where pigment had been removed, or had weathered, and bare rock was visible the classification was "rock" (*e.g.* Fig. 3.13).

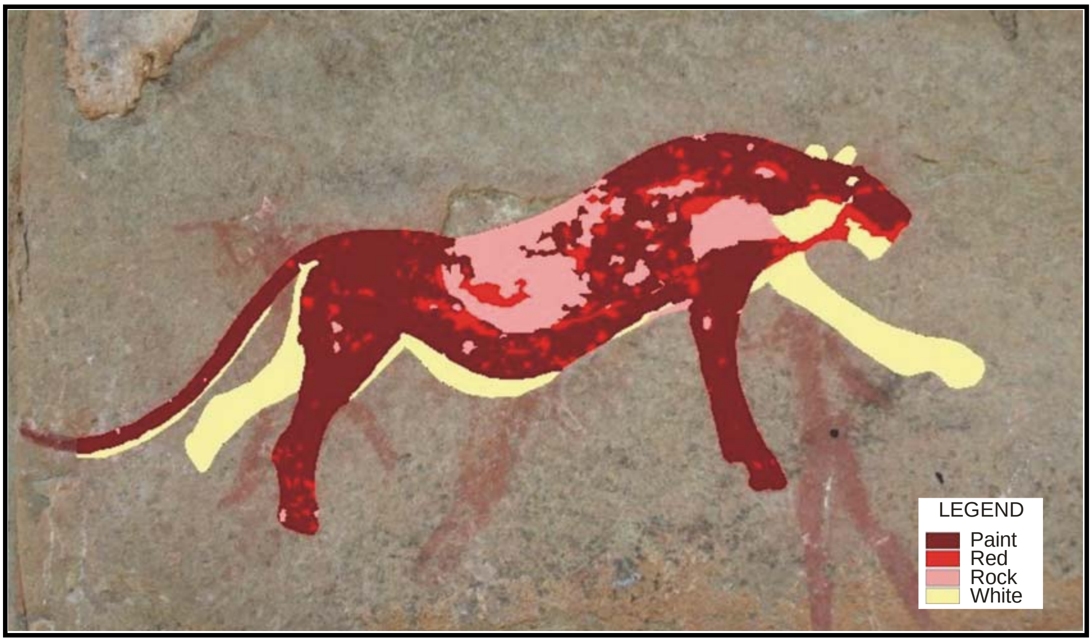

Figure 3.13: A layer from ArcView® showing different colour classification of both deteriorated pigment and undamaged paint.

A final theme (image) was created which combined all the previous themes (*e.g.* Fig. 3.14). These themes are superimposed, and colours corresponding to each theme can be observed only when a layer corresponding to such is checked or is at the top of all the layers. These have attribute tables and only the layer containing a "No Data" value was used in calculating the percentages of decayed pigment.

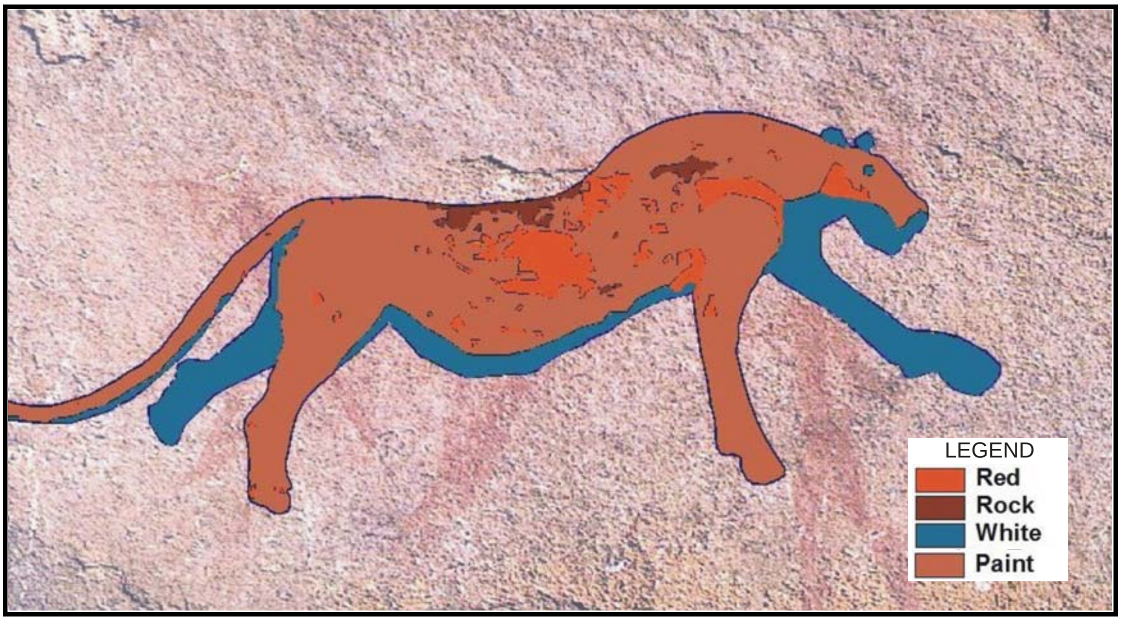

Figure 3.14: The Final Layout Containing All Themes.

3.4.2.4. Calculating Percentages and Deriving Charts to Present Deteriorated Areas

First, the sums of values in grid theme tables were added up. From these sums, percentages of each colour classification were then computed. Lastly, these percentages were employed to derive bar and pie charts in Excel® format in order to quantify the deteriorated areas in all the paintings. The results obtained from these graphs were then discussed, supported by the literature from previous publications. From the graphed representations of the decayed areas, conclusions and recommendations were then brought forth.

No known photographic dye is fade-proof and there is still lack of any form of permanent photographic or digitized storage of imagery (Dickman, 1984). In scientific photography it is therefore essential to know the size of an image, and for this purpose, the IFRAO Scale (Fig. 3.15) was designed to provide scale and to facilitate the reproduction of correct colour. This scale was used while capturing the digital photographs for this study. Its role was to serve as a general indication of the photographs' sharpness, and due to lack of well-defined lines in the rock art, focusing was much easier selecting one of the lines on the scale.

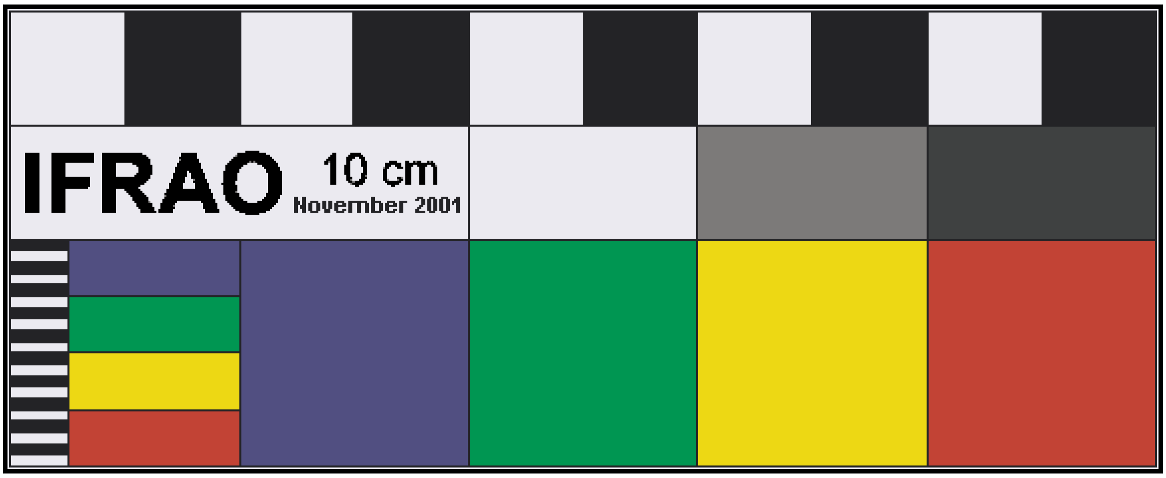

Figure 3.15: The IFRAO Standard Scale (Bednarik, 1994b)

Electronic colour enhancement methods have been used in rock art studies for many years (Rip, 1983). The main reason for needing a standard photographic scale is its function as a colour calibration device for a variety of computer-supported uses (Bednarik, 1994b). The purpose of the IFRAO Standard Scale is multifunctional (Bednarik, 1994b):

- To know the size of the object in study (so the IFRAO Standard Scale is 10 by 4cm);
- To provide the means to focus the photographic equipment (by means of black/white blocks);
- To provide cheap colour card (cheaper than the existing commercial ones), the IFRAO Standard Scale is free for AURA/IFRAO members; and,
- To provide a standard to be able to do colour calibration/optimization (to compensate for colour errors from the moment the picture is taken until and including its publishing).

The small scale on the left hand end of the IFRAO Standard Scale is intended for close-up photographs. For best digital results, slides or negatives are preferred to prints (Bednarik, 1994b). Further, the scale also includes a grey scale for comparing tone values.

Additionally, more important than the black and white scale markings are the colour blots. Since the colour properties of an object are always distorted in a photograph, by such factors as optics, film type, paper type, temperature and, most particularly, lighting conditions, a colour photograph cannot be expected to be a true record of chroma, value and tone (Bednarik, 1994b). However, by checking the colour distortion on a scale photographed with the rock art we can obtain an indication of its severity.

3.5. Summary

There are different causes of weathering; for example, moisture, temperature, frost action, organic activity. Temperature variations over a period of time allow the rock to expand and contract repeatedly causing pieces of rock to fall off. The occurrence of frost action has been excluded within the study sites. Weathering as a whole causes the rock to break down into smaller pieces, exposing more surface area, and the rock weathers faster. The presence of cracks or joints in the rock can allow water to penetrate and increase the rate of rock weathering and hence the deterioration of rock paintings.

To evaluate the rate of weathering, a methodology using remote sensing and GIS techniques was adapted and utilised to categorise parts of images that had deteriorated. The proportion of pigment that had weathered was calculated and compared to other images of the same painting to determine changes that had taken place.

CHAPTER 4: ANALYSIS AND DISCUSSION

The main intent of this chapter is to present the results of the study. Results are presented concurrently with the discussion of the major factors affecting the paintings found in the study sites. This discussion is supported by data from previously published material, mostly within the same study area. Such data relates to major causes of rock art weathering such as moisture, temperature, pigment and rock surface properties and the application of clay-based ground over the rock surface to ease the mode of painting. Following the analysis is a brief summary discussing the conclusions which are derived from the analysis and results of the study.

First, an observation is carried out by visually comparing the state of the paintings within a period of four decades. It is then followed by the presentation of results obtained from the GIS analysis. Such results are graphed to give an idea of what percentages of the different colour pigments have deteriorated when comparing the images of the same painting taken within the space of two decades.

Old scanned images can be compared to recent digital images to identify loss of pigment either by flaking, powdering or rock failure by exfoliation or cracking (Small & Clark, 1982). Colour is considered an important monitoring aspect in assessing the condition of rock paintings. Also, factors such as pigment loss, reactions with salts and surface mineralization, dust, can all give rise to colour change; so will pigment deterioration, which occurs in the form of clay hydration, salt spalling, substrate exfoliation, animal damage and water wash (Small & Clark, 1982).

In the analysis, the term paint is used interchangeably with pigment. Paint indicates places with pigment that have not experienced deterioration. The term rock provides an explanation for those parts of the picture where there is no pigment left (*e.g.* flake of rock surface removed), while the terms white and red indicate places which still have traces of the pigment.

4.1. Visual Observation and Qualitative Analyses

When studying the images (Figs 4.1 and 4.2), part of the paint has flaked off this is confirmation that the painting may have been painted on an already weathered surface, or that a clay-base may have been smoothed on the rock surface for easy pigment application as revealed by Arocena *et al*. (2008). In that case what might have occurred then would be the weathering of that clay-based ground and not the rock itself. If the feline image was painted on an already weathered surface then the expansion of its flaking may be an indication of the activity of the mechanisms causing the rupturing (Hoerlé, 2005).

Figure 4.1: A scanned photograph feline painting taken in 1965 at Battle Cave Study Site (Photograph: K.I. Meiklejohn)

Figure 4.2: The most recent digital image of the Battle Cave feline painting taken in 2006 (Photograph: T.C. Leuta).

Ochre paintings, consisting of very fine particles, penetrate deep into the rock and are therefore more durable, but do sometimes fade over time due to the deterioration of pigment, covering by minerals and dust, or when exposed to bright light (Meiklejohn, 1995). In addition to rock weathering processes, the pigments of the paintings most exposed to solar radiation have faded at Battle Cave study site, while those painted in more sheltered locations are in a better state of preservation (Meiklejohn, 1995). At Battle Cave, there is evidence of pigment fading because of ultra-violet radiation, and that most of the deterioration of the rock art is attributable to rock weathering processes (Meiklejohn, 1995).

A visual comparison of the two study sites, suggests that weathering processes are more active at the Main Caves than at Battle Cave study site (Meiklejohn, 1995). In the same way, rock weathering at both sites is observed to be more active beneath rock shelters than on the exposed rock faces. While the deterioration at the Main Caves site appears to be mainly caused by rock weathering processes, at Battle Cave, particularly on the most exposed surfaces, much of the deterioration of San paintings is because of the decay of the paint pigments themselves (Meiklejohn, 1995). More rock weathering seems to be taking place at the Main Caves site, which in itself may overhang than the Battle Cave site (Meiklejohn, 1995).

The forces acting on any object such as a rock can be a result of external causes such as pressure, impact, and vibration, or they can develop internally due to changes in temperature, relative humidity, and chemical composition (Mecklenburg & Tumosa, 1991a). Therefore, the factors that induce stress can originate externally or internally to the rock and will act to damage the rock physically. If sufficiently high, the stresses cause cracking and splitting of the rock surface.

Following is a discussion of factors that are likely to impact on the deterioration of rock art, based on visual analysis at the Main Caves and Battle Cave study sites.

4.1.2. Wind

While wind data, provides little information which directly relates to the weathering of the Clarens Formation, the principal wind direction at the Main Caves has been determined to be parallel to the rock face (Meiklejohn, 1995). Thus, the wind could have indirectly affected rock weathering because it would have aided evaporation at the rock surface thus enhancing weathering processes associated with the drying of rocks. Further, it is indicated that because the predominant wind direction is down-valley, it is likely to be dry, thereby increasing evaporation at the rock surface (Meiklejohn, 1995).

Micro-climatic variables of temperature and humidity operate on daily and seasonal cycles in unison with variations in surface topography, exposure to light, wind and the internal drainage of sites (Mirmehdi *et al*., 2001). Seasonal changes in humidity and temperature can affect the visibility and exfoliation of painted surfaces (Lorblanchet, 1992). Also, experimental research has shown that water from precipitation and human application promotes chemical and physical changes to painted surfaces (Mawk & Rowe, 1998; Mirmehdi *et al*., 2001). It is, therefore, necessary that in order to establish the active weathering processes at the study sites, it is crucial to determine the rock moisture regime, together with the rock properties, mineralogy and other controls on rock moisture (Meiklejohn, 1995).

4.1.3. Moisture

Chemical weathering, especially salt growth and hydration, produce granular disintegration and flaking, which are responsible for rock painting alteration, and that those processes are prompted by water circulation at the bedrock (Benito *et al*., 1993). The water infiltrated through the rock fractures, as well as what flows along the ceiling and walls of the shelters produces severe weathering of the rock paintings (Benito *et al*., 1993). Also, during the wet season rainwater may run down the rock face and then across sections of the rock art. It physically disrupts the porous pigment layer and washes the paintings off the rock surface.

As discussed above, rock weathering processes apparently occur at a more rapid rate in the Main Caves, and this is thought to be primarily due to the moisture regime which is more suitable for rock weathering than that at Battle Cave (Meiklejohn 1994, 1995). The increase of moisture combined with the daily temperature changes may increase severity and number of evaporation– condensation cycles at the rock surface (Benito *et al*., 1993). These daily variations of relative humidity can be responsible for deterioration of rock paintings at the Main Caves shelter.

Moisture is considered the primary agent of rock art deterioration in the study area (Avery, 1974; Rudner, 1989; Batchelor, 1990; Lewis-Williams, 1990; Loubser, 1991; Lewis-Williams & Dowson, 1992), but, few specific weathering processes have been identified (Meiklejohn, 1995). It has also been argued that temperature changes on their own may not be adequate to cause weathering of the Clarens Formation sandstone in the protected shelters (Meiklejohn, 1995). It is, thus, possible that moisture changes rather than temperature changes, or even a combination of the two, may be the major cause of rock weathering and rock art deterioration in the UKhahlamba-Drakensberg Park (Meiklejohn, 1995).

Atmospheric moisture may play a greater role in affecting the rock moisture contents than radiation in the moister environment of the Main Caves (Meiklejohn, 1995). Additionally, the little influence of radiation on rock moisture contents at the Main Caves may be due to the fact that only in winter is there any direct radiation on the rock surface. Therefore, the difference in rock moisture content between the Battle Cave and the Main Caves study sites is due to the fact that Battle Cave is more exposed to high radiation level causing evaporation of any rock moisture.

Moisture-based processes can also cause flaking (Yatsu, 1988; Loubser, 1991). There is no active water runoff close to the flakes as a direct source of running water and, capillary movement of moisture in the sandstone seems unlikely because of the low porosity of the rock (Meiklejohn, 1997). If the flakes in figures 4.1 and 4.2 are a result of moisture-based processes, the moisture could be of atmospheric origin. As previously discussed in Chapter 3, the uKhahlamba-Drakensberg is wet during half of the year, therefore, this humidity could be favourable to the deposition of atmospheric moisture.

4.1.4. Solar Radiation

Sometimes protective vegetation cover such as trees is removed for better tourist viewing. This action is an example of change in the local environment that can instigate significant differences in the thermal responses of the pigments as they are directly exposed to solar radiation (Arocena *et al*., 2008). In the long run, these thermal stresses can cause cracks in the pigments. Similarly, where the art occurs on top of a clay-based ground, the clays hinder water diffusion from the rock to the pigments such that any cracking may facilitate water movement from the rock to the air and hence facilitate microbial colonization; the cracking may be a response to the enhanced thermal fluctuations resulting from the removal of trees which might have acted sources of protection from solar radiation and strong winds (Arocena *et al*., 2008).

The paintings at Battle Cave receive a considerable amount of direct insolation in winter (Meiklejohn 1994) and some art in shelters, such as at Battle cave and Barnes' Shelter, has become more exposed where slabs upon which the art was painted have fallen from back walls onto shelter floors (Meiklejohn 1994; Sumner & Nel, 2006).

Both air and rock temperatures at the Battle Cave study site are higher than those of the Main Caves and that this is a result of greater incoming radiation received at Battle Cave (Meiklejohn, 1995). Temperature changes are greatest close to the rock surface and it is thus likely that these temperature changes will induce stresses close to the rock surface (Jenkins & Smith, 1990; Meiklejohn, 1995). The near-surface area is where the rock paintings are found and it is logical to suggest that this is where the processes of deterioration are likely to be the most active and where the art is the most vulnerable.

On cloudy days when the air temperature was greater than that of the rock or paint from the Battle Cave study site, the ochre pigment was slightly warmer than the white. In contrast, when the sun was shining and the rock or paint became hotter than the air, the white pigment could for some time turn out to be hotter than the ochre (Hall *et al*. 2007b). From these observations, it is suggested that the rise in temperature due to the sun would be more significant than the effect of light itself. One can therefore conclude that the rise in temperature may cause expansion between minerals within the sandstone leading to spalling, but the most significant effects would be promoting greater capillary rise in groundwater and accelerating chemical reactions.

Even though it is not always the case, white paintings appear to be better preserved where they are less exposed to direct solar radiation (Hall *et al*., 2005, 2007b); they appear thicker, brighter and less damaged. Ochre pigments also seem to frequently portray similar better preservation at these sites. Additionally, the ochre also shows colour deterioration where exposed to direct sunlight, and this indicates weathering to the pigment itself that may have ramifications for resilience and pigment-rock adhesion.

The flakes that have clearly fallen off the feline image at Battle Cave are unlikely to have been caused by frost shattering. Even though temperatures in the area can at times drop below zero in winter, the possibility of frost is limited by the dryness of the climate in that season (Tyson *et al*., 1976). However, quick variations in temperatures are possible in winter, when the air is relatively cold and the major source of heat is solar radiation. This might cause thermal shock and bring about thermal stress fatigue (Hall, 1999). Similarly, in summer, the numerous thunderstorms can also produce quick variations in temperature and moisture that might assist the flaking (Hoerlé, 2005).

4.1.5. Pigment Properties

Results from a recent study (see Hall *et al*., 2007b) at the Main Caves at Giant's Castle and Battle Cave at Injisuthi show that the pigment response to the surrounding environment is influenced by rock surface onto which San art is painted, the preparation of this surface, and the nature of the paints themselves. Furthermore, pigment albedo may influence resulting temperatures and hence impact directly on weathering of the art itself in addition to the rock on which the art was created (Hall *et al*., 2007b).

The largest temperature fluctuations in a rock are subsurface. In terms of the response of the pigment to temperatures, however, it is argued that when surfaces are close to or lower than air temperature, the albedo-controlled response is that the darker surface will be hotter than the light-coloured (Nienow, 1987; Meiklejohn, 1995). When the rock surface becomes hotter than the air, the lighter colour can become hotter than the dark (Hall *et al*., 2007b). In a nutshell, under certain conditions lighter coloured materials can reach temperatures equal to or higher than the darker materials notwithstanding the influence of albedo on warming by direct radiation (Arocena & Hall, 2004; Hall *et al*., 2005; Hall, 2007).

In the previous Chapters it was noted that the more porous the rock and the finer the pigment particles, the greater will be the penetration and adhesion of the paint. Additionally, dry pigments and those applied as paste (Fig. 4.4) are easily peeled off and deteriorate rapidly while those that are more fluid are able to infiltrate deeper into the rock making them more long-lasting. The pigments of white and black paints are composed of large particles and for this reason do not adhere easily or penetrate deep into the rock, and as a result are not resilient (Meiklejohn, 1995), for example, the ochre seems to have outlasted the white paint on the feline painting, as observed in Figure 4.3 below.

Figure 4.3: Images of paintings in white and ochre pigment (Photographs: K.I. Meiklejohn)

Figure 4.4: An eland painting showing that a thick pigment does not penetrate deep into rock (Photograph: T.C. Leuta)

4.2. Automated and Supervised Image Classification

The analysis of digital signals from pigments and the underlying surface were found to be too similar and neither automated nor supervised classification (see Lillesand *et al.*, 2007) was able to differentiate between these elements; this is clearly illustrated in Figure 4.5. The feline painting from Battle Cave was chosen as a test, given that visually, differentiation between the above elements was clear. The result showed that edges (shadows) are difficult to differentiate between darker pigments and lighter specks on the rock surface are indistinguishable from white pigments.

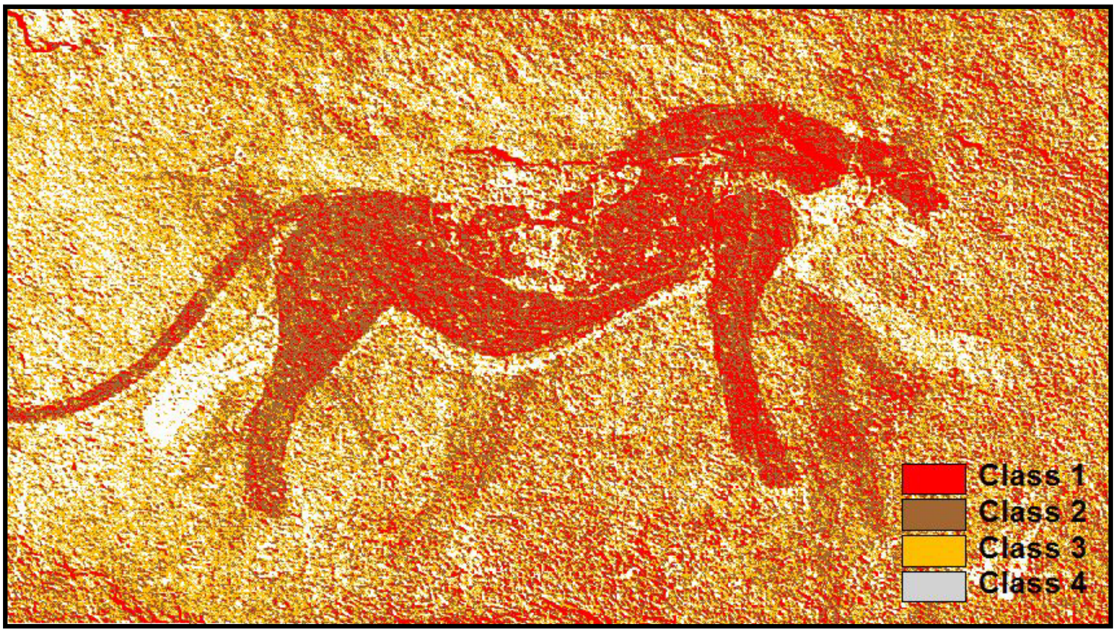

Figure 4.5: Automated classification of an image of a feline from Battle Cave, using ArcView® Image Analysis® Software (Original Photograph: K.I. Meiklejohn)

However, despite the relative lack of success of this method of image classification for rock art paintings in this study, it is a method that could be applied with success, especially if cameras utilising light outside of the visible spectrum are used. Given that this method of classification was not ideal, it was decided to use manual digitising of images in so-called “heads-up” fashion on the computer screen to classify images of rock art for this study. The results of automated image classification are presented in Figure 4.5, while Figure 4.6 shows the very same colour classifications in a layer digitised in a “heads-up” manner in ArcView GIS.

4.3. Manual Classification of Rock Art Images

The analysis of data following manual classification of two images of a feline painting from Battle Cave is summarised in Table 4.1 and in Figures 4.6 and 4.7. The painting in 1965 shows little deterioration (Table 4.1; Fig. 4.6), and substantial change is evident in an image of the same painting from 2006 (Table 4.1; Fig. 4.7), 41 years later. This presentation gives a perception of how little (only 2%) of the painting had already deteriorated into bare rock. 68% of the whole image was still covered in undamaged paint whereas 22% of the white pigment was still visible and 8% of the red pigment had faded.

Table 4.1: The Coverage of the Feline (Leopard) painting in 1965 and 2006.

Colour Classification	1965: Pigment (%)	2006: Pigment (%)	Difference (%)
White	22	19	-3
Red	8	8	0
Rock	2	15	+13
Unaltered Paint	68	58	-10
Total	100	100	0

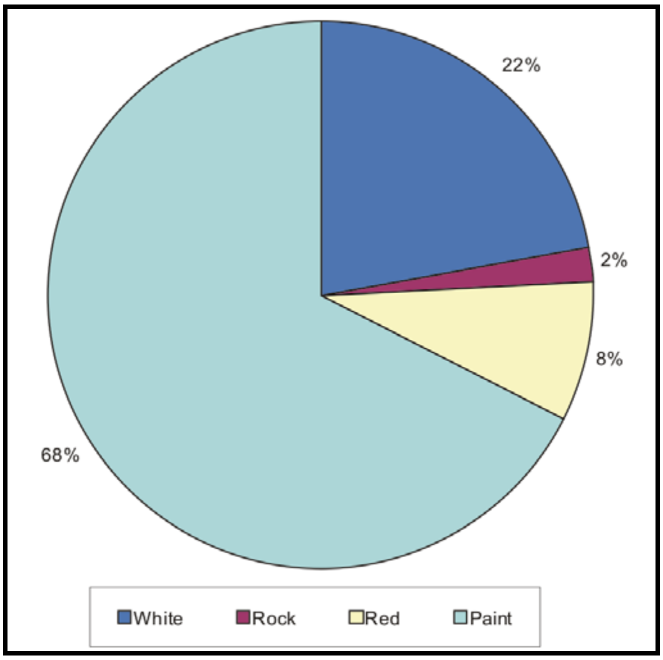

Figure 4.6: A Graphic Representation of the Coverage (%) of Pigment in 1965.

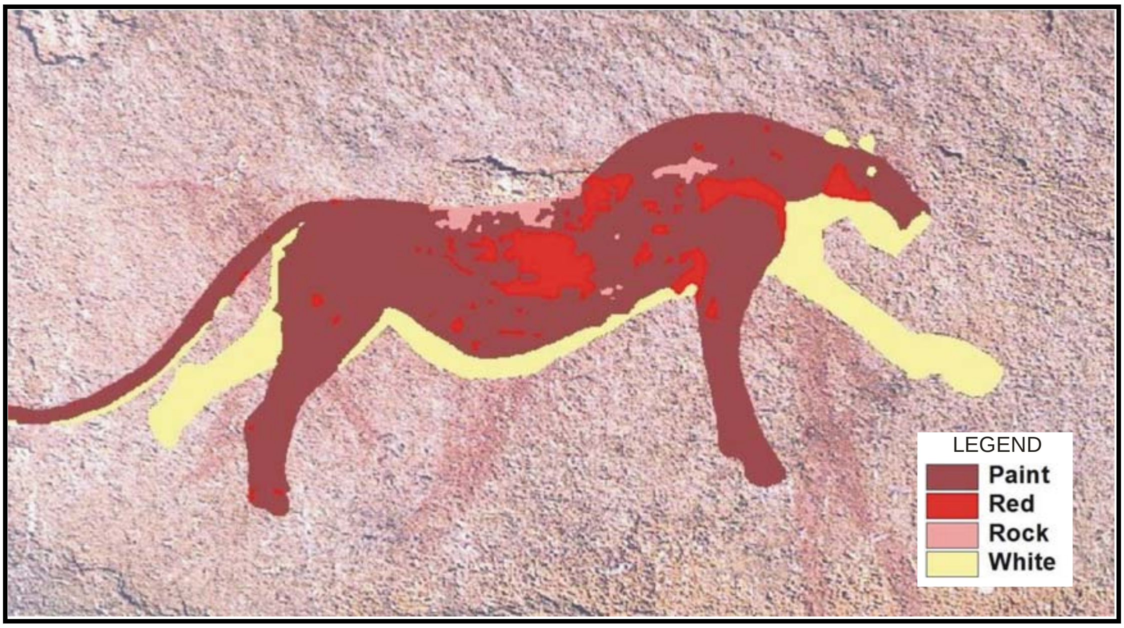

Figure 4.7: Pigment Decay in 1965, Shown, Using Colour Classifications.

Previously research suggests that the Battle Cave Study Site is exposed to more solar radiation than the Main Caves (see Meiklejohn, 1995). The latter was observed as being more prone to weathering may explain the relatively well preserved feline painting in Battle Cave. In four decades (see Figs 4.7 and 4.8), the proportion of "unaltered" ochre pigment has been reduced by 10% from 68% to 58% in the last two decades. The most striking of these changes has been an increase in a complete removal of the pigment to bare rock, which has increased by 13% (from 2%). The white pigment appears to have slowly faded and shows little evidence of rock decay, as demonstrated by a low increase of 2.8% of decay. In terms of conservation matters and preserving the heritage for future generations, this slow decay cannot however be regarded as insignificant. The even lesser change (0.3%) in the increase of the red paint decay indicates how ochre pigments are more resilient.

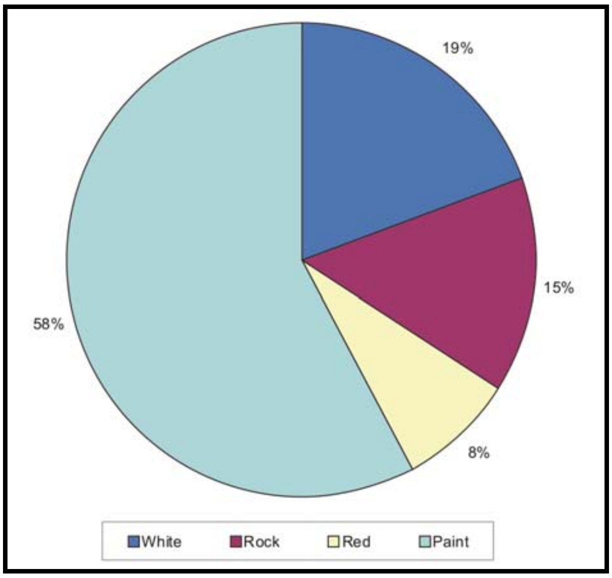

Figure 4.8: The state at which percentages of pigment were in 2006

The results portrayed show a significant amount of decay when comparing Figures 4.6 and 4.7 to Figures 4.4 and 4.5 respectively. The values of the changes may not be regarded as very high, but as the question of conservation and preservation comes into consideration, rapid measures need to be put in place to slow the rate at which rock art all over the world is deteriorating. This may include the option of ceasing all irremediable actions undertaken in prolonging the life of rock art more importantly for future generations.

Figure 4.9: The decay of pigment in 2006 as represented by different colour classifications.

The dependence of rock temperature on total incoming radiation increases with increasing exposure of the particular site, and that the dependence of rock temperatures on the air temperature increases with a decrease in exposure of a site (Meiklejohn, 1995). In addition, the effect of solar radiation on both air and rock temperatures is seen when comparing the two study sites as they are both higher at the Battle Cave site than at the Main Caves which is as a result of greater incoming radiation received at Battle Cave.

From these results it can be concluded that an increase in moisture content will provide an environment which is more conducive to weathering and thus increase the rate of rock breakdown. This proves not to be the case when observing Battle Cave study site which is more exposed to solar radiation but has low moisture content and hence the better preservation of the feline painting.

4.4. Application of a clay-based layer

High resolution analysis of the rock-pigment interface shows that the surface on which some paintings were created has been both smoothed (probably with a water-polished stone) and covered with clay-based ground, (Arocena *et al*., 2008). This procedure is clear in some paintings (but not all) found in the uKhahlamba-Drakensberg area, and that stones which are likely to have been used in the polishing had been observed on the floors at all the investigated sites (Hall, *et al*. 2007a).

In instances where it appears as if the pigment has been applied directly to the rock, the nature of the weathering seams quite different (Hall, *et al*. 2007a). The smoothing and application of a clay-based material considerably altered the physical and chemical characteristics of the rock surface. The pigments where there is a clay base serve as separate layers on the rock and do not penetrate the rock and therefore these pigments change the surface's albedo, porosity, chemistry, and thermal properties (Hall *et al*., 2007a, 2007b).

The smoothing of the rock changes surface porosity and increases strength, and also gets rid of any weakened, weathered surface that would otherwise be below the painting (Hall, *et al*. 2007a). Application of a clay-based ground is vital to the endurance of the paintings, as it serves to be resistant to moisture flow both into the rock and from the rock to the air (Hall, *et al*. 2007a). Recent findings further suggest that where the clay base has been damaged, it may have been mistaken to be the weathering of rock (Hall, *et al*. 2007a).

Changes in environmental conditions, notably of moisture and temperature, are suggested to affect the stability of the pigment–clay–rock bonds (Hall *et al*., 2007a). Both climatic change and human-induced environmental changes may cause loss of durability and strength of the rock–clay and clay–pigment bonds and, through other mechanisms, also affect paintings that are not on a clay base (Hall, *et al*. 2007a). The removal of vegetation (trees), mainly for visitor purposes, at sites such as the Main Caves, has influenced surrounding thermal and humidity conditions, thereby affecting the paintings and almost certainly resulting in accelerated deterioration (Hall, *et al*. 2007a).

Where art was painted over the clay ground, the ground itself has a 'surface modifier' on it, hindering moisture from reaching the clay, in that way causing physical and chemical changes (Hall *et al*., 2007a). More to the point, there is evidence indicating that the thermal changes may promote cracking of both pigment and clay and in so doing allowing moisture and endolithic organisms to infiltrate and in that manner further accelerating fading of the art.

Pigments also act as surface modifiers and in so doing prohibit light penetration, and, this may set up intricate stress fields with surrounding pigment-free rock where light penetrates (Hall *et al.*, 2007a, 2008). Light penetration into rock is considered the primary factor controlling the location of endolithic biotic communities (Friedmann, 1971; Nienow *et al.*, 1988a; Vincent, 1988; Mattes *et al.*, 2001; Hughes & Lawley, 2003; Hall *et al*., 2008). Light penetration into rock also has implications for weathering processes (André *et al.*, 2004; Duane, 2006) and for preservation of rock art (Camuffo, 1998; MacLeod & Haydock, 2002; Hall *et al*., 2008).

The age of the paintings can also play a role in the degree of degradation and may be very important in helping to identify pigments or sites that need utmost attention due to being more prone to rapid loss. However, dating of paintings can prove challenging as sites can contain several layers of paintings, suggesting a significant period of activity (Loubser, 1993) coupled with material that must be removed from the painting for dating (Mazel & Watchman, 2003; Hall *et al*., 2007a).

The preservation of a work of art depends on its original condition, the type of materials used by the artist, and on the quality of the environment surrounding the art (Odlyha *et al*., 1997). Also, there is need to consider the effect of fluctuations in relative humidity and temperature on the mechanical properties of paintings since there is a differential response of canvas, paint and size to fluctuations in relative humidity. The consequential movement in the paint composite structure may then contribute to visible damage such as the appearance of cracks, structural deformations, and paint loss.

Results from this study indicate that substantial deterioration of the feline painting at Battle Cave study site has taken place over the last forty years (Fig. 4.10). There has been an 11% increase in the decay of white pigment and only 1% of the red pigment. Parts of the painting have completely deteriorated leaving bare rock, and this is indicated by a 50% increase of this bare rock from what it used to be forty years ago.

This form of deterioration is characterised by the loss of paint flakes, from the surface of the painting, thus leading to a patchy appearance of the painting. The remaining overall proportion of “unaltered” ochre pigment has been reduced to 38%.

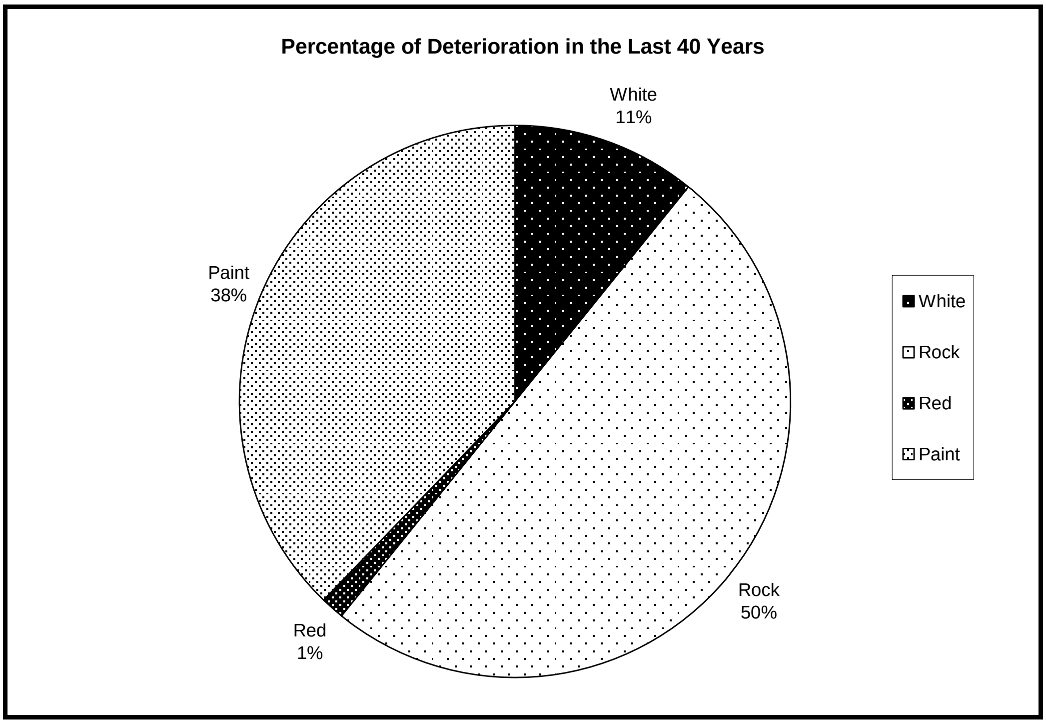

Figure 4.10: The increase in pigment deterioration over four decades

4.5. Summary

This study has shown that remote sensing techniques are able to be applied to investigate the deterioration of San paintings in the uKhahlamba-Drakensberg park. However, the nature of the pigments is such that automated classification of images is not possible and that manual digitising of images is, for now, the most appropriate method of depicting where rock paintings have changed over time.

CHAPTER 5: CONCLUDING REMARKS AND RECOMMENDATIONS

It is clear that white pigment degrades more rapidly than the ochre pigments. Observations suggest that the extensive damage of this figure is caused by the granular disaggregation and flaking of the rock surface. It is possible that the natural weakness of a surface that was weathered before the paintings were created has contributed to the observed damage.

Flaking seems to be the most destructive weathering process on the feline painting, and it is likely that future damage is to be similar, given the nature of the observable discontinuities on the rock surface. Salt-based weathering mechanisms, such as thermal expansion or hydration and crystallisation pressure, are known for causing or aiding flaking (Robinson & Williams, 1994). No salt was visible on the image analysed, but is clearly visible elsewhere in the site. Variations in rock moisture or thermal differences may support the movement of salt between these areas and the flakes (Rautureau, 1991), and salt may be present under the flakes surface or the paint, and therefore not directly observable.

Thermal fatigue and other thermally controlled weathering processes on their own were not thought to be responsible for the breakdown of rock in the rock shelters and rock weathering is most active in protected sites underneath rock overhangs due to favourable moisture conditions (Meiklejohn, 1995). Moisture is, therefore, likely to be more significant than rock temperature in promoting the rock weathering which leads to the deterioration of rock art. However, rock temperature is said to still influence all weathering mechanisms at the two study sites as it will affect for example, the rate of chemical reactions as well as evaporation and condensation cycles (Ollier, 1984; Yatsu, 1988; Meiklejohn, 1995).

This case study of rock art weathering at Battle Cave and Main Caves study sites shows that, generally speaking, rock art deterioration has taken place over the last four decades and that this is in the form of pigment deterioration, granular disintegration of the rock surface and flaking. The proper causes of the damage cannot, however, be conclusively identified. There is, thus, a need for clear and scientifically sound research to identify sites with rapid deterioration for documentation purposes and also before conservation measures are implemented.

In cases where rock art sites are documented over a long period, the weathering activity can be evaluated by comparing old photographs (Vinnicombe, 1966; Newlands, 1993; Walderhaug & Walderhaug, 1998), tracings, or copies (Pager, 1989; Ward & Maggs,1994; Ward, 1997) of the art with the present condition of the site (Hoerlé, 2005). In the case of this study, photographs were utilized in making such a comparison. The techniques used in this study are highly recommended because they assist with the evaluation of rock art deterioration but their main setback is that they are still mainly manual and require high-end software and computer hardware. The technique is largely new since manual digitising was used and not automated classification. This study has shown that with regard to conservation of indigenous San art in the uKhahlamba-Drakensberg Park, no two sites are the same and the methods that work at one site will not necessarily work at another. Even though methods developed in one country may not necessarily be appropriate in another, there is therefore need for some careful research before they are put into practice (Deacon, 1993). There are, however, principles which are useful and which can be used as starting points for investigations in South Africa. The measure to remove rock-art panels in order to save them from being destroyed is not recommended.

From what we have learnt so far, the first priority should be to preserve rock art in its original environment. When this is not the case, the message conveyed by the images also runs the risk of being lost and of no longer being able to be interpreted. The loss of these non-material and intangible aspects of the art might also in that sense endanger the art itself. If removed, in some unavoidable cases, one must be aware of the fact that this rock art has been ripped out of its original context and thus becomes a type of artefact, although one that can still be worth preserving as a piece of art.

When rock-art panels are cut loose from the bedrock and brought to a safer environment there are requirements for future care and preservation. Most conservation institutions and museums are located in big cities, and because the environment in cities can be much polluted and the air quality is often less than in the countryside, this relocation may pose new threats to the rock art (Bertilsson, 2002). Therefore, if such actions have to be taken it is vital to place the objects in a suitable climatic environment.

Also, one very important aspect in managing and maintaining rock art sites would be the need to analyse the moisture distribution and chemical composition, which will as a result allow the determination of the origin of the water, the nature of the species in solution and their potential influence to the paint and/or the rock. If water runoff appears to be the main source of damage, then it should be diverted from the paintings (Hoérle, 2005). The paint might be a cause of its own degradation (Hoérle, 2005). To attend to this issue, the exact composition of the paint should be established, to calculate its potential chemical reactivity and physical properties, especially its hydration susceptibility and permeability (Hoérle, 2005).

The fencing off of sites and the presence of guides accompanying visitors can alleviate the problem of vandalism. However, unintentional actions of an increasing number of visitors such as raising dust and its subsequent deposition on the rock surface may change in the future the conditions that have prevailed until now at the sites and contributed to their good preservation. The impact of visitors on the site therefore needs great conservation monitoring.

In recent years it has become abundantly clear that if rock art is not rapidly documented and conserved, most of it will be destroyed, whether it has been recorded or not (Whitley, 2001). Most sites that today are not yet documented may not survive. Therefore, a high priority task is to make records with all possible techniques and available resources. Even if a site is lost, and many will certainly be so, the records of the images can remain accessible for the future. Made in an orderly way with closely studied methods, this recording will prolong the life of the rock art although lose some of its original intangible content.

In deciding which techniques are to be applied in rock art conservation and preservation, the goal should be the most effective and efficient data recording and minimal resource destruction (Swartz, 2006). Varied photographic techniques are therefore stressed since they document and do not require any physical contact with the art. Also, Hoérle (2005) promotes the monitoring of sites by using macro-photographs because the evolution of most damages is difficult to track down with conventional photography.

Since rock art has been recorded for many centuries, specific traditions of documentation have evolved such as tracings and rubbings (Bertilsson, 2002). It is, therefore, of essence to combine these traditions in order to preserve and re-use the information contained in the old documents. Documenting is the only way to assure that these important records of our history are not lost.

One cannot emphasize enough the vital support of the surrounding community when matters of preservation are brought forth. Levin (1991) encourages the formation of a local constituency for site conservation and preservation, which in turn make that community part of the site management process. Training is also a solution, both for those professionals whose skills require improvement and for the local population surrounding the rock art sites. The training of technical personnel and site managers must go hand in hand with conservation organizations whose primary goal should be to educate government officials, including tourism ministries, regarding the benefits and dangers of site development, more so in these times of growing cultural tourism.

Weathering processes controlled by the ambient environment cannot be stopped by low-cost measures (Benito *et al*., 1993). If rock art is to be preserved, it is then imperative to protect the rock against moisture-related processes, either by protecting the rock itself or by changing the environment so that moisture and temperature changes are reduced (Hall *et al*., 2007a). In changing the local environment, care should be taken in not aggravating new conditions that would therefore introduce new harmful effects.

It is, however, shown that water runoff entering shelters through fractures can be avoided by filling joints and installing proper drainage for the water at the ceiling and at the overhanging walls. By improving the drainage, the processes activated by water such as salt and hydration weathering can be subsequently reduced. Then again, bedrock consistency may be improved by applying artificial chemical applications, although the cost of that is high (Benito *et al.*, 1993). The controls on the deterioration are environmental and by not using those chemical applications to preserve rock art then little can be done to prevent rock weathering processes (Hall *et al*., 2007a).

In their findings Arocena *et al*. (2008) discovered that some of the paintings they studied in the uKhahlamba-Drakensberg were created on a clay-based ground that was spread over the smoothed rock surface, and that it was the clay with pigment on top that seemed to be flaking off (Hall *et al*., 2007a). It is, therefore, suggested that in terms of weathering and conservation, consideration be given to preserving the clay–rock bond, or else the paint would keep on decaying; not through weathering of the rock but due to separation of the clay from the rock.

The scientific work of conservation is not conducted in a political vacuum and therefore decisions regarding the allocation of resources and the conservation of cultural sites frequently involve political considerations (Levin, 1991). Increased political support for conservation is dependent on greater public belief in its necessity. The conservation profession, therefore, must become effective and competitive in promoting its needs, or else it may never achieve the political standing and public support required to meet the considerable challenges that lie ahead (Levin, 1991).

As previously stated, in rock art conservation there are no standard diagnoses or treatments. Each site is different, and the management of each must be planned in a site-specific manner. In order to preserve rock art it is necessary to stop or at the very least minimize rock weathering processes. It must be remembered, however, that while conservation of rock art may involve a few measures that slow weathering processes, they will not guarantee the ultimate preservation of this valuable heritage (Hall *et al*., 2007a).

People visit painted places as part of a wider wilderness experience and care should, therefore, be taken not to preserve the aesthetic appearance of a place at the expense of other significance values. Rock art is an irreplaceable cultural resource that deserves our efforts in its protection and preservation. The art should also be seen as a monument to the San who struggled to retain their rights and their land (Lee, 1986). Therefore, this part of South African history needs to be conserved for future generations and it is our collective responsibility to see that this is done.

Last but not least, a nation's historical wealth can cultivate national pride and provide economic rewards as employment-generating attractions. But care is essential. A historic site is a heritage to be preserved, rather than a commodity to be exploited (Levin, 1991).

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