SURFACE PREPARATION AND THE EFFECTS ON ROCK ART DETERIORATION

By

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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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ABSTRACT

The Drakensberg is the highest part of a 1000-km long escarpment that also forms a natural border between South Africa and eastern Lesotho. The uKhahlamba-Drakensberg Park was declared a World Heritage site in 2000 and is globally significant, in particular due to the rock art painted by San hunter-gatherers who inhabited the area from about 8 000 years ago until the late 19th Century. Approximately 30 000 painted images can be found in nearly 600 rock shelters in the area.

Rock art heritage in the Drakensberg is unfortunately being lost through a variety of processes, some natural and others resulting from human impacts. Previous research on the weathering of San paintings has focused largely on either monitoring processes causing weathering in rock shelters or investigating rock surfaces that are adjacent to the rock paintings. Recent findings indicate that some of the San art has been painted onto surfaces that were prepared by smoothing the rock surface with a "grinding stone" and coated with a clay ("ground") layer prior to the application of pigments. This new information may have important implications for rock art conservation as smoothing of a rock surface could significantly modify the physical and chemical characteristics of the surface, thereby influencing the deterioration of the art.

In this study two classification systems are developed from data collected in four rock shelters situated in the Park. The first, a Type of Surface Classification System, is developed for the purpose of identifying different types of rock surfaces within rock shelters. The second, a State of Deterioration Classification System, is developed with the purpose of establishing, through visual inspection, how deteriorated the rock art on different types of rock surfaces is.

Linkages between the type of surface and the state of deterioration are also explored. Findings show that it is not only possible to determine which surface type a painting has been painted on, but that different rock surface types can deteriorate through different weathering mechanisms and to a

different degree. One type of rock surface, acknowledged but not yet recorded, was found amongst the rock art paintings selected for the purpose of this study. More importantly, the alteration of rock surfaces through human action in the past is found to cause rock surfaces to deteriorate either at an accelerated or a retarded rate as opposed to rock paintings that were made on surfaces that have only been altered by natural weathering mechanisms. For example, if a rock surface has only been smoothed with a grinding stone, results show that weathering mechanisms did not deteriorate the surface as quickly as in the case where a clay ground layer has been applied to the rock surface.

Different types of rock surfaces deteriorating through different weathering mechanisms (as a result of surface preparation) might have significant implications in terms of rock art conservation as the strategies implemented to conserve rock art should be adapted to consider surface type. In terms of rock art studies aiming to conserve this precious heritage, the two classification systems presented could, therefore, be useful non-destructive tools in assessing rock art deterioration.

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LIST OF ABREVIATIONS

NW	Naturally Weathered
NL	Naturally Weathered with Clay Layer
AS	Smoothed
SL	Smoothed with Clay Layer
CB	Clean Break
BC	Battle Cave
MC	Main Caves
GPS	Game Pass Shelter
SC	Sigubudu Cave
LS	Loss of Stone Materials
DD	Discoloration/Deposits
FD	Fissures/Deformation
EC	Environmental Conditions
CS1	Colour of Surface 1
CS2	Colour of Surface 2
CS3	Colour of Surface 3
TS1	Texture of Surface 1
TS2	Texture of Surface 2
TS3	Texture of Surface 3
SDCS	State of Deterioration Classification System
TSCS	Type of Surface Classification System
MDG	Main Deterioration Group
MDF	Main Deterioration Form
IDF	Individual Deterioration Form
I	Intermediate
R	Rough
S	Smooth
KZN	KwaZulu-Natal
UNESCO	United Nations Educational, Scientific and Cultural Organisation

CHAPTER 1: INTRODUCTION

The Drakensberg in the province of KwaZulu-Natal, South Africa, is the highest part of a 1000 kilometre long escarpment which is the plateau edge of southern Africa that separates the region's highland interior plateau from the coastal strip. The Zulu name for this majestic mountain range is uKhahlamba which translate to 'a barrier of spears' (Prinsloo *et al.,* 2008). It has a great variety of natural and cultural assets which consist of spectacular scenery, an abundance of biodiversity, and San hunter-gatherer archaeological materials consisting of rock paintings and occupation deposits found in numerous rock shelters (Mazel, 2008). It was based on both these cultural and natural assets, and for the purpose of conserving this valuable heritage, that a Park was established within the Drakensberg. This Park is now named the uKhahlamba-Drakensberg Park and was declared South Africa's fourth World Heritage Site in 2000 (Hoerlé, 2005). The uKhahlamba-Drakensberg Park is globally significant, in particular due to the rock art painted by San hunter-gatherers who have inhabited the area from about 8 000 years ago until the late 19th Century (KZN Nature Conservation Service, 2000). The Park contains approximately 30 000 painted rock art images that can be found in nearly 600 rock shelters in the area (Mazel, 2008). Some of South Africa's most renowned rock art paintings, such as the world famous Rosetta Stone in Game Pass Shelter, Kamberg, is found here.

Rock art of the southern African subcontinent is found within numerous rock shelters, where most of the art could date to between 4000 and 1000 B.P. (Deacon & Agnew, 2006). Rock art of the Drakensberg comprise the largest and most concentrated group of rock paintings in Africa South of the Sahara and is outstanding due to the diversity and quality of paintings (Mol & Viles, 2010). The San people of South Africa lived in the mountainous Drakensberg area for more than four millennia, leaving behind a heritage of exceptional rock art paintings, which can provide present and future generations with a glimpse of the San people's way of life as well as their beliefs (UNESCO, 2000).

Unfortunately this phenomenal heritage is being lost through a variety of natural and human induced processes. Although part of southern Africa's history is fading away with the paintings, the conservation of our heritage, such as rock art, is important for the country as it contributes to tourism opportunities which in turn can be of significant economic benefit. Rock art deterioration is also a concern to scientists as part of the record of human occupation, way of life, and belief systems is also being lost (Deacon & Agnew, 2006), together with great opportunities to educate the people of southern Africa about their past.

In order to create awareness of the deterioration of southern Africa's rock art heritage numerous authors (Meiklejohn, 1994 and 1997; Hoerlé & Salmon, 2004; Hoerlé, 2005 and Hall *et al.*, 2007a and b) have noted that the art is deteriorating, but little has been achieved with respect to the *in situ* conservation of the art (Meiklejohn *et al.,* 2009*)*. This is mainly due to the general lack of understanding concerning specific mechanisms of rock weathering and is considered to be the major reason for inadequate research into rock art preservation in southern Africa (Loubser, 1991; Meiklejohn, 1997). There is also still a lack of knowledge about the conservation status of many sites and how the rock art is deteriorating at each site. One problem affecting progress in this field is the limited availability of efficient and accurate non-destructive assessment methods for rock art research (Deacon & Agnew, 2006). It is therefore necessary to develop non destructive methods as well as to continue studying the processes of weathering and deterioration in order to conserve this irreplaceable heritage for generations to come.

1.1 Rock Art in South Africa

In the Drakensberg, San rock art occurs in shallow rock shelters situated within the sandstone of the Clarens Formation (Hoerlé, 2005). Throughout the Clarens Formation of KwaZulu-Natal, the deep incision of rivers has exposed less resistant sediments below desert dune deposits of the upper Karoo sandstones (Meiklejohn *et al.,* 2009). Facies that consist of fluvially deposited sandstones, mudstones and siltstones in the lower parts of the Clarens Formation (Eriksson, 1983) have weathered and eroded at a quicker rate than Aeolian deposits above. This resulted in the development of valley-side rock overhangs (Meiklejohn *et al.,* 2009). These rock overhangs provided shelter for indigenous hunter-gatherers, the San people, otherwise known as the Bushmen. Sandstone walls of rock shelters and isolated boulders provided an ideal canvas for the San to paint on (Lewis-Williams & Dowson, 1992). Although all rock art encompasses a large variety of traditions and techniques, it is the San rock paintings that are best known to the public. They are found in open-air sites, on boulders, and rock shelters and are therefore largely open to the elements and can be subjected to a full range of natural weathering process jeopardising their survival (Hoerlé *et al.,* 2007).

In contrast with rock art in France and Spain which is painted on limestone surfaces (e.g. Chalmin *et al.,* 2003), sandstone and quartzite are the most common surfaces on which the San artists of southern Africa painted (Bassett, 2001). Prehistoric rock art in most of Europe is found within deep caves where temperature fluctuations are minimal (Brunet *et al.,* 1990) and no direct sunlight penetrates. In such environments, the impact of tourism on temperature, air chemistry, and humidity can enhance microbial activity that is harmful to the art (Castellani, 2005). In contrast, the San rock art of southern Africa is deteriorating through a series of natural weathering processes. The shelters that contain San rock art are usually located at mid-mountain altitudes at about 1500-2000m and are open to the elements (Hoerlé, 2006). The downside to South African rock art being painted in shallow rock shelters is that the rock art is exposed to extensive diurnal (4-35 °C) and seasonal temperature fluctuations (with extremes of 2-43 °C) as well as to the impact of solar radiation, wind and rain (Hoerlé & Salomon, 2004; Hoerlé, 2005, 2006). All these elements serve to deteriorate, through various processes, the already fragile rock art images.

The term "cultural stone" is commonly used for stone that has been physically altered by humans (Pope *et al.,* 2002). Humans generally alter stone objects by abrading, engraving, quarrying, chipping/chiselling, or dressing and the rock surface that rock art has been created on can thus be classified as "cultural stone". Generally, rock art can be divided into two categories; rock paintings and rock engravings. Southern Africa is rich in both with thousands of rock paintings and engravings scattered across the sub-continent (Yates *et al.*, 1990).

Rock paintings are images painted onto rock surfaces, using naturally available pigments such as ochre and animal fat (Yates *et al.*, 1990). Paintings are found almost exclusively on vertical rock faces and in most cases in a protected position (Leuta, 2009). In southern Africa, rock paintings are situated in rock shelters and caves, on bare rock walls (Meiklejohn, 1994) and sometimes on large isolated boulders, in the rugged, hilly or mountainous parts of the countryside (Yates *et al.*, 1990). Rock engravings are images produced on rocks by chipping away the rock surface, or by cutting into the rock to form lines. Engravings occur in areas where caves and rock shelters are not common and where the rocks are of a different type (for example Granite). They are made on boulders and stones in the open veld, and often along ridges or escarpments across the plains (Yates *et al.*, 1990).

Since the San followed a hunter-gatherer way of life, the animated figures portrayed in these paintings typically depict activities such as dancing, hunting, running and fighting (Prinsloo *et al.,* 2008). The origin and arrival of the nomadic San hunter-gatherers in southern Africa is, unfortunately, lost to time. They were the only inhabitants of a large part of the interior of southern Africa until the late 19^{th} century but left behind a precious heritage through their paintings and engravings (Prinsloo *et al.,* 2008).

In this study the main focus will be on rock paintings in the Drakensberg as this is the type of rock art most commonly found in the study area. In contrast with rock engravings, which deteriorate only through the weathering of the rock surface, rock art paintings are being lost due to various weathering mechanisms deteriorating the rock surface as well as the art itself. Due to the nature of the paint, pigments and binders this deterioration process can be quite rapid especially in the case of rock shelters experiencing extreme environmental conditions. Therefore, the conservation of rock art has become crucial to conservationists who realise that San paintings will be lost without future generations having the privilege to experience these extraordinary pieces on history, if effective strategies are not in place.

1.2 Conservation and Preservation

The weathering and deterioration of southern African rock art is mainly due to natural processes that can be enhanced by human interference and carelessness. Conservation strategies that strive to inhibit weathering processes, as well as control human interference, should thus be the main objective when dealing with deterioration of rock art. In the next section the difference between preservation and conservation is discussed while also dealing with the effects tourists have on deterioration and how rock art sites can be managed in order to augment conservation efforts.

In order to ensure that this precious heritage is kept in place, rock art can either be preserved or conserved. Preservation can be defined as the act of keeping something in its original state or in good condition. This commonly refers to the degree to which something, such as a piece of art, has not been changed or damaged by age (Wehmeier, 2000). Although preservation seem practical it is important to realise that complete preservation of rock art is in most instances not possible. This is because no matter what is done, rock art will deteriorate regardless of attempts to preserve it *in situ* as weathering in a natural environment is nearly impossible to prevent (Avery, 1975) and deterioration of the art is thus inevitable. Despite methods that aim to preserve rock art, it is therefore probably sensible to rather consider measures that slow down weathering to extend the life of the paintings as this will possibly give scientists time to derive new, more permanent solutions (Walderhaug, 1998).

Since the total preservation of rock art is not possible (Mirmehdi *et al.,* 2001) the weathering processes at the rock surface will remain active (Walderhaug, 1998) until the rock art is totally destroyed. The need for good conservation measures is thus vital. Conservation can be defined as the protection of the natural environment or the act of preventing something from being lost, wasted, damaged or destroyed (Wehmeier, 2000). In order to slow down the weathering processes that affect rock art it is necessary to develop good, manageable conservation strategies. As preservation is not always realistic, especially in the case of rock art, conservation and the management of rock art sites and collections will be the main focus area discussed in this study.

1.2.1 Managing Rock Art Sites and Collections

Although rock art is typically managed by Conservation Authorities (for example Ezimvelo KZN-Wildlife) as well as private land owners, community involvement is important when formulating a site management strategy. By engaging a community in the site management process, a local constituency for site conservation and preservation in created (Levin, 1991). It is, however, very difficult to include the community in all aspects of site management. The reason for this being that despite specific guidelines that address site conservation, on-site heritage site management is often conducted in an *ad hoc* manner with limited understanding of planning and management options, while previous planning and management is likely to be ignored (Clark, 2001). Site management plans should thus be formulated with the knowledge that a comprehensive national and international approach to preventing rock art collections involves education, research, and outreach (Levin, 1991) which should first be taught to the community, who is involved in the site management plan, before being taught to the public. In addition to education, the recordings made of rock art as well as the actual site management plans are also crucial in order for conservation strategies to be successful.

1.2.1.1 Recording

Since the deterioration of rock art is inevitable, the recordings made of paintings will be the only evidence that will remain if strategies that ensure the preservation of rock art are unsuccessful. The last San painters of southern Africa applied their pigments to rock about a hundred years ago. Rock paintings in this country are thus non-renewable; once destroyed they cannot be brought back. It is vital to record surviving examples before they are damaged by natural and human agents.

In deciding which techniques are to be applied in any particular case, the goal should be to record the best possible data with minimal damage to the heritage resource in question (Swartz, 2006). Photography is not only the most common but also the most practical and cost-effective way to record rock art, and is widely recommended as the primary recording technique (Leuta, 2009). Good photographs are essential to rock art recording, and varied photographic techniques are stressed since they document while not requiring any physical contact (Whitley, 2001).

1.2.1.2 Training, Education and Awareness

The real answer to the problem of conserving our rock art heritage is a long-term commitment to conveying the message to people of all ages that this is a fragile, priceless and irreplaceable resource, which needs to be treasured and preserved for future generations (Leuta, 2009). Through creating awareness by people that rock art has value and is irreplaceable we in turn create the potential for it to be respected and conserved. It is only through sufficient publicity and education that the value of this legacy will be realised by the public (Meiklejohn, 1994). Education and awareness create the sense in people's minds that there is an undeniable connection between our natural environment and our cultural heritage (Deacon & Agnew, 2006). The public should thus always be aware that a historic site is a heritage that should be preserved at all cost, rather than a commodity to be exploited (Levin, 1991), as it is all of human kind that will benefit from the conservation of our precious rock art heritage.

1.2.1.3 On-site Management

Each site has its unique human, geological and environmental problems that change over time. As rock art mostly deteriorates through natural weathering mechanisms, intervention works best when the natural processes at the rock surface where weathering occurs, can be retarded by deflecting the flow of water over painted surfaces with a well-designed artificial drip line, or installing a boardwalk to cut down on dust, or discouraging the growth of algae or moss, or reducing the risk of fire in the vicinity of a site (Deacon, 2006). It is least successful, however, when the local environment is drastically changed, for example by clearing vegetation to make a site more accessible, covering painted surfaces with silicon sealant or linseed oil or by erecting wire cages around sites (Deacon, 2006).

For conservation purposes, the most vulnerable or badly damaged sites have been closed to the public, while the less damaged sites are being protected in a more visitor-friendly manner (Leuta, 2009). Each site has different needs and challenges and one approach will not necessarily fit all scenarios, but it has been shown that simple solutions such as site custodians, well-designed notice boards, boardwalks and visitors' books reduce the occurrence of vandalism (Deacon, 2006). Interpretive panels can also present several functions. They can, for example, provide visitors with an overall impression of the significance and heritage of a site and introduce the concept of protecting cultural resources, while also offering information of visitor etiquette, points of interest, fauna and flora, geology, and trail statistics such as length, time needed and hiker information (Swadley, 2002).

While the above measures are incorporated at most sites open to the public the main problem that is very difficult to control is that of vandalism. To prevent damage to sites by vandals, some measures can be undertaken but unfortunately some of the sites are just too isolated and therefore almost impossible to guard or fence off (Beltrán, 1982). While 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 (Leuta, 2009), it is appropriate to also include a visitor register at the start or end of each trail (Swadley, 2002). This would aid in giving the entrance some formality and is a visual focal point that marks the beginning of the trail. Visitor registers are also useful tools that can be used by law enforcement officers against vandalism as it should include visitor feedback information (Leuta, 2009). The best recommendation for slowing the rates of deterioration, other than to limit the environmental factors, is to limit human contact as far as possible (Pope *et al.,* 2002).

Although good conservation methods can prolong the total destruction of San paintings, it will weather, deteriorate and eventually disappear. While conservation of rock art is of utmost importance, the act of "conserving" can be considered as a foolish attempt to arrest nature (see Pope *et al.,* 2002). Weathering is not necessarily an act of destruction since it can crust, case harden, and even bind and indurate surfaces by the colonisation of biotic communities (Pope *et al.,* 2002) thereby protecting the rock surface rather than destroying it.

The management of rock art sites is not an easy task for any organisation, local or regional government as there is no single effective way to manage rock art sites (Leuta, 2009). The reason for this is that each site is unique and because conservation is a relative concept that changes over time

(Loubser, 2001). The main focus of current conservators around the globe is to slow the rate of decay and preserve the integrity of the site in question for future generations to enjoy, study, and preserve (Loubser, 2001). All role players should therefore work together to keep the impact that tourists and the environment have on the decay of rock art paintings to an absolute minimum.

1.3 Rock Paintings in Relation to Rock Surfaces

Ethnographic evidence of rock art shows that, whatever other associations or connotations southern African rock art may have had, it was essentially Shamanistic and mainly comprise symbols of the supernatural power shamans had in order to enter trance, depictions of hallucinations and activities associated with San Shamanism (Lewis-Williams & Dowson, 1990). In Shamanistic interpretation not only the pictures, but also the rock face was important, the latter being perceived as a veil between the known and the mystical world (Prinsloo *et al.,* 2008). There are thus features of the art itself that suggest that the rock face that was used to paint on was significant and in some sense part of the picture (Lewis-Williams & Dowson, 1990).

In the South-Western Cape it appears that immediately after rock paintings were painted they became a direct part of ritual activities, as the paintings in this area are frequently accompanied by round or oval patches of pigment, usually of the same colour that is used in the work of art (Yates *et al.*, 1990). This notion led scientists to recognise that many of these areas of pigment have been rubbed, in some cases enough to leave a noticeable polish to the rock surface (Yates *et al.*, 1990). Polishing of the rock surface is generally restricted to the area of the pigment patch, and the activity of rubbing (otherwise known as preparation of a rock surface) thus seems to have a connection with the paint and therefore the painting. As a consequence preparation must have been a deliberate action rather than an accidental one (Yates *et al.*, 1990).

In the past few years the practice of rock surface preparation in the Drakensberg has also been recognised (Hall *et al*., 2007a, b; Hall *et al.*, 2008; Prinsloo *et al.,* 2008; Arocena *et al.,* 2008). Previous research on the weathering of San paintings has focused largely on either monitoring rock shelters (Hoerlé & Salmon, 2004) or investigating rock surfaces that are adjacent to the rock paintings (Prinsloo, 2007). Recent research has shifted the focus away from investigating the weathering processes of the rock on which the art is located, to the interface between the rock and the pigments and that of pigment-to-pigment within the paintings themselves (Hall *et al.,* 2007a).

None of the methods applied in earlier investigations have considered the interface between rock and pigments mainly because of the potential damage that may result from the use of tactile monitoring equipment (Hall *et al*., 2007a). Recent advances in weathering research, using improved techniques to measure conditions at the rock surface where the San art is painted, provide new insights into the weathering processes at the rock face (Hall *et al*., 2007a). Findings suggest that some of the San art has been painted onto surfaces that have been prepared by smoothing the rock surface with a "grinding stone" and in some instances coated with a clay ("ground") layer prior to the application of pigments (Hall *et al.,* 2007a, b). As surface preparation is a relatively new concept, the recording and conservation of rock art in southern Africa has proceeded without taking the notion of surface preparation into account. At Game Pass Shelter, for example, smoothing of the rock surface of the world famous Rosetta Stone (Figure 1.2) is clearly apparent but has not been documented. This new information may have an enormous impact on approaches to rock art conservation as smoothing of a rock surface could significantly modify the physical and chemical characteristics of the surface and hence the process(es) of deterioration.

Application of a clay mineral-based ground (huntite) for paintings has also been reported from Australia where such ground was found to be predisposed to advanced deterioration (Hall *et al.,* 2007a). With the smoothing of a rock surface the situation is somewhat different. The reason for this being that smoothing changes surface porosity, increases rock strength (Katz *et al.,* 2000) and also serves to remove any weakened and weathered surface material that would otherwise be beneath the painting (Hall *et al*., 2007a; Sumner *et al*., 2009). In other words the weathering clock of the rock on which the art is painted, can theoretically be "zeroed" (Pope *et al*., 2002) by smoothing.

The smoothing of a rock surface together with the application of a clay ground thereafter impacts the nature of the weathering itself as it no longer pertains to the sandstone alone (Sumner *et al.,* 2009). It is important to consider that the application of a clay-based ground layer might contribute to the longevity of the paintings as the clay-based ground acts as an impermeable barrier for moisture flow, both into the rock and from the rock to the air (Hall *et al.,* 2007b). Even though the full impact of surface preparation on the deterioration of San rock art is not known, some studies have been undertaken. In order to understand how the weathering of a prepared surface might differ from weathering processes operating on rock surfaces that have not been prepared by humans (see Chapter 2), the impacts currently known to scientist will be presented in more detail in Section 1.5. Through the above discussion it is clear that it can no longer be assumed that all rock art is created on the same type of rock surface and it is therefore important to be able to identify the different types of rock surfaces that exist.

1.4 Types of Rock Surfaces

In recent years (2007-2009) the notion of prepared surfaces has been documented. Hall *et al*. (2007) and Sumner *et al*. (2009) acknowledge four types of surfaces:

The first type of surface is probably the most common in the Drakensberg and is that of a sandstone rock surface where rock art has been painted directly onto the naturally weathered rock face. This type of rock surface will typically be of light-dark brown colour and have a rough texture. For the remainder of this study this type of surface will be called a Naturally Weathered (NW) rock surface (Figure 1.1).

Figure 1.1: Example of a Naturally Weathered (NW) rock surface (Image approximately 4cm).

Figure 1.2: Example of an Anthropogenically Smoothed surface (AS) (Image approximately 40cm).

The second rock surface type is one where rock art is painted on an anthropogenically-smoothed rock surface. This surface has most probably been smoothed with a grinding stone (Hall *et al.,* 2007a) and will, therefore, be called an Anthropogenically-Smoothed Surface (AS) (Figure 1.2). The colour of a Smoothed surface will range between light grey to light brown and its texture will be smooth with perhaps a few scratches where the stone has ground it.

In some instances, a clay ground layer has been placed over a smoothed rock surface prior to paint application. This type of surface forms the third type of surface and will be called Smoothed with Clay Layer (SL) (Figure 1.3). A rock surface that has been smoothed with a clay layer being placed on it will typically look similar to a Naturally Weathered (NW) surface, except that in the instances where the clay layer has peeled off, the much lighter, smoother surface underneath will be revealed.

The fourth type of surface could be that of a Naturally Weathered rock surface with a clay ground layer placed on it. However, no field evidence for this type of surface has been recorded to date (Sumner *et al.,* 2009). A possible explanation for this might be that the surface underneath will look the same as the overlying clay layer, and since no sampling is permitted, it is difficult to visually determine if the surface involved could be that of a Naturally Weathered one with a clay layer. This Type of Surface will however, for clarification purposes, still be called a Naturally Weathered with Clay Layer (NL) surface for the remainder of this study.

A fifth type of rock surface not previously documented is the one formed when a section of rock has fallen from the rock face and the San artists has therefore painted on the fresh rock surface (either the one exposed on the rock face or the one that has fallen). This type of surface will be referred to as a Clean Break surface (CB) (Figure 1.4) and will mainly have the same characteristics as an Anthropogenically-Smoothed surface except that it will not be as smooth as a smoothed rock surface and no grinding marks will be present.

Figure 1.3: Example of a Smoothed rock surface with a Clay Layer (SL) (Image approximately 12cm).

Figure 1.4: Example of a Clean Break (CB) rock surface (Panel approximately 1m).

1.5 Impact of Prepared Surfaces on Rock Art Deterioration

Because the act of surface preparation by the San is a relatively new discovery, few data on the effects thereof on rock art deterioration have been documented. Some authors (Hall *et al*., 2007a, b; Hall *et al.*, 2008; Prinsloo *et al.,* 2008; Arocena *et al.,* 2008; Hall *et al.,* 2010) have noted several impacts of surface preparation on rock art deterioration but more research is needed before impacts can be understood. In order to aid in the understanding of the impacts of surface preparation on rock surfaces and the weathering thereof some literature on the preparation of cultural stone are included in the study as the rock surface that rock art has been created on could in effect classify as cultural stone.

The act of preparing cultural stone creates, as in the case with surface preparation for rock art creation, structural stresses that are different from those found in nature (Pope *et al.,* 2002). Polishing or smoothing can give the rock a waterproof, glassy seal (Bielby, 1921) that is resistant until the weakest areas finally give way to weathering agents (Pope *et al.,* 2002). If the preparation of a surface thus totally removes all the previous weathering that the rock surface may have endured, weathering begins anew on the fresh rock surface (Pope *et al.,* 2002). Because natural stone decay processes tend to produce uneven surfaces out of differential weathering of various minerals and inclusions, smoothed or polished surfaces will eventually become pitted and etched over time (Pope *et al.,* 2002). Even though the full impacts of surface preparation is not known the following weathering mechanisms enhancing rock art deterioration as well as the known consequences have been documented

1.5.1 Consequences of Surface Preparation

1.5.1.1 Temperature and Moisture Fluctuations

Because surface preparation might cause thermal and moisture fluctuations that are different from those that would occur on Naturally Weathered rock surfaces, this could cause some accelerated weathering to rock art paintings. Thermal infra-red data have shown that white and red pigments, as well as the rock, all have different responses to solar radiation that can lead to pigment-to-pigment as well as pigment-to-rock stresses (Hall *et al*., 2007a, b). In the case where paints cover the clay ground, the ground itself acts as a 'surface modifier' which inhibits moisture from accessing the clay, thereby causing physical and chemical changes (Hall *et al.,* 2007a) to the rock surface underneath the clay layer. Thermal and moisture fluctuations can thus lead to fracturing of the clay ground while consequently allowing the entrance of microbial activity (Arocena *et al*., 2008). Although a thorough investigation is yet to be undertaken, in many instances it is expected that the detachment of the clay ground rather than the weathering of the rock is the destructive factor (Sumner *et al.,* 2009).

1.5.1.2 Light Transmission

A clay based layer that is placed on top of a smoothed surface might have considerable impacts on the amount of light the rock surface underlying the clay layer receives. Data, primarily from Main Caves at Giant's Castle and from Battle Cave at Injisuthi, in the uKhahlamba-Drakensberg Park, show that the rock surface onto which San art is painted, the preparation of this surface, and the nature of the paints themselves all influence pigment response to the ambient environment (Hall *et al.,* 2007a). The pigments that the San people used will alter the surface's albedo, porosity, chemistry, and thermal properties (Hall *et al.,* 2007a). As the Clarens sandstone is composed mainly of quartz (Eriksson, 1983), which can be light transmissive, this will affect the thermal responses of the sandstone plus provide the photosynthetically attractive radiation necessary for endolithic colonisation (Hall *et al.,* 2010). The application of a non-light transmissive ground (a smooth clay base on which some art is painted) and the pigments alter thermal gradients between pigments and their sandstone substrate (Hall *et al.*, 2008). Although the pigments may inhibit light penetration there can still be transmission due to scattering around the edges of the pigments, thereby facilitating subsurface colonization below the edges of paintings (Hall *et al.,* 2010).

The mineral composition of the pigments used also has an effect on the weathering of the art as the pigment mineralogy may not only affect chemical responses (Prinsloo *et al.,* 2008) but also has a significant influence on thermal properties (Hall *et al.,* 2007b), which can lead to pigment-to-pigment as well as pigment-to-rock stresses (Hall *et al.,* 2007a). Thermal infrared data have shown that the rock and both the white and ochre pigments have quite different responses to solar heating, which can be explained by the different thermal properties of the materials (Hall *et al.,* 2007b). When a prepared surface is thus exposed to solar radiation, the materials comprising the paintings and painting-rock associations might experience shearing forces that cause cracking (Scott & Hyder, 1993) and ultimately failure (Hall *et al.,* 2007a).

In the case where the pigment lies directly on the sandstone and that specific painting is exposed to solar radiation, there will be thermal differences between the pigment and the underlying rock due to differential albedo and thermal properties (Hall *et al.,* 2007a). These thermal differences may be further exacerbated because all light-to-heat transformation will be at the surface, where there is pigment, and will occur also in the top few millimetres of the unpainted sandstone (Hall *et al.,* 2007a). This can lead to shearing forces that may induce cracking (Spagnolo *et al.,* 1997) and deterioration at the painting rock interface, and also facilitate the admission of endolithic organisms (Arocena *et al.,* 2008) leading to further deterioration.

1.5.2 Deterioration Enhancing Mechanisms

Rock art deterioration is a process of natural and human induced weathering mechanisms all working together, but where a ground layer is applied to a smoothed rock surface and the paint is then applied over that then the situation is somewhat different, although some of the memory attributes can still play a role at some point in the weathering process (Sumner *et al.,* 2009). Despite this, changes in environmental conditions, notably of moisture and temperature, have been known to affect the stability of the pigment-clay-rock bonds (Spagnolo *et al.,* 1997; Hall *et al.,* 2007b). Both climatic change and local, human induced environmental changes may cause loss of stability of the rock-clay and clay-pigment bonds (Hall *et al.,* 2008). It is important to note, however, that the change in environmental conditions may also affect San paintings that are not on a clay base. Further, the changes to atmospheric chemistry due to economic development, a notable factor in the past 100 years of southern Africa (Sumner *et al.,* 2009), have a significant impact as the present weathering activity may differ considerably from that of pre-human-impact weathering (Pope *et al*., 2002). It is also suggested with respect to human-induced changes, that the removal (or loss) of trees, largely for visitor purposes, at sites has influenced ambient thermal and humidity conditions, thereby affecting the paintings, possibly resulting in accelerated deterioration (Hall *et al.,* 2007a).

1.6 Research Aims and Objectives

1.6.1 Aims

Based on the above discussion on prepared rock surfaces it is evident that more research is needed in order to understand the extent to which surface preparation might impact rock art deterioration. Four possible types of rock surfaces have been noted (Hall *et al.,* 2007a; Sumner *et al.,* 2009) but the number of paintings created on prepared rock surfaces and the effect on deterioration of the art remains unknown. In order for conservation strategies to be adapted in terms of different weathering mechanisms, a classification system is needed to consistently and rapidly identify the type of rock surface involved. Therefore the aim of this study is to develop two classification systems; one to identify surface type (type of surface) and the other to establish the state of deterioration; both of which will be combined to determine if surface type influences how deteriorated the art is.

1.6.2 Objectives

The following primary objectives were set as guidelines in order to meet the above aim. More detail on the objectives as well as the methods implemented is presented in Chapter 3.

- To develop a Type of Surface Classification System.
- To develop a State of Deterioration Classification System.
- To apply these Systems in order to compare surface type and state of deterioration.

1.7 Project Outline

Chapter 1 provided a historical background into the establishment of the uKhahlamba-Drakensberg Park together with the setting and nature of the rock art heritage. The Chapter also discussed the phenomenon of rock surface preparation together with the impacts surface preparation might have on rock art deterioration and how the conservation of rock art should proceed in order to protect this valuable heritage. Finally Chapter 1 also presented the aims and objectives of the study.

Hereafter, Chapter 2 investigates all possible weathering agents that could cause and enhance rock art deterioration while Chapter 3 describes the setting of the study area by examining each rock art shelter individually. The methodology utilised to create the Type of Surface and State of Deterioration Systems is also presented in Chapter 3. Chapter 4 presents results and discussions on the findings of this project while Chapter 5 summarises main findings and recommendations for future research.

CHAPTER 2: WEATHERING AND DETERIORATION

Although geomorphologists are familiar with the term "weathering", other terms also appear in stone conservation literature (Pope *et al.,* 2002). Thus, depending on the field, terms such as surface diagenesis, deterioration, degradation, decay and stone pathology all have similar meanings; all imply changes to the rock and its component minerals as the rock aims to ultimately reach a state of equilibrium in the rock surface. Discoloration, structural alteration, precipitation of weathering products (mass transfer), and surface recession (mass loss) are all products of weathering processes (Pope *et al.,* 2002).

Since the rock art of the Drakensberg is predominantly painted on sandstone surfaces of the Clarens Formation, the weathering of sandstone will be discussed in detail in this Chapter. Different weathering processes, the mechanisms that enhance them and the drivers of rock art weathering will be included in the discussion.

2.1 Formation of Sandstone Rock Shelters

Approximately 15% of the land surface on earth is estimated to consist of sandstones (Robinson and Williams, 1994). In South Africa the Clarens Formation Sandstones of the Central Drakensberg region reach a thickness of up to 300m and is primarily of Aeolian origin with largely fine and medium grained sandstone, subordinate siltstones and mudstone horizons towards the base of the Formation (Sumner *et al.,* 2009). In the Drakensberg, San rock art is found in the numerous caves and shelters in the Clarens Formation (Hoerlé, 2005) which resulted from the enhanced weathering of the alluvial sandstones, that are less resistant than the overlying Aeolian deposited sandstone (Leuta, 2009).

The sandstone in which these shelters were formed is covered, at a regional scale, by basalt flows, forming the Drakensberg Massif (Denis *et al.,* 2009). Petrographically speaking the Clarens sandstones are composed of quarts grains, which are mainly associated with feldspars. Although these sandstone formations consist of layers of finely sorted sandstones with colours ranging from ochre to rust, there are some clay joints with a bluish colour that can reach up to a few decimetres in thickness (Denis *et al.,* 2009). Some sandstone layers show an abundance of sedimentary figures of cross layered stratification that not only confirm their partly alluvial origin, but also lead to fractures, which cause the broken aspect of the principal scarp (Denis *et al.,* 2009).

2.2 Weathering of Sandstone

The physical environment has a great influence on the rate of sandstone weathering and therefore rock art degradation (Leuta, 2009). The reason for this being that it can act on its own, as well as influence chemical reactions in the base rock, the pigments and at the interface between the pigments and the base rock (van Rijssen, 1987). Weathering processes can be mechanical, chemical or biological. Mechanical weathering refers to the breakdown of rock into fragments exclusively by mechanical processes. Chemical weathering involves the decomposition of rock minerals by agents such as water, oxygen, carbon dioxide and organic acids (Small & Clark, 1982) while biological weathering involves weathering by organisms and microorganisms that induce aesthetic changes to rock surfaces through chemical and mechanical alteration processes (de los Ríos *et al.,* 2009). The distinction between mechanical and chemical weathering is rather subjective though, as in most cases they not only act together but can reinforce each other as well (Small & Clark, 1982).

Over the last few decades two major environmental controls on physical and chemical weathering have been identified as temperature and moisture (Batchelor, 1990; Meiklejohn, 1994). Moisture is a key factor in many processes of weathering and deterioration of sandstones (Goudie & Viles, 1997). Since rock surfaces within sandstone rock shelters are mostly sheltered from rainfall, other sources of moisture must be considered, for example capillary rise from groundwater and mist (Mol & Viles, 2010). Studies have found that in most cases the largest source of moisture run-off on the rock surface appears to be from internal moisture transport especially along bedding planes and large fractures where porosity and permeability are locally higher (Mol & Viles, 2010). Higher temperatures mostly enhance the effect that moisture has on weathering rates and moisture fluctuations can occur as a result of temperature changes.

Through the above discussion it is clear that rates of chemical and mechanical weathering are a function of temperature and moisture conditions (Huggett, 2003). Even though sandstone is more durable than siltstones and mudstones and less prone to slaking (Sumner *et al.,* 2009) it will inevitably weather and erode. The conclusion can therefore be drawn that there are a number of factors responsible for sandstone weathering, operating through chemical and/or mechanical actions, which in turn contribute to the deterioration and weathering of San rock art. Although chemical and mechanical weathering actions act together in most instances, some factors responsible for sandstone weathering will be discussed further by addressing the actions of chemical and mechanical weathering individually.

2.2.1 Chemical Weathering

Chemical weathering is the breakdown of rock through chemical processes, although chemical reactions need moisture to operate, temperature mainly controls the response rate of the chemical reaction involved in sandstone weathering (Warke & Smith, 1998). Sandstone surfaces that are totally exposed, as opposed to within shelters or caves, can experience rapid temperature fluctuations, exceeding 2°C/Min, particularly when exposed under partly cloudy conditions (Meiklejohn *et al.,* 2009). Such fluctuations have consequences in terms of chemical weathering too as generally speaking, for every 10°C increase in temperature, the rate of a chemical reaction increases by a factor of two (Ollier, 1984). However, in cases where sites are found beneath rock overhangs with limited exposure to environmental factors, Meiklejohn (1994) found that although temperature plays a significant role in sandstone weathering, moisture appears to be the main driver. This notion has also been supported by chemical analyses from Main Caves at Giant's Castle which support the argument that the rock moisture regime in the sandstone has played a major role in the weathering thereof (Meiklejohn *et al.,* 2009; Leuta, 2009).

Quarts grains of the Clarens Formation sandstones are, as previously mentioned associated with feldspars. Feldspars play a crucial role in the weathering of sandstone as the proportion of feldspars in sandstone decreases with an increase in weathering/age (Meiklejohn, 1994). Feldspars are particularly vulnerable to internal rock stresses exerted by processes such as hydration, which leads to the minerals in the rock often degrading into clay minerals through chemical weathering (Kamh, 2005). Degraded clay minerals can also be a source of calcium that can form gypsum crusts (Meiklejohn, 1994; Hoerlé, 2005), which in turn deteriorate rock paintings through chemical weathering as these precipitates are frequently observed attached to pieces of rock that have "flaked-off" (Meiklejohn *et al.,* 2009).

Porosity and permeability also have an important effect on the rate of sandstone weathering and hence of the paintings (Leuta, 2009). Weathering products are transported through the rock's pore spaces, as it is a channel through which water moves, and as a consequence also the weathering products (Yatsu, 1988). Because pores and fractures channel the entry of moisture they also control the intensity of weathering processes (Leuta, 2009). If the porosity of a rock therefore increases, so do the chemical reactions that take place on the surface (Yatsu, 1988). Chemical reactions mainly operate at the scale of a rock outcrop, where the pattern and intensity of weathering is usually a function of a fracture (joint, bedding plane or fault) and density, and also at the mineral scale where alterations follow cracks, fissures and other surfaces of weakness (Bland & Rolls, 1998). A low porosity, together with high microporosity, however, precludes the movement of moisture through the sandstone massif in the Drakensberg, although some seepage does occur along joint lines (Meiklejohn, 1994).

Porosity will have a substantial impact on weathering processes affecting sandstone as sandstone is suggested to be a porous rock type in most instances. In the Clarens Formation it has been found, however, that the more weathered sandstone portions do not have any significant proportions of pores with diameters less than 0.1 µm and micropores are therefore not as responsible for rock art weathering as previously thought (Meiklejohn *et al.,* 2009). Instead, this suggests that the weathering processes that are active are as a result of the individual pores becoming even larger, rather than the formation of new pores (Meiklejohn *et al.,* 2009). Through this process porosity is increased even more by the enlargement of the existing rock pores during the process of chemical weathering thereby enhancing moisture movement in the rock which in turn enhances the weathering of the rock at or near the rock surface (Meiklejohn, 1994). Enlargement of existing pores is a threat to rock art conservation as fluctuations in surface moisture, which can also be driven by air humidity, may then give rise to other weathering processes such as salt crystallization, hydration and dehydration of minerals, precipitates and clays and solution processes (Meiklejohn, 1994).

The effectiveness of weathering solutions in the chemical weathering process is greatly influenced by pH, as well as by temperature (Leuta, 2009). The pH of rainfall is normally in the region of 5.5 – 6.2, while that of pure water is 7 (Bland & Rolls, 1998). Rainwater has a lower pH (meaning it is more acidic) because of the presence of dissolved carbon dioxide. The pH of rainwater is mainly affected on a local scale by factors such as the presence of aerosols (Bland & Rolls, 1998). Since the presence of calcite is essential in understanding the nature of chemical weathering of the Clarens Formation, the pH of rain water at each study site should be monitored individually as it may contribute to the formation of this precipitate (Meiklejohn, 1994) and hence enhance chemical weathering processes responsible for the destruction of the art.

2.2.2 Mechanical Weathering

Mechanically, sandstone can break down in numerous ways. 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 also very 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).

The compressive strength of sandstones depends on the porosity thereof, the amount and type of bonding material as well as the composition of the grains (Bell, 1983) comprising it. The total pore volume and pore size also affects 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 (Yatsu, 1988). The strength of sandstones is reduced further when the pores are saturated (Sumner & Nel, 2002). The porosity and mineralogy of the Clarens Formation is structured so that moisture exerts a major influence on weathering processes (Batchelor, 1990). In short, porosity will increase and micro-porosity will decrease as the rock becomes more weathered due to moisture fluctuations, thereby providing an environment that is even more susceptible to weathering (Rosenfeld, 1988).

Cycles of moisture, or 'wetting and drying' is known to have a weathering effect on rock (Sumner & Loubser, 2008). Weathering through wetting and drying is a process that involves the rock expanding during moisture uptake and then contracting on drying of the rock (Hall, 1988). In rock shelters, exposed rock surfaces experience cycles of wetting and drying when, for example, short rain events is followed by periods of evaporation (Leuta, 2009). Similarly, summers in the Drakensberg experience frequent thunderstorms which can also produce rapid changes in temperature and moisture presenting an environment favourable for flaking (Meiklejohn, 1994). In the Drakensberg the minimum temperature recorded for exposed sites is -6.1°C and the maximum 50.1°C (Sumner & Nel, 2006) while daily ranges regularly exceed 30°C (Meiklejohn, 1994). Great temperature variability, like those recorded in the Drakensberg region, creates the potential for thermal fatigue and shock (Sumner *et al.,* 2009).

It has been suggested that rapid weathering, mainly due to wetting and drying cycles, is expected in instances where sandstone grains are loosely packed with little or no point contact as well as where the clay content is high (Sumner *et al.,* 2009). As with chemical weathering, wetting and drying is equally dependent on moisture and temperature fluctuations. At the study sites moisture and temperature variability is apparent, but despite the evidence at these shelters that active chemical weathering is taking place, it is unlikely that it will be continuously active at especially the dry Battle Cave site since the weathering reactions require moisture (Walderhaug, 1998; Meiklejohn *et al.,* 2009).

Although feldspars play a significant role in the chemical weathering of sandstone other forces that include moisture should not be neglected. As the rock wall is an outlet for water that is transported from the interior of the rock mass to the rock surface, so it contributes to weathering and the reduction in hardness of the rock surface itself (Mol & Viles, 2010). Honeycombing, for example, along the bedding planes act as water outlets, resulting in a drier rock face, but the movement of moisture in these areas decreases the rock strength. Where no outlet is available flaking will occur as moisture will accumulate behind the rock surface (Mol & Viles, 2010).

Sandstone is thus continuously weathering through a series of chemical and mechanical processes. Because the sandstones of the Drakensberg are the canvas on which the San people of this region chose to leave their history on, the weathering of the sandstone massive is considered to be mainly responsible for the deterioration of these San paintings. Ideally all processes involved in the weathering of sandstone should be fully understood before efforts can be made to conserve rock art as conservation strategies should be developed in such a manner that addresses weathering processes acting individually as well as together.

2.3 Rock Art Weathering

While weathering of stone is essential for the evolution of life on earth, the deterioration of culturally significant stone artefacts represents an irretrievable loss of our cultural heritage and history (Warcheid & Braams, 2000). In the Drakensberg, which is well known for its high concentration of painted San rock art, it has been established that the art suffers from the natural weathering of the Clarens Formation sandstone (Hoerlé, 2005, 2006). The fracture pattern of the Clarens Formation is often a cause of the deterioration of rock art, along with chemical, mechanical and biological weathering processes (Denis *et al.,* 2009). The massive structure of the sandstone layers and their natural tendency to break out in meter sized blocks constitutes a major risk for the conservation of rock art (Denis *et al.,* 2009).

Weathering is an ongoing process and without lasting preservation methods deterioration of stone will continue as it is exposed to weathering agents. Environmental agents that affect rock art weathering the most are wind, sunlight and temperature, as well as rain, snow and moisture (Warcheid & Braams, 2000). These agents encourage both physical and chemical weathering processes. While physical weathering processes will affect the stability of the rock matrix, chemical weathering will act through chemical corrosion of the stone-forming minerals, such as oxidation and hydration reactions as well as dissolution of carbonates and solubilsation of some elements from silicate bearing minerals (Keller, 1957).

During chemical and physical weathering studies, three key factors, namely rock temperature, rock moisture and rock properties have to be taken into account (Hall & André, 2001). Temperature and humidity act as shearing forces between layers or portions of a rock wall (Spagnolo *et al.,* 1997). This results in weakened material being formed during the numerous cycles of these forces and causes the appearance of micro-cracks or anomalous strains on the surface which ultimately result in the decay of rock art paintings. Changes in moisture and temperature can induce deformations in the artwork thus contributing to the decay process (Spagnolo *et al.,* 2003). Studies on cultural stone revealed the importance of specific weathering agents such as these factors, acting independently or together, and have shown that they have a major influence on the type, degree and rate of weathering taking place at any given site (Hall & André, 2001).

Biotic agents, including bacteria, algae, fungi and lichens are also common, if not ever-present in most weathering environments (Pope *et al.,* 2002). Biotic weathering agents are among the most aggressive factors in rock weathering as they contribute to acid dissolution, oxidation, chelation, and physical fracturing induced by root hyphae (Pope *et al.,* 2002). Salts also contribute to the weathering of rock art acting through both chemical and physical weathering processes. Salts not only exert physical pressure by thermal expansion, hydration and crystallisation (Goudie & Viles, 1997) but also catalyse dissolution reactions, causing accelerated chemical weathering (Xie & Walther, 1993).

Despite the impact that biotic and chemical agents have on the weathering of stone, human weathering factors have been the key subject of numerous cultural stone studies (Pope *et al.,* 2002). The reason for this being that cultural stone is, by definition, physically altered in the first place by human activity as it is mechanically broken down by processes of carving, abrasion and quarrying (Pope *et al.,* 2002). Human effects are not limited to mechanical forces since casual human contact such as touching, walking and breathing (additions to humidity) impacts on the deterioration of cultural stone and should not be neglected (Paradise, 1995).

From the above discussion it is evident that there are numerous factors that influence rock weathering and consequently rock art deterioration. Although these factors act together in most instances, it is important to understand the impacts each factor has independently on rock art deterioration. The following discussion will therefore consider the impacts of some major factors playing a role in rock art weathering.

2.3.1 Rock Temperature

Although the precise impact of rock temperature on San paintings is not clear (Meiklejohn *et al.,* 2009), it is possibly the most significant control on mechanical rock breakdown (Warke & Smith, 1998). The role of rock temperature on weathering is not only important because of stresses induced in rocks, it is also a direct influence upon factors such as moisture availability and evaporation rates (Smith, 1977). Temperature operates indirectly on rock weathering through its control on moisture movement and processes such as salt weathering and freeze/thaw and directly through the process of “insolation” weathering (Warke & Smith, 1998). Temperature also controls chemical weathering processes which may contribute directly to disturb the rock fabric through, for example, alteration of primary minerals to expanding lattice clays (Warke & Smith, 1998).

Broadly speaking, rock surfaces in the Drakensberg are exposed to two main sources of heat: the sun, through solar radiation and natural fire (Leuta, 2009). According to Jenkins & Smith (1990), rock surface temperatures may vary in response to numerous factors which can be divided into two categories:

1. Rock properties, such as albedo, thermal conductivity, specific heat capacity and moisture content, and
2. Climatic and meteorological controls operating over a range of temporal and spatial scales.

Climatic and meteorological controls comprise the distribution of incoming solar radiation, cloud and wind conditions, air temperature and relative humidity (which controls moisture evaporation from within the rock). All these factors are then (independently or in synergy) influenced by time of day, time of year and altitude (Jenkins & Smith, 1990).

Despite being influenced by the above mentioned controls, the primary control on rock temperature is seen to be exposure to direct insolation (Smith, 1977). "Insolation" weathering can be defined as weathering by direct heating of a rock body in which the thermal properties of the rock control temperatures kept by the rock as a whole or by individual mineral grains (Warke & Smith, 1998). The surface layer of a rock expands when heated by the sun's rays and then contracts when the heat source is temporarily cut off. Breakage (in the form of flaking, granular disintegration etc.) occurs when the strain due to expansion and contraction exceeds the rock's elastic limit (Bland & Rolls, 1998).

High rock temperatures due to insolation heating, particularly on vertical rock surfaces at high latitudes, cause steep temperature gradients between the temperature of the air and that of the rock surface (Sumner *et al.,* 2004). Insolation heating can contribute to the faster stimulation of temperature variations between the rock surface and the rock interior (Zhu *et al.*, 2003). These variations in temperature relate mostly to rock mineral composition and to a lesser extent to pore size and density, and therefore imply that rapid temperature variations may lead to the constant expanding and contraction of the rock minerals (Zhu *et al.*, 2003) consequently leading to weathering.

Although temperature fluctuations cause rock weathering, the possibility that it causes weathering in its own capacity has been widely debated. Irrespective of whether temperature changes alone can cause the fracturing of rocks, it is generally accepted that weathering is enhanced where rapid and repeated high magnitude temperature changes occur in conjunction with moisture absorption and/or chemical weathering (Smith, 1977). Under conditions of rapid surface heating internal temperature gradients are established which are usually much greater over the first 5cm below the surface than over the second 5cm. The stresses caused by steep thermal gradients in the outermost layer may thus aid in the scaling, flaking and granular disintegration of the rock (Smith, 1977). Removal of the heat source, or wind blowing on the surface, can in turn cause rapid cooling (Sumner *et al.,* 2004). If the heating and cooling cycles are short-term high magnitude events then the situation may be even more serious as heating and cooling cycles not only establish compressive and tensile stress within the rock (Sumner *et al.,* 2004), but may also reflect a range of additional environmental factors (Jenkins & Smith, 1990). Temperature cycles can also generate fatigue in rock (Hall, 1999) which may result in the mechanical breakdown thereof (Sumner & Nel, 2006).

Generally, rocks that undergo short-term, but high frequency temperature fluctuations are associated with greater levels of temperature-induced stress at the rock surface which enhance fatigue failure and the operation of a number of mechanical weathering mechanisms (Jenkins & Smith, 1990). By their nature, the relatively short duration of these fluctuations suggests that only a thin layer immediately beneath the rock surface will be affected as the heat is not transmitted to the interior of the rock (Jenkins & Smith, 1990). In many instances mechanisms of rock breakdown are restricted to this outer layer as the thermal gradient is much steeper in the outer layer of the rock (Leuta, 2009) and is therefore responsible for granular disintegration (Whalley, 1984) and surface flaking. In the case of rock art this is a concern as the San used the outer layer of sandstone rock facies to paint on. Also important is that any surface microfracturing would in fact promote further weathering by allowing the entrance of moisture and/or salt in solution (Jenkins & Smith, 1990) which will harm the art further.

Through the above discussion it is clear that solar radiation and the ambient temperatures surrounding a specific site both influence rock temperatures significantly (Meiklejohn *et al.,* 2009). In sheltered areas like Main Caves, in the Giants Castle Game Reserve, diurnal rock temperature regimes mostly follow air temperature trends. At more exposed shelters like Battle Cave, situated in the Injisuthi Valley, rock temperatures have the influence of direct solar radiation on the rock surface (Meiklejohn *et al.,* 2009) which will cause more temperature variability. In order to understand this temperature variability within different rocks at different sites it is important to have some knowledge about the movement of heat (in all forms) through a rock body.

2.3.1.1. Thermal Conductivity

Heat is normally conducted through the sub-surface of a rock body when the temperature of the rock surface is raised (Bland & Rolls, 1998). Thermal conductivity is therefore defined as a measure of the rate at which heat is transmitted through a substance, such as rock mass (Bland & Rolls, 1998). Generally rocks have a low thermal conductivity, which consequently results in a marked temperature gradient (Bland & Rolls, 1998; Huggett, 2003). Steep temperature gradients in turn result in weathering processes such as thermal shock and thermal stress fatigue.

Thermal shock occurs when thermally induced stress is of such magnitude that the rock is unable to accommodate the required deformation fast enough and fails (Hall, 1999). A rock will fail, in other words, if the temperature gradient is too steep and the amount of time to accommodate it is short. The typically quoted theoretical $\Delta T/\Delta t$ (change in temperature/ change in time) threshold for thermal shock to occur is 2°C/min (Yatsu, 1988). If the threshold thus exceeds 2°C/min, then thermal shock may occur and the rock may fail. The process of thermal shock is accelerated in the case of vegetation burning or lightning strikes on the rock (Sumner *et al.,* 2004). Rapid rock temperature changes can also occur under partly cloudy or windy conditions, or where shading occurs (Hall *et al*., 2002).

Thermal shock is a threat to southern African rock art as it is a natural occurrence operating in an environment that is open to the elements. If, however, the short-term but large magnitude ΔT/Δt fluctuations are too slow to cause thermal shock at any given site, then there is a possibility that they can nevertheless be factors of thermal stress fatigue (Hoerlé, 2006). Thermal stress fatigue is a process where the rock experiences a series of thermal events that may not cause immediate rock failure, but through repetition on a diurnal or seasonal scale, can ultimately result in granular disintegration or the production of new fractures (Yatsu, 1988). Stressing of rock occurs when a temperature gradient is established between surface and subsurface material and when differences exist in coefficients of thermal expansion between adjacent mineral grains (Ollier, 1984; Yatsu, 1988). To explain possible damage to rock art caused by thermal stress fatigue, however, requires knowledge of rock properties (such as mechanical strength, porosity, chemical composition and structural properties) at individual sites (Leuta, 2009).

2.3.1.2 Frost Weathering

The Drakensberg is well known for its cold winters. Although snowfalls in the region are uncommon, light falls may occur in winter at some altitudes (Sumner & Nel, 2006). Changes in temperature during winter months, in especially cold regions, may give rise to freeze-thaw cycles which facilitate other types of deterioration (Aberg *et al.*, 1999). Frost weathering is suggested to be the process of rock disintegration that takes place when water freezes and so expands within rock (Ollier, 1984). The action of frost weathering is thought to break off small grains while large boulders end up being split into smaller pieces (Aberg *et al.*, 1999). In order to know if a specific site is likely to experience frost weathering, data on rock moisture and temperature are required (Ollier, 1984) as it is the water occupying the pores within a rock body that expands upon freezing which then increases the volume of the liquid by about 9% (Aberg *et al.*, 1999). It is because of this expansion that pressure in the pores builds up which result in fissures, causing the physical breakdown of rocks (Huggett, 2003).

Temperature clearly exerts an important control on frost weathering processes through freezing rates and the number of oscillations across 0°C (Lautridou & Ozouf, 1982). Cryoclasty is a temperature-controlled weathering mechanism, which is dependent on the availability of water within the rock as well as temperatures low enough for ice to form and cause damage (Hoerlé, 2006). The temperature at which ice is formed in rocks is known to decrease below 0°C under the following conditions:

- A decrease in pore size;
- A decrease in water contend and;
- An increase in dissolved salt content (Matsuoka, 1994).

Despite freeze-thaw weathering being a recognised weathering mechanism there has been a substantial amount of debates around the effectiveness thereof. The reason for this being that although it has been shown that the behaviour of water at temperatures around the freezing point gives rise to a process of rock breakdown (Hall, 1997), the temperature at which freezing occurs can vary substantially, even for the same site (Hall, 1995). It has been argued that there is, contrary to popular belief, no particular value of temperatures within which freezing of water will take place in rock (Hall, 1995). Substantial doubt also exists as to the actual freeze-thaw mechanisms and whether the mechanism is active at all (Hall, 1995). It is thus clear that freezing conditions in a specific area are not necessarily adequate evidence of frost weathering taking place (Hall, 1995; Sumner & Nel, 2006) and careful studies should be conducted at each rock art site individually before conclusions on the process of freeze-thaw weathering can be drawn.

Through data acquisition Meiklejohn (1994) showed that despite temperatures dropping below 0°C in the study area during winter, the possibility of frost is restricted to moisture availability. The Battle Cave study site, due to being exposed to direct radiation, experience not only the warmest, but also the coldest rock temperatures of any known rock art site in the study area (Meiklejohn, 1994). Despite these extreme climatic conditions Battle Cave does not experience temperatures cold enough for freeze-thaw weathering to occur (Meiklejohn, 1994; Hall *et al.,* 2002) and the conclusion can be drawn that it is unlikely that many, if any, other sites will experience this process (Leuta, 2009). However, considering snow-free rock surfaces, and accepting the need for moisture availability, it must be recognised that chemical and/or water-based mechanical processes may occur over a much greater portion of the year than air temperatures suggest (Hall *et al.,* 2002). Rock temperatures of 20-30°C could, indeed, give rise to active chemical weathering, salt weathering as well as wetting and drying in the presence of moisture (Hall *et al.,* 2002) resulting mainly from mist and some snowfalls during winter months in the Drakensberg.

Despite evidence that temperature fluctuations can be held accountable for weathering processes on sandstone and hence the deterioration of rock art, it has been argued that temperature changes on their own may not be sufficient enough to cause the weathering of the Clarens Formation sandstone in protected rock art shelters (Meiklejohn, 1994). The possibility that moisture changes rather than temperature changes or even a combination of the two should thus be considered as being the major reason for rock weathering and rock art decay in the Drakensberg (Leuta, 2009).

2.3.2 Rock Moisture

Considering the above discussion there is thus a great potential for weathering through thermal stresses at exposed locations (Meiklejohn *et al.,* 2009). Most rock art sites in the Drakensberg are located within rock shelters and on exposed surfaces though and therefore it can be assumed that thermal fatigue and other thermally affected weathering processes are not singularly responsible for the breakdown of rock and the deterioration of San paintings in rock shelters (Meiklejohn *et al.,* 2009). Although temperature is considered to have an impact on rock art weathering other ambient environmental data should be considered, in particular, the role of rock moisture. The reason for this is that rock weathering is most active in protected sites, underneath rock overhangs, where the rock temperature regime is the most stable (Meiklejohn *et al.,* 2009) and therefore not contributing, to a great extent, to the weathering processes operating at the rock surface.

Rock moisture is considered to play a crucial part in rock weathering processes causing damage to rock art (Leuta, 2009). Transport mechanisms leading to the leaching of minerals and accretion of salts or other solutes on the art, chemical weathering and biotic activity are all dependent on the presence of water (Leuta, 2009). Weathering processes that take place at or near 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, 1994). Weathering processes possibly operating at this boundary are salt crystallisation, hydration/dehydration of minerals, clay minerals and precipitates, solution processes, and hydrolysis. These processes are enhanced by changes in humidity (Meiklejohn, 1994) which might lead to the weakening of rocks as saturation may reduce the dry compressive strength of sandstone by up to 60% (Bell, 1983; Meiklejohn, 1994).

Currently, the rock moisture regime is considered to be the most important contributor to weathering-related rock art deterioration at Main Caves and Battle Cave (Meiklejohn *et al.,* 2009). Rock moisture can act through a number of weathering mechanisms. However, the most detrimental weathering processes are, as previously mentioned, those that occur at or near the rock surface as they are the most likely to cause granular disintegration and the enlargement of pores and bedding planes (Meiklejohn, 1994, 1997).

Rock moisture operating at pore scale can pose a great threat to rock art paintings, but where water runs down the rock surface and over the paintings (Figure 2.2) destruction of the art is at its greatest (Bednarik, 2003). The reason for this is that wherever surface run-off occurs regularly, mosses, fungi and lichens may grow (Leuta, 2009). Running water not only dissolves soluble pigments, causing paintings to fade, but can also deposit minerals on the surface that may cover the art (Batchelor, 1990). Water running over painted rock surfaces can also dissolve minerals and precipitate salts (Figure 2.1) on or near the surface (Rosenfeld, 1988; Batchelor, 1990). The presence of precipitates, like those on the "Battle" scene of Battle Cave, 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 rock overhangs, some is, nevertheless, exposed directly to rain and running water (Hoerlé & Salomon, 2004; Hoerlé, 2005, 2006; Hall *et al.*, 2007a). Wherever this is the case fading, leaching precipitates and growing biological organisms will inevitably lead to the decay of rock art paintings.

Figure 2.1: Example of precipitates on the rock face of the Battle Scene (Central image approximately 12cm).

Figure 2.2: Example of water running over the rock surface at Game Pass Shelter (Central image approximately 30cm).

As San paintings are located on the rock surface (Hall *et al.*, 2007a, b), they are affected by any rock weathering that occurs in the area close to the rock surface (Meiklejohn *et al.,* 2009). The presence of moisture at, in or near the rock surface is thus likely to be damaging to the rock art itself as it not only affects the art through the processes described, but also allows mechanical and biological weathering to take place. Given that weathering is enhanced where the moisture regime is dynamic, the deterioration of rock paintings will possibly be accelerated where water is able to penetrate into the rock (Meiklejohn, 1994, 1997). It is therefore crucial for conservation strategies to focus on decreasing moisture, in any way that will not cause more harm, at rock art sites.

2.3.3 Aspect

Microscale factors are very important in studies of cultural stone (Pope *et al.*, 1995). The "microscale" ranges from a few tens of meters down to submillimeter scale (in the pores and mineral boundaries of the rock) (Pope *et al.,* 2002). One microscale factor that has received significant attention is the orientation to solar insolation and the impact of solar insolation on weathering has been debated for over a century (Pope *et al.,* 2002). While some authors argue that thermal expansion causes enough stress to affect the rock and cause mechanical weathering, others state that thermal expansion is not efficient enough (Bland & Rolls, 1998).

Despite these differences one thing is clear; studies on cultural stone have shown preferences for sun-facing and sun-shaded weathering (Pope *et al.,* 2002). One author who supports enhanced weathering of cultural stone due to thermal stress in sun-facing exposures is Paradise (1995). Although direct exposure to the sun can cause thermal shock when the heat source is removed, or the wind blows over the surface, shaded exposures are subject to different extremes. The reason for this is that moisture efficiency on exposures protected from evaporation could account for enhanced weathering (through increased dissolution or solution of more common organics such as lichen or algae) (Pope *et al.,* 2002).

Aspect not only influences the amount of solar radiation that a rock receives. It has been suggested that rock outcrops, stone buildings and gravestones in the humid temperate zone also weather more rapidly on sides facing prevailing wind and rain than on their sheltered or lee sides (Williams & Robinson, 2000). The impacts of wind and rain are thus dependent on aspect and according to Smith (1977) rock weathering, especially the mechanical breakdown of rocks, is enhanced at sites where moisture is absorbed and rapid and marked temperature changes occur (through for example the wind). Therefore, weathering should typically be enhanced on east and west facing slopes, below cliffs, as they remain in the shadow for longer than other slopes while still experiencing rapid increases and decreases in temperature when exposed to insolation (Smith, 1977).

2.3.4 Albedo, Light Transmission and Rock Art Pigments

Absolute surface temperatures are controlled by two factors, namely albedo and thermal conductivity (André *et al.,* 2004). The albedo of a rock will influence the amount of solar heat that a rock surface absorbs (Hall *et al.,* 2005), and is expressed as a percentage of total solar radiation received (Bland & Rolls, 1998). When an object reflects most of the light that hits it, it appears bright and therefore has a high albedo. When an object absorbs most of the light that hits it, it appears dark and has a low albedo (Leuta, 2009). Because dark rocks absorb heat faster than lighter ones they induce a low albedo and therefore, they tend to have higher surface temperatures (Dirmhirn, 1958). These temperatures will remain high, however, only if the thermal conductivity of the rock remains low (Kerr *et al.,* 1984). If both these conditions exist within a rock surface (low albedo and low thermal conductivity), then steep thermal gradients between the rock surface and subsurface might cause rock weathering forms like spalling, flaking, and cracking (André *et al.,* 2004).

The albedo of a rock is determined by the light regime in the first centimetre of a rock outcrop which is, in turn, dependent on the incident light flux (André *et al.,* 2004). The light regime will vary with season, time of day, and surface orientation and also depends on certain rock properties such as colour, translucence, porosity, and size of the framework grains as well as the water content of the rock (Nienow & Friedman, 1993). Broadly, the colour of any rock body is dependent on three main parameters namely:

1. Original mineralogical composition of the rock (e.g. light-coloured acidic rocks versus dark basic rocks);
2. Vegetal colonisation of the rock, which alters the thermal regime of the rock surface;
3. Chemical and biochemical weathering processes operating at the surface (for example Aeolian and organic).

Despite controlling many processes at the rock surface, light penetration into rocks is considered to be the primary factor controlling the location of endolithic biotic communities (Hall *et al.,* 2008). Light penetration into rocks also influences other weathering processes (André *et al*., 2004; Duane, 2006) which in turn will influence the preservation of rock art (Hall *et al.,* 2008). In Light transmissive lithologies, like sandstone, there is a progressive transfer of heat. The reason for this being that light penetrates the outer shell of the light transmissive rock and therefore the thermal gradient will not be as steep as is the case where total exchange occurs at the rock surface (Hall *et al.,* 2008). Consequently, higher temperatures and more rapid thermal changes will be found in rocks where light can penetrate, as opposed to within non-transmissive lithologies (Hall *et al.,* 2008).

Thermal properties are lithologically variable where, for example, dark coloured rocks (with a low albedo) may absorb more incident solar energy resulting in higher surface temperatures compared to light coloured (with high albedo) rock exposed to the same conditions (Warke & Smith, 1998). The general conclusion that can be drawn is that dark rocks will be hotter as they will absorb more solar energy than light-coloured rocks (Hall *et al.,* 2005). This argument may extend to within-rock mineral-to-mineral colour differences inducing thermal differentiation, and hence weathering differences within a specific rock (Hall *et al.,* 2005).

Although darker coloured rocks are expected to achieve higher temperatures than lighter coloured rocks due to their low albedos, Hall *et al.* (2005) found that under certain conditions the reverse may also apply (Sumner & Nel, 2006). Their study based in northern Canada proved that the high albedo components can have the same (or possibly higher) temperatures compared to low albedo components (Hall *et al.,* 2005). It was clear that while minerals absorb available energy as a function of their albedo, with dark absorbing more than white, two factors had an impact with respect to the anticipated and observed temperatures (Hall *et al.,* 2008). The first factor is that albedo changes with angle of incidence of the sun to the receiving mineral and that the angle of the sun to any given mineral will thus not only affect (for light-transmissive minerals) the amount of penetration, but it will, by means of changing albedo, also impact the amount reflected (Hall *et al.,* 2008). For rocks with light-transmissive minerals, the thermal gradient will therefore be less and stresses commensurately lower. Where light penetrates larger thermal variations at depth can be expected which will worsen the responses of the mineral properties (thermal conductivity of thermal coefficient and expansion) and in turn influence the thermal response of the mineral through time (Hall *et al.,* 2008). The second factor is that although darker minerals must absorb more radiation, studies have shown that where the mineral is hotter than the air it may release energy faster than the light-coloured minerals and also cools faster, thereby inverting the expected dark is hotter than light response (Hall *et al.,* 2008). The result of a more rapid loss of energy will also impact grain-to-grain thermal regimes and consequently the stresses associated with it (Hall *et al.,* 2008, Hall *et al.,* 2010).

Light transmissive properties as well as the albedo of rocks thus have an impact on the weathering of rocks, but with regard to San rock art paintings a knowledge of the chemical composition of the pigments and binders used by the San artists is also essential for the interpretation of rock weathering studies (Prinsloo *et al.,* 2008). The reason for this being that pigment albedo may influence temperatures, thereby having a direct impact on the weathering of the art itself in addition to the rock on which the art was created (Hall *et al.,* 2007b).

It has been established that minerals such as iron oxides and clays form the principle components of pigments used in many rock art paintings (Arocena *et al.,* 2008). In most cases rock art pigments do not penetrate into a rocks pores but rather comprise a discrete layer on the rock surface (Hall *et al.,* 2007b). Generally the mineral composition of pigments consists of whewellite, gypsum, hematite, quartz, and alumino-silicate minerals (Arocena *et al.,* 2008). Hematite is the mineral that provides the red hue to pigments, while gypsum generates a whitish hue to pigments. The black pigments in San rock art is thought to be an inorganic material (e.g. hydrated manganese oxides) which is undetectable by XRD (X-Ray Diffraction) analysis (Arocena *et al.,* 2008).

San rock art that has been stable for some time may, under changing local and world conditions, experience accelerated deterioration (Arocena *et al.,* 2008). Recently, Hall *et al.* (2007b) recognised the important role of the mineral composition of the pigments in regulating the thermal responses and moisture transfer in rock art and, therefore, also their potential influence on the deterioration of the art (Arocena *et al.,* 2008). Data regarding the thermal responses of the white and ochre pigments specifically show that the pigments themselves exert a significant influence on the resulting temperatures. Results indicate that not only can the white pigment be hotter than the darker ochre, but can also exhibit large short-term thermal variations that may impact rock art weathering (Hall *et al.,* 2007b) through processes such as thermal shock and thermal fatigue.

Furthermore, where rock art is exposed to solar radiation, the pigment temperatures can differ from those of the immediately surrounding paint-free sandstone. These differences consequently create differential stresses at the painting boundary thereby facilitating both pigment-to-pigment as well as pigment-to-rock stresses (e.g. thermal and moisture fluxes) that can lead to the deterioration of San art (Arocena *et al.,* 2008). These differential stresses are in many cases a result of a large number of high magnitude $\Delta T/\Delta t$ events and are the product of wind and cloud on heat exchange at the rock surface (Hall *et al.,* 2007b). Such $\Delta T/\Delta t$ events are damaging to the rock and hence the paintings and can possibly be as a result of changes to the cave surroundings for touristic purposes, such as the removal of shading trees to provide better access and visibility (Hall *et al.,* 2007b).

In correlation with the study by Hall *et al.* (2005), on rocks, a study by Hall *et al.* (2007b) on pigment albedo also showed that dark pigments can be cooler than lighter pigments. The reason for this is that the conduction of heat through the pigment to the underlying sandstone is a function of the thermal conductivity and thickness of the pigment and the temperature gradient (Hall *et al.,* 2007b). In contrast to the ochre which has a higher thermal conductivity and is thinner, consequently resulting in greater conduction of heat into the sandstone, the white pigment has a lower thermal conductivity and is considerably thicker, ensuing in less effective heat conduction to the rock beneath which would cause the pigment to tend towards accumulating more heat under sunlit conditions (Hall *et al.,* 2007b).

In addition to the impacts of pigments on light transmission and albedo, the role and attributes of the paints themselves in the weathering of San rock art needs to be considered. The reason for this is that paint acts as a 'surface modifier' (Bullet & Prosser, 1983) that interacts in numerous ways with the material that it was used on. Paint has different physical properties to the material on which it is painted and might act in the following ways:

1. Protect the substrate as well as modify surface properties, including by chemical reactions with the substrate (Bullet & Prosser, 1983);
2. Act as a barrier to moisture exchange from the rock to the atmosphere thereby creating moisture beneath the pigment as well as salt stresses (Hall *et al.,* 2007b);
3. Because of the mechanical properties of paints the paint can respond to environmental stresses differently (Hall *et al.,* 2007b).

2.3.5 Microbiological Organisms

San rock art, although naturally deteriorating with the passing of time, is not only threatened by environmental factors but also by organisms and microorganisms that induce aesthetic changes to our rock art heritage through chemical and mechanical alteration processes (de los Ríos *et al.,* 2009). The effectiveness of biological weathering varies over a wide range of environmental conditions (Viles, 1995). The weathering processes caused by biological activity in stone are commonly known as biodeterioration. Biodeterioration is a degradation process caused by inorganic agents that condition stone surfaces for microbial invasion (Warcheid & Braams, 2000). This is due to the structural changes and the enrichment of inorganic and organic nutrient substrates that these inorganic agents introduce into the stone surface (Warcheid & Braams, 2000). Biological and microbial colonisation of stones and the intensity of the biodeterioration processes on them are strongly influenced by the availability of water (Warcheid & Braams, 2000). The availability of water is in turn determined by the following factors:

- Material-specific parameters, such as porosity and permeability ;
- Environmental conditions of the site as well as the exposure of the art;
- Other environmental factors including rainfall, pH of rainwater, climatic exposure and nutrient sources;

- Petrologic parameters, such as mineral composition and the type of cement of the rock material (Warcheid & Braams, 2000).

Lichens, bacteria and other organisms, individually or in all their possible associations, are known to influence the weathering of rocks in natural or architectural settings (Arocena & Hall, 2004). Depending on the optical properties of the rock, phototrops (such as algae, cyanobacteria and the photobiont of lichens) can be found up to 10mm beneath the rock surface where photosynthetically active radiation is sufficient enough for photosynthesis (Hughes & Lawley, 2003, Hall *et al.,* 2010). The microbiota that colonise building stone form part of a complex ecosystem organised as a biofilm which develops in a way that depends on environmental conditions as well as the physiochemical properties of the material (Denis *et al.,* 2009). These biofilm, often containing bacteria, algae and fungi, (not lichens) have been found to play a key role in the dissolution and precipitation of various minerals and also play a role in weathering processes on many rock surfaces, where they form a skin of organisms, mucal slime, mineral particles and organic salts (Viles, 1995).

Golubic *et al*. (1981) grouped all known rock surface communities by dividing the lithobiontic niche (rock surface community) into:

1. Epiliths (which live entirely on the surface);
2. Euendoliths (which actively bore their own tunnels into the rock);
3. Chasmoendoliths (which live in fissures and cracks);
4. Cryptoendoliths (which occupy pore spaces below the rock surface).

The four lithobiontic niches each in turn have some microbiological species that carries its characteristics. These species are Lichens, Microorganisms, Bacteria, Cyanobacteria, Fungi and Algae (Viles, 1995) and will be discussed in more detail below.

Bacteria are simple microscopic prokaryotes which are able to grow under a wide range of conditions and are often actively involved in mineral transformations (Viles, 1995). Bacteria are unicellular life forms, and are smaller than ca. 2 µm in diameter (Viles, 1995). Many different types of bacteria play an active role in weathering. Chemoorganotropic bacteria, for example, excrete organic acids (such as oxalic and citric acids) which can weather minerals such as calcite. They also produce slimy extracellular polymeric substances which protect them from desiccation and can clog the pores of rocks, and affect their water holding capacity (Sand *et al.*, 1991).

Cyanobacteria, formerly known as blue-green algae, are autotrophic bacteria which rely on photosynthesis for energy and growth (Viles, 1995). They are commonly found on different rock surfaces and their affects are well known, especially in terms of their activity on limestone surfaces where they form a noticeable discoloured (often black) layer (Viles, 1995). Cyanobacteria weather stone chemically through the action of extracellular organic acids (oxalic, citric etc.) which dissolve rock minerals. These acids act directly through boring species (euendoliths), who produce recognisable boreholes, and indirectly through epilithic communities that produce an etched surface (Viles, 1995). Physically cyanobacterial weathering occurs through wetting and drying cycles where the cyanobacteria and their associated mucilage swell and contract upon wetting and drying, especially when the cyanobacteria are growing cryptoendolithically in confined spaces (Viles, 1995).

In contrast microorganisms are defined as organisms which can exist in nature as single cells and are therefore generally microscopic in size (Viles, 1995). Rock surface weathering by microorganisms in general is carried out mainly by microorganisms, as well as lichens (which are eukaryotic lower plants comprised of a symbiotic association of a fungus and an alga), all of which do not require soil as a growth medium (Viles, 1995).

Fungi are eukaryotic, heterotrophic microorganisms which are found mainly on terrestrial and freshwater rock surfaces (Viles, 1995). Characteristically, fungi found on rocks comprise hyphae (often 2-10 µm in diameter) connected to sporangia (Viles, 1995). Fungal colonisation of rock surfaces are affected by the porosity characteristics of the stone involved, which condition the bioreceptivity of the stone (de los Ríos *et al.,* 2009). The weathering actions of fungi involve chemical weathering by organic acids or other substances produced by the fungi (Viles, 1995). Fungi can substantially weaken calcareous substrates and often prepare the substrate for invasion by other species by weakening the calcite cements that hold grains together, thereby allowing rhizoid penetration (de los Ríos *et al.,* 2009).

Green algae, diatoms and other algae have also been found to play a weathering role in rock weathering (Viles, 1995). Similar to cyanobacteria green algae weather rocks through wetting and drying cycles which cause swelling and shrinking of the green algal cell sheaths (made of gelatinous mucilage) which aid the detachment of rock flakes (Viles, 1995). Chemical attack by the green algae may, on the other hand, also play a role in the development of the flaking (Viles, 1995). The weathering action of green algae can thus not be limited to only one process but should be studied at each site to determine the specific cause of weathering at that site.

Lichens are very common on artistic stoneworks and contribute to their deterioration, frequently creating serious problems for their recovery, restoration and conservation (Adamo & Violante, 2000). Lichens are formed through fungi and algae growing in symbiotic associations which, like bacteria, can live on and within rock surfaces (Viles, 1995). Certain features such as water retention or direct exposure to rainwater could be determinants of lichen colonisation as they typically grow in nutrient-rich substrates where water are found (de los Ríos *et al.,* 2009). Lichens can easily be identified as their external effects are noticeable because of epilithic lichen colonisation or the presence of green and dark colorations (de los Ríos *et al.,* 2009).

The bioweathering action of lichens is twofold as it consists of intense disaggregation and fragmentation of the rock surface immediately below the lichen by surface adhesion and hyphal penetration and also aids in dissolution processes and the precipitation and formation of new minerals (Adamo & Violante, 2000). This weathering action involves both biogeophysical and biogeochemical processes. Biogeophysical and biogeochemical deterioration has been mainly identified in the fracturing of substratum surfaces and in the build-up of encrustations formed as a result of the reaction between lichen by-products and the minerals in the stone (Adamo & Violante, 2000). The ability of lichens to absorb and retain water also allows chemical weathering reactions to continue for longer than on bare rock (Adamo & Violante, 2000). In the following sections the biogeophysical and biogeochemical weathering of lichens will be discussed in more detail

2.3.5.1 Biogeophysical Weathering

The early stages of substrate invasion by lichen, fungi and mosses appear to be characterised by mechanical and biochemical weathering producing weathering pits, cavities and fractures (Duane, 2006). The mechanical action of lichen thalli on the rock generally consists of the extensive disaggregation and fragmentation of the lithic surface immediately below the lichen crust (Adamo & Violante, 2000).

Mechanical processes involved in biophysical weathering generally proceed in the following three manners:

1. Rhizoid penetration;
2. Hyphal penetration, and
3. Expansion/contraction of the organic structures during water processing, and production of hydrophilic minerals such as weddelite (Duane, 2006).

The main mechanical action in biogeophysical weathering is the loosening of the rock fabric by encapsulating large grains which ultimately lead to the development of weathering pits (Duane, 2006). Chemical weathering is enhanced where the surface area is increased by redistribution of space beneath the lichen thallus and the mosses (Duane, 2006). This works in conjunction with mechanical weathering processes as rainwater falling on the lichen surfaces and retained in the surface weathering pits will allow expansion/contraction of the biotic structures which provides additional biophysical disintegration (Duane, 2006). Furthermore if biophysical weathering continues it is responsible for the enlargement and deepening of the small-scale structures by mechanical disintegration resulting in the cement (calcite) being preferentially removed by penetrating hyphae and the remaining quartz grains consequently being bound up in moss and lichen hyphae (Duane, 2006).

2.3.5.2 Biogeochemical Weathering

As is the case with many rock weathering scenarios the chemical weathering of rocks could proceed at the same time as physical disintegration (Adamo & Violante, 2009). Microdivision of minerals is generally considered a result of the mechanical action of the thalli. Accelerated chemical decomposition is in turn a result of the above mentioned mechanical fragmentation which mainly increases the surface area of the mineral or rock (Adamo & Violante, 2009). Biogeophysical weathering proceeds when dissolution processes, mainly by organic acids, occur at the microsites where lichens adhere to the rocks. As a result extensive surface etching of the grains incorporated into the lichen thallus and of the rock surfaces immediately below the lichen thallus will follow (Adamo & Violante, 2009). The amount of rock removed by the decay of rock caused by lichens can make a significant contribution to the small-scale formation of fine-grained material deposits (Adamo & Violante, 2009) consequently destroying rock art paintings on the rock surface.

Although lichens weather rocks physically and chemically, biodeterioration is a much slower process than physical or chemical deterioration (Adamo & Violante, 2009). In some instances this slower processes can also have a positive impact on the conservation of rock art as the result of these slower processes is that lichens can offer a protective cover for stones. The reason for this being that the presence of lichen on rock surfaces can retard rainwater absorption, thereby partially lessening dissolution and precipitation processes, and it also prevents the abrasive action produced by airborne sand particles, the impact of raindrops and changes in temperature (Adamo & Violante, 2009).

2.3.6 Plants and Animals

While it has been shown in the above discussion that microbiological organisms can have an impact on the deterioration of rock art, bigger plants such as trees and scrubs can be just as detrimental to the paintings, especially the removal thereof. The removal (or loss) of trees at rock art sites, largely for visitor purposes, influence ambient thermal and humidity conditions (Hall *et al.,* 2007a). Any change in temperature and moisture at rock art sites can, as seen through the discussion of this chapter so far, have an enormous influence on numerous weathering mechanisms thereby posing a threat to the conservation of the art.

The binders that the San people used in pigments can also contribute to the more rapid deterioration of the rock art. It is suspected that San artists used plant sap as binder and, as many plants have oxalic acid as a constituent of the sap, it may have been introduced into the paint in this way (Prinsloo *et al.,* 2008). Even though there is no direct evidence, it has been speculated that San artists also used animal fat as binder as it is still used for the preparation of cosmetic and ritual body paint in San communities in the Kalahari (Rudner, 1983). Although practical experiments have shown that ochre mixed with animal fat can enhance weathering, it would have been very difficult for the San to draw the delicate lines that San rock art is famous for with such a mixture (Rudner, 1983).

Prinsloo *et al.* (2008) found that fat may not only be a component of the pigments used for rock art, but fat can also be found on rock surfaces underneath rock paintings. In their study a concentration of fat on the rock fragment behind certain paintings was found which suggests that the surface of the rock face was first prepared before painting by covering it with fat (probably hot), which would penetrate into the sandstone and prevent the paint from soaking into it (Prinsloo *et al.,* 2008). If this is the case then the fatty layer would hinder the natural flow of moisture through the sandstone and bring about an accumulation of soluble salts, such as sulphates behind the fatty layer, which would cause the layer with the applied pigment to detach from the rock face with time (Prinsloo *et al.,* 2008). Concrete conclusions can, however, not be drawn as to the origin of the fatty layer as the possibility exists that the layer might have another origin than animal fat. The reason for this being that humans (other than the San) have for long periods of time occupied rock shelters such as Barnes' shelter in Giant's Castle where other archaeological evidence has been found. The fatty layer might therefore originate from cooking activities in the shelter (Prinsloo *et al.,* 2008), and might not have been deliberately placed on the rock surface by the San.

While many rock art sites are protected by fences, small animals such as lizards, birds and rock hyraces can still impact on rock art deterioration. Where larger animals such as baboons manage to enter rock art sites or where sites are unprotected, they can cause damage to rock art. As is the case with humans, the impacts of larger animals would mainly include rubbing against paintings or stirring up dust (Leuta, 2009). The accumulation of excreta, by animals such as rock hyraces (Prinsloo, 2007) in deposits may enrich rising groundwater in organic compounds, including urea, with possible consequent salt influx through the rock (Rosenfeld, 1988).

2.3.7 Salt Weathering

Salt weathering is a weathering mechanism that operates predominantly within the first few centimetres of a rock, as the rock may in many instances be saturated with water containing a high concentration of minerals and salts (Batchelor, 1990; Lewis-Williams, 2000). Loubser (1990) notes that the ions found in salts that cause rock breakdown can derive from several sources namely;

- The weathering of cement between quartz grains;
- The decay of organic materials;
- The action of biological processes;
- Or alternatively they can be leached from soils.

For salts to be effective weathering agents they need to enter rock pores in solution (Ollier, 1984). Salts in water are deposited when the water evaporates (Loubser, 1990). As water evaporates, it deposits mineral substances on the paintings (Leuta, 2009). At the same time these minerals are dissolved by water thereby strengthening the tiny particles of sand that make up the sandstone on which so many of the paintings have been created, consequently causing the particles to weather and the paintings to fade (Leuta, 2009). Since many of the pigments used by the San soaked into the rock, this process can continue for long periods of time without a noticeable effect on the painting but when the critical depth for weathering is reached the paintings fade rapidly (Lewis-Williams, 2000).

Salt weathering has been known to cause damage to rock art through a number of ways. Cooke & Smalley (1968) identified three potentially disruptive sources of stress associated with salt weathering namely:

1. Crystal wedging, when salts form from solution under evaporative conditions;
2. Volumetric expansion, when salts become hydrated; and
3. Thermal expansion when salts are heated.

In the Drakensberg changes in temperature during winter may, but most probably do not, as previously discussed, give rise to freeze-thaw cycles in rock. Freezing of water increases the volume of the liquid by about 9% and normally occurs when temperatures are below 0°C and water thus turned into ice. During periods of the year when the temperature remains above 0°C, which is most of the year in the Drakensberg, a similar mechanical weathering effect may be induced by salts penetrating the rock surface through microcracks (Aberg *et al.*, 1999). Because salts are hygroscopic they absorb moisture, resulting in the rock being wetter for longer and consequently prolonging the expansion/contraction cycles (Aberg *et al.*, 1999). Whenever there is a change in humidity, salts can change state between crystallisation and solution, subsequently giving rise to an increase in volume upon crystallisation, leading to the cracking and flaking of the stone (Aberg *et al.*, 1999). The process of crystallisation is enhanced even more whenever salt solutions are able to enter rock discontinuities through hydration (Fahey, 1986) as well as in the case where low temperatures are experienced.

Salt crystals occur on rock surfaces as efflorescences or just behind rock surfaces as subefflorecences (Loubser, 1990). Subefflorecences exert great pressure in spaces between quartz grains and cement and can lead to spalling of the sandstone matrix (van Rijssen, 1987). Case hardening happens when silica from the quartz grains and the cement dissolve in slightly acidic groundwater and is drawn to the rock surface by capillary action (Loubser, 1990). When the water evaporates near the surface the silica is precipitated out, forming a highly resistant bond between the grains near the surface. Because crystallisation is concentrated in the evaporation zone near the surface, it is probably the single most important reason for the flaking of the almost impermeable outer crust and skins of case hardened stone (Loubser, 1990). Although siliceous crust and skins are relatively resistant to weathering agents, salt crystallisation can cause them to fracture and spall. This process is enhanced with the breaking away of loose chunks, leading to the softer inner rock being exposed to weathering agents and hence pigments loss (Loubser, 1990).

2.3.8 Wind

Although the impact of wind on the deterioration of rock art mostly involves other weathering mechanisms, wind-blown particles can themselves also be identified as agents of rock art deterioration (Leuta, 2009). These particles act as abrasives that can cause considerable damage to paintings (Batchelor, 1990). Wind abrasion is generally a very slow process but abrasion can eventually produce cavities at the foot of rock walls facing the prevailing wind (Matsuoka *et al.,* 1996).

In addition, wind can affect weathering processes by evaporating moisture from the rock surface. Indirectly wind could affect rock weathering by aiding the process of evaporation of moisture at the study sites at the rock surface thereby enhancing weathering processes associated with the drying of rocks (Meiklejohn, 1994). At exposed shelters, greater wind speeds are experienced and for this reason wind may increase evaporation at the rock surface contributing towards lower rock surface moisture content (Meiklejohn, 1994). Wind evaporation can also cause salt precipitation which can consequently weather rock art due to crystallization pressures (Batchelor, 1990).

2.3.9 Human-Induced Causes

Through the discussion of previous sections it is clear that natural agents are responsible for the weathering of sandstone and hence rock art. The impact of humans on deterioration cannot be neglected as it is humans who, in many cases, introduce and enhance many of these weathering agents. Although many factors are responsible for the processes causing rock art decay, the main factors are changes in humidity, introduction of light, and with an increase in tourism, an increase in carbon dioxide and an increase in temperature (Rosenfeld, 1988). People also introduce external organisms, including algae and higher plants which are able to establish themselves, particularly near light sources (Rosenfeld, 1988). The presence of fungal hyphae in cracks is an indication of the deterioration of San rock art (Arocena *et al.,* 2008). In turn it is the formation of these cracks, through other weathering mechanisms, that facilitate the growth of fungal colonies. Cracks allow water to enter the pigment and with water absorption the cracks provide a favourable environment for the growth of algae, bacteria, and other microorganisms which are otherwise unable to penetrate (Arocena *et al.,* 2008).

Another human-induced cause of rock art deterioration is the removal of vegetation at sites. The removal of protective vegetation cover, mostly for better touristic viewing, is an example of how humans change the local environment thereby exposing rock art to direct solar radiation (Arocena *et al.,* 2008), consequently increasing thermal stresses and possibly the formation of cracks in the pigments. In cases where surface preparation has taken place and the paintings are on top of a clay-based ground, the clays inhibit water penetration from the rock to the pigments in such a way that any cracking may facilitate water movement from the rock to the air and hence assist in microbial colonisation (Arocena *et al.,* 2008).

For more than a century the deterioration of rock paintings, both from weathering and vandalism, has been recognised as posing a threat to the survival of rock art in South Africa (Vinnicombe, 1966). Vandalism is probably the most offensive action of human beings on San rock paintings (Leuta, 2009) and dates as far back as 1893, when farmers damaged the paintings by creating crude charcoal imitations, scribbling over them, trying to remove them, and lighting fires in rock shelters (Wright & Mazel, 2007). Since then, vandalism has included graffiti, scratching, chiselling, throwing stones at the art, and coating the art with varnish (Wright & Mazel, 2007). The impact of vandalism can only be lessened if management strategies are focussed on educating people about the significance of the art and if the art is protected by fences and guides.

Weathering and deterioration of stone is a natural process, but this process of natural decay has been accelerated by the emission of different man-made pollutants on local, regional and global scales (Aberg *et al.*, 1999). Atmospheric pollution brings new products into the composition of dust and increase the acidity of rainwater (Aberg *et al.*, 1999) which will in turn have a negative impact on rock art. Despite this it has to be mentioned though that the impact of tourism in the Drakensberg is less common in shelters found there (due to being in the open) than in caves (Leuta, 2009) as the atmospheric changes caused by human interference in rock shelters are less severe in open rock art shelters and are also easier to control (Leuta, 2009). Although the original artists also impacted on their environment, the nature and degree of human-induced environmental alteration at present is increased under the impact of developing industrial societies (Rosenfeld, 1988). Man-made processes have therefore in many instances, had a catalytic effect on deterioration through synergetic effects from a combination of different processes (Aberg *et al.*, 1999).

2.4 Summary

Weathering of the sandstone that rock art was painted on by the San people possibly poses the biggest threat to rock art conservation. From this chapter it is evident that chemical, biological and physical weathering processes on sandstone rock surfaces are largely responsible for the deterioration of rock art. Sandstone surfaces weather through numerous ways, including through moisture and temperature fluctuations, wind, salt, human impacts and biotic agents. These factors can work in their own capacity as well as together to enhance sandstone weathering. The paints themselves can also impact weathering processes. If a rock surface was prepared, however, this might protect rock paintings from deterioration or enhance weathering activity underneath the clay layer. Light transmission to sandstone rock surfaces might for example enhance endolithic colonisation where rock art is painted on naturally weathered rock surfaces. The development of endolithic activity appears to be subsequent to cracking of the clay ground though and therefore the ground provides a physical barrier to colonisation and of access to both light and water (Hall *et al.,* 2010). Moisture can also enhance weathering as in the case where the paints cover the clay ground, the ground itself act as a 'surface modifier' which inhibit moisture from accessing the clay, thereby causing physical and chemical changes (Hall *et al.,* 2007a) which might lead to accelerated deterioration.

When taking all processes involved in sandstone weathering into account it can be concluded that chemical processes are more important than purely physical processes in the weathering of sandstones in the study area (Meiklejohn, 1994). In the case of rock art though, the major cause of rock painting deterioration has been argued to be weathering of the rock surface (altered by human actions or not) rather than alteration of the paintings themselves, through a variety of all of the discussed mechanisms (van Rijssen, 1987). In the case of this study, all of the above discussed weathering mechanisms that influence and cause weathering of Sandstone rock surfaces will be considered during the development of the State of Deterioration Classification System as it is these factors that cause, influence and enhance rock art decay in the Drakensberg.

CHAPTER 3: GEOGRAPHIC SETTING AND METHODOLOGY

The aim of this chapter is to provide a background to the uKhahlamba-Drakensberg Park as well as to give a description of the region's physical characteristics that relate to rock art deterioration. The location of the four study sites situated within the Park will be included after which each study site and its characteristics will be discussed individually. The objectives are listed and the methodology used in compiling a Type of Surface Classification System as well as a State of Deterioration Classification System will then follow.

3.1 Location of the Study Sites

The Drakensberg is southern Africa's most spectacular mountain chain and covers an area of approximately 202 200km² (Ecoregions South Africa, 2005). It reaches from the Cape Province to Mpumalanga and is the towering outer rim of the Great Escarpment of the interior plateau of South Africa (McGinley, 2008). The uKhahlamba-Drakensberg Park forms part of the Drakensberg region (Figure 3.1). The Park's western boundary runs along the South African border with Lesotho where the eastern part of the Lesotho range is called the Maluti Highlands. The altitude of the mountain range is between 1 400m and 3 482m above sea level (a.s.l.), while it is positioned between 100km and 300km from the Indian Ocean (Schulze, 1997). The Drakensberg can be divided into two distinct zones. The first region is formed by the main basalt and sandstone escarpment rising to more than 3 400m a.s.l. while the second region is that of the foothill escarpment or Little Berg which consists of steep-sided spurs, terraces and valleys below 2 000m a.s.l. (McGinley, 2008).

The Drakensberg is one of the least drought-prone areas of southern Africa. The climate is dominated by subtropical anticyclones (McGinley, 2008). Annual precipitation is in the region of 1 000-2 000mm on the escarpment, with precipitation being the greatest between November and March accounting for 70% of the annual total while winter months only contribute less than 10% (McGinley, 2008). Mean annual air temperatures are in the region of 16°C, but both seasonal and diurnal variations should be considered. The highest air temperatures (up to 35 °C) occur during summer months on north-facing slopes at lower altitudes, while the lowest temperatures occur during winter nights in the summit areas (McGinley, 2008).

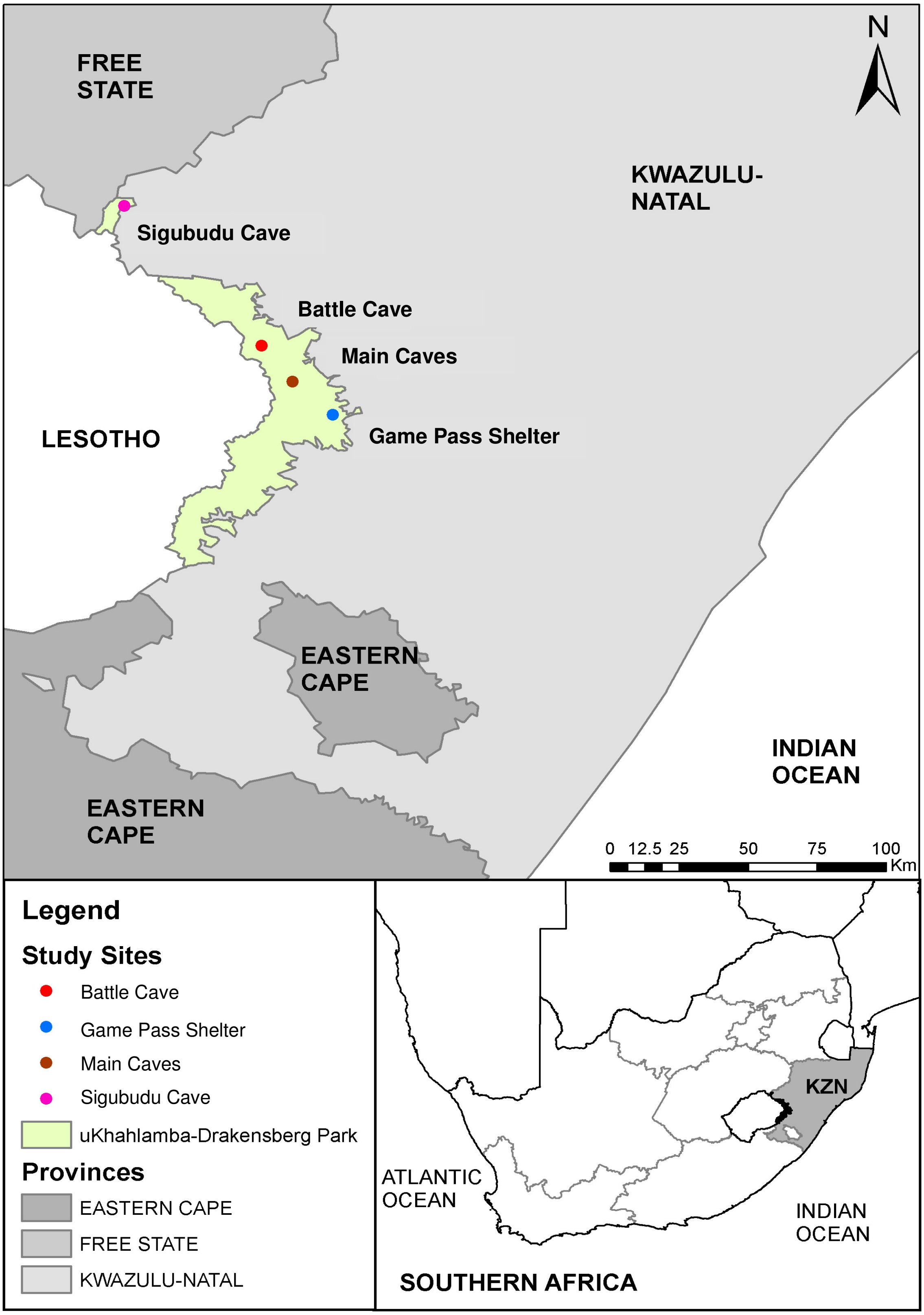


Figure 3.1: Location map of the four study sites.

The uKhahlamba-Drakensberg Park comprises 12 protected areas established under 4 different designations established between 1903 and 1973. Although the 12 protected areas consist of one National Park, four Nature reserves, six State Forests, and one Game Reserve (McGinley, 2008), this study focussed on four protected rock art shelters in the uKhahlamba-Drakensberg Park administered by Ezimvelo KwaZulu-Natal Wildlife. Even though these sites are termed caves at times, it would be more appropriate to identify them as shelters as they are open to climatic factors such as the sun, wind and rain (Hall *et al*., 2007a). The four rock art shelters are (Figure 3.1):

1. Game Pass Shelter near the Kamberg Rest Camp, at an altitude of 1970m a.s.l.
2. Battle Cave (29°17'S. 29°31'E.) near the Injisuthi Rest Camp, at an altitude of 1700m a.s.l. to the north-west of Giant's Castle
3. Main Caves (29°09'S. 29°25'E.) near the Main Rest Camp at Giant's Castle, at an altitude of 1800m a.s.l.
4. Sigubudu Cave (at an altitude of 1500m a.s.l.) located within Royal Natal National Park which is situated at the northern part of the uKhahlamba-Drakensberg Park (28°38' to 28°46'S and 28°52' to 29°00'E).

The closest weather station that provides data for most of the study sites is at Giant's Castle. There, the mean air temperature is 17°C in summer and 12.5°C in winter. During the period 1990-2002 the maximum daily air temperature recorded at Giant's Castle was 34.1°C and the minimum -6°C. The mean daily thermal amplitudes were 10.4°C and 13.4°C in January and July respectively (Hoerlé, 2005). On average there is little frost in this part of the Drakensberg but sub-zero air temperatures may occur from time to time between May and September (Tyson *et al.,* 1976). Two other weather stations Kamberg (in close proximity to Game Pass Shelter) and Cathedral Peak (60km North of Kamberg) are also considered in the study.

Fog depositions (about 50mm per month in summer and 5mm per month in winter at Cathedral Peak) can contribute to the total annual precipitation (Tyson *et al.,* 1976). Rainfall mostly takes place in the form of thunderstorms which are very frequent (about 100 per year) and typically occur in summer months in the mid-late afternoons (Tyson *et al.,* 1976). Lightning flashes consequently accompany these thunderstorms with the density of lightning ground-flash being quite high (12 to 14 flashes/km^2/year) which might be responsible for the outbreak of veld fires in the region (Schulze *et al.,* 1997).

Game Pass Shelter faces towards the north-northeast and is cut into a large Clarens Formation sandstone body (Hoerlé, 2005). The shelter is 80m long and covered by a large overhang (approximately 4m high and between 5-8m wide) that shields the painted walls in most cases from direct precipitation and also, partly, from solar radiation (Hoerlé, 2005). Main Caves is also situated within the Clarens Formation sandstone and comprises two shelters, one east-facing and the other north-facing, while Battle Cave is a shallow shelter with a north-facing aspect receiving more radiation than any other rock shelter within the Clarens Formation (Meiklejohn, 1994; Meiklejohn *et al*., 2009).

The four study sites were chosen as they are accessible and have an abundance of rock paintings. They are also exposed to all the above mentioned environmental factors and weathering agents (Chapter 2) and comprise the same lithofacies (Eriksson, 1983). Another factor that was taken into account in choosing the study sites was the fact that a lot of research has already been done in recent years on most of these sites and, therefore, this study can contribute to better conservation strategies that could be developed in the future. In order for this study to be objective and accurate in terms of the state of deterioration of rock art in southern Africa, Sigubudu Cave was chosen due to the extremely deteriorated rock art found there.

3.2 Background to the Study Sites

3.2.1 Game Pass Shelter (Kamberg)

Figure 3.2: Game Pass Shelter viewed from below.

Figure 3.3: Game Pass Shelter viewed from within.

The total annual precipitation at Kamberg is 1050 mm, of which the summer rainfall (December-January) represents 50% of the annual precipitation and winter rainfall (June-August) only 5% (Hoerlé, 2005). Snow and hail can also contribute to the overall moisture, but to a limited extent (Tyson *et al.,* 1976) than rainfall would.

Generally, the paintings of Game Pass Shelter are grouped in four panels (Hoerlé, 2005). The two most significant panels are the Main Panel and the Dying Eland Panel. Most of the paintings in this shelter are found on the Main Panel, on the far right of the shelter. Although the paintings have never been dated, the mechanical strength of the un-weathered sandstone appear to be quite good because of the high content of small quartz grains and of the possible silica cement found within the sandstone of this shelter (Hoerlé, 2005).

The sandstone of the shelter shows planar stratification that is inter-layered with siltstones and mudstones. The clay-rich layers are roughly parallel and horizontal with the back wall of the shelter presenting many cracks and fractures (Hoerlé, 2005). Weathering processes that cause these fractures and cracks include a combination of thermal stress fatigue associated with variations in the rock moisture regime which is said to mostly affect Aeolian sandstones (Denis *et al.,* 2009). The development of large scales and many flakes on the surface of the Main Panel at Game Pass Shelter may be attributed to these phenomena (Hoerlé, 2005, 2006). The intense vertical fracturing of the whole cliff at Game Pass Shelter is, at a larger scale, associated with at least four thin clayey interstratified low resistant levels (stratification joints) that are responsible for the cutting of the painted wall in many meter-sized blocks (Denis *et al.,* 2009).

Some major risks at Game Pass Shelter contributing to the weathering of rock paintings are caused by several water seepages close to the paintings, with the possible development of microbiological threats in these wet areas (Hoerlé *et al.,* 2007). At present microbiological weathering is not so active on the Main Panel as the water is running on the side of the Panel and far away from the paintings, but marks on the wall show that water was flowing in the past where paintings have been painted (Hoerlé, 2005). On the Dying Eland Panel the situation is somewhat different as it is directly influenced by active, but seasonal, water runoff from the bedding joints (Hoerlé, 2005). Active water runoff is also accompanied by the growth of organic slime and a few mosses. Although lichen colonies can cover large portions of more exposed rocks, there is no lichen on or nearby painted areas.

Fortunately for the conservation of rock art, Game Pass Shelter is fenced off and visitors to the site are allowed only under the supervision of trained guides. Although baboons can still enter the site and cause damage to the paintings, the management of the site in this manner should prevent damage caused by humans and large animals (Hoerlé, 2005). Unfortunately though, it is impossible to keep birds and insects from the shelter and they are therefore free to move and nest close to the art. Some plants, mainly grass and a few shrubs are localised in the wettest areas of the shelter, close to water runoff. Plants can otherwise be found completely out of the shelter, where the rock overhang does not prevent rainfall (Hoerlé, 2005).

3.2.2 Battle Cave (Injisuthi valley)

Figure 3.4: Battle Cave viewed from below.

Figure 3.5: Battle Cave viewed from within.

Numerous San rock art sites are found on isolated sandstone boulders in the Injisuthi Valley, which is part of the Giant's Castle Game Reserve (Sumner & Nel, 2006) and home to the Battle Cave study site. The Battle Cave study site is a relatively shallow, north-facing shelter, and is exposed to a range of environmental conditions (Meiklejohn *et al.,* 2009). Due to its north-facing aspect, this shelter receives substantial direct solar radiation input, particularly in winter when rock shelter backwalls, and hence the paintings on them, receive early morning and/or late afternoon sun (Meiklejohn, 1994; Meiklejohn *et al.,* 2009).

General climatic conditions for the area are based on information from the nearest weather station at the Main Camp in Giant's Castle Game Reserve. Rainfall is estimated to be in the region of

1050 mm annually with a predominance of summer rainfall, extending from November towards the end of March. Rainfall is scarce during winter months, but can occur occasionally with the passage of mid-latitude cold frontal systems. The possibility of snowfalls is also uncommon, although light falls may occur in winter (Sumner & Nel, 2006).

The mean annual air temperature recorded for the area is in the region of 14°C (Sumner *et al.,* 2004). Although air temperature determines the environmental conditions of the area, such data will, however, not be sufficient for rock art studies as it is the temperature of the rock body and not that of the air that should be considered. Over the past 15 years studies have included the measurement of temperature of the sandstone facies onto which the art is painted (Meiklejohn *et al.,* 2009). Within the Main Caves and Battle Cave study sites, the maximum temperature of the sandstone ranges between 33.4 and 40.8°C (Meiklejohn *et al.,* 2009). This has implications for rock art weathering as insolation still heats the rock surfaces regularly to above 25°C at the study site even in winter months. Consequently different weathering mechanisms driven by temperature are thus active all year around.

It is important to acknowledge that despite the possible evidence for chemical weathering through high temperatures and the presence of moisture, it is unlikely that mechanical weathering will be continuously active at the dry Battle Cave site, since weathering reactions operating through a change in temperature will in most instances also require moisture (Meiklejohn, 1994; Walderhaug, 1998) which is not that readily available due to its exposure to the sun. Chemical weathering would therefore be inhibited by the absence of water during the dry winter months but the presence of clay minerals (illite) in the sandstone facies (Meiklejohn, 1994) makes the Battle Cave rock particularly vulnerable to weathering through wetting and drying cycles which will operate whenever a change in moisture occurs.

Although exposed to extreme environmental conditions, the Battle Cave study site is protected relatively well from the impacts of humans and large animals as it is fenced off. This site can only be reached when accompanied by a guide and through a 17 kilometre return walk. Vandalism is not such a big problem at this site mostly due to its remoteness and the rock art at Battle Cave weathers mainly due to environmental impacts. These environmental impacts include not only temperature and moisture and all its associated mechanisms, but also fire which might be damaging to the art because of the vegetation found close to the rock shelter.

3.2.3 Main Caves (Giant's Castle)`

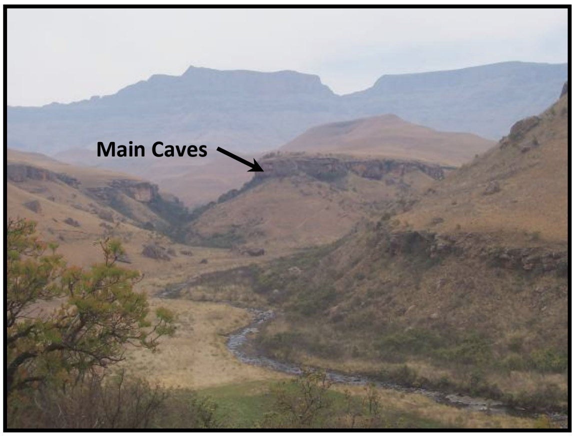


Figure 3.6: Main Caves viewed from afar.

Figure 3.7: Main Caves (North Shelter) viewed from within.

Giant's Castle Game reserve is the only proclaimed "Game Reserve" in the uKhahlamba-Drakensberg Park and was established in 1903 by Government Notice 735 (McGinley, 2008). It is within this Game Reserve, with the total area of 34,638 hectares, that the Main Caves study site is found. Main Caves consist of two adjoining caves comprised of relatively well-protected shelters of north and east-facing aspects (Meiklejohn *et al.,* 2009).

General climatic data for Main Caves are derived from the weather station situated at the Main Camp in the Giant's Castle Game Reserve (2km's north-east of the caves and at a similar altitude). It is difficult, however, to determine the impact of temperature on rock art weathering at Main Caves because at both the Main Caves and Battle Cave, rock thermal regimes display complex seasonal trends with summer temperatures sometimes being cooler than winter temperatures (Meiklejohn *et al.,* 2009). One explanation for this is that the low sun angle during winter months might result in near perpendicular radiation consequently leading to a higher net radiation input on the vertical rock faces than during summer (Meiklejohn *et al.,* 2009).

As with the Battle Cave site moisture is also needed here, working in synchronisation with temperature, to induce weathering on the rock art. Moisture brings about biotic growth, salt and wind weathering as well as weathering through wetting and drying cycles. Studies on moisture movement by Meng (1992) showed that little, or no, capillary movement of moisture is possible in sandstone samples such as those collected for the Main Caves and Battle Cave study sites, and that rock moisture fluctuations are therefore likely to occur through a series of adsorption and absorption processes as well as through gaseous and surface diffusion, that in turn depend on the pore architecture and inter connectivity thereof (Meng, 1992; Meiklejohn, 1994, 1997).

Due to its close proximity to the Main Camp (about 2 kilometres walk), Main Caves is a flourishing tourist destination. It is a fenced off area, which can only be entered with a guide. Boardwalks have been installed in order to keep deterioration due to human impacts to the minimum, but some graffiti can be seen in the Caves. Although economically viable, the downside to Main Caves being such a big tourist attraction is that (as discussed earlier) vegetation had to be removed for better access and viewing opportunities to tourists (Hall *et al.,* 2007b). The weathering taking place at Main Caves can possibly be ascribed to humans as well as environmental impacts.

3.2.4 Sigubudu Cave (Royal Natal National Park)

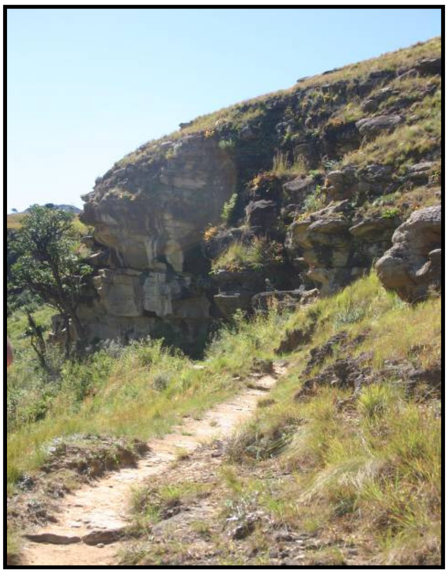


Figure 3.8: Sigubudu Cave viewed from afar.

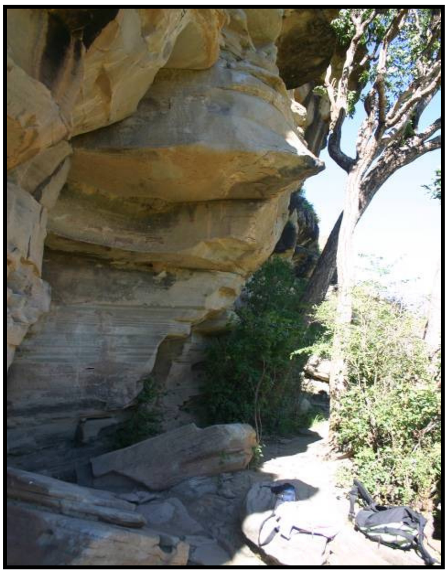


Figure 3.9: Sigubudu Cave viewed from within.

In 1947 the northern section of the current uKhahlamba-Drakensberg Park was named Royal Natal National Park after a royal family visit (McGinley, 2008). This Park is the only “National Park” forming part of South Africa’s fourth World Heritage Site and it is in Royal Natal National Park, with its total area of 8,094 hectares (McGinley, 2008) where the fourth study site, Sigubudu Cave is found. Sigubudu Cave was chosen as it is easily accessible from the main road and also because the paintings here are visibly more deteriorated than those found at the other three study sites. Climatic conditions are generally the same as at other sites found within the Park (such as Giant's Castle), although mean annual precipitation is 1314mm at the Park office (Nel & Sumner, 2006) which could contribute to accelerated deterioration of rock art paintings.

Sigubudu Cave is a small and shallow shelter (2km north of the Park office) that can be reached after a 15 minute guided walk from the access gate. The rock paintings found here are considerably deteriorated, where some are barely visible, likely due to the exposure of this shelter to environmental factors such as solar radiation and rain. Although not fenced off, the site is well protected as a guide is needed to access the site. Animal access is not restricted, but the paintings are relatively high up on rock walls and are therefore only damaged by birds who nest close to paintings. Other factors that could pose a threat to the deterioration of rock art paintings are pollutants as communities and roads are common features found close by or in the Park. The shelter is still protected relatively well by vegetation as large trees and shrubs are found in or just outside the shelter. Although this protects the art from temperature and moisture fluctuations it can cause damage through (as discussed in Chapter 2) the introduction of fire closer to the painting surface which can lead to thermal shock and thermal fatigue.

3.3 Research Methodology

The aim of this section is to present the methods undertaken to produce a Type of Surface Classification System as well as a State of Deterioration Classification System which will be applied in the four study shelters. Because the aim of the study comprises two parts the study will be divided into two sections, each with its own objectives and methodology. Even though the third objective will be discussed here, the results that are derived through implementation of this objective will be discussed in Chapter 4.

3.3.1 Aim

The aim of this study (Section 1.6 p15) is to develop two classification systems; one to identify surface type (type of surface) and the other to establish the state of deterioration of rock art paintings; both of which will be combined to determine if surface type influences how deteriorated the art is.

3.3.2 Objective 1: Type of Surface Classification System

The following secondary objectives were set as guidelines in order to develop a Type of Surface Classification System:

- To get acquainted with all the types of surfaces that rock art is found on
- To determine factors indicative of the Type of Surface involved
- To use these factors to develop a Type of Surface Classification System

3.3.3 Objective 2: State of Deterioration Classification System

The following secondary objectives were set as guidelines in order to develop a State of Deterioration Classification System:

- To get acquainted with the factors that influence deterioration of rock art
- To determine which of these factors were most important to meet the aims of the study
- To use these factors to develop a State of Deterioration Classification System

3.3.4 Objective 3: Compare Type of Surface and State of Deterioration Classification Systems

The following secondary objectives were set as guidelines in order to determine the relationship between Type of Surface and State of Deterioration:

- To determine through the use of the Type of Surface Classification System which surface each picture/scene was painted on
- To determine through the use of the State of Deterioration Classification System which factors influenced rock art deterioration in each shelter and to what extent
- To combine data derived from the two Systems as well as to analyse the data.

3.3.5 Fieldwork

In order to visit the proposed shelters, permits were obtained from both Ezemvelo KwaZulu-Natal Wildlife as well as Amafa after which numerous visits to the rock art sites were undertaken, first for general acquaintance with the study sites, and second for collection of photographs of the rock art and the study sites. Seeing that conventional photography is an inadequate recording medium for digital image processing (Mirmehdi *et al.,* 2001), especially in the case of such a colour sensitive project, more advanced digital equipment had to be used. Thus to enable precise monitoring of differing colours between different types of rock surfaces a high resolution digital camera combined with a standardised colour calibration chart (18% Grey Card) was used.

At least ten photographs of rock art scenes were taken from each rock shelter. Following Hall *et al.* 2010 (Figure 2) and section 1.4 p10, the scenes were chosen so that what appeared to be a variety of rock surfaces was included in the selection (Note: surface confirmation was undertaken after the Type of Surface Classification System was completed as per Section 3.3.5). Recordings at sites always took place around noon (from February to May 2010) in order to assure that lighting conditions were as similar as possible from one site to another. Notes were made on general weather conditions and both new and old published material was consulted and used in the development of the two classification systems.

3.3.6 Methodology of Part 1: Type of Surface Classification System

Although the San painted mostly on the Sandstone surfaces of the Clarens Formation in the Drakensberg, each type of surface is unique in the sense that each has its own distinct characteristics through which it can be identified. Because San rock art is such a precious South African heritage, studies must proceed without damage in any form to the art. In the absence of making direct contact with rock surfaces upon which the art was created, the study had to proceed by using observational techniques only. Through visual inspection it was possible to determine that different rock surfaces can most commonly be identified by a significant difference in the colour and texture of surfaces. Consequently, the most significant contributors that were used to create the Type of Surface Classification System were colour and texture.

Seeing that only the rock surface is considered when creating a Type of Surface Classification System, single paintings as well as whole painting scenes were included, according to the specific surface characteristics of that particular scene. Three general areas of importance (in each scene) were identified within the two main contributors (colour and texture). The two main contributors were incorporated in each of these three areas (in the form of a flow chart) in order to ultimately ascertain the type of surface that a specific painting was painted on. The areas that were used to determine the distinct characteristics of each Type of Surface are as follows (see Figure 3.10):

1. The immediate rock surface that the painting is painted on (colour and texture thereof);
2. The surface adjacent to the painting (colour and texture thereof); and
3. The surface behind any flaked-off pieces from the painting (colour of texture thereof), if there are any flaked-off pieces.

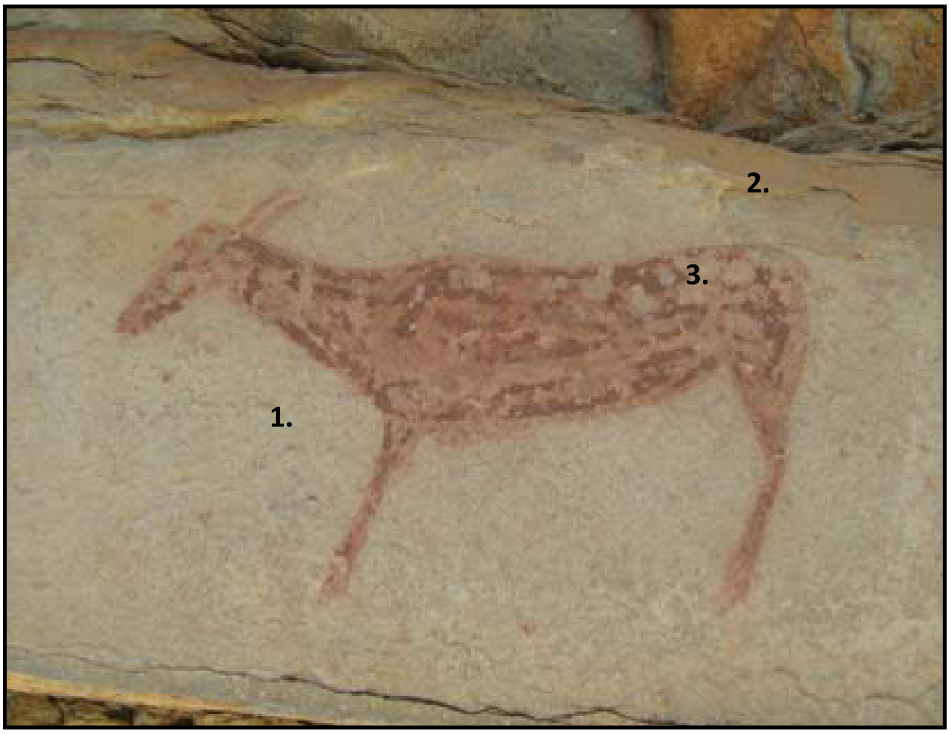


Figure 3.10: Example of the three areas used to determine the type of surface the scene is on. 1 – Immediate rock surface that the scene is on, 2 – Surface adjacent to the scene, 3 – Surface behind chipped/flaked-off rock pieces.

3.3.6.1 Colour

Only after colour and texture characteristics of the three general areas of each scene were determined was it possible to create a flow chart which was used to determine the different types of surfaces found at each shelter. Each specific surface type's characteristics had to be determined first and therefore, in order to determine the characteristics of the colour of each type of surface the following steps were undertaken:

1. A minimum of ten rock art scenes from each rock shelter were selected for the study. The ten scenes that were used were determined onsite and were photographed accordingly.

2. An 18% grey card was used while the scenes were photographed (each with the grey card included in the scene) in order to enable colour correction, which was done offsite.

3. Colour corrections were then done in Adobe Photoshop on all photographs (see Colour correction procedure, Section 3.3.6.4) in order to take the change in light conditions from site to site as well as different environmental conditions (e.g. cloud cover) into account.

4. After all the photographs had been colour corrected, each scene was printed with a calibrated photo printer on quality photographic paper.

5. A Munsell Colour Chart (Munsell Soil Colour Chart, 1994) was then used on the three general areas of each scene in order to determine the colours involved on each type of surface.

6. Each colour was then assigned a name, according to the Munsell Colour Chart, so that the possible colour difference between each of the three general surface areas of each type of surface could be determined (if a difference existed).

3.3.6.2 Texture

Since only photographical evidence could be used, the texture characteristic of each type of surface was determined by visual inspection. In order to determine the texture characteristic each type of surface was given a rating on the texture of the three areas of the rock surface ranging from: Rough, Intermediate to Smooth looking.

Rough looking refers to a rock surface that appears to be weathered. A surface that is rough will typically be pitted and etched. Some break out, flaking and back weathering would have taken place and the painting would partly be lost due to this. A surface that is Intermediate looking on the other hand might show some sign of weathering, although very limited, and might also show evidence of grinding on the surface as well as some granular disintegration. An Intermediate looking surface will hence not appear to be rough or smooth, but in between. Smooth looking describes a rock surface with very little discontinuities under and around the rock art scene. A surface that appears to be smooth will typically not appear weathered but may have some grinding marks that occurred through the process of surface preparation.

After the above methods were carried out, the colour and texture characteristics of each type of surface were incorporated into a flow chart which will enable the user to proceed through different stages on the flowchart which will ultimately define the type of surface involved. This flowchart will be presented and discussed in Chapter 4 when used to determine the types of rock surfaces found at each study site.

3.3.6.3 Colour Correction Procedure

The Munsell Soil Colour Chart (Munsell Soil Colour Chart, 1994) was used to determine the colour characteristics of the three general areas. Before this Chart could be used however, colour correction of the chosen photographs was done as the colour on the photographs does not portray real life colours according to how it appears to the naked eye in rock shelters. Colour corrections are undertaken by capturing each photograph with an 18% grey card in the same lighting conditions and correcting that photograph to the grey. The colour correction procedure, using a grey card, which was followed, is as set out in the Workflow Technique #065 by Hinkel (2007). The colour correction procedure on all photographs proceeded in Adobe Photoshop S5 as follows:

1. A photograph of the scene in question was taken with a D300 Canon Camera (Figure 3.11)

Figure 3.11: Original image showing the colour cast of the scene.

2. An 18% grey card was placed into the scene and a second exposure was taken (Figure 3.12). These two shots do not have to be identical (i.e. shot on a tripod), however they do need to be as close to one another as possible for the colour corrected version of the scene to be accurate.

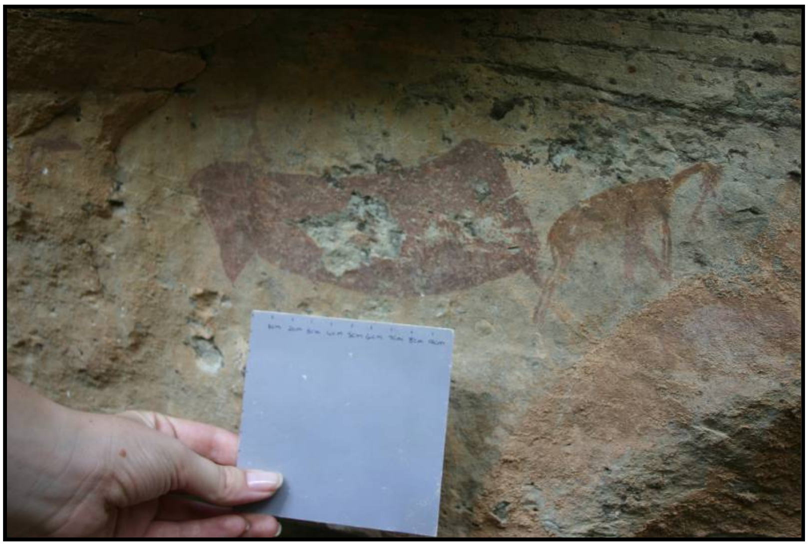


Figure 3.12: The same scene with the Grey Card added.

3. The image with the grey card in was then opened in Adobe Photoshop and the colour sampler tool (hidden under the eyedropper tool) selected (Figure 3.13). A sample point, which indicates the precise R, G, B (Red, Green and Blue) values for each point, was then taken on the grey card (see the info palette for sample point values). Note that the values for the grey card will not be equal as the card is not yet grey in this image.

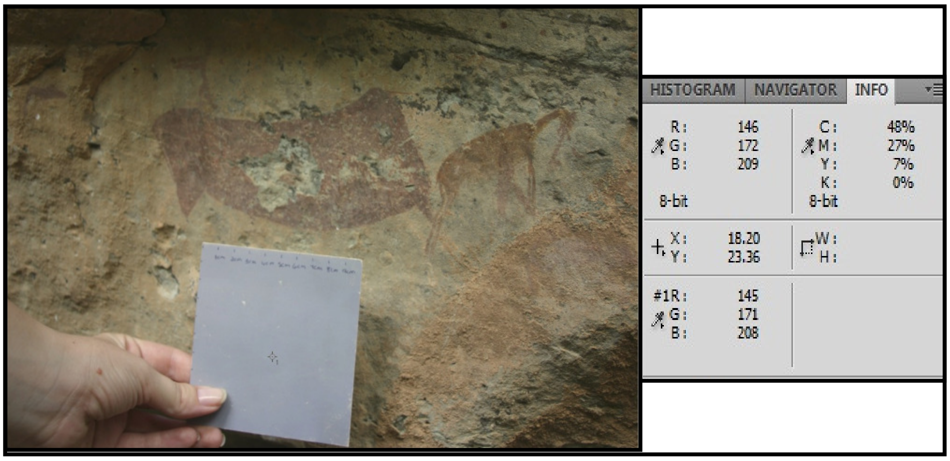


Figure 3.13: A colour sampler point on the grey card.

4. The R, G, B values of the grey card were then adjusted so that it takes on its natural colour (18% grey) by selecting the Image – Adjustments - Levels icons at the top of the page and by adjusting the colours so that it is the same as the colour with the lowest value (in this case Red) (refer to Figure 3.14).

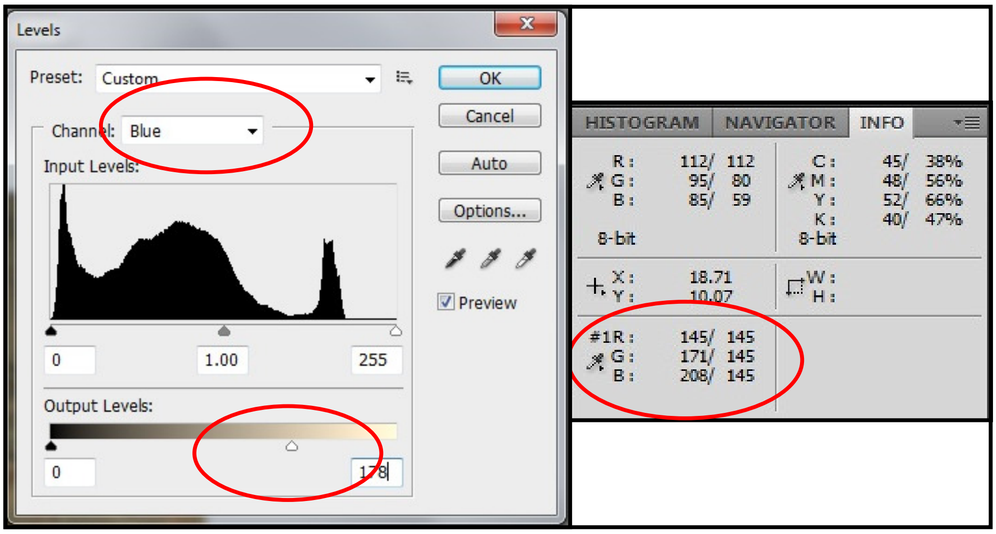


Figure 3.14: Adjustments levels in order to retrieve the original colour of the Grey Card.

5. Because the R, G, B values of an 18% Grey Card is 128/128/128 the exposure levels of the photograph had to be adjusted to 128. For this purpose the Image – Adjustments – Exposure icons were again selected at the top of the page whereafter the exposure of the image could be changed so that the R, G, B values were all 128 (Figure 3.15).

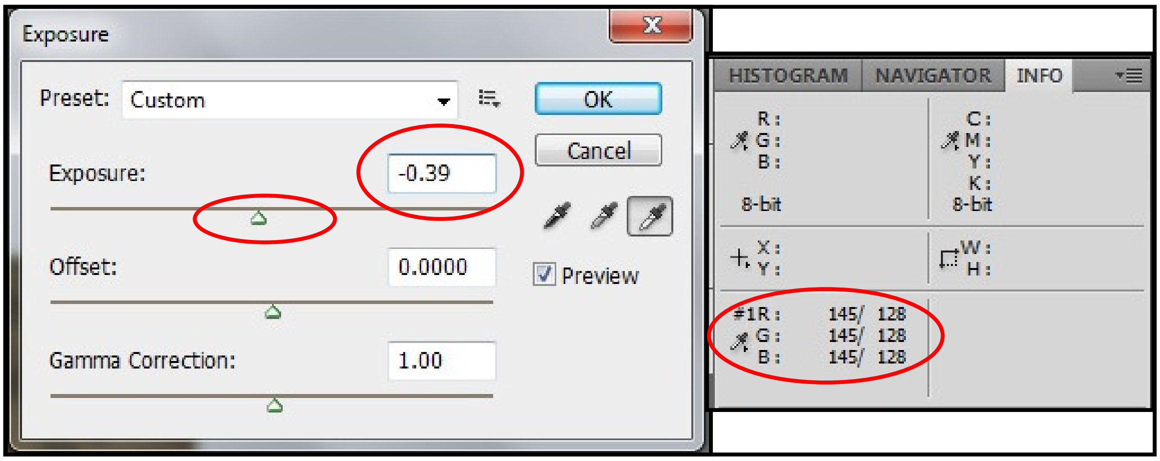


Figure 3.15: Adjustments levels in order to adjust Exposure of R, G, and B Values to 128.

6. Lastly, changes to the Adjustments levels as well as the Exposure of the colour corrected image were copied over to the image without the grey card (Figure 3.16).

Figure 3.16: The final Colour Corrected Image.

7. The above six steps were then repeated on all photographs used in this study before the Munsell Soil Colour Chart could be used to determine the colours found on each Type of rock Surface.

3.3.7 Methodology of Part 2: State of Deterioration System

Determining how deteriorated rock art is has for long been a challenge for many researchers practicing in this field. Previously, rock art deterioration studies focused largely on comparing old photographs with recent ones in order to determine how much of a painting has been lost (e.g. Hoerlé, 2005). This method can be effective but weathering rates are unlikely to be linear (Hall *et al*., 2007a) and environmental conditions have probably changed through time, which mean that this approach, although practical, still has its limitations (Sumner *et al*., 2009) and other methods should thus be investigated.

As it is the rock surface being investigated in this study, the sandstone that the art was painted on was inspected to determine deterioration thereof. It was important to find a non-destructive method that could be used in order to visually determine how deteriorated a certain rock surface is. Fitzner *et al.* (2003) conducted a study on the weathering damage on Paranoiac sandstone monuments in Luxor-Egypt. In their study a standard classification scheme of weathering forms that was developed by the Aachen working group "Natural stones and weathering" was used, but modified to fit the sandstone monuments in Upper Egypt (see Appendix A).

Here a modified version of the Fitzner *et al.* (2003) classification scheme was adapted and then applied in the field. Changes to the Fitzner *et al.* (2003) version included the following:

- One section in their study, namely Detachment of stone materials was replaced with a section on Environmental Conditions present in rock art shelters.
- The section called Discoloration/deposits in their study was broadened to also include organic growth such as fungi, algae and lichen on rock surfaces as well as fire which could severely damage rock art paintings.

Although the above mentioned study had a hands-on approach where measurements could be taken and compared, this study needed to be (as mentioned previously) purely observation based. Therefore, only the factors that cause, influence and indicate deterioration have been included in this study and were placed into a State of Deterioration Classification System. The State of Deterioration Classification System comprises four Main Deterioration Groups which were divided into 12 Main Deterioration Forms. The 12 Main Deterioration Forms were then sub-divided into 33 Individual Deterioration Forms which are all weathering mechanisms indicating and causing rock art decay (mechanisms are discussed in Chapter 2). The four Main Deterioration Groups are as follows:

Group 1 - Loss of stone materials (LS)
Group 2 - Discoloration/Deposits (DD)
Group 3 - Fissures/Deformation (FD)
Group 4 - Environmental Conditions (EC)

To separate the Main Deterioration Groups into smaller, more manageable sub-groups, each of the Main Deterioration Groups were subdivided. These smaller sub-groups were then named Main Deterioration Forms (Table 3.1). The 12 Main Deterioration Forms used in this study are:

1. Loss of stone materials (LS) • Back Weathering • Flaking • Break Out	2. Discoloration/Deposits (DD) • Discoloration • Soiling • Loose salt Deposits • Organics
3. Fissures/Deformation (FD) • Fissures	4. Environmental Conditions (EC) • Sunlight • Precipitation • Wind • Vegetation Loss

Table 3.1: Main Deterioration Forms of the State of Deterioration Classification System.

Each of the Main Deterioration Forms was then divided into a number of Individual Deterioration Forms, which ultimately describe what factors influence and cause deterioration to rock art. The 33 Individual Deterioration Forms used in this study are as follows:

1. Loss of Stone Materials (LS)

- Under **Back Weathering** Individual Deterioration Forms included: Back weathering due to loss of scales, Back weathering due to loss of crusts and Back Weathering due to loss of indefinite stone aggregates/ pieces.
- Under **Flaking**, Single flakes and Multiple flakes are considered.
- Individual Deterioration Forms in the **Break Out** section included: Break out due to constructional cause, Break out due to natural cause and Break out due to non-recognisable cause.

2. Discoloration/ Deposits (DD)

- Under **Discoloration** Individual Deterioration Forms included: Coloration, Coloration due to Dust settling in the cave, Coloration due to fire damage on the surface.
- In the **Soiling** section the following Individual Deterioration Forms were included: Soiling by particles from the atmosphere, Soiling by particles from water, Soiling by droppings and Soiling due to anthropogenic impact.
- Individual Deterioration Forms in the **Loose salt deposit** section included: Gypsum and Efflorescence.
- Under **Organics,** Fungi or algae growing on the surface and Lichen growing on the surface are considered.

3. Fissures/Deformation (FD)

- Section 3 comprises one Main Deterioration Form namely **Fissures** which included the following Individual Deterioration Forms: Fissures independent of stone structure and Fissures dependent on stone structure.

4. Environmental Conditions (EC)

- Individual Deterioration Forms under **Sunlight** include: Direct sunlight on painting panel during summer months, Direct sunlight on painting panel during winter months, Indirect sunlight from surrounding painting panels during summer months, and Indirect sunlight form surrounding painting panels during winter months.

- In the **Precipitation** section the following Individual Deterioration forms were included: Water running directly over the surface of the painting panel, Rain reaching surface of painting panel directly, Water coming out of rock surface and Mist entering the cave/shelter.

- The **Wind** section included: Direct Wind blowing onto surface of painting panel and Painting panel exposed to windy conditions.

- Individual Weathering forms under **Vegetation** include: Vegetation loss due to natural causes and Vegetation loss due to anthropogenic impacts.

Through visual inspection each of the Individual Deterioration Forms included in the modified State of Deterioration Classification System (Table 2) was then assigned a value to which they were rated. These values range from 0-4 and were applied to each Individual Deterioration Form so that:

0 Refer to Not Occurring, implying that no evidence of the Individual Deterioration Form is found on that specific painting/scene

1 Refer to Very rare, meaning that there is rarely any evidence of the Individual Deterioration Form on the painting/scene in question

2 Refer to Rare, implying that some evidence of the Individual Deterioration Form is found on that particular painting/scene

3 Refer to Frequent, meaning that there is repeated evidence of that specific Individual Deterioration Form on the painting/scene

4 Refer to Very frequent, implying that plenty of evidence of the Individual Deterioration Form in question are found or exist on the painting/ scene

After data collection had taken place on the State of Deterioration Classification System (Table 3.2), the contribution of each of the Main Deterioration Groups to the table was calculated and graphs were draw in order to determine which of the Main Deterioration Groups played the greatest role in the deterioration of each shelters rock art. The Type of Surface each of the paintings was made on was then linked to how deteriorated they are in terms of the four Main Deterioration Groups included in the State of Deterioration Classification System through the use of graphs.

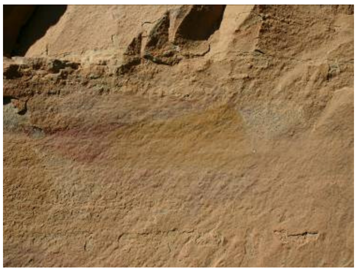
Cave name:	Time :		
Main Group	**Main Deterioration Form**	**Individual Deterioration Form**	**Photographs of Pictures/Scenes**
Surface Type			
1 Loss of stone materials (LS)	Back Weathering (Bw)	Back weathering due to loss of scales (sBw)	
		Back weathering due to loss of crusts (cBw)	
		Back weathering due to loss of indefinite stone aggregates/pieces (zBw)	
	Flaking (F)	Single flakes (cF)	
		Multiple flakes (mF)	
	Break out (O)	Break out due to constructional cause (bO)	
		Break out due to natural cause (nO)	
		Break out due to non-recognizable cause (oO)	
		Total for section 1	
		z =	
2 Discolour-action/ Deposits (DD)	Discoloration (D)	Coloration (Dc)	
		Coloration due to Dust settling in the cave (Dcd)	
		Coloration due to fire (Dcf)	
	Soiling (I)	Soiling by particles from the atmosphere (pI)	
		Soiling by particles from water (wI)	
		Soiling by droppings (gI)	
		Soiling due to anthropogenic impact (aI)	
	Loose salt Deposits (E)	Gypsum (Eg)	
		Efflorescences (Ee)	
	Organics (Or)	Fungi or algae growing on surface (fgOr)	
		Lichen growing on surface (lOr)	
		Total for section 2	
		z =	
3 Fissures/ Deformation (F/D)	Fissures (L)	Fissures independent of stone structure (vL)	
		Fissures dependent on stone structure (IL)	
		Total for section 3	
		z =	
4 Environ-mental Conditions (EC)	Sunlight (SI)	Direct sunlight on painting panel during summer months (dsSI)	
		Direct sunlight on painting panel during winter months (dwSI)	
		Indirect sunlight from surrounding painting panels during summer months (isSI)	
		Indirect sunlight from surrounding painting panels during winter months (iwSI)	
	Precipitation (Pp)	Water running directly over surface of painting panel (dPp)	
		Rain directly on painting panel (rPp)	
		Water coming out of rock surface (sPp)	
		Mist entering the cave/ shelter (iPp)	
	Wind (W)	Direct wind blowing onto surface painting panel (dW)	
		Painting panel exposed to windy conditions (iW)	
	Vegetation Loss (V)	Vegetation loss due to natural causes (nV)	
		Vegetation loss due to anthropogenic impacts (aV)	
		Total for section 4	
		z =	

Scale	Formula (z) Values	Surface Type
0 = Not occurring	I = 33	NW = Naturally Weathered
1 = Very rare	s = 4	NL = Naturally Weathered with Clay Layer
2 = Rare	i(1) = 8, i(2) = 11, i(3) =2, i(4) = 12	AS = Smoothed
3 = Frequent	q = total points for section	SL = Smoothed with Clay Layer
4 = Very frequent		CB = Clean Break

Table 3.2: State of Deterioration Classification System.

3.3.8 Definitions and Identification

This section is aimed at providing the user of the above mentioned Systems with a description of certain terms in order to simplify the identification thereof when using the State of Deterioration Classification System in rock shelters/caves.

Term	Definition	Identification	Example
Algae	Very simple plants with no real leaves, stems or roots that grow in or near water (Wehmeier, 2000)	Algae can be identified by looking for small green plants that grow on the painting surface especially were water run regularly over the surface	
Break Out	To become detached, separated, or disassociated from something or the separation of something into components or parts (Collins English Dictionary, 2009)	Break Out can be identified by looking for "large" pieces of rock that broke out from the paintings and painting panel	
Discoloration	To change colour, or to make the colour of something change, in a way that makes it look less attractive (Wehmeier, 2000)	Discoloration can be identified by faded painting surfaces. Fire can also cause coloration to the surface where black ash will cause coloration. Dust can also cover the painting surface.	
Efflorescence	The growth of salt crystals on a surface caused by evaporation of salt-laden water (The American Heritage Dictionary, 2009).	Efflorescence can be identified by seeking white and yellow salt crystals on the rock surface.	

Fissure	A long deep crack in something, especially in rock or in the earth (Wehmeier, 2000)	A fissure will be a long, narrow, deep crack on the painting panel. It will typically run through a part of a painting which will divide the painting into two or several pieces.	
Flaking	*Noun*: A small, very thin layer or piece of something, especially one that has broken off from something larger. *Verb*: To fall off in small thin pieces (Wehmeier, 2000)	Flaking can be identified by very thin pieces of the upper rock layer that is peeling from the painting surface. It will look like the painting is peeling off in certain areas.	
Fungi	Any plant without leaves, flowers or green colouring, usually growing on other plants or on decaying matter (Wehmeier, 2000)	Fungi are a biotic weathering mechanism and might appear as a dark green almost black coverage on the rock surface. Fungus can also be wild mushrooms and could therefore be dark grey	
Gypsum	An *evaporite* mineral composed of calcium sulphate with water	Gypsum can be identified by seeking small white dots on or near to the rock paintings	
Lichen	A very small grey or yellow plant that spreads over the surface of rocks, walls and trees and does not have any flowers. (Wehmeier, 2000)	Lichens can be identified by their external effects on rock surfaces which is noticeable by the presence of green and dark colorations on the surface	

Precipitation	The deposition of water in a solid or liquid form on the Earth's surface from atmospheric sources. Include : dew, drizzle, hail, rain, sleet and snow	Water running over the surface can be identified by white runoff marks over or near to the painting. It is important to have general knowledge of the rock shelter that is being examined in order to know precipitation patterns	
Soiling	*Noun*: The top layer of the earth in which plants, trees, etc. grow. *Verb*: to make something dirty. (Wehmeier, 2000)	Soiling is associated with animal droppings and therefore that should be the first thing to look for at a site. Soiling also goes hand in hand with tourists and animals stirring up dust which makes the painting look faded and dirty.	
Vegetation Loss	Vegetation: Plants in general, especially the plants that are found in a particular area Loss: The state of no longer having sth. or as much of sth. (Wehmeier, 2000)	Vegetation Loss can be identified by looking for paintings that are too high for a human to reach without something (like a tree) to sit in while painting. It can also be assumed that vegetation had to be removed at tourist rock art sites for better access and visibility	

Table 3.3: Table of Definitions and Identification.

Through developing a Type of Surface Classification System as well as a State of Deterioration Classification System by following the above methodology it was possible to draw some conclusions as to the relationship between surface type and state of deterioration of rock art found on specific rock surfaces. The results that derived from these systems will be discussed during the next chapter (Chapter 4) and conclusions as to contribution thereof in terms of this study will be drawn.

CHAPTER 4: RESULTS AND DISCUSSION

The purpose of this chapter is to present the results of the study as well as to discuss their significance in terms of the objectives set out in Chapter 3. Because the aims were to create a Type of Surface Classification System as well as a State of Deterioration System, the completion of these Systems will therefore ultimately form the results of this study. As a first attempt to integrate the two Classification systems, the Systems will also be analysed in concert to determine what the relationship is between the Type of Surface a rock art painting was made on and how deteriorated it is.

In the first section of this chapter the final stages in creating a flowchart which forms the Type of Surface Classification System will be presented. The specific surface characteristics linked to each Type of Surface in terms of colour and texture will first be determined whereafter the final System will be created. As every Type of Surface has unique colour and texture characteristics, some exclusions to the flowchart might come forth, especially in instances where sufficient data are not available, and therefore a few rules for this purpose have been developed. If all methods and rules are followed correctly the Type of Surface Classification System should be a relatively straight forward tool for determining rock surface type by inspection. The second section of this chapter will discuss the Table that originated through following the methodology set out in Chapter 3 for the purpose of creating a State of Deterioration System.

In the third section of this chapter the data obtained as well as the results that originated from the implementation of both Systems in the four rock shelters are presented and discussed. The data obtained from the study shelters in order to create these Systems will be presented and their significance to the study will be analysed.

4.1 Type of Surface Classification System

During the design stages of the Type of Surface Classification System the Colour and Texture characteristics of a rock surface proved to be (see Section 3.3.5) the most important determinants of the Type of Surface that a certain scene was painted on. The way in which these two characteristics were used and analysed in order to create the final Type of Surface flow chart will therefore be discussed in detail during the next section.

4.1.1 Colour

Colour was used in this study to determine the difference between one rock surface and another. Although rock surface colour was used for the purpose of this study, colour is, in many rock art deterioration studies, considered to be an important monitoring aspect in assessing the condition of rock paintings themselves (Small & Clark, 1982) with a change in the colour of the paint indicating deterioration taking place. Not only will factors such as pigment loss, reactions with salts and surface mineralization and dust, give rise to colour change but also pigment deterioration, which occurs in the form of clay hydration, salt spalling, substrate exfoliation, animal damage and water wash (Small & Clark, 1982). Despite these factors all having an effect on rock art deterioration, which will be used during the State of Deterioration Classification System further on in the study, rock surface colour was incorporated in order to create a Type of Surface Classification System mainly through the use of the Munsell Soil Colour Chart.

4.1.1.1 Munsell Soil Colour Chart

Although the Munsell Colour Chart is mainly used in studies concerning soil colour, it has been used in determining rock colour as well (Danin & Caneva, 1990; Arocena *et al.,* 2003). Here the Munsell Colour Chart was used to create a fixed reference point viable for use in further rock art studies. The Munsell Colour Chart consists of nine charts in the Soil Collection and displays 322 different standard colour chips systematically arranged according to their Munsell notations (Munsell Soil Colour Charts, 1994). Each of the nine charts is arranged by three combined dimensions that describe all colours. These dimensions are known in the Munsell system as Hue, Value and Chroma. The Hue notation of a colour indicates its relation to Red, Yellow, Green, Blue, and Purple. The Value notation indicates its lightness and the Chroma notation indicates its strength (or departure from a neutral of the same lightness) (Munsell Soil Colour Charts, 1994).

For the purpose of this study the 10Y Hue was used as this was the chart that best matched all rock colours found on the Sandstone of the Clarens Formation. By using the 10Y Hue colour chart, accurate comparison was obtained by holding each of the three general areas of each photograph (as described in Chapter 3) directly behind the apertures separating the closest matching colour chips. This process was done in natural daylight as to obtain the nearest colour match to that of the rock found in nature. It is important, however, to remember that the colour of the samples will rarely be perfectly matched by any colour in the chart. The probability of having a perfect matching of the sample colour is less than one in one hundred (Munsell Soil Colour Charts, 1994) and the nearest colour should thus be used as it should at least be evident which colours the sample lies between, and which is the closest match.

From the 40 rock art scenes selected from the four study sites (Battle Cave, Main Caves, Game Pass Shelter and Sigubudu Cave) 18 colours (from the 10Y Hue Colour Chart) existed in the three general areas on all rock surfaces. These colours range from Light Grey to Very Dark Brown (7/1-2/2) and are summarised in Table 4.1.

Colour Name	Colour Value
Light Grey	7/1
Light Grey	7/2
Grey	6/1
Light Brownish Grey	6/2
Pale Brown	6/3
Light Yellowish Brown	6/4
Grey	5/1
Greyish Brown	5/2
Brown	5/3
Yellowish Brown	5/4
Dark Grey	4/1
Dark Greyish Brown	4/2
Brown	4/3
Dark Yellowish Brown	4/4
Very Dark Grey	3/1
Very Dark Greyish Brown	3/2
Dark Yellowish Brown	3/6
Very Dark Brown	2/2

Table 4.1: The 18 Munsell Colour Chart colours and values found on sandstone surfaces in the Drakensberg.

4.1.2 Texture

With texture contributing an equal portion to the development of the Type of Surface Classification System as colour, different specific classifications had to be ascribed to the type of texture of each of the three general areas. Visually the texture of all types of sandstone rock surfaces found within the three study sites therefore had to fall into the following categories (see Section 3.3.5):

- Smooth;
- Intermediate and;
- Rough Looking

Because texture characteristics could be determined through visual inspection only, these are the three categories used to describe weathered sandstone samples of the Drakensberg and were used at all study sites.

4.1.3 Abbreviations

In order to simplify data capturing, the colour and texture of each of the three general areas was abbreviated, whereafter each scene was analysed and the data then captured. For the purpose of this study the different areas of colour and texture analyses will be called the following:

- **CS1** (Colour of Surface 1) refer to the category of the colour of the surface that the painting is on (in other words area 1; see Figure 4.1)
- **CS2** (Colour of Surface 2) refer to the category of the colour of the surface adjacent to the painting (thus area 2; see Figure 4.1)
- **CS3** (Colour of Surface 3) refer to the category of the colour of the rock surface behind any chipped/flaked of rock pieces behind the painting if any exist (area 3 from Figure 4.1)
- **TS1** (Texture of surface 1) refer to the category of the texture of the direct rock surface that the painting is on
- **TS2** (Texture of Surface 2) refer to the category of the texture of the surface adjacent to the painting and
- **TC3** (Texture of Surface 3) refer to the category of the texture of the surface behind any chipped/flaked of rock pieces from the painting (if any exist).

Through the use of the Munsell Soil Colour Chart on the entire collection of colour corrected photographs as well as through thorough visual inspection of the surface texture it was possible to establish what colour and texture characteristics each surface type consisted of. In order to form a general idea of the characteristics of each type of surface the same process of data capturing had to be followed for all 40 scenes. Figure 4.1 provide an example of the areas of colour (refer to Table 4.1) and texture that was used in each photograph for data capturing.

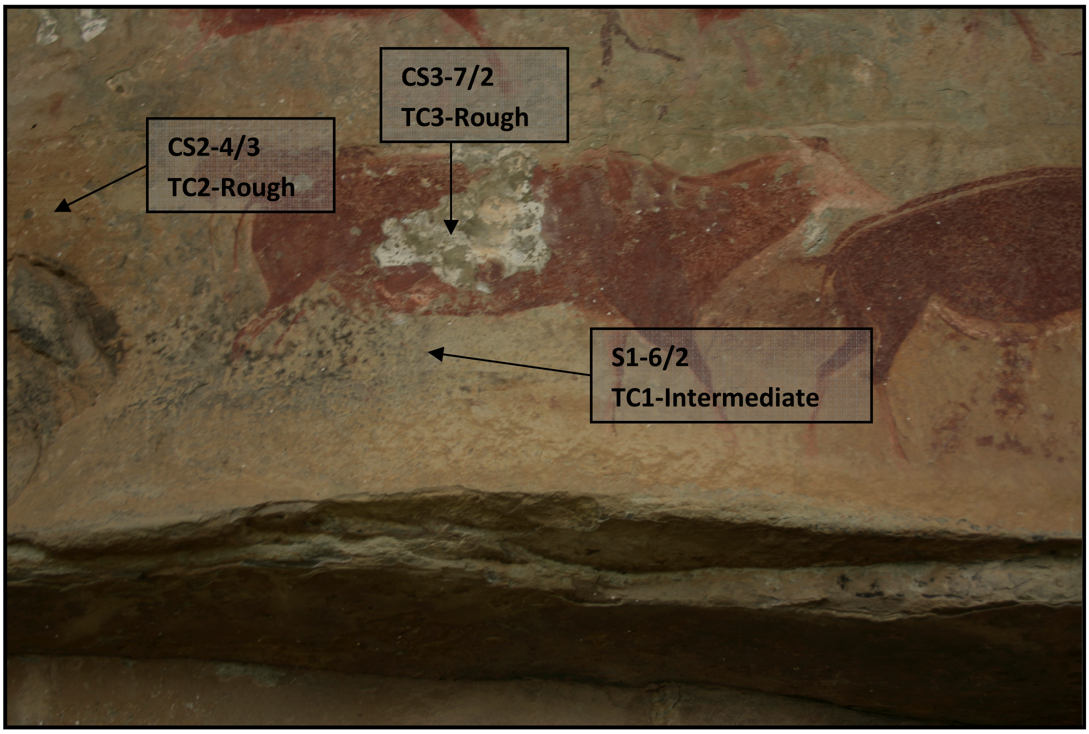


Figure 4.1: Example of the three general areas looked at in terms of colour and texture.

4.1.4 Data Capturing

After field visits to the four study sites, ten scenes from each study site were chosen for data analyses. These scenes were chosen according to their different surface attributes in order to include as wide a variety of rock surfaces in the study as to get more accurate results. The photographs selected from each study site are as follows (figure 4.2-4.5):

4.1.4.1 Game Pass Shelter (GP)

Figure 4.2: Scenes selected for data analysis from Game Pass Shelter.

4.1.4.2 Main Caves (MC)

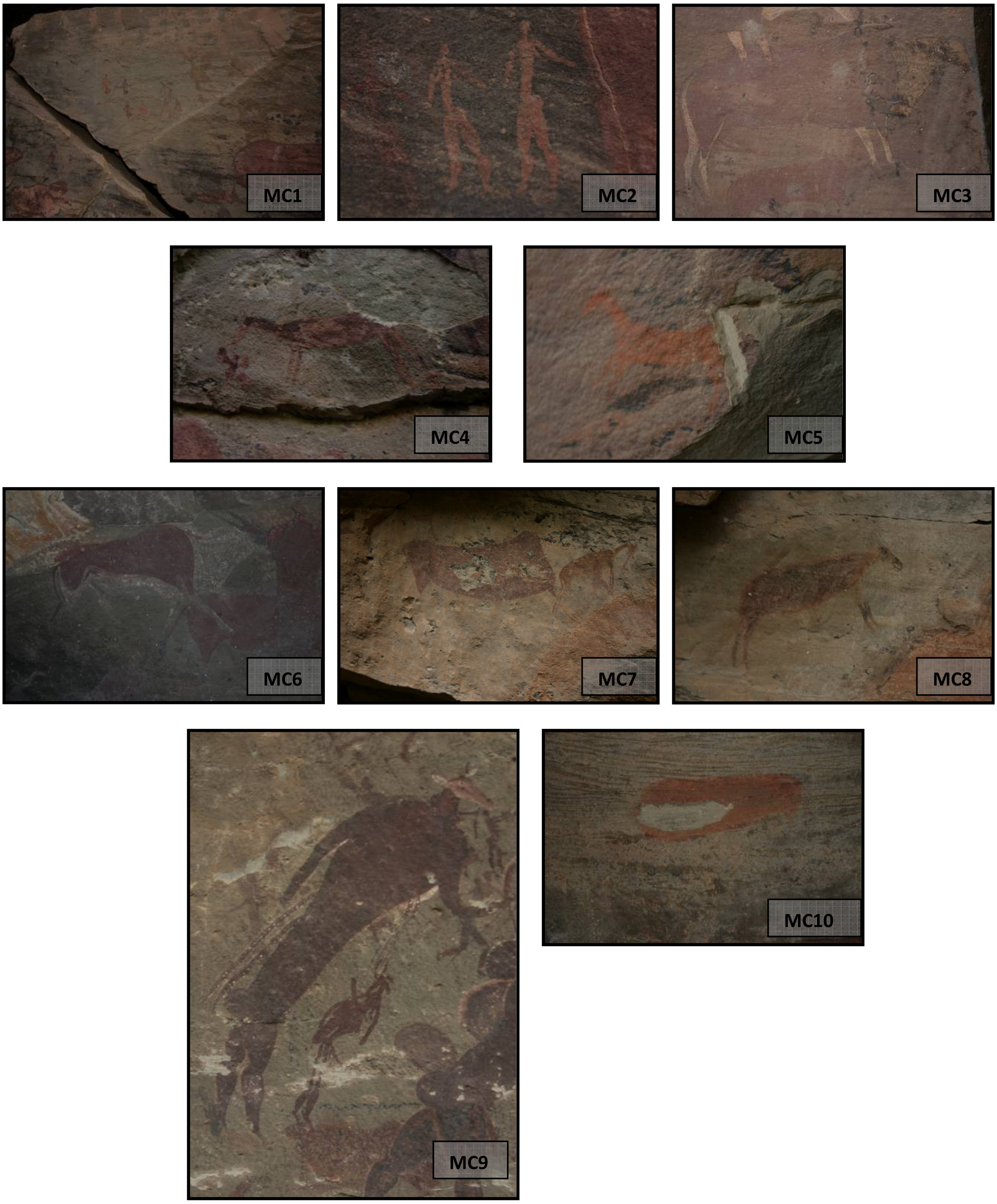


Figure 4.3: Scenes selected for data analysis from Main Caves.

4.1.4.3 Battle Cave (BC)

Figure 4.4: Scenes selected for data analysis from Battle Cave.

4.1.4.4 Sigubudu Cave

Figure 4.5: Scenes selected from Sigubudu Cave.

4.1.4.5 Derived Data

The data that consequently originated from the application of the above methods on all 40 photographs from the four study sites are summarised in the table below (Table 4.2).

Picture Nr.	CS 1	CS 2	CS 3	TS 1	TS 2	TS 3
MC1	5/3	4/2	N/A	I	S	N/A
MC2	3/1	3/1	6/3	I	R	R
MC3	5/1	5/1	6/3	I	R	R
MC4	5/1	3/1	5/1	I	R	R
MC5	4/1	4/1	6/3	R	R	R
MC6	2/2	2/2	N/A	S	S	S
MC7	6/3	4/2	7/2	S	R	R
MC8	6/2	4/3	N/A	I	R	N/A
MC9	4/1	4/2	5/1	R	R	R
MC10	4/2	3/1	6/3	R	R	R
BC1	5/2	5/3	5/2	I	R	R
BC2	5/2	5/2	4/1	R	R	R
BC3	4/1	5/2	N/A	R	R	N/A
BC4	6/2	3/3	6/2	I	S	S
BC5	5/2	4/3	6/3	I	R	R
BC6	6/1	5/3	N/A	R	R	N/A
BC7	5/2	4/4	5/2	R	R	R
BC8	5/2	5/4	6/3	R	R	R
BC9	5/3	5/3	6/1	I	S	I
BC10	6/4	6/4	N/A	R	R	N/A
GP1	4/1	2/2	N/A	S	R	N/A
GP2	6/1	4/1	6/1	I	R	S
GP3	4/2	4/1	6/3	R	R	R
GP4	5/1	5/1	6/3	R	R	R
GP5	6/1	2/2	N/A	I	R	N/A
GP6	6/3	4/3	7/2	I	S	R
GP7	5/2	4/2	6/3	R	R	R
GP8	5/2	4/2	N/A	R	R	N/A
GP9	5/2	5/2	6/3	R	R	R
GP10	6/1	5/3	6/2	I	R	S
SC1	5/2	3/2	6/3	R	R	R
SC2	6/1	5/4	N/A	R	R	N/A
SC3	5/2	5/2	N/A	R	R	N/A
SC4	5/2	5/3	N/A	R	R	N/A
SC5	5/2	2/2	5/2	R	R	R
SC6	6/2	2/2	6/2	I	S	S
SC7	5/2	5/3	5/3	R	R	R
SC8	5/1	5/2	5/3	R	R	R
SC9	5/2	3/1	N/A	R	R	N/A
SC10	5/2	6/3	N/A	R	R	N/A

Table 4.2: Data on colour and texture characteristics obtained from ten scenes at each of the four study sites. MC – Main Caves, BC- Battle Cave, GP- Game Pass Shelter, SC – Sigubudu Cave.

4.1.4.6 Surface Type Characteristics

From Table 4.2 it was possible to group the colour and texture characteristics of the five different Types of rock Surfaces (see Section 1.4) found at the study sites in such a way that the dominant colours of each type of surface as well as texture of the three general areas could be established. The dominant colour characteristics of all types of surfaces were grouped into sections on the Munsell Colour Chart in order to simplify the use of the Type of Surface Classification System. These sections can be seen in Table 4.3 below:

MUNSELL SOIL COLOUR CHART COLOURS AND VALUES				**HUE 10YR**
Light Gray 7/1	Light Gray 7/2	Very Pale Brown 7/3	Very Pale Brown 7/4	Yellow 7/6
Gray 6/1	Light Brownish Gray 6/2	Pale Brown 6/3	Light Yellowish Brown 6/4	Brownish Yellow 6/6
Gray 5/1	Grayish Brown 5/2	Brown 5/3	Yellowish Brown 5/4	Yellowish Brown 5/5
Dark Gray 4/1	Dark Grayish Brown 4/2	Brown 4/3	Dark Yellowish Brown 4/4	Dark Yellowish Brown 4/6
Very Dark Gray 3/1	Very Dark Grayish Brown 3/2	Dark Brown 3/3	Dark Yellowish Brown 3/4	Dark Yellowish Brown 3/6
Black 2/1	Very Dark Brown 2/2			

Section 1
Section 2
Section 3
Section 4
Section 5

Table 4.3: Sections on the Munsell Soil Colour Chart dividing surface colour characteristics.

Through grouping the colour and texture characteristics of all five types of rock surfaces as well as by establishing which characteristics are most dominantly found on each Type of Surface it has been determined that each of the five types of rock surfaces typically consist of the following colour and texture characteristics:

- *Surface Characteristics of a Naturally Weathered Rock Surface*

CS1 – Colours would range between Light Yellowish Brown and Very Dark Grey (thus any colour found in section 1 of Table 4.3)

CS2 – The colour of the surface adjacent to a rock art painting made on a NW rock surface would be any colour from section 1, 3 or 4 (Table 4.3)

CS3 – The surface colour behind any lost rock pieces would also consist of colours from section 1, 3 or 4

TS1 – The texture of the rock surface that the painting is made on would be Rough looking

TS2 – The texture of the surface would be Rough looking

TS3 – Texture characteristics would also consist of Rough looking rock surfaces behind lost rock material.

- *Surface Characteristics of a Smoothed Rock Surface*

CS1 – Colours of a Smoothed/ Prepared rock surface would range between Light Gray to Light Brownish Grey (Section 2 of Table 4.3)

CS2 – Colours of the surface adjacent to the scene would in this instance be any colour found in Section 1, 3 or 4

CS3 – The colour of the surface behind any chipped/ flaked-off rock pieces would derive from Section 2

TS1 – The texture of the direct rock surface that a painting was made on would be Intermediate looking

TS2 – The texture of the adjacent rock surface would be Rough looking while

TS3 - Texture characteristics of the surface behind any lost stone material would be Smooth looking.

- *Surface Characteristics of a Naturally Weathered Rock Surface with a Clay Layer*

Although no field evidence has been recorded up to date for this type of surface a Naturally Weathered rock Surface with a Clay Layer on top might have the following surface characteristics:

CS1 – The colour of the direct surface that the painting was made on might be any colour from Section 3 or 4 (see Table 4.3)

CS2 – The adjacent rock surface colour might be any colour found in Section 1, 3 or 4 from Table 4.3

CS3 – The colour of the rock surface behind any chipped of rock pieces will possibly be of light colour and will therefore derive from Section 2

TS1 – The texture of the direct rock surface that the painting was made on might be Smooth looking

TS2 – Texture characteristics of the adjacent rock surface might be Rough looking while

TS3 – The texture of the surface behind chipped/flaked of rock pieces might also be Rough looking.

- *Surface Characteristics of a Smoothed Rock Surface with a Clay Layer*

CS1 – The direct surface colour of a painting on the SL type of surface would be any colour from Section 3 or 4 (Table 4.3)

CS2 – The surface colour in this instance would be any colour from Section 1, 3 or 4

CS3 – The surface colour behind any lost stone materials from the painting would be light and therefore could be any colour from Section 2

TS1 – The texture of the direct surface of a SL type of surface would typically be Intermediate looking

TS2 – The texture of the adjacent surface to the painting would mostly be Smooth looking

TS3 – The texture behind any chipped of stone material would portray an Intermediate looking surface.

- *Surface Characteristics of a Clean Break Rock Surface*

CS1 – The colour of the surface in this instance would be from Section 2 or 3 (Table 4.3)

CS2 – The colour of the surface adjacent to the painting would in the case of a Clean Break rock surface also be any colour from Section 2 or 3 while

CS3 – The colour behind any chipped of pieces will once again be one from Section 2

TS1 – The texture of a Clean Break surface in this instance will typically be Smooth looking

TS2 – Texture characteristics will also be Smooth looking on adjacent rock surfaces and

TS3 – The texture will also be Smooth looking if any loss of stone material on the painting itself has taken place.

4.1.5 Exceptions to the System

Since it is not possible to always obtain all data regarding the colour and texture characteristics of a specific scene, some situations may exist which might make the use of the Type of Surface Classification System difficult. In Table 4.2 for example the colour and texture characteristics of the surface behind any chipped/flaked-off rock pieces on the painting does not exist on a few of the rock art paintings found within the four study shelters. In these cases the term N/A were used to indicate that data is Not Available. In order to simplify the use of the System in these instances some rules have been set up so that any confusion that might result as a consequence of these gaps can be avoided. The rules are as follows:

1. In the instance where the colour of the rock surface behind any chipped/flaked-off rock pieces (thus the colour of CS3) is N/A, the user of the System should skip over (Figure 4.6) to the next surface characteristic (TC1) and continue with the System from there.

2. If the texture of the rock surface behind any chipped/flaked-off rock pieces (TC3) is however N/A then the following will apply:

   - If a colour from Section 1 (from Table 4.3) have been chosen in CS1 then the Surface Type will be that of a NW one

   - If a colour from Section 2 have been chosen in CS1 and TS2 in Rough looking then the surface Type would be an AS one

   - If any colour from Section 2 have been chosen in CS1 and both TS1 and TS2 is Smooth looking however then CB Surface Type is applicable

   - If a colour from Section 3 or 4 have been chosen in CS1 and TS1 is Smooth looking while TS2 is Rough looking then the surface Type might be a NL one

   - If any colour from Section 3 or 4 have been chosen in CS1 and TS1 is Intermediate looking while TS2 is Smooth looking then the Type of Surface involved is a SL one.

If the above mentioned rules are followed and all methods have been implemented correctly in order to obtain as accurate results as possible regarding the colour and texture characteristics of a rock surface, then the Type of Surface Classification System (Figure 4.6) should be a simple tool in determining the Type of Surface involved in rock art studies by inspection.

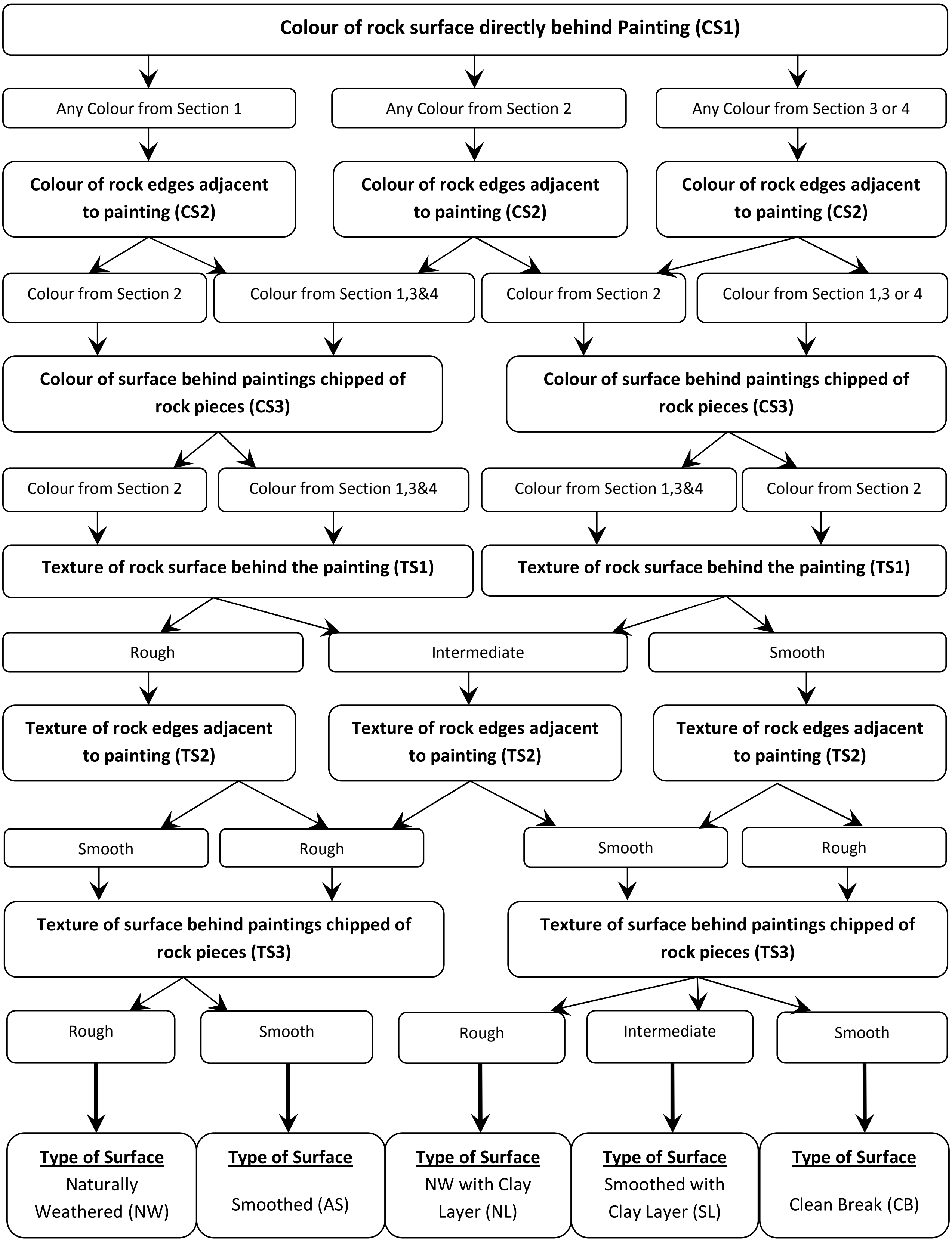


Figure 4.6: Type of Surface Classification System.

4.2 State of Deterioration Classification System

In order to assess how deteriorated rock art is, a State of Deterioration Classification System was created. This was done through following the methods as set out in Chapter 3 to create a Table that consisted of deterioration categories ranging from four Main Groups of Deterioration to Individual Deterioration Forms.

4.2.1 Data Capturing

Data were again captured through field visits to the study sites. A rating from 0-4 was assigned to each of the Individual Deterioration Forms depending on how much, or to what extent, each deterioration form occurred in the studied rock shelters or on painting surfaces. Values were assigned on the Table where after graphs were created to establish general trends within rock shelters regarding deterioration as well as the deterioration of rock art in general.

All weathering mechanisms affecting rock art deterioration (Chapter 2) were divided into Four Main Groups of Deterioration (Section 3.3.6). Since each of the four Main Groups of Deterioration consisted of weathering mechanisms that could harm rock art significantly, each Group was assumed to exert the same degree of deterioration on the art. Each Main Group (Loss of stone materials, Discoloration/Deposits, Fissures/Deformation and Environmental Conditions) thus contributed 25% of the State of Deterioration System. Each of the four Main Groups of Deterioration had a different number of Individual Deterioration Forms, and therefore the weight of each Group had to be adjusted in order to contribute 25% of the State of Deterioration System. These adjustments were done through implementing the following formula on all Main Groups of Deterioration of each scene:

$$Z = \frac{(q)(l)}{(i)(s)}$$

z= Actual contribution of Main Group
q= Total points of painting in the Group in question
l= Total lines for the whole table
i= Total lines for the Group in question
s= Total of Groups

After data capturing took place, and the actual contribution of each scene to the four Main Groups and the State of Deterioration Classification System as a whole was calculated, final Tables for each study site was completed (Table 4.4-4.7). A flow diagram summarising the steps that should be followed to classify surface type and state of deterioration is also given (Figure 4.7).

Main Caves

Cave name:	Main Caves	Time : 12h20										
Group	**Main weathering form**	**Individual weathering form**	**Investigation areas**									
			MC1	**MC2**	**MC3**	**MC4**	**MC5**	**MC6**	**MC7**	**MC8**	**MC9**	**MC10**
Surface Type			SL	NW	NW	NW	NW	CB	NL	AS	NW	NW
1 Loss of stone materials (LS)	Back Weathering	Back weathering due to loss of scales	0	1	2	3	1	2	4	0	4	4
		Back weathering due to loss of crusts	1	3	2	1	2	4	3	2	2	1
		Back weathering due to loss of indefinite stone aggregates/pieces	0	0	1	1	2	0	1	0	0	0
	Flaking	Single flakes	0	1	1	1	0	0	2	1	1	0
		Multiple flakes	0	0	0	2	2	2	4	0	3	0
	Break out	Break out due to constructional cause	0	0	0	1	2	0	1	0	0	2
		Break out due to natural cause	0	2	2	3	2	3	4	0	3	3
		Break out due to non-recognizable cause	0	0	0	2	4	0	0	0	0	2
		Total for section 1	**1**	**7**	**8**	**14**	**15**	**11**	**19**	**3**	**13**	**12**
		z =	**1.03**	**7.22**	**8.25**	**14.44**	**15.47**	**11.34**	**19.59**	**3.1**	**13.41**	**12.38**
2 Discolour-action/ Deposits (DD)	Discoloration	Coloration	2	2	3	2	1	2	2	3	1	1
		Coloration due to Dust settling in the cave	1	1	1	1	1	1	1	1	1	1
		Coloration due to fire	1	2	1	1	1	4	0	0	2	1
	Soiling	Soiling by particles from the atmosphere	1	1	1	1	1	1	1	1	1	1
		Soiling by particles from water	0	0	2	1	2	1	2	1	1	0
		Soiling by droppings	1	1	1	1	1	1	1	1	1	1
		Soiling due to anthropogenic impact	3	3	3	3	3	3	3	3	3	3
	Loose salt Deposits	Gypsum	2	1	3	0	1	2	1	2	2	1
		Efflorescences	0	0	0	0	0	0	0	0	0	0
	Organics	Fungi or algae growing on surface	0	0	2	0	3	0	2	1	0	1
		Lichen growing on surface	0	0	0	0	0	0	0	0	0	0
		Total for section 2	**11**	**11**	**17**	**10**	**14**	**15**	**13**	**13**	**12**	**10**
		z =	**8.25**	**8.25**	**12.75**	**7.5**	**10.5**	**11.25**	**9.75**	**9.75**	**9**	**7.5**
3 (FD)	Fissures	Fissures independent of stone structure	3	0	0	0	0	0	0	0	0	0
		Fissures dependent on stone structure	0	3	3	0	2	3	2	3	2	0
		Total for section 3	**3**	**3**	**3**	**0**	**2**	**3**	**2**	**3**	**2**	**0**
		z =	**12.38**	**12.38**	**12.38**	**0**	**8.25**	**12.38**	**8.25**	**12.38**	**8.25**	**0**
4 Environ-mental Conditions (EC)	Sunlight	Direct sunlight on painting panel during summer months	2	2	2	0	0	0	0	0	0	0
		Direct sunlight on painting panel during winter months	0	0	0	2	2	2	2	2	2	2
		Indirect sunlight from surrounding painting panels during summer months	2	2	2	0	0	0	0	0	0	0
		Indirect sunlight from surrounding painting panels during winter months	0	0	0	2	2	2	2	2	2	2
	Precipitation	Water running directly over surface of painting panel	0	0	2	0	0	0	2	0	0	0
		Rain directly on painting panel	0	0	2	2	0	0	0	0	0	0
		Water coming out of rock surface	0	0	1	1	1	1	2	1	1	1
		Mist entering the cave/ shelter	3	3	3	3	3	3	3	3	3	3
	Wind	Direct wind blowing onto surface painting panel	3	3	3	3	3	2	2	2	2	2
		Painting panel exposed to windy conditions	0	0	0	0	0	2	1	1	1	1
	Vegetation Loss	Vegetation loss due to natural causes	1	1	1	1	1	1	1	1	1	1
		Vegetation loss due to anthropogenic impacts	3	3	3	3	3	3	3	3	3	3
		Total for section 4	**14**	**14**	**19**	**17**	**15**	**16**	**18**	**15**	**15**	**15**
		z =	**9.63**	**9.63**	**13.1**	**11.69**	**10.31**	**11**	**12.38**	**10.31**	**10.31**	**10.31**

Scale	**Formula (z) Values**	**Surface Type**
0 = Not occurring	I = 33	NW = Naturally Weathered
1 = Very rare	s = 4	NL = Naturally Weathered with Clay Layer
2 = Rare	i(1) = 8, 1(2) = 11, i(3) =2, i(4) = 12	AS = Smoothed
3 = Frequent	q = total points for section	SL = Smoothed with Clay Layer
4 = Very frequent		CB = Clean Break

Average	1 (LS)	2 (DD)	3 (FD)	4 (EC)
NW	11.86167	9.25	6.876667	10.89167
NL	19.59	9.75	8.25	12.38
AS	3.1	9.75	12.38	10.31
SL	1.03	8.25	12.38	9.63
CB	11.34	11.25	12.38	11

Table 4.4: State of Deterioration Classification System for ten scenes in Main Caves.

Battle Cave

Cave name:	Battle Cave	Time :12h10										
Group	**Main weathering form**	**Individual weathering form**	**Investigation areas**									
			BC1	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**	**BC10**
Surface Type			NW	NW	NW	CB	NW	AS	NW	NW	SL	NW
1 Loss of stone materials (LS)	Back Weathering	Back weathering due to loss of scales	1	1	0	3	2	0	0	3	3	1
		Back weathering due to loss of crusts	1	1	2	2	1	0	1	2	3	3
		Back weathering due to loss of indefinite stone aggregates/pieces	0	0	0	0	0	0	0	0	0	0
	Flaking	Single flakes	1	2	0	2	2	1	2	1	1	0
		Multiple flakes	2	0	0	3	2	0	0	2	3	0
	Break out	Break out due to constructional cause	0	0	0	0	0	0	0	0	2	0
		Break out due to natural cause	2	0	0	3	3	1	2	1	4	0
		Break out due to non-recognizable cause	0	0	0	1	0	0	0	0	2	0
		Total for section 1	**7**	**4**	**2**	**14**	**10**	**2**	**5**	**9**	**18**	**4**
		Z=	**7.22**	**4.13**	**2.1**	**14.44**	**10.31**	**2.1**	**5.16**	**9.28**	**18.56**	**4.13**
2 Discolour-action/ Deposits (DD)	Discoloration	Coloration	4	2	2	2	3	3	1	3	2	3
		Coloration due to Dust settling in the cave	2	2	2	2	2	2	2	2	2	2
		Coloration due to fire	0	0	2	0	0	0	0	0	1	0
	Soiling	Soiling by particles from the atmosphere	1	1	1	1	1	1	1	1	1	1
		Soiling by particles from water	1	1	1	1	2	2	1	1	2	3
		Soiling by droppings	2	2	2	2	2	2	2	2	2	2
		Soiling due to anthropogenic impact	2	2	2	2	2	2	2	2	2	2
	Loose salt Deposits	Gypsum	0	1	2	1	1	1	1	1	3	1
		Efflorescences	0	0	1	0	1	0	0	0	1	0
	Organics	Fungi or algae growing on surface	1	1	1	1	1	0	0	0	1	0
		Lichen growing on surface	0	0	0	0	0	0	0	0	0	0
		Total for section 2	**13**	**12**	**16**	**12**	**15**	**13**	**10**	**12**	**17**	**14**
		Z=	**9.75**	**9**	**12**	**9**	**11.25**	**9.75**	**7.5**	**9**	**12.75**	**10.5**
3 (FD)	Fissures	Fissures independent of stone structure	0	0	0	0	0	0	0	0	0	0
		Fissures dependent on stone structure	0	3	1	2	2	0	0	1	0	1
		Total for section 3	**0**	**3**	**1**	**2**	**2**	**0**	**0**	**1**	**0**	**1**
		Z=	**0**	**12.38**	**4.13**	**8.25**	**8.25**	**0**	**0**	**4.13**	**0**	**4.13**
4 Environ-mental Conditions (EC)	Sunlight	Direct sunlight on painting panel during summer months	3	3	3	3	3	2	3	3	2	2
		Direct sunlight on painting panel during winter months	4	4	4	4	3	3	4	3	3	3
		Indirect sunlight from surrounding painting panels during summer months	1	1	1	1	1	1	1	1	1	0
		Indirect sunlight from surrounding painting panels during winter months	1	1	1	1	1	1	1	1	1	0
	Precipitation	Water running directly over surface of painting panel	0	0	1	2	1	2	1	0	3	4
		Rain directly on painting panel	3	2	2	2	2	2	1	1	2	2
		Water coming out of rock surface	1	1	1	1	2	4	1	2	3	4
		Mist entering the cave/ shelter	2	2	2	2	2	2	2	2	2	2
	Wind	Direct wind blowing onto surface painting panel	2	3	3	3	3	3	3	3	3	3
		Painting panel exposed to windy conditions	0	0	0	0	0	0	0	0	0	0
	Vegetation Loss	Vegetation loss due to natural causes	1	1	1	1	1	1	1	1	1	2
		Vegetation loss due to anthropogenic impacts	1	1	1	1	1	1	1	1	3	3
		Total for section 4	**19**	**19**	**20**	**21**	**20**	**22**	**19**	**18**	**24**	**25**
		Z=	**13.06**	**13.06**	**13.75**	**14.44**	**13.75**	**15.13**	**13.06**	**12.38**	**16.5**	**17.19**

Scale	**Formula (z) Values**	**Surface Type**
0 = Not occurring	I = 33	NW = Naturally Weathered
1 = Very rare	s = 4	NL = Naturally Weathered with Clay Layer
2 = Rare	i(1) = 8, 1(2) = 11, i(3) =2, i(4) = 12	AS = Smoothed
3 = Frequent	q = total points for section	SL = Smoothed with Clay Layer
4 = Very Frequent		CB = Clean Break

Average	1 (LS)	2 (DD)	3 (FD)	4 (EC)
NW	6.047143	9.857143	4.717143	13.75
NL	0	0	0	0
AS	2.1	9.75	0	15.13
SL	18.56	12.75	0	16.5
CB	14.44	9	8.25	14.44

Table 4.5: State of Deterioration Classification System for ten scenes in Battle Cave.

Game Pass Shelter

Cave name:	Game Pass Shelter	Time : 11h40										
Group	**Main weathering form**	**Individual weathering form**	**Investigation areas**									
			GP1	**GP2**	**GP3**	**GP4**	**GP5**	**GP6**	**GP7**	**GP8**	**GP9**	**GP10**
Surface Type			NW	AS	NW	NW	AS	NL	NW	NW	NW	AS
1 Loss of stone materials (LS)	Back Weathering	Back weathering due to loss of scales	0	1	3	3	1	3	0	0	3	1
		Back weathering due to loss of crusts	1	2	2	3	2	3	1	1	3	1
		Back weathering due to loss of indefinite stone aggregates/pieces	0	0	0	0	0	0	0	0	0	0
	Flaking	Single flakes	0	2	2	2	2	3	1	0	2	1
		Multiple flakes	0	0	3	3	1	4	0	0	3	0
	Break out	Break out due to constructional cause	0	0	0	0	0	0	0	0	0	0
		Break out due to natural cause	0	0	2	4	0	4	0	0	2	0
		Break out due to non-recognizable cause	0	0	0	0	0	2	0	0	0	0
		Total for section 1	**1**	**5**	**12**	**15**	**6**	**19**	**2**	**1**	**13**	**3**
		Z=	**1.03**	**5.16**	**12.38**	**15.47**	**6.19**	**19.59**	**2.1**	**1.03**	**13.41**	**3.1**
2 Discolour-action/ Deposits (DD)	Discoloration	Coloration	2	3	2	2	2	2	2	1	3	3
		Coloration due to Dust settling in the cave	2	2	2	2	2	2	2	2	2	2
		Coloration due to fire	1	1	1	1	1	1	1	1	1	1
	Soiling	Soiling by particles from the atmosphere	1	1	1	1	1	1	1	1	1	1
		Soiling by particles from water	3	1	1	1	1	1	1	1	1	2
		Soiling by droppings	2	2	2	2	2	2	2	2	2	2
		Soiling due to anthropogenic impact	3	3	3	3	3	3	3	3	3	3
	Loose salt Deposits	Gypsum	3	3	2	2	2	3	2	0	2	2
		Efflorescences	0	1	0	1	1	2	2	0	1	3
	Organics	Fungi or algae growing on surface	1	3	0	3	3	3	2	0	2	2
		Lichen growing on surface	0	0	0	0	0	0	0	0	0	0
		Total for section 2	**18**	**20**	**14**	**18**	**18**	**20**	**18**	**11**	**18**	**21**
		Z=	**13.5**	**15**	**10.5**	**13.5**	**13.5**	**15**	**13.5**	**8.25**	**13.5**	**15.75**
3 (FD)	Fissures	Fissures independent of stone structure	0	0	0	0	0	0	0	0	0	0
		Fissures dependent on stone structure	1	0	2	2	1	1	1	1	2	1
		Total for section 3	**1**	**0**	**2**	**2**	**1**	**1**	**1**	**1**	**2**	**1**
		Z=	**4.13**	**0**	**8.25**	**8.25**	**4.13**	**4.13**	**4.13**	**4.13**	**8.25**	**4.13**
4 Environ-mental Conditions (EC)	Sunlight	Direct sunlight on painting panel during summer months	1	1	1	1	1	1	1	1	1	1
		Direct sunlight on painting panel during winter months	2	2	2	2	1	2	2	2	2	2
		Indirect sunlight from surrounding painting panels during summer months	1	1	1	1	1	1	1	1	1	1
		Indirect sunlight from surrounding painting panels during winter months	1	1	1	1	1	1	1	1	1	1
	Precipitation	Water running directly over surface of painting panel	3	1	1	1	2	1	0	0	4	0
		Rain directly on painting panel	1	2	0	0	0	0	0	0	1	1
		Water coming out of rock surface	3	2	2	2	2	2	2	2	3	1
		Mist entering the cave/ shelter	3	3	3	3	3	3	3	3	3	3
	Wind	Direct wind blowing onto surface painting panel	3	3	3	3	2	2	2	2	2	2
		Painting panel exposed to windy conditions	0	0	0	0	2	2	2	2	2	2
	Vegetation Loss	Vegetation loss due to natural causes	1	1	1	1	1	1	1	1	1	1
		Vegetation loss due to anthropogenic impacts	1	3	2	3	2	3	3	3	3	3
		Total for section 4	**20**	**20**	**17**	**18**	**18**	**19**	**18**	**18**	**24**	**18**
		Z=	**13.75**	**13.75**	**11.69**	**12.38**	**12.38**	**13.1**	**12.38**	**12.38**	**16.5**	**12.38**

Scale
0 = Not occurring
1 = Very rare
2 = Rare
3 = Frequent
4 = Very Frequent

Formula (z) Values
I = 33
s = 4
i(1) = 8, 1(2) = 11, i(3) =2, i(4) = 12
q = total points for section

Surface Type
NW = Naturally Weathered
NL = Naturally Weathered with Clay Layer
AS = Smoothed
SL = Smoothed with Clay Layer
CB = Clean Break

Average	1 (LS)	2 (DD)	3 (FD)	4 (EC)
NW	7.57	12.125	6.19	13.18
NL	19.59	15	4.13	13.1
AS	4.816667	14.75	2.753333	12.83667
SL	0	0	0	0
CB	0	0	0	0

Table 4.6: State of Deterioration Classification System for ten scenes in Game Pass Shelter.

Sigubudu Cave

Cave name:	Sigubudu Cave	Time : 11h45										
Group	**Main weathering form**	**Individual weathering form**	**Investigation areas**									
			SC1	**SC2**	**SC3**	**SC4**	**SC5**	**SC6**	**SC7**	**SC8**	**SC9**	**SC10**
Surface Type			NW	AS	NW	NW	NW	CB	NW	NW	NW	NW
1 Loss of stone materials (LS)	Back Weathering	Back weathering due to loss of scales	3	1	0	0	3	2	0	3	0	0
		Back weathering due to loss of crusts	3	2	2	1	3	2	2	2	2	1
		Back weathering due to loss of indefinite stone aggregates/pieces	0	0	0	0	0	0	0	0	0	0
	Flaking	Single flakes	2	0	1	0	2	1	1	1	0	1
		Multiple flakes	4	0	0	0	4	2	3	3	0	1
	Break out	Break out due to constructional cause	2	0	0	0	0	0	0	0	0	0
		Break out due to natural cause	3	0	1	0	3	2	2	3	0	0
		Break out due to non-recognizable cause	0	0	0	0	0	0	0	0	0	1
		Total for section 1	**17**	**3**	**4**	**1**	**15**	**9**	**8**	**12**	**2**	**4**
		Z=	**17.53**	**3.1**	**4.13**	**1.03**	**15.47**	**9.28**	**8.25**	**12.38**	**2.1**	**4.13**
2 Discolour-action/ Deposits (DD)	Discoloration	Coloration	4	3	4	4	3	2	4	2	3	4
		Coloration due to Dust settling in the cave	2	2	2	2	2	2	2	2	2	2
		Coloration due to fire	1	1	2	2	2	2	2	3	3	2
	Soiling	Soiling by particles from the atmosphere	3	3	3	3	3	3	3	3	3	3
		Soiling by particles from water	1	1	1	1	1	1	2	2	2	2
		Soiling by droppings	2	2	2	2	2	2	2	2	2	2
		Soiling due to anthropogenic impact	3	3	3	3	3	3	3	3	3	3
	Loose salt Deposits	Gypsum	0	1	0	0	1	1	1	1	1	2
		Efflorescences	0	0	1	0	0	1	0	0	0	0
	Organics	Fungi or algae growing on surface	0	2	2	0	2	2	1	2	2	0
		Lichen growing on surface	0	0	0	0	0	0	0	0	0	0
		Total for section 2	**16**	**18**	**20**	**17**	**19**	**19**	**20**	**20**	**21**	**20**
		Z=	**12**	**13.5**	**15**	**12.75**	**14.25**	**14.25**	**15**	**15**	**15.75**	**15**
3 (FD)	Fissures	Fissures independent of stone structure	0	0	0	0	0	0	0	0	0	3
		Fissures dependent on stone structure	0	0	3	2	3	3	0	3	0	0
		Total for section 3	**0**	**0**	**3**	**2**	**3**	**3**	**0**	**3**	**0**	**3**
		Z=	**0**	**0**	**12.38**	**8.25**	**12.38**	**12.38**	**0**	**12.38**	**0**	**12.38**
4 Environ-mental Conditions (EC)	Sunlight	Direct sunlight on painting panel during summer months	1	1	1	1	1	1	1	1	1	1
		Direct sunlight on painting panel during winter months	3	2	3	2	2	1	2	0	2	2
		Indirect sunlight from surrounding painting panels during summer months	1	1	1	1	1	1	1	0	0	1
		Indirect sunlight from surrounding painting panels during winter months	1	1	1	1	1	1	1	0	0	1
	Precipitation	Water running directly over surface of painting panel	0	0	0	0	0	0	0	2	0	0
		Rain directly on painting panel	1	1	2	1	1	0	1	1	1	1
		Water coming out of rock surface	1	1	2	1	1	2	2	2	1	1
		Mist entering the cave/ shelter	3	3	3	3	3	3	3	3	3	3
	Wind	Direct wind blowing onto surface painting panel	3	3	3	3	3	2	3	1	1	3
		Painting panel exposed to windy conditions	0	0	0	0	0	1	0	1	1	0
	Vegetation Loss	Vegetation loss due to natural causes	2	2	2	2	2	2	2	2	2	2
		Vegetation loss due to anthropogenic impacts	3	3	3	3	3	3	3	1	1	3
		Total for section 4	**19**	**18**	**21**	**18**	**18**	**17**	**19**	**14**	**13**	**18**
		Z=	**13.1**	**12.38**	**14.44**	**12.38**	**12.38**	**11.69**	**13.1**	**9.63**	**8.94**	**12.38**

Scale
0 = Not occurring
1 = Very rare
2 = Rare
3 = Frequent
4 = Very Frequent

Formula (z) Values
I = 33
s = 4
i(1) = 8, 1(2) = 11, i(3) =2, i(4) = 12
q = total points for section

Surface Type
NW = Naturally Weathered
NL = Naturally Weathered with Clay Layer
AS = Smoothed
SL = Smoothed with Clay Layer
CB = Clean Break

Average	1 (LS)	2 (DD)	3 (FD)	4 (EC)
NW	8.1275	14.34375	7.22125	12.04375
NL	0	0	0	0
AS	3.1	13.5	0	12.38
SL	0	0	0	0
CB	9.28	14.25	12.38	11.69

Table 4.7: State of Deterioration Classification System for ten scenes in Sigubudu Cave.

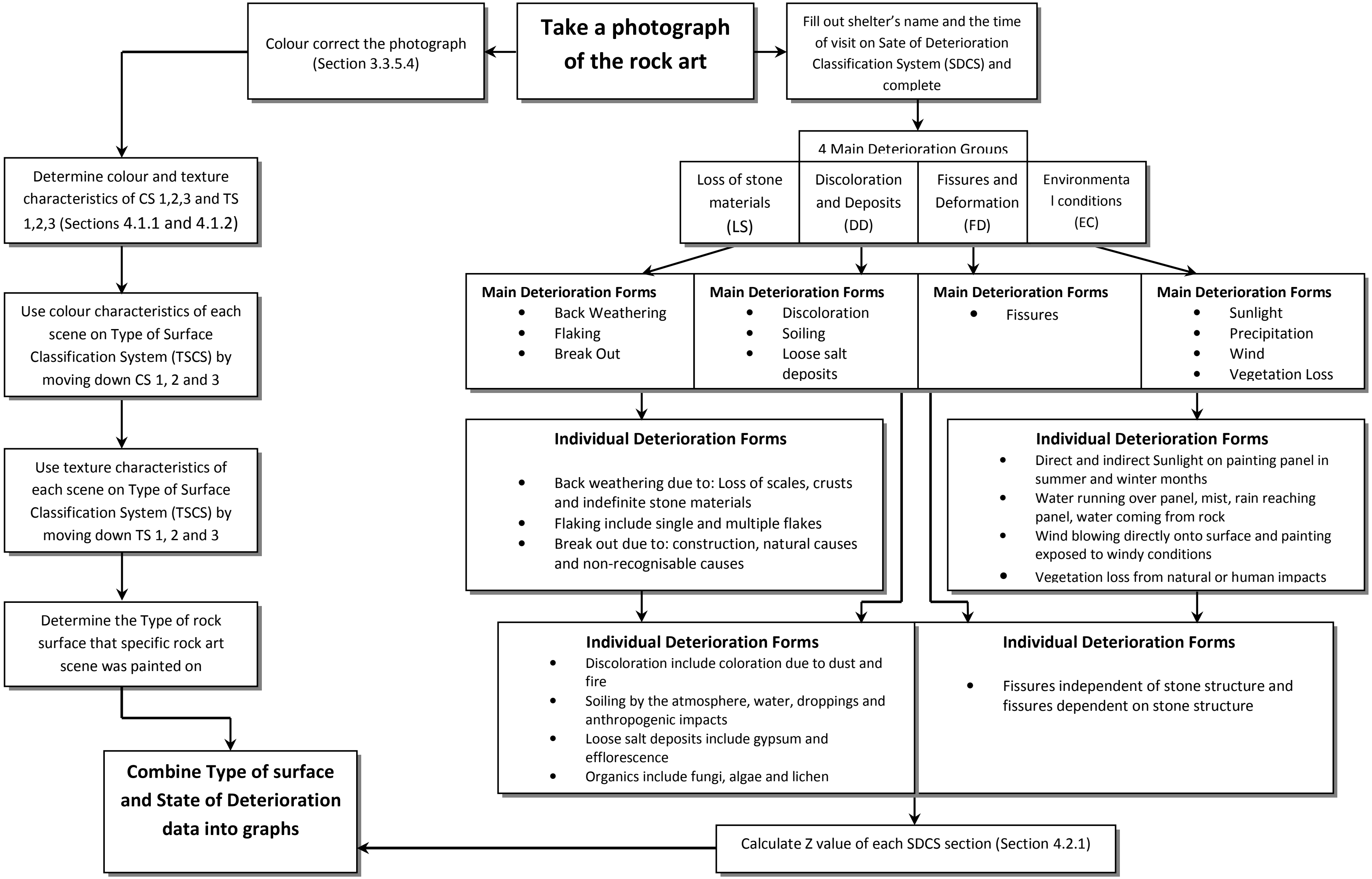


Figure 4.7: Flow diagram summarising the steps that should be followed to classify surface type and state of deterioration.

4.2.2 Results

After data collection at the four study sites, for the purpose of the State of Deterioration Classification System, graphs could be created which show the extent to which the four Main Groups of Deterioration affected rock art painted on different Types of Surfaces. During the following section results from the four study sites will first be discussed, followed by a discussion on the Type of rock Surfaces found in each shelter in relation to how deteriorated the rock art of each shelter is.

4.2.2.1 Main Caves

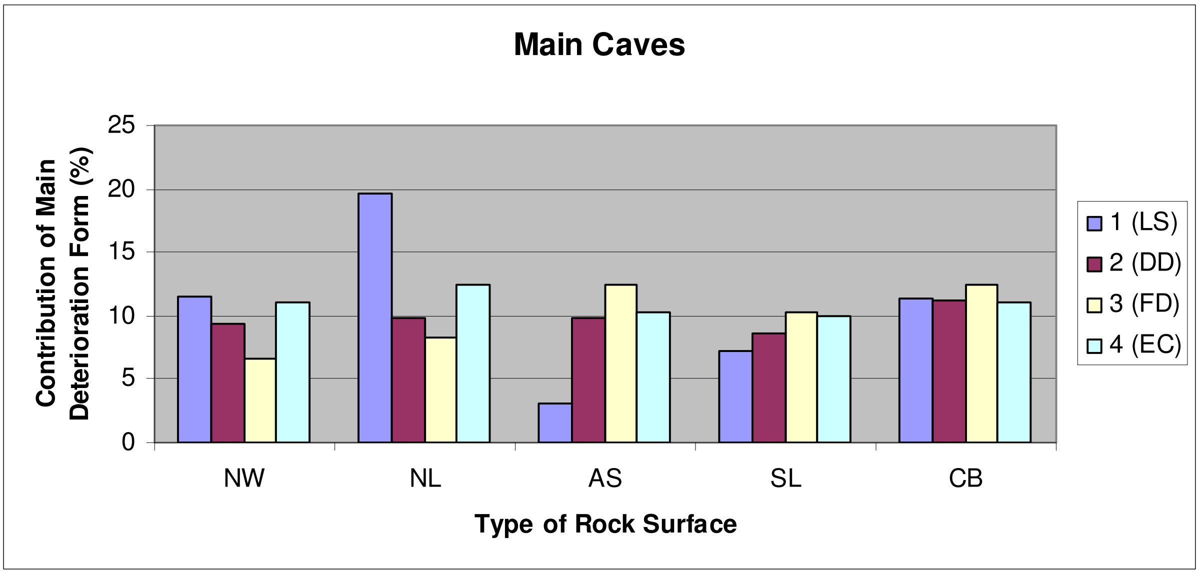


Figure 4.8: State of Deterioration of Main Caves. Main Groups of Deterioration: LS – Loss of Stone Material, DD - Deposits/ Discoloration, FD – Fissures/ Deformation, EC – Environmental Conditions. Types of Rock Surfaces: NW – Naturally Weathered, NL – NW with Clay Layer, AS – Smoothed, SL – S with Clay Layer, CB – Clean Break

From the ten scenes selected at Main Caves (Figure 4.8) five Naturally Weathered (NW) rock surfaces, one Smoothed with a Clay Layer (SL), one Naturally Weathered with a Clay Layer (NL), one Smoothed (AS) and one Clean Break (CB) rock surface were included.

The Naturally Weathered rock surface with a Clay Layer (NL) placed on top showed the greatest Loss of stone materials (LS) with the Smoothed rock surface with a Clay Layer placed on top showing the least. The Smoothed rock surface also had a very low rating of stone material loss while Naturally Weathered and Clean Break rock surfaces had a moderate Loss of stone materials. Environmental conditions (EC) were found to be almost similar throughout the study site with the NL rock surface receiving the harshest environmental conditions which might be the reason for the high amounts of stone material loss. All scenes seemed to be moderately Discoloured (DD) while Fissures (FD) are a common occurrence throughout all rock surfaces at Main Caves. The SL and S rock surfaces appear to be the least deteriorated at Main Caves while the NL rock surface, on the other hand, appears to be very deteriorated mainly due to its high loss of stone material.

4.2.2.2 Battle Cave

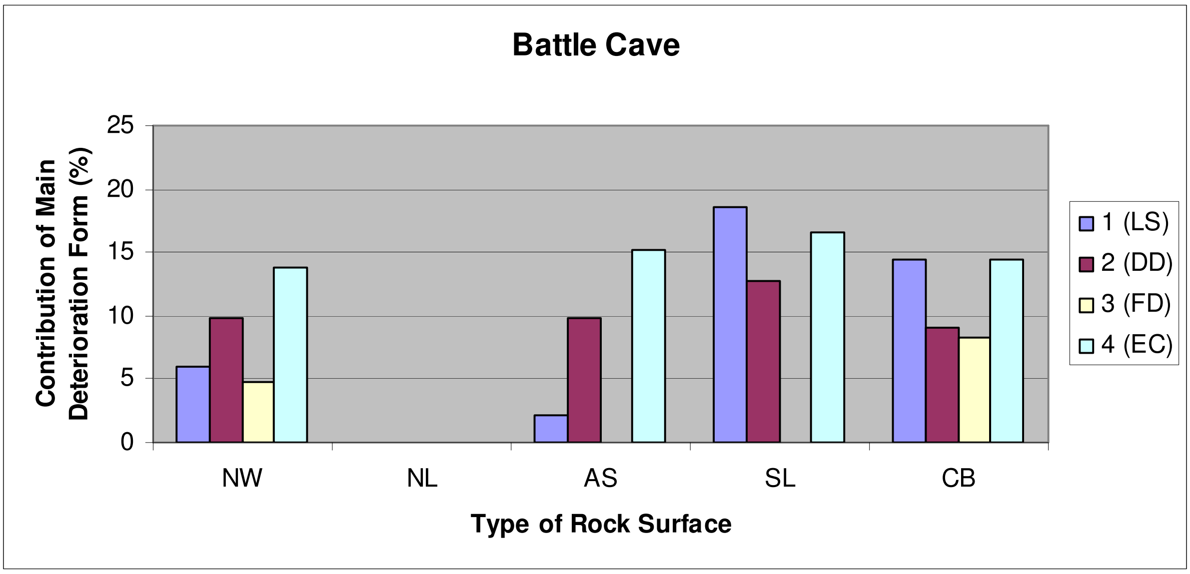


Figure 4.9: State of Deterioration of Battle Cave. Main Groups of Deterioration: LS – Loss of Stone Material, DD – Deposits/Discoloration, FD – Fissures/ Deformation, EC – Environmental Conditions. Types of Rock Surfaces: NW – Naturally Weathered, NL – NW with Clay Layer, AS – Smoothed, SL – S with Clay Layer, CB – Clean Break

The Battle Cave study site included seven Naturally Weathered (NW), one Smoothed (AS), one Smoothed with Clay Layer (SL) and one Clean Break (CB) rock surface. As The Battle Cave study site is a shallow, north-facing shelter, it is exposed to many environmental conditions (Meiklejohn *et al.,* 2009). Due to its north-facing aspect, this shelter receives substantial direct solar radiation input especially in winter as rock shelter backwalls, and hence the paintings on them, may receive early morning and/or late afternoon sun (Sumner and Nel, 2006; Meiklejohn, 1994). The high amounts of solar radiation that

Battle Cave receives might therefore be the reason for moderated to high percentage discoloration seen in many of the paintings.

In contrast with Main Caves, fissures are not commonly found at Battle Cave and where present data show (Figure 4.9) that it does not have such a big impact on the deterioration of the rock art as the other Main Groups of Deterioration. The Loss of stone materials occurred mostly on the SL rock surface where a significant amount (almost half) of that painting (BC9) has flaked of. The Smoothed rock surface show the smallest amount of stone material lost, while the Naturally Weathered rock surfaces showed the second least. The Naturally Weathered rock surfaces at Battle Cave also seemed to be the least deteriorated overall with low to moderate ratings in all four Main Groups of deterioration.

4.2.2.3 Game Pass Shelter

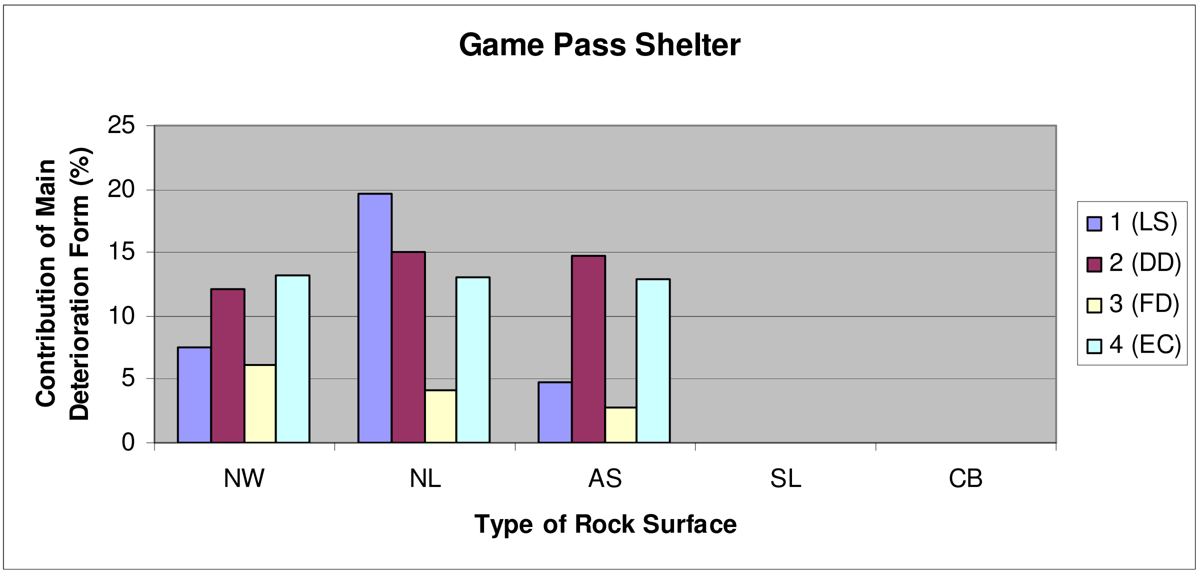


Figure 4.10: State of Deterioration of Game Pass Shelter. Main Groups of Deterioration: LS – Loss of Stone Material, DD – Deposits/ Discoloration, FD – Fissures/ Deformation, EC – Environmental Conditions. Types of Rock Surfaces: NW Naturally Weathered, NL – NW with Clay Layer, AS – Smoothed, SL – Smoothed with Clay Layer, CB – Clean Break

At Game Pass Shelter only three types of surfaces exist within the ten scenes that were selected. From these six were Naturally Weathered (NW), three Smoothed (AS) and one Naturally Weathered with a Clay Layer on top (NL). Environmental conditions at Game Pass Shelter are moderate with paintings receiving some solar radiation, but moisture posing the greatest threat to the conservation of the art (Figure 4.10). Rock overhangs mostly protect painting panels from direct moisture although some moisture does influence the paintings through mist entering the cave as well as through seepage (Hoerlé *et al.,* 2007).

At Game Pass Shelter clay-rich layers are roughly parallel and horizontal with the back wall of the shelter which in turn causes many cracks and fractures (Hoerlé, 2005). Fissures were found on the ten scenes analysed at Game Pass Shelter but are not estimated to cause extensive damage to the paintings as their rating is low on all rock surface types. The intense vertical fracturing of the whole cliff at Game Pass Shelter is however, at the larger scale, associated with at least four thin clayey interstratified low resistant levels (stratification joints) that are responsible for the cutting of the painted wall in many meter sized blocks (Denis *et al.,* 2009) which might harm rock art paintings if it were to break loose from the sandstone rock body.

As is the case with the Main Caves study site, what is thought to be the Naturally Weathered with Clay Layer (NL) rock surface has a very high Loss of stone materials. The Smoothed rock surfaces, however, showed the least amount of stone material loss. The reason for this might be that although the paintings have never been dated, the mechanical strength of the un-weathered sandstone appears to be quite good (Hoerlé, 2005) and a Smoothed surface that has not yet weathered greatly, as it's weathering clock is "zeroed" by smoothing (Pope *et al.,* 2002), will therefore have a good mechanical strength.

At Game Pass Shelter the NL surface also showed the highest degree of Discoloration/ Deposits with NW rock surfaces proving to be the least discoloured. Generally the paintings found in this shelter do not appear to be very deteriorated, except the NL rock surface which show signs of extreme deterioration mainly due to a high loss of stone materials.

4.2.2.4 Sigubudu Cave

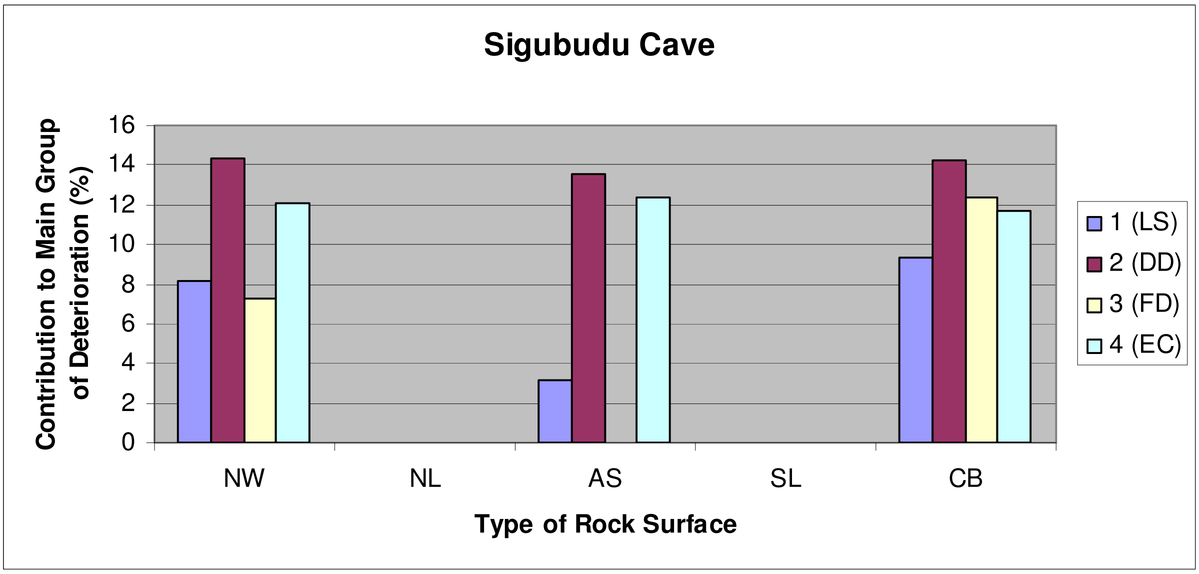


Figure 4.11: State of Deterioration of Sigubudu Cave. Main Groups of Deterioration: LS – Loss of Stone Material, DD – Deposits/ Discoloration, FD – Fissures/ Deformation, EC – Environmental Conditions. Types of Rock Surfaces: NW – Naturally Weathered, NL – NW with Clay Layer, AS – Smoothed, SL – AS with Clay Layer, CB – Clean Break.

Although the scenes selected for analysis from Sigubudu Cave only included three types of surfaces, these types of surfaces (Naturally Weathered, Smoothed and Clean Break) mainly followed the same trends as the other three study sites. Data showed that the shelter is exposed to moderately high Environmental conditions and discoloration was high on all three types of rock surfaces. The Loss of stone materials is not as prominent in this shelter as at the other three study sites; however it was evident that it was the highest on the CB surface (Figure 4.11) which also showed deterioration due to fissures on the rock surface. The Smoothed rock surface again appeared the least deteriorated with the CB rock surface being most deteriorated. It has to be noted though that all the rock paintings found in Sigubudu Cave are already badly deteriorated with some paintings being barely visible.

Data from the four study sites on surface type and State of deterioration was further combined in order to establish the impact that each of the Main Groups of Deterioration have on each Type of Surface. These results as well as the impact of certain factors involved in the deterioration of rock art will also be outlined in the discussion where after some final thoughts as to what the results may implicate and the consequences thereof will be discussed.

4. 3 Surface Type vs. State of Deterioration

It has been shown in the previous sections of this Chapter that the Surface Type plays a role in the deterioration of rock art. This is mainly due to the fact that each Type of Surface has different surface attributes which in turn respond differently to the same mechanical and chemical weathering reactions even if conditions that cause and enhance these weathering mechanisms are similar. In this section the extent of deterioration of each Type of Surface at all four study sites will be discussed in relation to the four Main Groups of Deterioration that cause deterioration to these Types of Surfaces.

4.3.1 Naturally Weathered

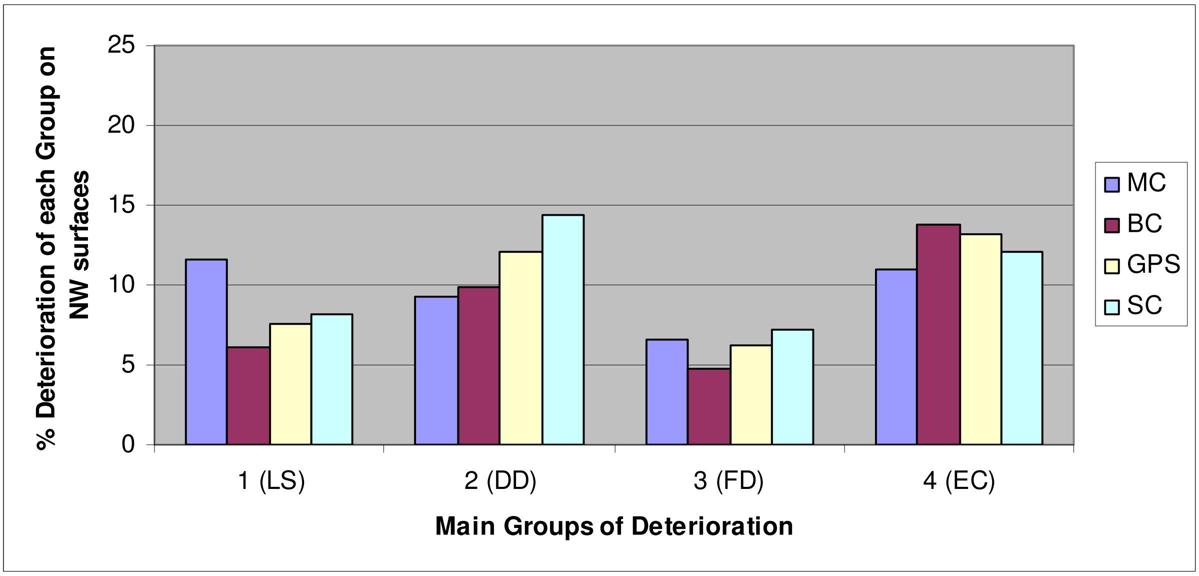


Figure 4.12: Deterioration of Naturally Weathered rock surfaces (n=27). Main Groups of Deterioration: LS – Loss of Stone Material, DD – Deposits/ Discoloration, FD – Fissures/ Deformation, EC – Environmental Conditions. Study Sites: MC – Main Caves, BC – Battle Cave, GPS – Game Pass Shelter, SC – Sigubudu Cave.

Because a Naturally Weathered rock surface is a rock surface where no human-induced alteration has taken place on the rock surface, this Type of Surface should deteriorate through impacts of all four Main Groups of Deterioration. Through this study it was clear that Environmental Conditions played the biggest role in the deterioration of the rock on which the art is painted, where Naturally Weathered surfaces are concerned (Figure 4.12). Battle Cave does, however, display the harshest environmental conditions mainly due to the high amount of solar radiation this shelter receives (Sumner & Nel, 2006; Meiklejohn *et al.,* 2009).

On the Naturally Weathered rock surfaces of Main Caves the Loss of stone material is the greatest. The reason for this could be the high moisture content found in rock surfaces at this shelter (Meiklejohn *et al.,* 2009). At Sigubudu Cave Discoloration is at its greatest on Naturally Weathered rock surfaces (in other words the majority of the paintings sampled there) with some of the paintings almost not being visible at all. The reason for this might also be due to high solar radiation to the painting panels, but air pollution from the nearby community can also play a role in the deterioration of the rock art there. Fissures seem to play a less significant role in the deterioration of Naturally Weathered stone surfaces as the occurrence thereof (on NW surfaces) is quite low at all study sites.

4.3.2 Naturally Weathered with Clay Layer

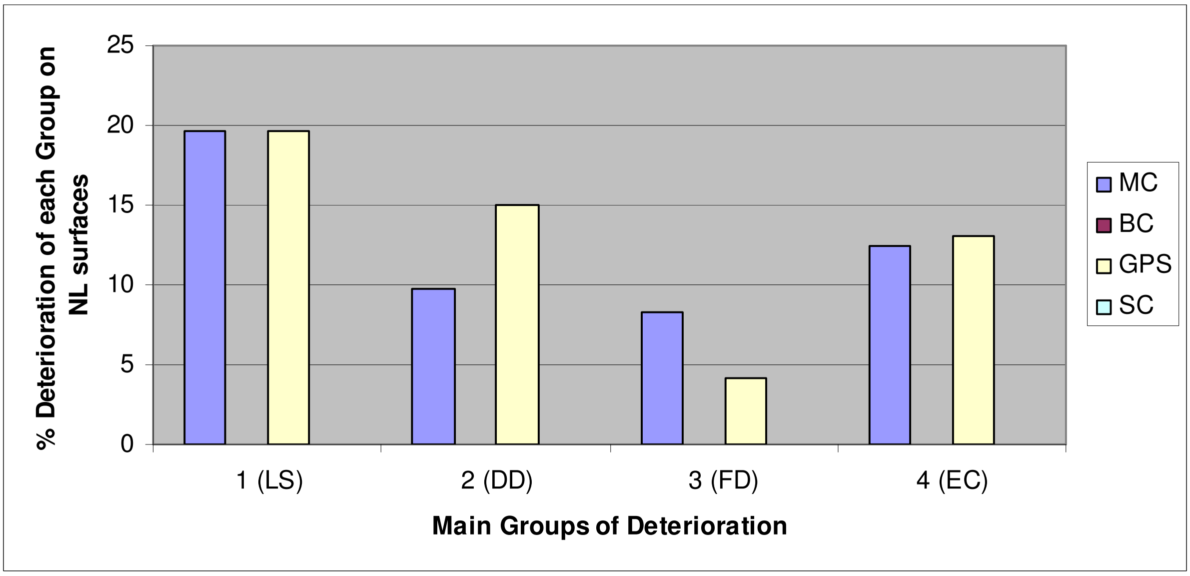


Figure 4.13: Deterioration of Naturally Weathered with Clay Layer rock surfaces (n=2). Main Groups of Deterioration: LS – Loss of Stone Material, DD – Deposits/ Discoloration, FD – Fissures/ Deformation, EC – Environmental Conditions. Study Sites: MC – Main Caves, BC – Battle Cave, GPS – Game Pass Shelter, SC – Sigubudu Cave.

Although the existence of Naturally Weathered rock surfaces with a Clay Layer placed on top has only been speculated. This Type of Surface appears to exist at Main Caves as well as at Game Pass Shelter (Figure 4.13). In the two instances where this Type of Surface occurred a significant amount of Loss of Stone Materials has taken place. This high loss of stone material could be as a result of the Naturally Weathered layer underneath weathering through different weathering mechanisms which in turn exert pressure on the Clay Layer on top causing it to spall off. Both Battle Cave and Game Pass

Shelter have high moisture content (Meiklejohn *et al.,* 2009) and although moisture does not necessarily run directly over the rock surface, a lot of moisture transfer occurs through seepage (Hoerlé, 2005).

The deterioration of rock paintings made on Naturally Weathered rock surfaces with a Clay Layer (NL) on top seems to be somewhat more extreme at Game Pass Shelter where Discoloration and Environmental Conditions are the highest. Fissures is also not a common feature found on NL surfaces as both rock art shelters show a low rating thereof.

4.3.3 Anthropogenically Smoothed

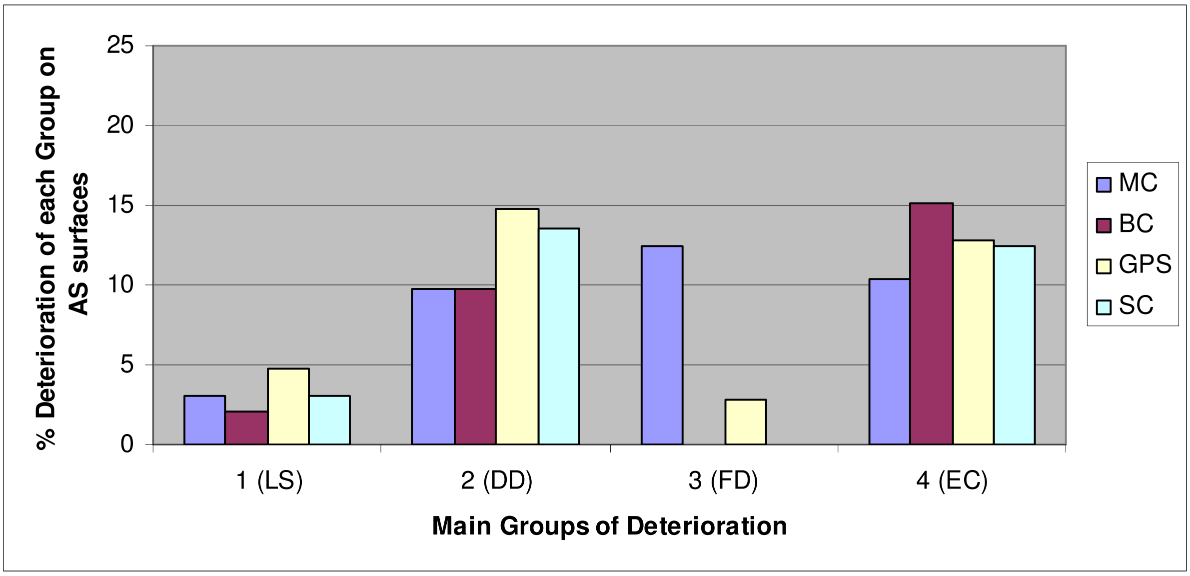


Figure 4.14: Deterioration of Smoothed rock surfaces (n=6). Main Groups of Deterioration: LS – Loss of Stone Material, DD – Deposits/ Discoloration, FD – Fissures/ Deformation, EC – Environmental Conditions. Study Sites: MC – Main Caves, BC – Battle Cave, GPS – Game Pass Shelter, SC – Sigubudu Cave.

As Smoothed rock surfaces are surfaces that has been cleaned before painting has taken place it is expected to react in a totally different manner to the same Main Groups of Deterioration as the other Types of rock Surfaces. Through this study it has been found that the Smoothed rock surfaces experience the lowest rating of Loss of Stone Materials than any other rock surface Type (Figure 4.14). The reason for this might be that the already weathered stone material has been removed and as weathering thus starts “anew” on Smoothed surfaces (Pope *et al.,* 2002) not enough time has passed for the rock surface itself to show signs of weathering.

Although Discoloration of Smoothed rock surfaces seemed to be moderate to high in all rock art shelters, Game Pass Shelter showed the highest rate of discoloration. This could be linked to the impact of environmental conditions on Smoothed surfaces as high amounts of solar radiation on these surfaces can cause paintings to fade. With the addition of moisture and human interaction to varying degrees of temperature change, discoloration could also take place through soiling and loose salt deposits forming on the painting surface.

4.3.4 Smoothed with Clay Layer

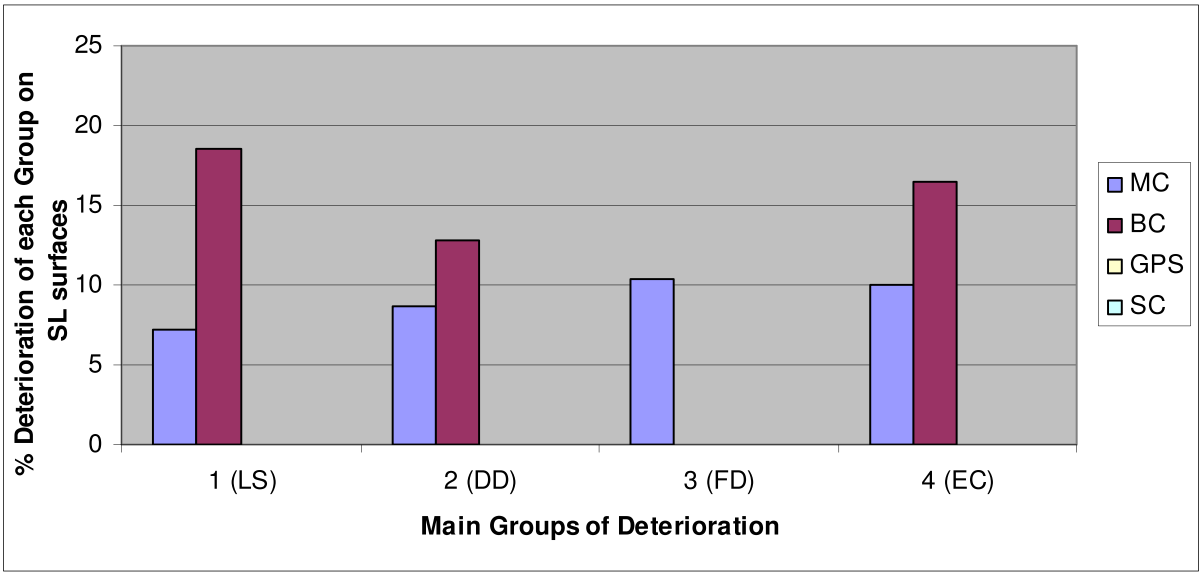


Figure 4.15: Deterioration of Smoothed with Clay Layer rock surfaces (n=2). Main Groups of Deterioration: LS – Loss of Stone Material, DD – Deposits/ Discoloration, FD – Fissures/ Deformation, EC – Environmental Conditions. Study Sites: MC – Main Caves, BC – Battle Cave, GPS – Game Pass Shelter, SC – Sigubudu Cave.

The occurrence of Smoothed rock surfaces with a Clay Layer placed on top could, as in the case of Naturally Weathered with Clay Layer (NL) rock surfaces, only be found at two of the study sites. What is evident here is that Battle Cave had a much higher degree of Loss of Stone Materials than Main Caves (Figure 4.15). The reason for this high loss could be ascribed to the same reasons as the NL surface where moisture being trapped behind the clay layer could cause the Clay ground Layer to spall/flake off (Hall *et al.,* 2007a). In this instance though the break out of rock pieces is not as high and flaking will occur more as just the Clay Layer will spall from the rock surface and not the pieces of the rock behind it. At Main Caves this might not have happened yet and therefore the painting have lost little stone material up to date. Harsher environmental conditions are found at Battle Cave which could also accelerate this process.

Discoloration was also the highest on Smoothed surfaces at Battle Cave, again due to higher solar radiation input to the rock surface when compared to Main Caves. Fissures did on the other hand only occur on the Smoothed surface at Main Caves and no fissures could be found on the Smoothed surface found at Battle Cave.

4.3.5 Clean Break

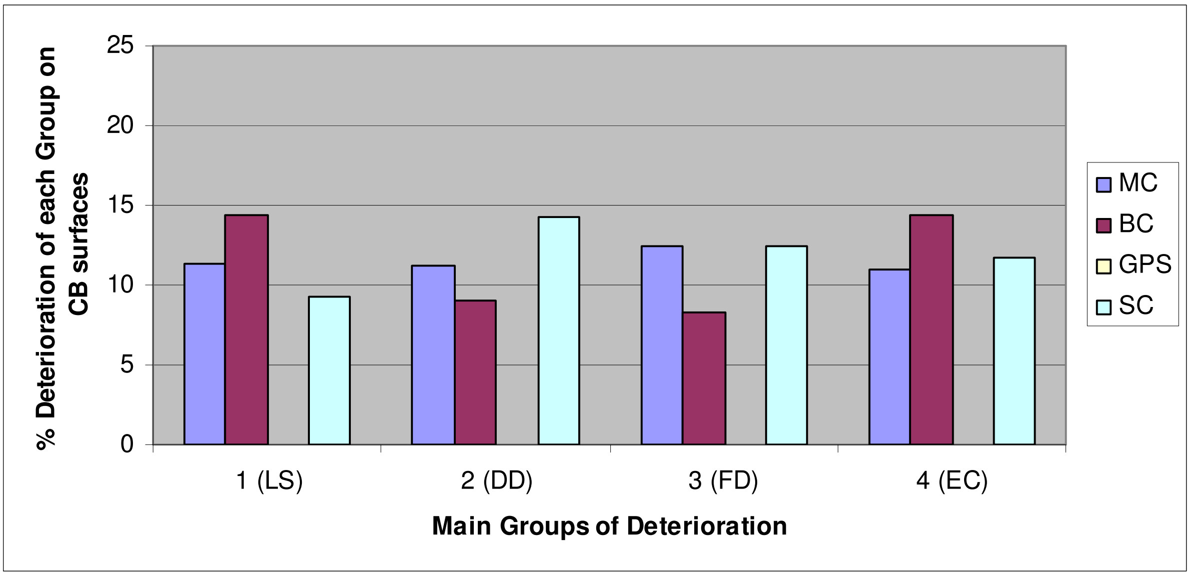


Figure 4.16: Deterioration of Clean Break rock surfaces (n=3). Main Groups of Deterioration: LS – Loss of Stone Material, DD – Deposits/ Discoloration, FD – Fissures/ Deformation, EC – Environmental Conditions. Study Sites: MC – Main Caves, BC – Battle Cave, GPS – Game Pass Shelter, SC – Sigubudu Cave.

From the photographs analysed Clean Break surfaces could be found in all study shelters except one, Game Pass Shelter. As already mentioned are Environmental Conditions at Battle Cave the harshest which might be the reason for the most deterioration taking place there especially in the case of Clean Break surfaces mainly due to a high Loss of Stone Materials.

At Sigubudu Cave Discoloration is again the highest, but a higher rating could be seen in all four Main Groups of Deterioration in this shelter compared to the other two shelters (Figure 4.16). Clean Break rock surfaces at Main Caves seem to be deteriorating to a moderate degree through all four MGD.

Generally though, it can be concluded that the paintings found on Clean Break rock surfaces are not as deteriorated as those found on other rock surfaces. The reason for this might be that CB surfaces largely follow the same trend as smoothed surfaces. The rock surface is thus "fresh" after it has fallen from the rock face and weathering will start anew which is a process operating over time.

4.4 Discussion

In this Chapter a Type of Surface Classification System as well as a State of Deterioration Classification System was developed, applied and analysed. The purpose of the two Systems was first so that easy-to-use non-invasive techniques could be developed to determine what type of surface a painting is on as well as to determine through visual inspection how deteriorated the rock art found on these surfaces is. Second, these Systems were developed in order to determine whether different Types of Surfaces deteriorate through different deterioration forms and to what extent. Results were obtained from these Systems and were analysed and discussed and some similarities as to the Main Groups of Deterioration operating on the different Types of Surfaces were observed.

Even though the existence of Naturally Weathered rock surfaces with a Clay Layer on top has only been speculated up to date this type of surface was observed during the course of this study. Two of the study sites (Main Caves and Game Pass Shelter) contained one example of this Type of Surface in the ten pictures/scenes selected for each site (Refer to Figure 4.2 – GP6, and Figure 4.3 – MC7). What was significant about this observation is that rock art scenes believed to have been painted on Naturally Weathered rock surfaces with a Clay Layer on proved to be the most deteriorated Type of Surface found in the study.

Results showed that rock surfaces that has been prepared by human action before paint has been applied to it definitely deteriorate in a different manner when compared to rock surfaces that has only been weathered through natural processes. This is especially the case where a Clay ground Layer has been placed over either a Naturally Weathered rock surface or a Smoothed one (Figure 4.12 & Figure 4.14). The Loss of Stone Materials is in some of these cases so extreme that a significant amount of the painting has been lost due to break out, flaking and spalling of the surface. It should be noted though that it is not the rock surface in most of these cases (especially with Smoothed surfaces) that is deteriorating but rather the Clay Layer itself (Hall *et al.,* 2007a). The reason for this being that where the art was painted over the clay ground, the ground acts as a 'surface modifier', consequently hindering moisture from reaching the clay, in that way causing physical and chemical changes (Hall *et al.*, 2007a) to occur behind the Clay Layer. When a Clay Layer is placed on top of a Naturally Weathered rock surface the moisture can thus not be exchanged with the atmosphere.

The reason for high amounts of stone material loss at Main Caves could be ascribed to the high moisture content found in rock surfaces at this shelter (Meiklejohn *et al.,* 2009) as the Naturally Weathered with Clay Layer rock surface proved to have more precipitation running over and coming from the rock surface. High moisture content (behind the Clay Layer) in rocks will ultimately lead to deterioration processes such as expansion and contraction, salt weathering and biotic growth which in turn will cause granular disintegration and flaking of the stone surface (Meiklejohn, 1994). The high loss of stone materials at Game Pass Shelter also went hand in hand with moisture coming from the rock surface which led to fungi and algae growth on the surface. Lichens, bacteria and other organisms, individually or in all their possible associations, are known to influence the weathering of rocks (Arocena & Hall, 2004). Through this study it was clear that whenever biological organisms were present in rock shelters, a high loss of stone materials was observed. Algae can lead to the deterioration of rock art through cycles of wetting and drying which will aid in the detachment of rock flakes, while the weathering actions of fungi involve chemical weathering by organic acids (Viles, 1995).

Rock moisture operating at pore level can pose a great threat to rock art paintings, but where water runs down the rock surface and over the paintings destruction is at its greatest (Bednarik, 2003). Through this study it has been shown that whenever painting panels are exposed to rain, the loss of stone materials is generally low but discoloration is high. The reason for this being that running water not only dissolves soluble pigments, causing paintings to fade, but can also deposit minerals on the surface that may cover the art (Batchelor, 1990). Water running over the painted rock surface can also dissolve minerals and precipitate salts on or near the surface (Rosenfeld, 1988; Batchelor, 1990) leading to further destruction. The reason for the low loss of stone material in this instance might be that water cannot penetrate the rock deeply enough by only running over it. Seeing that weathering is enhanced where the moisture regime is dynamic, the deterioration of rock paintings will possibly be accelerated where water is able to penetrate into the rock (Meiklejohn, 1994, 1997). San paintings are located at the rock surface, however, and any weathering that occurs in the area close to the rock surface will also affect the paintings (Meiklejohn *et al.,* 2009). The presence of moisture at, in or near the rock surface is thus likely to be extremely damaging to the art itself as it may lead to the discoloration of paintings.

At Battle Cave the Smoothed with Clay Layer rock surface was found to be very deteriorated due to a high loss of stone materials. Once again this observation might be ascribed to the extreme environmental conditions at this shelter as enhanced deterioration takes place due to high solar radiation input. Wherever moisture and temperatures fluctuations are present at this site, whole pieces of rock art scenes have flaked-off. On the Smoothed with Clay Layer rock painting (BC9) high loss of stone material is the greatest. The high solar radiation input that this painting receives could be the reason as thermal change may promote cracking of both pigment and, in the instances where a clay layer has been applied, also the clay which allows moisture and endolithic organisms to infiltrate (Arocena *et al.,* 2008) adding to accelerated fading of the art. However, at the Battle Cave study site discoloration is the greatest threat where moisture is not that evident causing rock art pigments to fade.

Sigubudu Cave also show varying degrees of deterioration (Figure 4.11), but where solar radiation is at its greatest, paintings are mostly discoloured while those paintings that are protected by vegetation cover experience a Loss of stone materials due to moisture that is retained within the rock. High ratings of discoloration at this shelter is mainly due to direct sunlight falling on the painting panels causing fading but discoloration (which proved to be the worst at Sigubudu Cave) can also be as a result of higher precipitation in the form of thunderstorms (Nel & Sumner, 2006) in the area. More moisture will not only lead to enhanced deterioration through the above mentioned mechanisms, but might also lead to discoloration of rock art through direct moisture running over paintings during a storm event.

Whenever a Clay Layer has been applied to a Smoothed rock surface the response as assessed within the Four Main Deterioration Groups proved to be diverse. This was especially the case at the Main Caves study site where MC1 was rarely deteriorated and MC9 very deteriorated. Loss of stone material was once again the main cause of destruction on MC9. Both these paintings had undergone little discoloration, had a high rating of fissures and experience almost the same environmental conditions. MC1 is, however, situated in the shelter facing northwards while MC9 is situated in the shelter facing eastwards. The enhance deterioration on the east facing slope can be explained by the impact that slope aspect has on rock weathering. Since the impacts of wind and rain are dependent of aspect, rock weathering, especially the mechanical breakdown of rocks is enhanced at sites where moisture is absorbed and rapid marked temperature changes occur. Therefore, weathering should be greatest on east and west facing slopes below cliffs as they remain in the shadow for longer than other slopes while still experiencing rapid increases and decreases in temperature (Smith, 1977).

The cleaning of a rock surface can by itself enhance rock art deterioration as cleaning and resurfacing can destroy the rock's natural protection (Pope *et al.,* 2002). In the case of this study Smoothed rock surfaces (without a clay ground) showed few signs of deterioration in terms of stone material loss. The reason for this might be that the already weathered stone material has been removed by surface preparation and weathering thus starts "anew" (Pope *et al.,* 2002) which means that insufficient time has passed for the rock surface itself to show signs of weathering, but other weathering mechanisms might still cause destruction of the art. At Game Pass Shelter, for example, Smoothed rock surfaces had a low rating of stone material loss, but a high discoloration rating. Discoloration at this shelter can be ascribed to efflorescence found on the rock surface which plays a big role in rock art deterioration due to salt being deposited on the rock surface through surface runoff.

Although rock paintings at Main Caves deteriorate due to moisture fluctuations (Meiklejohn, 1994) the paintings studied here have been preserved relatively well as all four Main Groups of Deterioration had a low to moderate rating of deterioration. The biggest threat to rock paintings at this shelter though is humans as some of the paintings found at this shelter have been badly damaged by human action. Tourism also poses a threat to this study site as vegetation had to be removed for better viewing purposes (Hall *et al.,* 2007a) and discoloration due to soiling and dust may cause the paintings to fade at an accelerated pace.

The last significant observation was that Naturally Weathered and Clean Break surfaces seemed to be the least deteriorated by the weathering mechanisms included in the State of Deterioration Classification System (Figure 4.12 & Figure 4.16). Naturally Weathered rock surfaces in all four study shelters display a wide variety of weathering mechanisms affecting the surface. In the case of Naturally Weathered and Clean Break rock surfaces, however, some deterioration has taken place, especially through Discoloration due to Environmental Conditions, but the rock surfaces that have been altered through human actions have nevertheless suffered deterioration to a greater extent.

Although data are limited the following general conclusions (which could be explored further once more data are available) after a first assessment, can be made:

- Although not recorded previously Naturally Weathered rock surfaces with a Clay Layer on top was found to exist in the study area.
- Naturally Weathered rock surfaces with a Clay Layer on top weather at an accelerated pace with a high loss of stone materials being evident on scenes thought to be painted on this type of surface.
- Whenever biological organisms were present on painting surfaces, a high loss of stone material was evident.
- Moisture coming from the rock surface or running over the rock surface is extremely damaging to rock paintings, especially in the case were a rock surface has been prepared and a Clay Layer has been placed over the surface.
- Discoloration of rock art paintings is greatest whenever a high solar radiation input, but low moisture content, exists within rock shelters.
- Whenever a Clay Layer has been applied to a Smoothed rock surface the response as assessed within the Four Main Deterioration Groups proved to be diverse.
- Smoothed rock surfaces showed few signs of deterioration in terms of stone material loss.
- Paintings at the Main Caves study site have been preserved relatively well.
- Rock surfaces that have been altered through human actions appear more deteriorated compared to rock surfaces that have only been deteriorated through natural weathering mechanisms.

CHAPTER 5: CONCLUSION

The aim of this study was to develop two non-destructive classification systems namely the Type of Surface Classification System and State of Deterioration System with the purpose of using these systems to determine what surface a painting was made on as well as to determine to what extent the painting had deteriorated. In order to develop a Type of Surface Classification System, colour and texture data from four rock art shelters in the uKhahlamba-Drakensberg Park were collected, analysed, placed into a System and applied. Further, a modified version of the Fitzner *et al*. (2003) classification system was applied and analysed for the purpose of developing a State of Deterioration Classification System. Through the development of these Systems it was clear that there are numerous factors that influence and contribute to the rate and degree of rock art deterioration.

Environmental conditions proved to influence rock art deterioration the most with temperature and moisture causing most of the damage. Generally, temperature operates indirectly on rock weathering through its control on moisture movement and processes such as salt weathering and directly through the process of insolation weathering (Warke & Smith, 1998). Temperature also controls chemical weathering processes which may contribute directly to disturb the rock fabric through, for example, alteration of primary minerals to expanding lattice clays (Warke & Smith, 1998). Rock moisture on the other hand plays a role in the deterioration of San rock art by acting as a transportation mechanism, consequently leading to the leaching of minerals and accretion of salts or other solutes on the art (Meiklejohn, 1994). Moisture dependant weathering processes possibly operating at this rock boundary where the art was painted are salt crystallisation, hydration/ dehydration of minerals, clay minerals and precipitates, solution processes, and hydrolysis (Meiklejohn, 1994).

Naturally Weathered rock surfaces showed little deterioration but in the two instances where a Clay Layer has been placed on top before paintings were made severe deterioration has taken place. The thermal and moisture fluctuations that can occur due to the preparation of a surface might cause some accelerated weathering to rock art paintings. In the case where the paints cover the clay ground, the ground itself act as a 'surface modifier' which inhibits moisture from accessing the clay, thereby causing physical and chemical changes (Hall *et al.,* 2007a) behind the Clay Layer as moisture is trapped there. When the Clay Layer finally gives way to thermal and moisture fluctuations operating at the rock boundary, this can lead to fracturing of the clay ground while consequently allowing the entrance of microbial activity (Arocena *et al*., 2008).

Loss of stone materials proved to be one of the greatest threats to rock art conservation. This can be due to temperature and moisture fluctuations and its associated weathering mechanisms but can also be ascribed to changes in environmental conditions. 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).

At the study sites where environmental conditions (in the form of solar radiation and wind) were extreme (Battle Cave and Sigubudu Cave) discoloration proved to be the main form of deterioration operating at the rock surface. Colour is, in many rock art deterioration studies, considered to be an important monitoring aspect in assessing the condition of rock paintings themselves (Small & Clark, 1982) with a change in the colour of the paint indicating deterioration taking place. Soiling and dust, due to tourists and animals also contribute to discoloration which in turn cause accelerated deterioration.

Even though Environmental Conditions, Loss of Stone Materials, Discoloration and Fissures all impact rock art deterioration, human interference can possibly be the greatest weathering mechanism enhancing all other chemical and physical weathering processes taking place at the rock surface. In this study it has been shown that human alteration (in the form of surface preparation) causes accelerated deterioration. Despite this, the main factors currently caused by humans are changes in humidity, introduction of light (through removal of vegetation), and with an increase in tourism, also an increase in carbon dioxide as well as increases in temperature (Rosenfeld, 1988). People also introduce external organisms, including algae and higher plants which are able to establish themselves, particularly near light sources (Rosenfeld, 1988). Humans furthermore bring about vandalism at rock art sites. This deliberate act of destruction can only be controlled by the implementation of practical conservation strategies at rock art sites all over the country and as any research into the weathering of San paintings should have the aim of conserving and ultimately preserving it (Leuta, 2009) the development and implementation of these conservation strategies should be scholar's and conservator's main focus.

Conservation of rock art is in most cases not an easy task. This is especially the case where rock art has been created on prepared rock surfaces. When cultural stone are prepared either by smoothing and/or the application of a clay layer before rock art creation structural stresses that are different from those found in nature are caused (Pope *et al.,* 2002). A clay based layer that is placed on top of a Smoothed surface might, for instance, have an enormous impact on the amount of light a rock surface receives. The application of a non-light transmissive ground (a smooth clay base on which some paintings are located rather than being put directly on the sandstone) and pigments by the San to the sandstone surface spatially alters the thermal gradients between pigments and their sandstone substrate (Hall *et al.*, 2008) and although the pigments may protect the rock from weathering by inhibiting light penetration, there can still be transmission due to scattering around the edges of the pigments, thereby facilitating subsurface colonisation below the edges of paintings (Hall *et al.,* 2010).

The findings of this study thus confirm that the preparation of rock surfaces for the purpose of rock art creation by the San can influence how deteriorated these rock paintings are today. Conservation of prepared surfaces is difficult as in many instances it is the detachment of the clay ground rather than the weathering of the rock that is the destructive factor (Sumner *et al.,* 2009). In terms of weathering and conservation, therefore, consideration must also be given to maintaining the clay-rock bond or, otherwise the painting deteriorates; not through weathering of the rock but as a result of separation of the clay from the rock (Hall *et al.,* 2007a). It is for that reason essential that conservation strategies take the Type of Surface that rock art has been created on into account as differential conservation strategies created for each Type of Surface might prolong the existence of San rock art.

Despite adequate interventions and conservation strategies that have been and are still being developed for Naturally Weathered rock surfaces the need for such strategies conserving considering prepared rock surfaces is thus identified. Therefore, through this research study a Type of Surface Classification which can be used to determine the surface type in question as well as a State of Deterioration Classification System was developed. By implementing these Systems in the field it was clear that rock surfaces that have been altered by humans definitely react differently to the same weathering forces as those rock surfaces that have not been prepared. This was especially the case where a Clay Layer has been placed on top of a Smoothed or Naturally Weathered rock surface. It must be noted though that 40 photographed scenes were used during data analysis as these were the scenes used to develop the Type of Surface and State of Deterioration Classification Systems. Results might therefore not be sufficient enough to draw final conclusions as to the relationship between Type of Surface and State of Deterioration and further data are needed through widespread implementation of the systems before final conclusions can be drawn. Only once these two classification systems have been used in all rock shelters where paintings is found on Sandstone surfaces can conclusions be drawn as to the impact of surface preparation on rock art deterioration. Once the impact has been determined conservation strategies can be developed so that each Type of Surface is protected in the best possible way.

Another limiting factor which was excluded from the study is the age of rock paintings. The age of rock art paintings in southern Africa is mostly unknown and because studies on rock art should proceed without any physical contact to the art as well as the surface it has been painted on, age could unfortunately not be considered in the State of Deterioration Classification System. If practical non-destructive methods were to be developed in the future though, my recommendation would be to include this factor into the State of Deterioration System in order to obtain as accurate results as possible with regard to how deteriorated rock paintings is.

In order to conserve San rock art for generations to come, conservationists must keep in mind each rock art site is unique even with the same weathering mechanisms operating at each site, and the management of each must therefore be planned in a site-specific manner. It must be remembered 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). Constant research into the weathering and deterioration of rock art is thus vital. Further research into rock art deterioration could therefore focus on implementing the Type of Surface and State of Deterioration Systems to rock art in South Africa in order to establish further linkages between surface type and state of deterioration as well as human agents impacting on deterioration processes.

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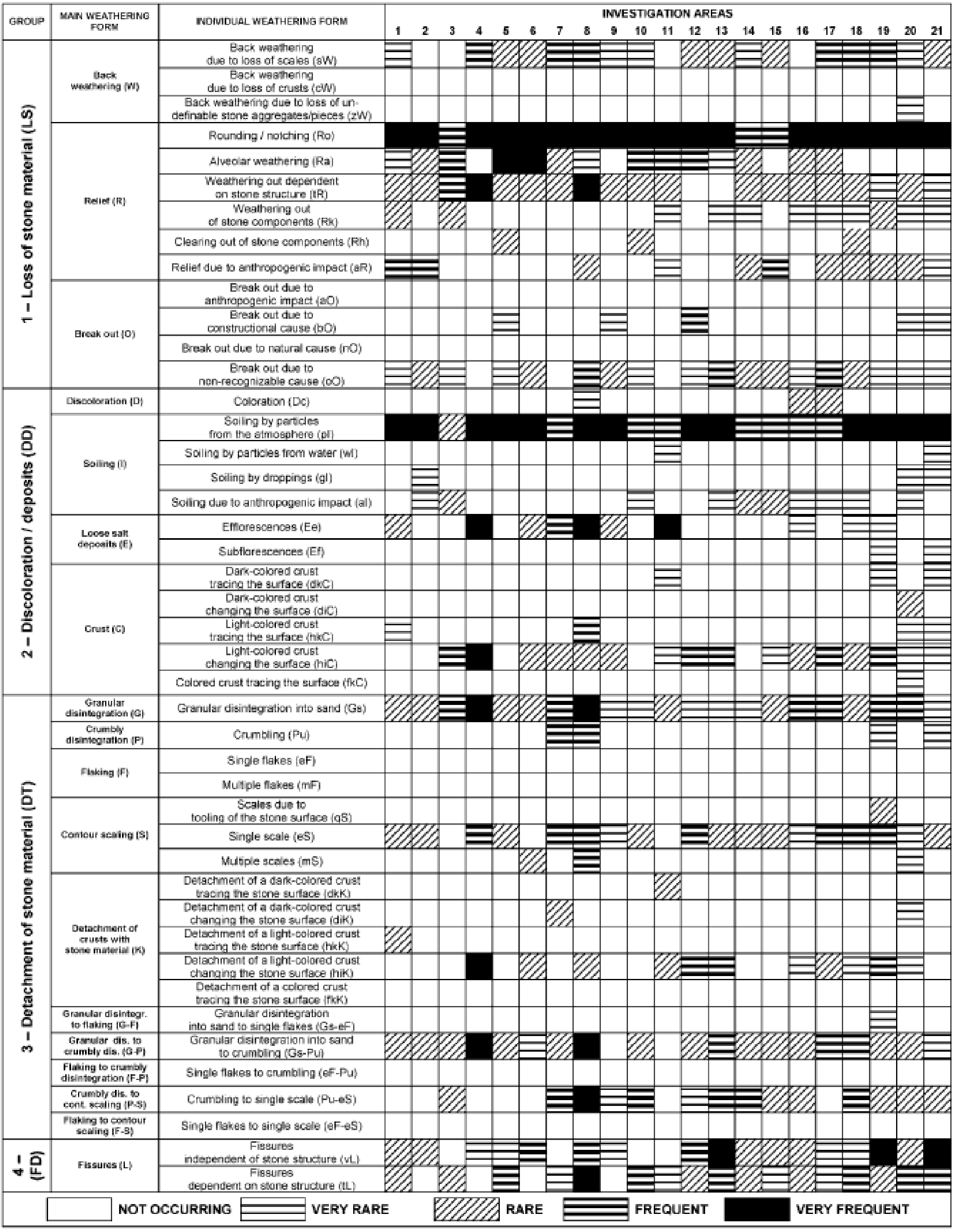
APPENDIX A



Appendix A: Weathering forms and their frequency. Investigation areas 1–21, Karnak Temple and Luxor Temple, Egypt. (by Fitzner *et al.,* 2003)