Deterioration of San rock art: New findings, new challenges

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The heritage of San rock art in southern Africa is globally acknowledged, and was one of the primary reasons for the successful nomination of the uKhahlamba/Drakensberg Park in South Africa as a World Heritage Site.[1] Deterioration of rock paintings in the reserve could adversely affect the international status of the region, particularly as little has been achieved with regard to preserving the art for future generations. A study is currently under way in the Injisuthi and Giant's Castle areas of the park, to investigate the deterioration of San art; this article serves to introduce the project and to highlight some initial findings. Previous research on the weathering of San paintings has focused largely on either monitoring rock shelters[2] or investigating rock surfaces that are adjacent to the paintings. None of the methods applied in earlier investigations has considered the interface between rock and pigments, mainly because of the potential damage that may result from the use of tactile monitoring equipment. Recent advances in weathering research, using improved techniques to measure conditions at the rock surface where the San art is painted,[3] provide new insights into surficial processes and suggest new lines of investigation.

New findings

New data, primarily from the Main Caves at Giant's Castle and at Battle Cave at Injisuthi, in the uKhahlamba/Drakensberg Park, South Africa, show that the rock surface onto which San art is painted, the preparation of this surface, and the nature of the paints themselves influence pigment response to the ambient environment. A key attribute of the application of pigments to rock, or indeed to any surface, is that they comprise a surface modifier.[3,4] The pigments alter the surface's albedo, porosity, chemistry, and thermal properties, and this becomes even more complex[5] if there are multi-layer paintings (such as those at Tandjesberg[6] in the Free State). Recent studies,[3] as with some earlier investigations,[20] have shown that both white and ochre pigments contain whewellite, quartz and alumino-silicate minerals, with haematite providing red colouration in the ochre pigment and gypsum (and perhaps gum from aloes[3,7]) the source of the white attribute of the white pigment. Both pigments may have plant sap as the origin of the whewellite, where that has been used as a binder and/or whitener.[3,7] These findings appear to be consistent with those for other rock art sites in the world[10–12] and with previous studies from southern Africa.[17–20] Pigment mineralogy not only affects chemical responses[9] but also has a significant influence on thermal properties,[3] which can lead to pigment-to-pigment as well as pigment-to-rock stresses. 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.[3] Where exposed to solar radiation, therefore, the materials comprising the paintings and painting–rock associations may well experience shearing forces that cause cracking[10] and, ultimately, failure. Changes in humidity can produce the same physical outcome (cracking of the clay-based ground—see below) and thus may work synergistically with the thermal stresses.

A further new observation,[7] applicable to some paintings (but not all) found in the Drakensberg area, is that the surface on which a painting (or paintings) was created had been both smoothed, probably with a water-polished stone (such stones were observed on the floor at all the sites investigated), and covered with a (white) clay-based ground (Fig. 1). Application of a mineral-based ground (huntite) for paintings has also been reported from Australia, where such ground was found to be predisposed to advanced deterioration, especially under damp or humid conditions.[11] Both the smoothing and the clay-based ground significantly modify the physical and chemical characteristics of the surface. Smoothing of the rock changes surface porosity and increases strength,[8] and also serves to remove any weakened, weathered surface that would otherwise be beneath the painting. It is the application of a clay-based ground, however, that is perhaps more significant to longevity of the paintings. The clay-based ground acts as an impermeable barrier for moisture flow, both into the rock and from the rock to the air; it also greatly changes thermal properties.[3] Furthermore, observations suggest that in many instances what was interpreted as weathering of rock is, in fact, loss of the clay attachment *to* the rock (Fig. 1), and this has ramifications for remediation or preservation.

The pigments, at least where there is a clay base, do *not* penetrate the rock, but

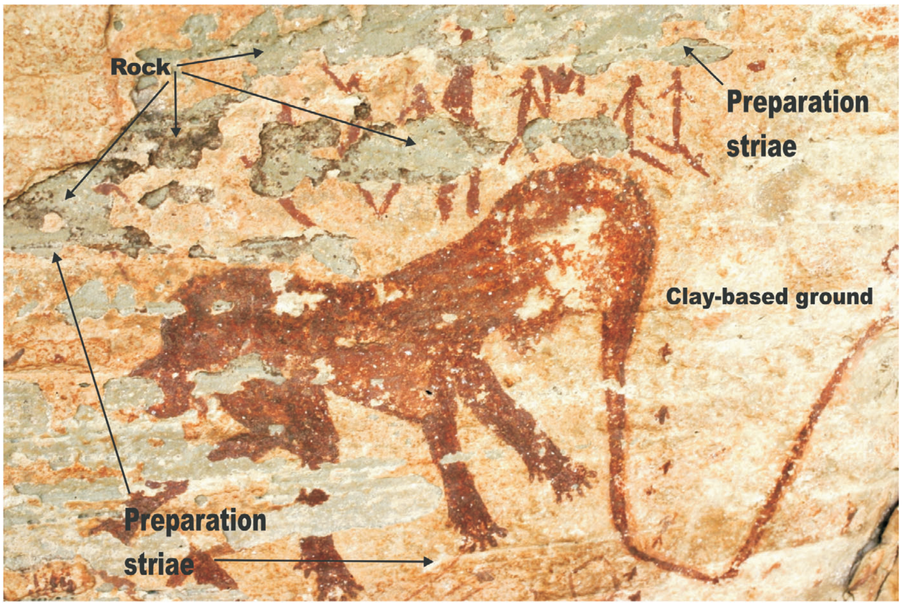

Fig. 1. A typical example, from the Giant's Castle area, of an ochre painting on a clay-based ground that exhibits disassociation of the ground from the underlying rock as a result of weathering. Also illustrated are examples of striae (scratches) associated with the surface cleaning and preparation of the painting surface prior to application of the thin ground layer.

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occur as discrete layers *on* the rock (see Fig. 4 of Hall *et al.*[3]). In terms of weathering and conservation, therefore, consideration must be given to maintaining the clay–rock bond or, otherwise as in Fig. 1, the painting deteriorates; not through weathering of the rock but as a result of separation of the clay from the rock. Changes in environmental conditions, notably of moisture and temperature, are suggested to affect the stability of the pigment–clay–rock bonds.[3,13] It is argued[3,7,15] that both climatic change and local, human-induced environmental changes may cause loss of stability of the rock–clay and clay–pigment bonds and, through other mechanisms,[14] also affect San paintings that are *not* on a clay base. It is also suggested, in respect of human-induced changes,[3] that the removal (or loss) of trees, largely for visitor purposes, at sites such as Giant's Castle Main Caves, has influenced ambient thermal and humidity conditions, thereby affecting the paintings and possibly resulting in accelerated deterioration. Global climatic changes, particularly those leading to increased precipitation and humidity, would serve to exacerbate the situation.

In instances where the paints cover the clay ground (as observed in Fig. 1), the ground itself has a 'surface modifier' on *it,* inhibiting moisture from accessing the clay and thereby causing physical (expansive) and chemical changes. Evidence to date[3,7,15] indicates that the thermal changes may induce cracking of *both* pigment and clay that thereby allow ingress of moisture (and endolithic organisms) and so cause accelerated deterioration of the art. Where there is no mineral base for the painting, a factor not yet reported (but currently under investigation), which can serve to enhance the pigment–rock thermal stresses, is that of light penetration into the sandstone.[14] Quartz-rich sandstone transmits light[16] and this serves to affect the thermal gradient within the surface zone of the rock. Because the pigments act as a surface modifier that inhibits light penetration, this can create thermally induced stresses with the pigment-free surrounding rock at the pigment–rock interface. Where the pigment lies *directly* on the sandstone and that panel is exposed to solar radiation, therefore, there will be thermal differences between the pigment and the rock due to differential albedo and thermal properties. 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. This can lead to shearing forces that may induce cracking[13] and deterioration at the painting–rock interface, and also facilitate the admission of endolithic organisms,[15] leading to further deterioration.

New challenges

On the basis of the above observations and findings,[4,8,10,16] researchers at the universities of Pretoria, South Africa, and of Northern British Columbia in Canada are undertaking a detailed *in situ* study of the key parameters associated with the weathering of San rock art exposed, at least in part, to solar radiation (at Giant's Castle Main Caves). Field investigation is complemented by laboratory work involving X-ray diffraction, scanning electron microscopy and Raman spectroscopy analyses of pigments and pigment–rock associations. Reconstructions of the pigments, based on chemical analyses, are being undertaken at a fine arts research laboratory at the University of Concordia (Montreal, Canada) to evaluate the hues and tones of the original pigments and to understand better the means of application to the rock—the outcomes of this investigation will be used in laboratory simulations (see below). At the field site, thermal responses of white and ochre pigments and associated rock are monitored using a combination of infrared thermography and micro-thermocouples. Light penetration and heat flow into the rock is measured using progressive thicknesses of sandstone coupled with pyranometers and micro-thermocouples. Rock moisture conditions are being studied by means of newly patented micro-sensors located *in situ* at several depths within the first 5 mm of the surface zone of the sandstone; these sensors also monitor the salt content of any moisture present. All data are being collected at 10–20-s intervals. Laboratory simulations using rapid response (10°C min^{-1}) thermal stages driven by field data on radiation receipts, rock temperature, and moisture will be used for micro-analysis of heat flow and pigment–pigment/pigment–rock stresses. The experiments will be conducted on pieces of local sandstone covered with ground and painted with various pigment reconstructions. Data from these field and laboratory studies will help us better to understand the stresses affecting the San paintings and their causes.

The challenge now is to evaluate and use these data to undertake real-time modelling of the surface conditions affecting the art and, hence, suggest possible protective or remedial actions that will not, by default, worsen the situation. Ancillary studies, notably analyses of the pigment composition, field-based Raman spectroscopic analyses of paintings, and the application of a new approach for classifying painting panels in terms of weathering attributes, are also being undertaken at other sites within the uKhahlamba/Drakensberg area.

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