Silcrete Skins — Their Significance in Rock Art Weathering

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Introduction

With the broad spectrum of skills and professions respresented at this Workshop, it is my hope that this paper on silcrete skins will further the understanding of this physio-chemical process. There is much ambiguity caused by the use of several different terms to describe this feature. Other terms used to describe a hard surface on various types of rock are:

Orthoquartzite: "A classic sedimentary rock composed of a silica-cemented quartz sand. The cement is commonly deposited in crystallographic continuity with the quartz of the worn grains".[1]

Silcrete: "A superficial quartzite formed by the cementation of rock fragments (as soil, sand or gravel) by silica. Pocket word for siliceous concreted gravel. A synonym for puddingstone, but useful for finer grained varieties".[1]

Desert Varnish: "A surface stain or crust of manganese oxide and iron oxide, of brown or black colour, and usually with a glistening luster, which characterizes many exposed rock surfaces in the desert".[1]

Casehardening: "The geological process by which the surface of a porous rock, especially a sandstone or a tuff, is coated by a cement or a desert varnish, formed by the evaporation of mineral bearing solution".

The proper and original metallurgical use of the term case-hardening is defined as, "a ferrous alloy that the outer portion, or case, is made substantially harder than the inner portion or core. Typical processes used for case-hardening are carburizing, cyaniding, carbonitriding, nitriding, induction hardening, and flame hardening".[1]

Silcrete skins have been studied extensively in Australia and South Africa. Dury[2] refers to "siliceous skins" and "silica skin" and Hutton, et al[3] used the terms "silcrete skins", "skin type silcrete" and "skin silcrete". Smale[4] in his study here in Australia as well as in South Africa uses the terms "quartzitic silcrete" and "case-hardening". Walston and Dolanski[5] use the term "silicrete skin" in their study of this feature as noted at Mootwingee and Mount Grenfell, N.S.W. Silcrete skin is crucial to all forms of rock conservation, but especially to rock art and engraving sites. This feature and its process of formation, is capable of both conserving and destroying sites.

Nature of silcrete skins

I define silcrete skin on sandstone, as a superficial orthoquartzite that is coated with a mixture of cryptocrystalline to amorphous silica with some oxides of iron, manganese, and titanium in varied amounts. It is of secondary origin and forms a semi-impervious layer less than a few millimetres thick. It is formed by silica in solution being concentrated at the rock surface by the physio-chemical reaction of water evaporation and nucleation of the silica by metal oxides on existing quartz grains as overgrowths. Silica reacting with metal oxides is also precipitated as a fine grained to amorphous silica.

Formation

The development of a silcrete skin is by a simple solution and evaporation of silica bearing fluids driven by percolation and capillary forces to the rock surface. There water is evaporated, the silica in solution concentrated, and reacts with metal oxides to form a siliceous coating on the rocks, see Fig. 1. For this process in sandstones the silica is most probably derived from the weathering of feldspars, see Figs. 2 and 4.[6]

The probable solubility of quartz in water at 25^{o}C is between 7.25 and 14 p.p.m., and that of amorphous silica is 160 p.p.m.,[7]. The solution and crystallization of quartz is accelerated several orders of magnitude by a NaOH or NaCl solution. This however is still very low and would be a poor source for silica.

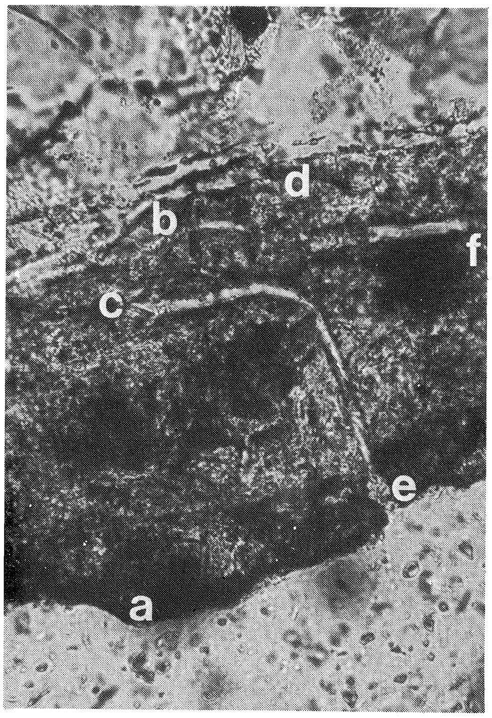

Figure 1: Is a photomicrograph of a silcrete skin thin section greatly enlarged, from (a) at the surface of the rock to (b) it is 0.3mm thick. This shows the amorphous to cryto-crystalline composition of the material, the semi-impervious nature, and capillaries. A lateral capillary starting at point (c) intercepts a hairline crack (d to e), that is perpendicular to the rock face, makes a right angle turn and discharges it's water at point (e). A second lateral capillary may be seen from point (b to f).

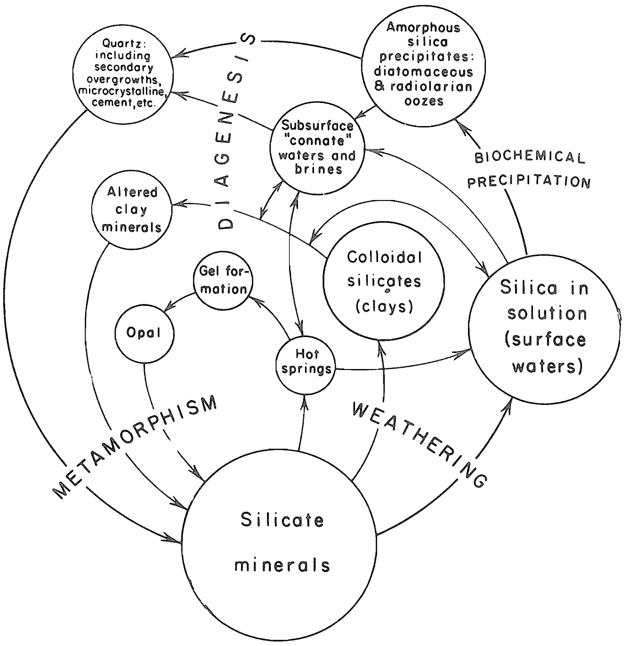

Figure 2: Is a diagram[7], that shows quite simply the complexity of the silica cycle.

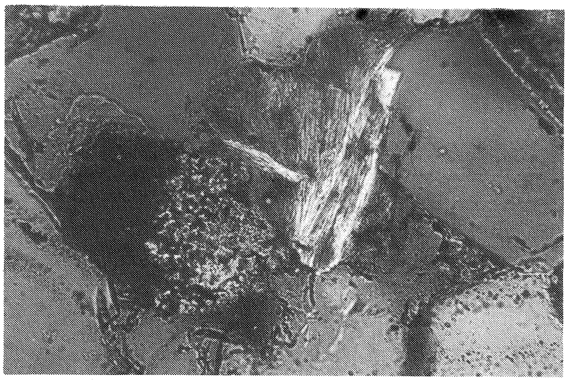

Figure 3: Shows under polarized light wisp-like authogenic illite in a thin section of sandstone from Mootwingee. It is 0.75mm in size and is very susceptible to swelling when coming in contact with water. Just to the left of the illite with a speckled appearance is kaolinite.

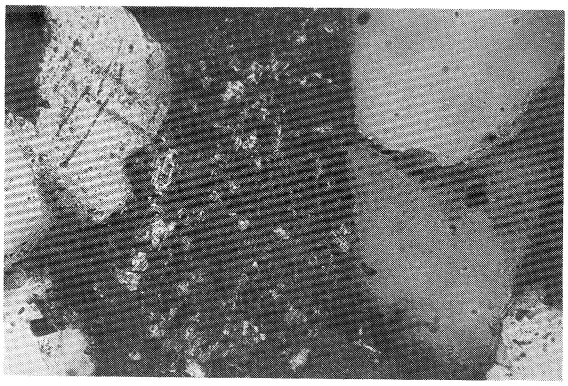

Figure 4: Shows feldspar in the process of weathering to kaolinite. In a thin section under polarized light it has a speckled appearance. It is 1.2mm in size. Kaolinite tends to slacken when wet, this feature breaks down the cohesiveness of a sandstone.

Feldspar releases far more silica in solution as they break down to clays and quartz.

$2K\ Al\ Si_3O_{8c} + 2H^+_{aq} + 9\ H_2O, =$

K-feldspar

$H_4\ Al_2Si_2O_c + 2K^+_{aq} + 4H_4SiO_4\ aq$ [8]

kaolinite dissolved silica

Kaolinite and illite are found extensively in the sandstone examined at both Mootwingee and at Mount Grenfell and is in part derived from the weathering of feldspar that is common in these sandstones. Some of the illite is authogenic, see Fig. 3.

The potassium released in the weathering of feldspars promotes growths of lichen and may

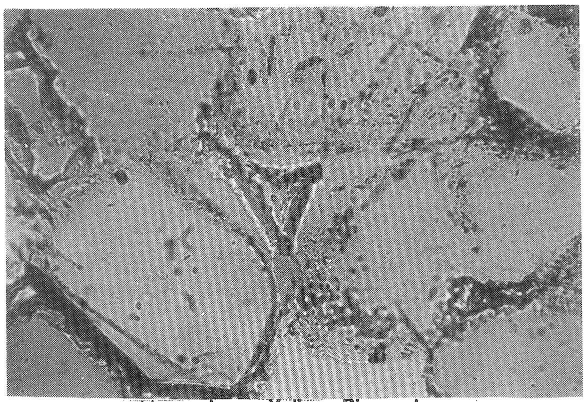

Figure 5: Is a thin section of sandstone from Mootwingee showing silica overgrowths to sub-rounded quartz grains. The overgrowths have converged to close off the pore space between sand grains to a small triangular size opening of less than 0.3mm.

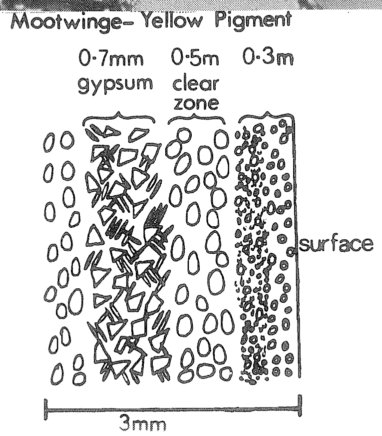

Figure 6: Is an idealized cross section sketch of a pigment surface from a Mootwingee site. The lateral spreading of water has cleared a zone 0.5mm wide just in the back of the silcrete skin and pigment. The crystallized gypsum now occupies part of the clear zone.

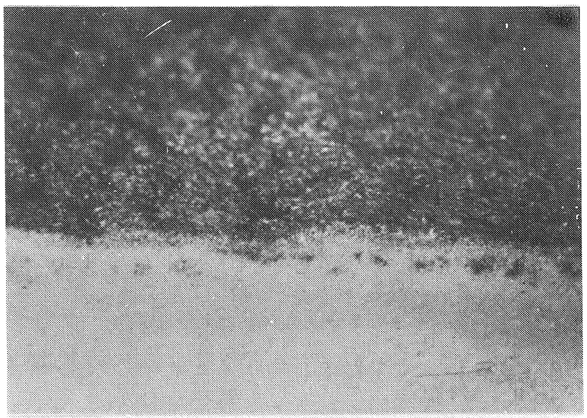

Figure 7: Is a close-up oblique angle view of the rough surface of a rock engraving from Mootwingee. The lower half of the view is the freshly-sawn surface that produced the cross section in Fig. 8. The line of dark spots parallel to and 1.0mm below the surface have not been identified but may be organic matter. The indentations of the engraving may be seen on the left and right edges of the rough surface.

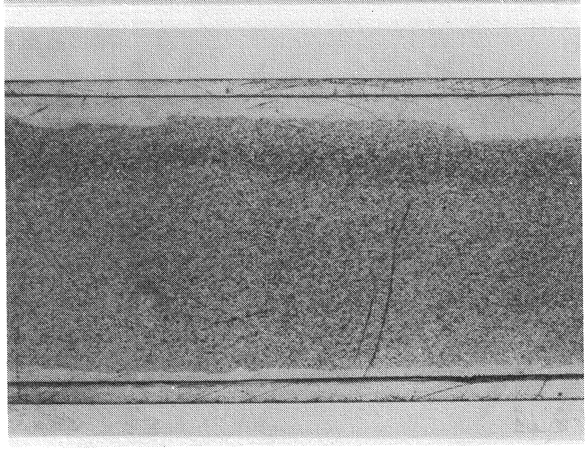

Figure 8: Is a thin section of the engraving profile in Fig. 7 shown 2½ times it's actual size. The engraving depressions on the top edge of the figure, have been healed by a new layer of silcrète skin that protects them from further abrasion.

when combined with sulphate and iron form jarosite[9]. Illite present may in part be from the weathering of feldspathic fragments. Authogenic illite that is forming in these sandstones may also be using some of the $2K^{+}_{aq}$ present[10]. Illite is more susceptible to swelling than kaolinite, see Fig. 4[11].

Weathering

It is not known why silcrete skins rarely exceed 1.0mm in thickness before it is exfoliated along with the rock slab it coats. During a wet season it appears that the silcrete skin begins to develop, sealing off the normal outlet flow for ground water through the rock face, with its load of salts and clay, see Fig. 5. This daming over a prolonged period causes a lateral spread of the confined water, see Fig. 6. The accumulated water builds up excessive pressures on the rock face and simultaneously causes a clay expansion of illites or slacking of kaolinite which may loosen a rock slab.

During the dry season, salts, mainly gypsum, that are dissolved in the ground water tend to precipitate as the water evaporates. These accumulate behind and on the silcrete skin and recrystallize, see Fig. 6. This subjects the rock face to continuing prying forces from the crystal growth. The salts, as well as the clay, also act as an insulation layer between the rock surface and the body of the rock, and create a differential expansion and contraction rate. Temperatures at Mootwingee and Mount Grenfell range between minus 4°C to 48°C. Such a range, though far less temperature changes than that experienced in alpine zones, does cause considerable weathering. The rock surface may then spall off completely or be left attached by one edge to the parent rock. If attached, it can start to develop a new silcrete skin on the freshly broken surface of the rock fragment which when fully developed, forms a very durable rock slab plated with silcrete skin.

If the gravity flow of water is minimal, as compared to the rate of evaporation and capillary action, the upward surface of near horizontal sandstone blocks are strengthened by development of a silicrete skin. The sides and bottom of the block however, become more friable as salts and/or clay accumulate. If the silcrete skin on the upper surface of the rock slab is damaged, as by an engraving, there is a healing of the engraving by a new layer of silcrete skin that preserves it from further weathering, see Figs. 7 and 8. The length of time for this to occur is now being investigated.

Conclusion

The formation of a silcrete skin is a function of rainfall, so that its thickness on dated surfaces, such as rail and roadway cuttings may provide data applicable to chronology elsewhere.

With further research and experimentation, the dating of various sites might be made possible. The thickening of the silcrete skins may be encouraged by a man made process and any further deterioration may then be minimized or stopped.

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