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DESERT VARNISH COATINGS AND MICROCOLONIAL FUNGI ON ROCKS OF THE GIBSON AND GREAT VICTORIA DESERTS, AUSTRALIA

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Desert varnish coatings rich in manganese are reported, to the authors' knowledge, for the first time on desert rocks from Australia. Varnish was found on chert, dolomite, sandstone, siltstone, and conglomerate rocks in stony pavements of the Gibson Desert and the Great Victoria Desert of Western Australia and South Australia. The widespread occurrence of desert pavements in Australia suggests that desert varnish, also, may be widespread. Fungi that form microcolonies have been found on rocks with desert varnish. Manganese was found in higher concentrations inside some of the microcolonies than in the surrounding substrate, suggesting that microcolonial fungi are involved in the formation of desert rock varnish in these areas.

Introduction

According to Potter & Rossman (1977, 1979), there are two types of desert varnish, a coating found on rocks from desert regions. The most common type is reddish orange in appearance and contains iron oxides mixed with clay minerals. Darker coatings that contain, in addition, high concentrations of manganese oxides have a more limited distribution. Manganese-rich desert varnishes have been reported to occur in many of the desert regions of the world, including the Negev and Sinai deserts of the Middle East (Humboldt, 1793; Krumbein & Jens, 1981), the Mojave Desert (Laudermilk, 1931; Engel & Sharp, 1958) and the Sonoran Desert of the southwestern United States (Perry & Adams, 1978) and northwestern Mexico (Hayden, 1976), the Gobi Desert of China, and the Sahara Desert of northern Africa (Lucas, 1905). Recently, manganese-deficient desert varnish has been reported in Antarctica, (Glasby & others, 1981).

In this paper the occurrence of manganese-rich desert varnish in the Gibson and Great Victoria deserts of Western Australia and South Australia is documented. In addition, evidence is submitted that implicates microcolonial fungi in the formation of some of these varnish coatings.

Method of study

The samples were collected in 1971 and 1972 during regional geological mapping of the Gibson and Great Victoria Deserts (Fig. 1) by the Bureau of Mineral Resources and Geological Survey of Western Australia, jointly (Jackson & van de Graaff, 1981; Jackson & Muir, 1981). Over 1500 samples were collected, but, at the completion of the program, the collection was reduced to about 300 samples, which were retained as a set representative of bedrock lithology and surface weathering textures. The collection was re-examined in 1980, when this study of desert varnish in Australia was initiated. About 50 of the specimens showed various forms of case-hardening, ferruginous or siliceous skins, or manganiferous surfaces. Twenty were selected for study, being chosen to cover a range of bedrock ages (mid-Proterozoic to Tertiary), rock types (volcanic, sedimentary), and types of varnish (thin brown coatings to thicker black shiny surfaces).

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Chips from the rocks were mounted on scanning electron microscope (SEM) stubs with low resistance contact cement. Critical-point drying was found not to be necessary for the preservation of biological structures on these specimens. The samples were then sputter-coated with palladium and examined in a Cambridge S4-10 SEM equipped with an energy dispersive X-ray analyser (EDAX).

Portions of coating were scraped from the rock surface, placed on solidified water agar (1.5%) in petri dishes, and tested for manganese, using the benzidine reaction (Feigl, 1958). Positive reactions for manganese were recorded when blue, indicative of Mn IV, diffused into the agar from the scrapings. The presence of manganese was independently confirmed in many samples by SEM-EDAX analyses.

Small black, globular structures found on the rocks resemble microcolonial fungi that have been recently reported from rocks in other desert regions (Staley & others, 1982). Individual structures, which are generally less than 100 μm in diameter, were picked from some of the specimens, using 40-mm, 26 gauge inoculating needles under a dissecting microscope at 30x or 60x magnification. These were fixed with osmium tetroxide in 0.1 M cacodylate buffer (pH 7.0), dehydrated in acetone, and embedded in an Epon 812-815 mixture. Thin sections were cut with a Zeiss Ultramicrotome, stained with lead citrate, and examined at 60 kV in a Jeol JEM 100 B transmission electron microscope (Staley & others, 1982).

Results

The chemical and SEM-EDAX analyses indicate that many of the dark coatings contain manganese (Table 1) as well as iron and other elements indicative of varnish. Proterozoic rocks from near the margins of the sampled area have the best-developed desert varnish. All five samples from the mid-Proterozoic Bangemall Basin, on the northwest margin of the area, contained desert varnish. These included chertified carbonates from the Skates Hills Formation, feldspathic sandstone from the Durba Sandstone, and a dolerite sample from a sill intruding the sequence. Proterozoic conglomerate, sandstone, and siltstone from the Townsend Quartzite and Punkerri Beds of the Officer Basin sequence in the eastern part of the area also had good desert varnish coatings, as did a sample of Proterozoic brecciated chert from the rimrocks of a salt diapir at Woolnough Hills in the far north of the region.

In contrast to the Proterozoic samples, the Phanerozoic samples collected showed less impressive development of desert

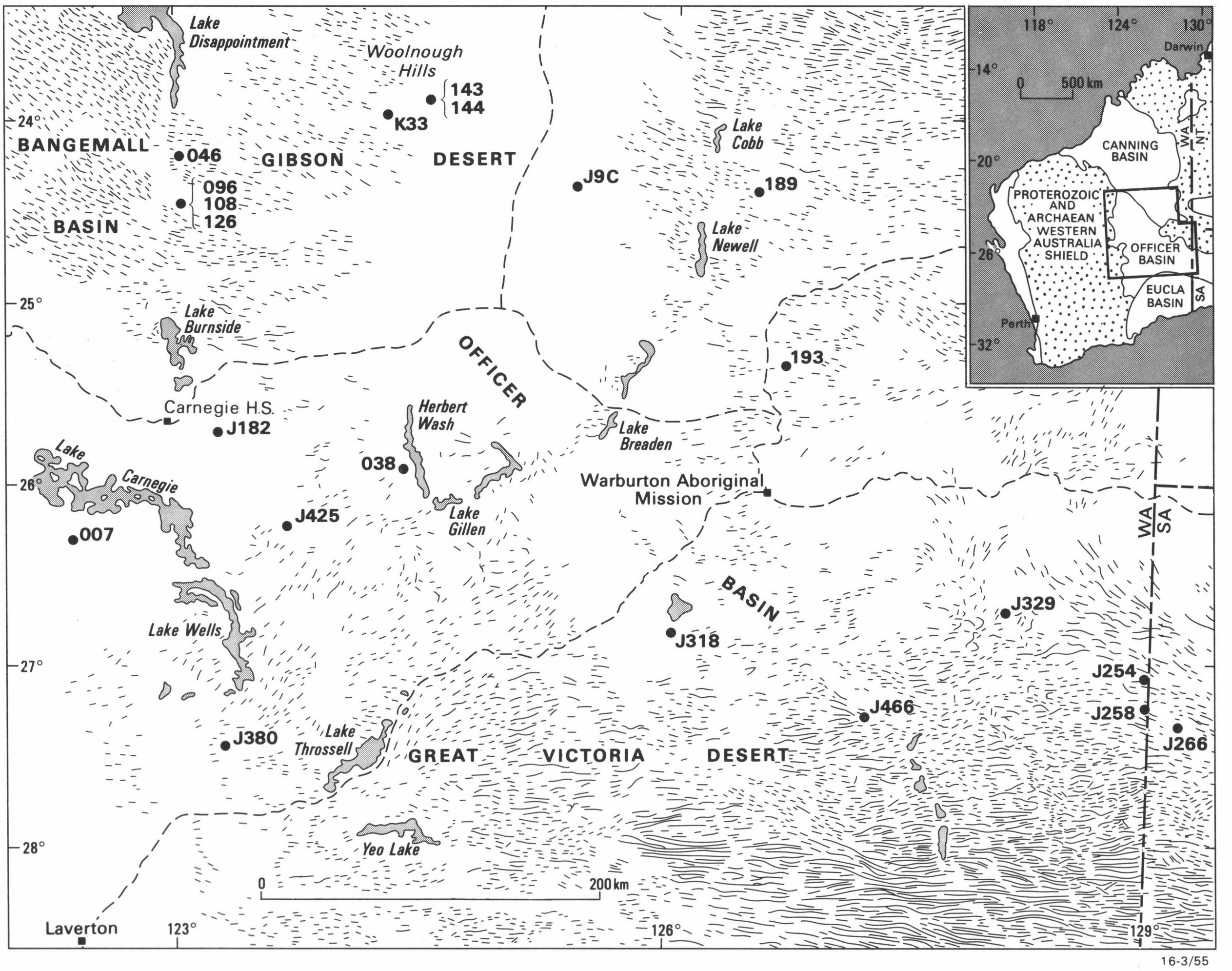

Figure 1. Map showing location of Gibson and Great Victoria Deserts in which rock specimens (identified by number) were collected.

varnish (Table 1). A manganese-enriched coating from a basalt sample was collected from the Early Cambrian Table Hill Volcanics of the Great Victoria Desert, but only two of the six specimens from the Permian Paterson Formation had significant amounts of manganese.

The appearance of the varnish on these Australian rocks is quite distinctive. The black areas that are manganese-rich appear most commonly as patches over the surface of the rock; in some places these overlap to form a confluent black area (Fig. 2). The patches are generally round and range in diameter from less than 1 mm to several mm. The appearance is almost as if black paint were spattered over the surface by the flicking of a brush. The varnish coatings appear to overlie an almost uniform coating of hematite.

Lichens were found only rarely on the varnished specimens examined and algal growth was uncommon. However, we frequently observed microscopic black, globular structures (10–100 μm across), which resemble the microcolonial fungi recently reported to occur on desert rock surfaces (Staley & others, 1981). To test whether or not these were indeed microorganisms, they were picked from the rock, embedded in Epon resins, and sectioned for observation with the transmission electron microscope. Their ultrastructural appearance is identical to that of the known microcolonial fungi. The most distinctive feature is the concentric body that is uniquely associated with certain fungi (Griffiths & Greenwood, 1972; Samuelson & Bezerra, 1977). Also, we have cultivated fungi from the microcolonial structures on rocks collected in August 1981 from the same area. The discovery of microcolonial fungi associated with desert varnish in these Australian rocks is consistent with the finding of microcolonial fungi and desert varnish in the southwestern United States, the Sahara Desert in Egypt, and the Gobi Desert in China.

Evidence that microcolonial fungi on the surface of these Australian rocks are involved in manganese accumulation and, hence, desert varnish formation has been obtained from SEM-EDAX analyses. Five rocks were carefully examined (Table 2). In all cases we examined rocks that contained both varnish patches and fungal microcolonies, but for these studies we confined the SEM-EDAX analyses to areas on the rock that were away from a macroscopic patch of varnish (for example, the circled area in Figure 2). We then compared the concentration of manganese within the microcolony with that outside the microcolony (Table 2; Fig. 3). Manganese is present in the microcolony, but was not detected in the areas immediately next to it. Not all microcolonies away from macroscopic patches of varnish contain manganese, and it is not known whether this is due to variations in species composition, physiological state, or some other factor. Microcolonial fungi were also found within the macroscopic patches of varnish.

Discussion

Although siliceous skins on Australian silcretes have received some study (Hutton & others, 1972, Milnes & Hutton, 1974),

Table 1. Manganese analyses and description of rock specimens with black coating obtained from the Gibson and Great Victoria Deserts.

BMR registration number	*Field collection number*	*Stratigraphy* *Formal Name*	*Age*	*Rock type*	*Manganese analysis** *SEM-EDAX*	*Chemical*
71880007	None	Unnamed	Middle Proterozoic	Dolerite	+	+
72880038	J111	Table Hill Volcanics	Lower Cambrian	Porous fine-grained sandstone	N.A.	+
72880046	None	Durba Sandstone	Middle Proterozoic	Pink feldspathic sandstone	N.A.	+
72880096	J134	Skates Hill Formation	Proterozoic	Chertified stromatolitic carbonate	+	+
72880108	K73	Skates Hill Formation	Proterozoic	Vuggy chertified sandy carbonate	N.A.	+
72880126	J132	Skates Hill Formation	Proterozoic	Chertified silty carbonate	+	+
72880143	J28	Woolnough Beds	Proterozoic	Dolomite/chert breccia	N.A.	+
72880144	J30	Madley Beds	Proterozoic	Chalcedonic ferruginous silt	—	—
72880189	J123	Paterson Formation	Lower Permian	Intensely ferruginised sandstone	N.A.	—
72880193	J52	Paterson Formation	Lower Permian	Intensely ferruginised sandstone	N.A.	—
None	J9c	Samuel Formation	Lower Cretaceous	Silicified fine sandstone	N.A.	—
None	J182	Paterson Formation	Lower Permian	Silicified burrowed clayey fine sandstone	+	+
None	J254	Townsend Quartzite	Proterozoic	Ferruginous conglomerate	+	+
None	J258	Punkerri Beds	Proterozoic	Coarse silicified sandstone	+	+
None	J266	Punkerri Beds	Proterozoic	Silicified sandstone and siltstone	+	+
None	J329	Table Hill Volcanics	Lower Cambrian	Purple basalt	N.A.	+
None	J380	'Silcrete'	Tertiary	Silicified angular quartz wacke	+	+
None	J425	Paterson Formation	Lower Permian	Silicified coarse sandstone with siltstone clast	N.A.	+
None	J466	Lennis Sandstone	Cambrian	Fine-grained silicified sandstone	N.A.	—

* + manganese detected.
— manganese not detected by the method used.
N.A. Not analysed.

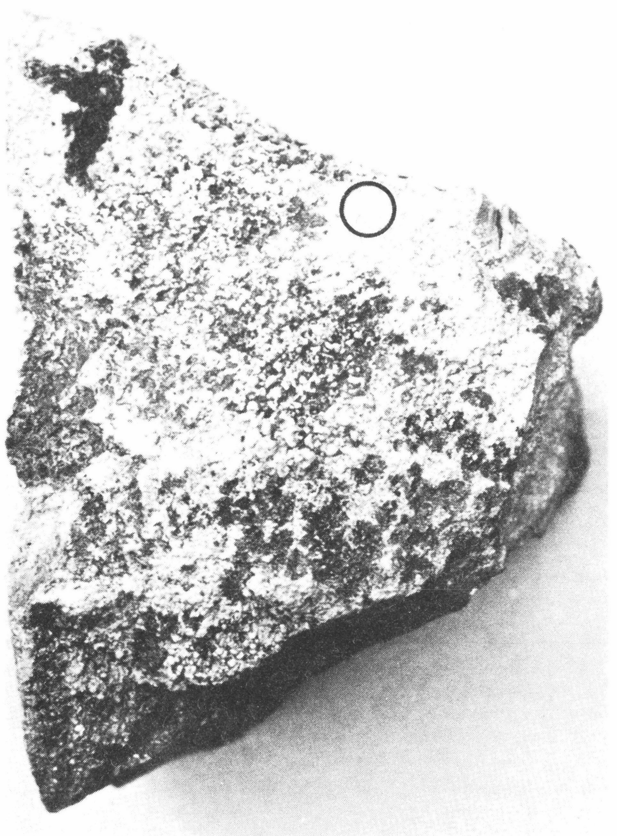

Figure 2. Photograph of a typical rock specimen (J266).
The desert varnish appears as black patches, which are progressively smaller away from larger patches. Some areas appear to be devoid of varnish (e.g., the circle outlined). Microcolonial fungi occur in such areas and some are enriched in manganese relative to their immediate surroundings. Sample is about 10 cms across.

to our knowledge, manganiferous desert varnish has not been previously reported in Australia. However, Francis (1920) described black, manganese-rich coatings found on rocks in stream beds in Queensland rain forests. Also, archaeologists have described aboriginal tools with dark coatings that have been regarded as desert varnish (C. Elvidge, personal communication). The widespread stony pavement characteristic of many Australian desert areas indicates that desert varnish coatings are also likely to be widespread.

In the southwestern United States and in Egypt, desert varnish is associated with a variety of lithologies that, through mechanical weathering, produce the most stable surfaces. In Australia, the desert varnish coatings studied also occur on a variety of rock types, including dolomite, sandstone, siltstone, conglomerate, and chert. The older Proterozoic samples have much better developed desert varnishes than their younger Permian and Tertiary counterparts. The most obvious logical explanation for this is that the Proterozoic rocks are more indurated and resistant to erosion, and have, therefore, formed more stable, longer-lived physiographic features upon which the varnish has developed. The Permian and younger rocks are generally deeply weathered and kaolinised and much more easily eroded.

Although our evidence does not prove that microcolonial fungi are responsible for desert varnish in these Australian samples, it is consistent with the results of other recent investigations that have implicated microorganisms in the formation of rock

Table 2. Relative manganese content within and outside microcolonies in areas away from macroscopic varnish patches.

Rock specimen	*Within microcolony*	*Outside microcolony* *Area 1*	*Area 2*	*Area 3*
J266*	0.09	0.02	0.02	0.02
J380	0.12	0.01	0.02	0.01
J254	0.07	0.02	0.02	0.01
J182	0.11	0.02	N.A.	N.A.
J258	0.42	0.02	N.A.	N.A.

Relative concentrations of manganese as determined by SEM-EDAX. Counts were normalised by bringing the silicon count accumulations to 1.0 in each case.
N.A. Not analysed.
* Shown in Figure 3.

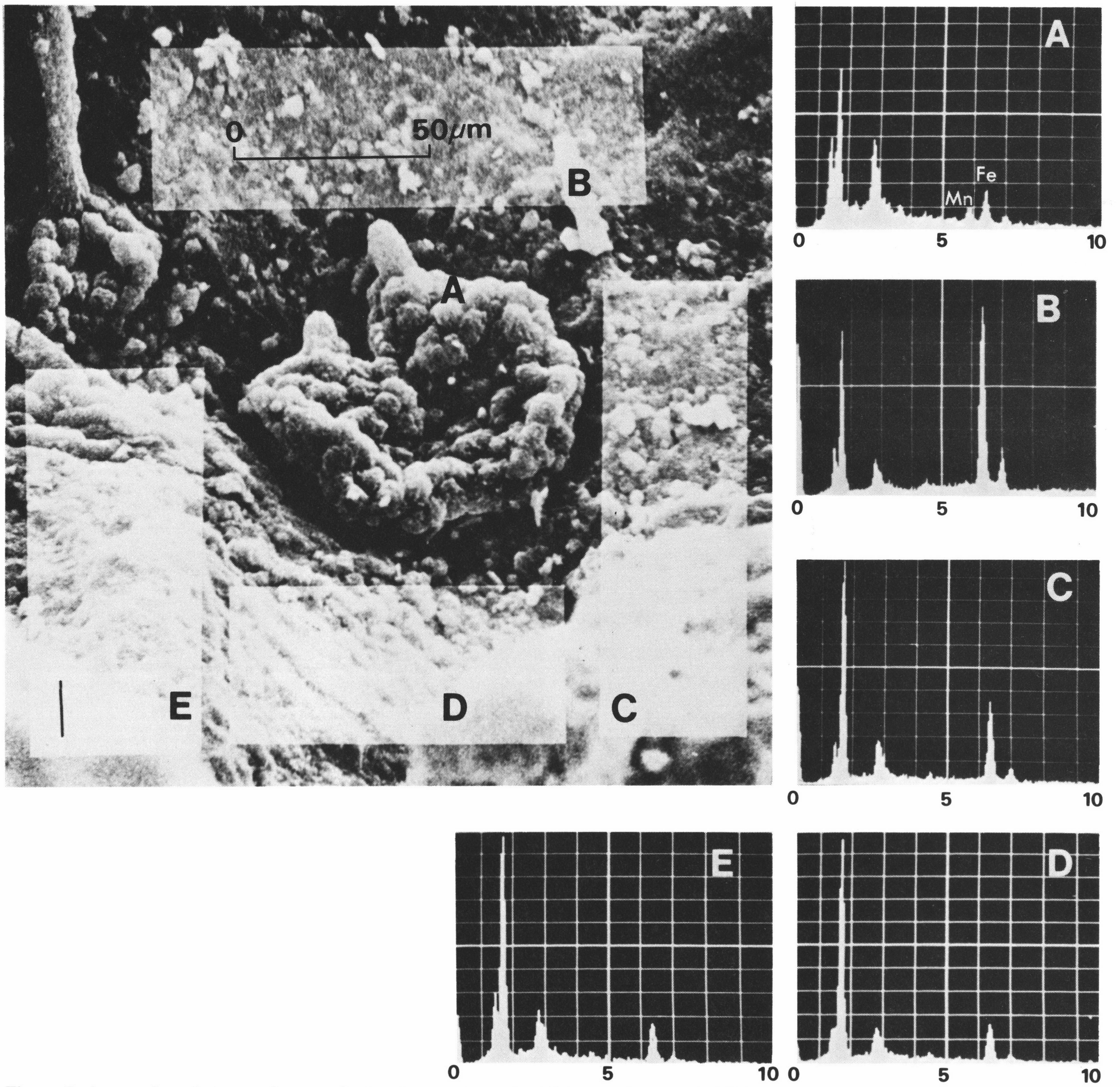

Figure 3. A scanning electron micrograph showing a microcolonial fungus from rock J266.
EDAX analyses were performed on the microcolony and the adjoining areas. The Kα and Kß peaks for manganese are located at 5.89 and 6.49, respectively. For iron the Kα peak is 6.40 and the Kß peak is 7.06. Note that manganese is concentrated within the microcolony.

varnishes (Perry & Adams, 1978; Krumbein & Jens, 1981; Dorn & Oberlander, 1981a,b). The major piece of evidence in support of a biological origin for the Australian desert varnish is the discovery of isolated fungal microcolonies where manganese is found within but not outside the microcolony, implying that some of the fungi act as sites for the start of varnish formation. An alternative explanation is that the microcolonial fungi are simply settling and growing in areas where manganese is rich on the rock surfaces. Also, it is possible that bacteria could be associated with the microcolonial fungi and be responsible for the manganese deposition. These possibilities will be investigated in future studies in which we plan to cultivate organisms from freshly collected rocks and determine their capabilities in pure culture.

References

Dorn, R.I. & Oberlander, T.N., 1981a — Microbial origin of desert varnish. *Science*, 213, 1245–1247.

Dorn, R.I. & Oberlander, T.M., 1981b — Rock varnish origin, characteristics and usage. *Zeitschrift Geomorphologie* N.F. 25(4), 420–436.

Engel, C.G. & Sharp, R.P., 1958 — Chemical data on desert varnish. *Bulletin of the Geological Society of America* 69, 487–518.

Francis, W.D., 1920 — The origin of black coatings of iron and manganese oxides on rocks. *Proceedings of the Royal Society of Queensland*, 32, 110–116.

Glasby, G.P., McPherson, J.G., Kohn, B.P., Johnston, J.H., Keys, J.R., Freeman,A.G., & Tricker, M.J., 1981 — Desert varnish in Southern Victoria Land, Antarctica. *New Zealand Journal of Geology and Geophysics*, 24, 389–397.

Griffiths, H.B. & Greenwood, A.D., 1972 — The concentric bodies of lichenized fungi. *Archives of Microbiology*, 87, 285–302.

Hayden, J.D., 1976 — Pre-altithermal archaeology in the Sierra Pinacate, Sonora Mexico. *American Antiquity*, 41, 274–289.

Humboldt, A. von, 1793 — Florae Fribergensis specimen plantas cryptogamicas praesertim subterraneas exhibens. Edidit Accedunt Aphorismi en doctrina physiologiae & chemicae plantarum, Berolini, Rottmann, I-XIV.

Hutton, J.T., Twidale, C.R., Milnes, A.R., & Rosser, H., 1972 — Composition and genesis of silcretes and silcrete skins from the Beda Valley, southern Arcoona Plateau, South Australia. *Journal of the Geological Society of Australia*, 19(1), 31–39.

Jackson, M.J. & van de Graaff, W.J.E., 1981 — Geology of the Officer Basin. *Bureau of Mineral Resources, Australia, Bulletin* 206.

Jackson, M.J. & Muir, M.D., 1981 — The Babbagoola Beds, Officer Basin, Western Australia: correlations, micropalaeontology and implications for petroleum prospectivity. *BMR Journal of Australian Geology & Geophysics*, 6, 81–93.

Krumbein, W.E., & Jens, K., 1981 — Biogenic rock varnishes of the Negev Desert (Israel) an ecological study of iron and manganese transformation by Cyanobacteria and fungi. *Oecologia*, 50, 25–38.

Laudermilk, J.D., 1931 — On the origin of desert varnish. *American Journal of Science*, 21, 51–66.

Lucas, A., 1905 — The blackened rocks of the Nile cataracts and of the Egyptian deserts. *Egypt Geological Survey, Report*, 55 pp.

Milnes, A.R., & Hutton, J.T., 1974 — The nature of microcryptocrystalline titania in 'silcrete' skins from the Beda Hill area of South Australia. *Search*, 5(4), 153–154.

Perry, R.S., & Adams, J.B., 1978 — Desert varnish: evidence for cyclic deposition of manganese. *Nature*, 276, 489–491.

Potter, R.M., & Rossman, G.R., 1977 — Desert varnish: the importance of clay minerals. *Science*, 196, 1446-1448.

Potter, R.M., & Rossman, G.R., 1979 — The manganese-and iron-oxide mineralogy of desert varnish. *Chemical Geology*, 25, 79-94.

Samuelson, D.A., & Bezerra, J., 1977 — Concentric bodies in two species of the Loculoascomycetes. *Canadian Journal of Microbiology*, 23, 1485-1488.

Staley, J.T., Palmer, F.E., & Adams, J.B., 1982 — Microcolonial fungi: common inhabitants of desert rocks? *Science*, 215, 1093–1095.