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The geology of Australian Mars analogue sites

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ABSTRACT

Australia has numerous landforms and features, some unique, that provide a useful reference for interpreting the results of spacecraft orbiting Mars and exploring the martian surface. Examples of desert landforms, impact structures, relief inversion, long-term landscape evolution and hydrothermal systems that are relevant to Mars are outlined and the relevant literature reviewed. The Mars analogue value of Australia's acid lakes, hypersaline embayments and mound spring complexes is highlighted along with the Pilbara region, where the oldest convincing evidence of life guides exploration for early life on Mars. The distinctive characteristics of the Arkaroola Mars Analogue Region are also assessed and opportunities for future work in Australia are outlined.

1. Introduction

Australia has much to offer researchers interested in Earth analogues of both ancient and modern environments on Mars. The ancient terrains and arid regions of central Australia have preserved many landforms that are unique to Australia. Low-relief deserts with extensive duricrust plains, stony deserts and continental-scale dune fields abound along with numerous well-preserved impact structures. Examples of drainage aligned playas, clay pans, acid lakes, hypersaline embayments and mound spring complexes can also be found and are analogous to features suspected of existing on Mars in the past. Australia also possesses some of the best studied and largest hydrothermal systems on Earth and the earliest convincing evidence of life is recorded in the Pilbara region of Western Australia.

In addition to the array of interesting geological sites, Australia has a stable political situation, excellent local infrastructure and modern services, researchers with extensive experience operating in the arid interior and a scientific community well versed in planetary geology. The climate is bearable and the areas of interest are remote enough that land use does not create problems with interpreting deposits; a common problem elsewhere (Cooke and Reeves, 1976). Furthermore, the country is well imaged by various orbiting instruments and results from sophisticated airborne remote sensing instruments are available locally.

In this work, the geology of various landforms are reviewed in the context of their Mars analogue value and comparisons are made with features observed or inferred on Mars. This work aims to augment similar reviews of Mars analogue science activities at locations in the Canadian Arctic, United States, South America, Europe and North Africa (Lee and Osinski, 2005; Osinski et al., 2006; Pollard et al., 2009; Pacifici, 2009; Léveillé, 2010). The testing of technologies and strategies for Mars exploration in Australia's analogue sites are discussed in a companion work (West et al., 2009) and the education and public outreach opportunities of Mars analogue research activities in the Australian context are discussed elsewhere (Laing et al., 2004, 2006; West et al., 2009).

2. Desert landforms

2.1. Gibber plains

The gibber plains of the Strzelecki and Sturt Stony Deserts bear a striking resemblance to the panoramas produced by several

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Mars landers. Many features common to Australia's desert regions have also been identified in images taken from Mars orbit. To date, however, there has been little exploration of the potential of Australian examples of quintessential desert landforms, dunes and dry fluvial deposits as Mars analogues. For example, the large areas of duricrust materials in central Australia, particularly silcrete, may have formed when silica-rich ground water met saline waters contained in paleolakes. Given the evidence for paleolakes on Mars and for earlier wetter conditions, the formation of silcrete in a fashion similar to that found in Australia's gibber plains might be possible. Thomas et al. (2005) have discussed the gibber plains of the Sturt Stony Desert (Fig. 1) as an analogue of deflation surfaces imaged at Chryse Planitia by the *Viking 1* lander. In the Sturt Stony Desert silcrete gibbers armour a surface dominated by fine silt with scattered floating silcrete clasts.

2.2. Dune fields and sands

Australia's desert dune fields represent more the 38% of the world's aeolian landscape (Wasson et al., 1988) yet few studies have investigated their potential as Mars analogues. Contained in seven interconnected deserts, most dunes are longitudinal and are up to 300 km long, 10–35 m high and spaced 16–200 m apart. Linear dunes such as these are rare on Mars. However, a localised occurrence of mobile crescentic dunes (barchans) at Gurra Gurra Waterhole on the edge of the Strzelecki Desert were studied by Bishop (2001, 1999) and compared to dunes on Mars. In particular, Bishop (2001) noted the importance of the formation of cementing crusts in stabilising dunes. This was borne out by Bourke et al. (2008) who attributed the immobility of some dunes and the mobility of others to the presence or absence of cementing crusts. The Gurra Gurra dunes were also cited as possible analogues of the barchans imaged on the floor of Proctor Crater by the Mars Orbital Camera (Fenton et al., 2003; Taniguchi and Endo, 2007).

The dune sands of Australian ergs range in colour from white to dark red. Debate continues as to whether this is a function of age or sediment source. Kuhlman et al. (2001) investigated red dune sand from a desert region near Kata Tjuta/Mt Olga, Northern Territory as a potential martian regolith analogue. Microanalytical techniques, including pseudoconfocal microscopy and transmission electron microscopy, revealed the ubiquity and non-uniformity of the red-orange coating on every grain of sand. Nanocrystals were identified with a distinctly hexagonal shape that is strongly indicative of hematite, which has recently been detected by the Mars Exploration Rover *Opportunity* at Meridiani Planum (Calvin et al., 2008). A very small amount of hematite nanocrystals could be responsible for the intense red colour of the dune sand at Kata Tjuta/Mt Olga, Northern Territory.

Fig. 1. The gibber plains of the Sturt Stony Desert in South Australia which Thomas et al. (2005) has proposed as an analogue of deflation surfaces imaged at Chryse Planitia by the *Viking 1* lander.

Greeley and Williams (1994) have also proposed 'parna' as an analogue of dust deposits on Mars. 'Parna' is an Aboriginal word meaning 'sandy and dusty ground' and describes a hybrid aeolian deposit consisting of a mixture of sand, silt and clay. Parna deposits, also know as desert loess, occur in many parts of Australia (Haberlah, 2007; Haberlah et al., 2007) and several possible sites on Mars that may be similar to the Australian deposits have been identified by Greeley and Williams (1994). Understanding sediment sources, transport distances and mechanisms and the ages of dune fields in Australia also has implications for understanding similar features on Mars.

Mars also contains many examples of streamlined erosional wind forms, known as yardangs, that are similar in form to inverted boat hulls (Ward, 1979; Fergason and Christensen, 2008). In terrestrial deserts yardangs can range in length from meters to kilometers but despite Australia's extensive deserts and eolian features, few good examples are known (Goudie, 2007). The consensus in the literature is that Australia's deserts are not characterised by extremely low rainfall (less than 50 mm per annum) and there is not sufficient transport of materials (Goudie, 2007). Some very small examples are known at Lake Mungo in New South Wales and the examples at the Gurra Gurra dunes discussed by Bishop (1997) as a Mars analogue are very ephemeral and could not be found by an expedition investigating Mars analogues in the region in 2004 (Clarke et al., 2006).

2.3. Desert flood outs

Flood outs are very low-relief, unconfined, and fine-grained depositional features that form at the distal end of arid rivers where they discharge into dune fields or playas. They form the termini of major rivers such as the Finke and the Todd in inland Australia. Unlike the better defined coarse-grained alluvial fans deposited proximal to high-relief features (Waclawik and Gostin, 2006) (and also found on Mars, see Howard, 2007), flood outs are often poorly defined and can extend considerable distances (many hundreds of kilometers) from the range fronts in which the ephemeral streams have their source. Flood outs in central Australia were postulated by Bourke and Zimbelman (1999, 2000, 2001) and Bourke (2003) as potential analogues for some of the major channels on Mars that flow out onto and apparently merge with the sedimentary cover of the northern plains of Mars without obvious terminal fans. Although not specifically referring to these studies, the observation by Howard (2007) that the apparent scarcity of well developed fans on Mars may be due to extremely fined-grained distal sediments suggests the utility of analogues based on central Australian flood out deposits.

3. Impact craters

Australia's arid climate, generally low-relief and long-term tectonic stability has resulted in one of the best-preserved records of terrestrial impact cratering that has been reviewed by (Glikson, 1996) and more recently by Haines (2005). The great age of the basement rocks in the Australian craton means that the Proterozic impact record is without peer and the density of impact sites is similar to that of North America and parts of northern Europe (Haines, 2005). Most known impact sites are located in Australia's arid interior and in easily accessible pastoral districts, suggesting