Research Note

Surveying for Mars Analogue Research Sites in the Central Australian Deserts

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Abstract
In anticipation of a future crewed mission to Mars, the international non-profit organisation known as the Mars Society is currently establishing four mockup bases at which planetary surface operations simulations, equipment testing and personnel training exercises will be conducted over the next decade. These should provide valuable design data for, and raise public awareness about, plans to explore the red planet. One of these bases, which are organised around a habitat of the kind that is likely to serve as shelter for surface-dwelling astronauts, is to be sited in central Australia under the name MARS-OZ. To find a suitable location, the Mars Society Australia has conducted a ground-truth survey of 15 potential sites as practical scientific analogues of the Martian surface, recording these in a specialised database. Each site was assessed on a set of geomorphic, science/engineering, logistic and visual analogue criteria. Six circular exploration zones 200 km in diameter were identified as clusters of the most significant, observed, comparative planetological features. These zones were then ranked to recommend a series of 'landing sites', at which future field seasons of exploratory science may be conducted.

KEY WORDS *Mars; analogue research; Jarntimarra database; deserts; mound springs; Arkaroola*

Introduction

None of the world's space agencies — National Aeronautics and Space Administration (United States), European Space Agency (Europe), Japanese Aerospace Exploration Agency (Japan), Russian Space Agency (Russia), and China National Space Administration (China) — is yet fully committed to a plan to send human explorers to Mars. All proposals so far have foundered on the prohibitive cost. For example, the perceived US$550 billion (>A$700 billion) price tag in NASA's '90-Day Report' (Cohen, 1989) caused the US Congress to reject the proposal. Today, most of the effort of the spacefaring nations is directed toward military, commercial and scientific operations in near-Earth orbit, such as the International Space Station. Yet there are many who believe that the proper business of space agencies has been forgotten, that too much time has been wasted orbiting the Earth and that a program of peaceful human exploration of the planets should be reinstated. Voicing the impatience of his generation, aerospace engineer Robert Zubrin put it bluntly:

> The American space program, begun so brilliantly with Apollo and its associated programs, has spent most of the subsequent twenty years floundering, without direction. We need a central overriding purpose to drive our space program forward. At this point in history, that focus can only be the human exploration and settlement of Mars. (1996, xiv).

Arguing that explorers of the past have succeeded on account of their willingness to 'travel light and live off the land', Zubrin proposed that automated processing plants capable of extracting oxygen from the Martian atmosphere, and of synthesising methane for use as fuel, could begin supplying the base with consumables months before the first astronauts arrived. Furthermore, the base could be sited near a useable supply of water ice at or near the surface. This *in-situ* resource utilisation would enable a journey to Mars to be accomplished without the need for a very large spacecraft to haul the oxygen, fuel and water needed for an extended mission. This approach makes possible a drastic reduction in the cost — to approximately US$25 billion (>A$32 billion). At present, this approach has been adopted as NASA's Design Reference Mission (DRM) (Hoffman and Kaplan, 1997) but so far no decision has been made to undertake it.

In 1998 Zubrin founded the Mars Society, a non-profit organisation designed to do what governments would not: begin building the technologies, tools and methods needed for the mission, while rallying support from individuals, private companies and public organisations. The Mars Society deployed the first of its planned Mars stations at Haughton Crater (75°22′N 89°41′W) on Devon Island in the Canadian high Arctic and conducted its first field season there in August 2001. Several crews of six to eight volunteers spent periods of approximately one week living inside an 8 m × 8 m, two-storey cylindrical habitat under simulation conditions of moderate fidelity. They ventured outside only wearing mockup spacesuits, under strict NASA-style extravehicular activity protocols. Communication links were modified to insert an artificial delay of ten minutes each way to represent the time taken for radio signals to travel the interplanetary distance. The crews performed operations such as setting up equipment, repairing the habitat, tele-operating inspection robots, and conducting field geological excursions away from the habitat using small all-terrain vehicles.

In 1998 interested individuals across Australia organised themselves into the Mars Society Australia (MSA) and subsequently won agreement from Zubrin on behalf of the US Mars Society to participate in the planned research activities. By October, 2001, they had scientific personnel, equipment and funds to conduct their first field trip. The Jarntimarra expedition (from the Warlpiri word meaning 'star') was to build up a publicly-accessible database of Mars analogue sites, to recommend a site for the Australian Mars Analogue Research Station (MARS-OZ) and to raise public awareness of the value of planetary exploration. A route connecting a number of possibly interesting sites was formulated (Figure 1). Because of time constraints the route could not include several potentially important sites in Western Australia, Queensland and New South Wales, but focused instead on the most likely prospects in South Australia and the Northern Territory; Woomera, the Sturt Ranges, the Simpson Desert, the South Lake Eyre Basin, the Sturt Stony Desert, the Strzelecki Desert and the North Flinders Ranges. MSA hopes to visit sites in the omitted states on future expeditions.

Assessment criteria for analogue sites

Suitable assessment criteria for the site of a simulated Mars station were developed during email forums before the expedition. As a result a database information sheet consisting of a set of 13 prompts was developed for the survey crew. These prompts consisted of the site name, date, latitude/longitude, ownership, access, risks, maps, geology, climate, flora/fauna, history, analogue value and references.

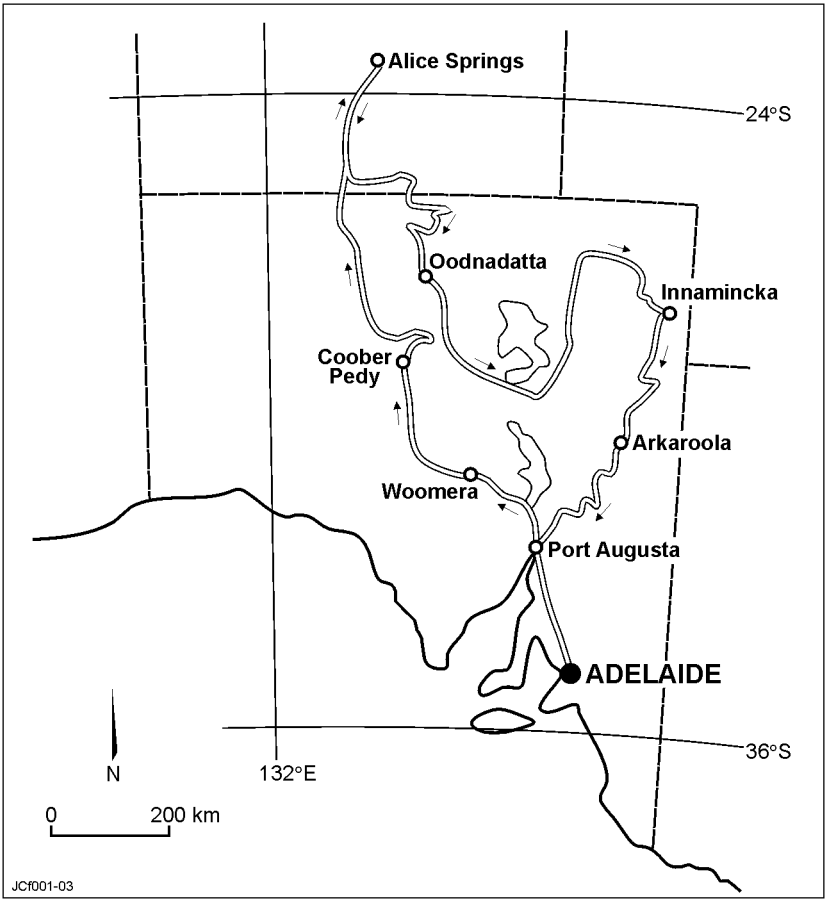

Figure 1 Route of the Jarntimarra Expedition.

Completing these database site sheets would provide for factual entries in the Jarntimarra database but not comparative judgments with respect to the MSA's specific needs. For this, a separate assessment sheet was developed (Table 1). It began as a list of nine scientific and eight engineering criteria, favouring sites that have intrinsic scientific value and offering a range of conditions in which to test analogue vehicles, spacesuits and other equipment. This was later supplemented by a set of seven logistical criteria relating to the distance from facilities and practical difficulty of operations, and eight visual criteria reflecting the public relations requirement for the site to photograph as if it was the Martian surface.

Methods

The expedition party, consisting of four 4WD vehicles carrying the support crew (drivers, navigators and cooks) and the MSA survey team (scientists, engineers, students, a journalist and a doctor), departed from Adelaide in October, 2001 (Figure 2a). Site locations were negotiated continuously by radio between the vehicles. Once a site was selected, survey team members went

Table 1 Assessment criteria for Mars analogue sites.

SCIENTIFIC CRITERIA	ENGINEERING CRITERIA	LOGISTIC CRITERIA	VISUAL CRITERIA
Bedrock geology (does bedrock geology include lithologies, e.g. basalts, found on Mars?)	**Rocky** (extent of rocky surfaces, as might be found on Mars)	**Security** (can the area be easily secured against intrusion?)	**Climate** (how arid is the climate?)
Geomorphology (are the landforms similar those found on Mars, e.g. flood-outs, mesas?)	**Boulders** (extent of boulder-covered surfaces, similar to those on Mars)	**Accessibility** (how accessible is the area?)	**Surface water** (is there surface water present?)
Surficial deposits (are these similar to those found on Mars, e.g. dunes?)	**Sandy** (are extensive areas present, as occur on Mars?)	**Infrastructure** (is there nearby infrastructure support, e.g. roads, accommodation?)	**Colour** (what colours are present in the area — red, yellow, brown preferred)
Groundwater (are groundwater-related landforms, e.g. sapping channels present?)	**Dusty** (presence and extent of dust mantles, especially easily mobilised dusts, as on Mars)	**Land tenure** (are the land owners supportive of Mars analogue research in the area?)	**Vegetation** (how vegetated is the site — the less the better)
Weathering (is the weathering style similar to that expected on Mars?)	**Firm** (are there areas of smooth firm going, as on Mars?)	**Liabilities** (what negative features are associated with using this site?)	**Physiography** (does the landscape visually resemble Mars, i.e. craters, mesas?)
Palaeontology (are relevant fossils, e.g. stromatolites, present?)	**Chemical Activity** (is the surface chemically reactive, i.e. saline, as on Mars?)	**Safety** (what safety concerns exist at this site?)	**Landscape process** (are there particular processes evident in the landscape that heighten the visual resemblance, e.g. cratering?)
Microbiology (are there relevant microbial communities, e.g. endoliths?)	**Wind** (is the area subject to wind that might mobilise sand and dust, as on Mars?)	**Outreach potential** (what special opportunities exist in the area for public education and outreach?)	**Cultural association** (is there a cultural association between Mars and the site, e.g. history of Mars analogue research?)
Extremophiles (are these present?)	**Temperature variation** (are there extreme temperature variations, especially freezing, as occurs on Mars?)		**Cultural disturbance** (how much cultural disturbance has there been, e.g. buildings, fences, roads?)

Figure 2 (a) The expedition departs from Adelaide (b) Island Lagoon salt lake near Woomera (c) Plant growth in a mound spring at Stangways Station (d) Sampling a radioactive hot spring at Paralana.

to work collecting their assigned information. GPS locators were used to specify the locations of interesting features. Every effort was made to obtain permission from the stakeholders, owners or custodians of the selected land, though in all cases the site work was non-intrusive.

Each evening of the survey, data collected from the sites were entered into the Jarntimarra database, images from digital cameras were backed up on computer hard disks, and daily field reports with images were emailed via satellite telephone for posting to the MSA website and to interested stakeholders. This required consolidation of the contributions made by each member of the survey team into one laptop computer, with the files then backed up on two separate machines.

To simplify the daily data entry task, text and data from the site assessment sheets were simply typed into a single document, to be transferred later to a web-based database format, and subsequent dissemination to interested users via the MSA website. Other deliverables from the expedition included about 2884 MB of high resolution and 76 MB of low resolution digital images, hydrochemical and microbiological analysis of bore water samples taken from three flowing thermal bores, and mineralogical and petrographic analysis of rock samples from the Strangways mound spring.

While surveying near Island Lagoon dry salt lake near Woomera (Figure 2b) the expedition party took up an unusual opportunity, offered by the Range Safety Officer of Woomera Rocket Range, to tour the nearby Narrungar communications base which was abandoned by the United States government in 1998. Sited as it is within the Nurrungar Restricted Area, no other use has been found for the secure buildings, carparks, workshops and domed satellite dish. However, the disused infrastructure might be of value to the MSA if a base were to be established at the Island Lagoon site.

The Henbury craters were surveyed for several reasons. As well as being easy to access, Henbury displays a cluster of several relatively recent impact craters, including one that has an internal swamp. Mars has many craters peppering its surface. Some show signs of water seepage and may retain heat from the impact event. Thus evidence for life should be searched for within the lakes that once existed in the larger Martian craters (see Newsome *et al*., 1996). Another Earth analogue is the Canadian Haughton impact structure (Osinski *et al*., 2001), the site of the first Mars Society habitat and the NASA Haughton-Mars Project for that reason.

Springs of various types appear to be present on Mars. For example, recent analysis of images of the Athabasca Valles channel system south and southwest from the lava-covered Cerberus Planum, just north of the Martian equator, obtained by the Mars Orbital Camera onboard the Mars Global Surveyor spacecraft, showed evidence of water flooding from springs associated with volcano-tectonic fissures (Burr *et al*., 2002). While the fissures themselves may be older, the latest eruption of water was geologically recent (probably 10 million years ago). Areothermal sites (Martian hot springs) of this kind would be of great scientific and practical importance to a landing party, so terrestrial experience with geothermal springs is needed to design Mars-destined equipment and plan human sorties. The Jarntimarra expedition studied several active and recently fossilised water springs in the desert at the Dalhousie and Strangways mound spring complexes that may be useful analogues for those on Mars (Figure 2c). The geology of these mound springs is well summarised in Drexel and Preiss (1995, 57) while a more general geology of desert playas, dunefields and watercourses is presented later in the same publication (see pages 244–251).

Survey outcomes and conclusion

A number of key issues for the MSA were resolved during a three-day workshop at Arkaroola village in the northern Flinders Ranges. Here the expedition members worked at choosing a suitable site for MARS-OZ, the proposed design and operation of the base, and specific projects associated with the surface simulations operations to be conducted there.

The 15 surveyed sites were first reduced by clustering. By charting all the interesting features found during the survey on a single topographical map it was found to be possible to enclose almost all sites inside only six 200 km diameter circles (Figure 3). The significance of these exploration zones is that each specifies a set of features within plausible reach of one simulated Mars mission, given a vehicle capable of traversing the surface (the MSA is currently constructing such a vehicle). If the centre of a circle represents a habitat landing site, all the features within that zone would be reachable by return sorties of less than 300 km total travel distance. Using the proposed exploration vehicles, safety considerations would certainly limit exploratory journeys to a radius of approximately that dimension. Thus, circumscribing the sites of interest in this way gave six centres, each a possible 'landing site' for the MARS-OZ facility.

Based on the collective experience gained while filling in the site assessment sheets, each zone was rated on five-point scale according to the above specific characteristics (Table 1). All ratings for each site were combined into a weighted sum, representing the overall score for a each site. Engineering and science scores were doubly weighted to reflect their importance relative to the other criteria in the total score.

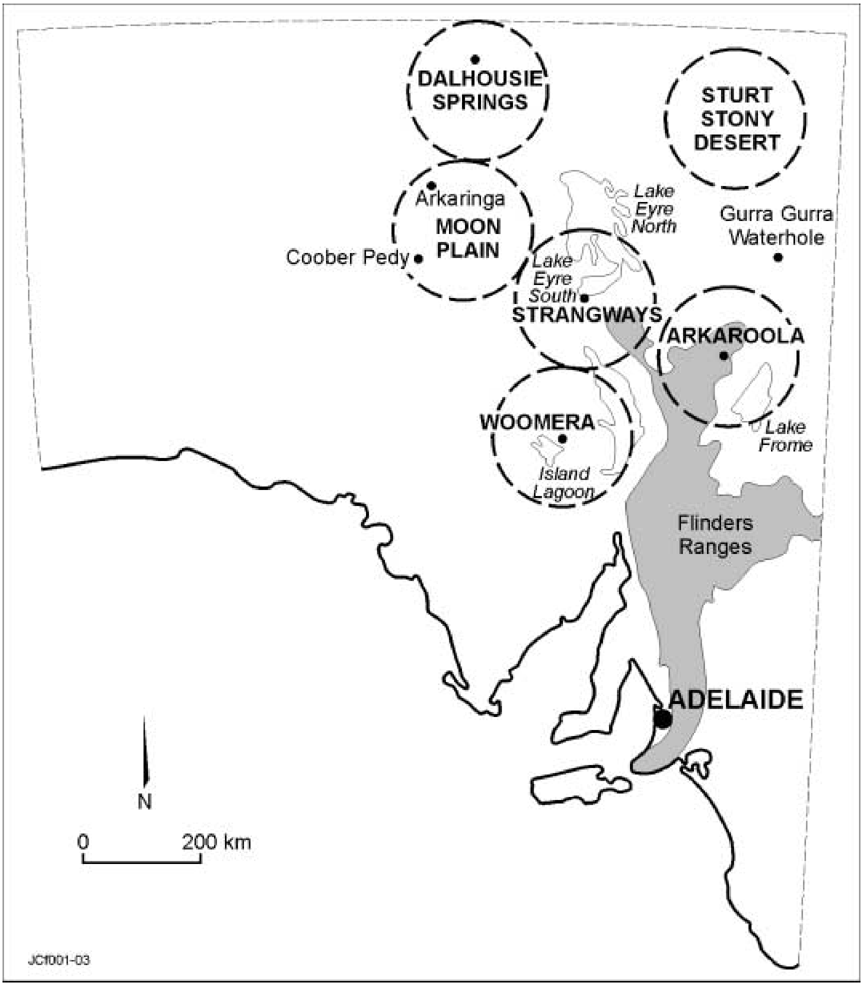

Figure 3 Six 200 km diameter exploration zones, enclosing clusters of the most important analogue features, are centred on possible 'landing sites' for the proposed Australian Mars station.

On this basis, the Moon Plain, Woomera and Arkaroola zones achieved equal ranking.

To support the goal of recommending a premier site for MARS-OZ, the tie was then broken by considering the arguments of individual expedition members advocating each zone. Eventually the case for the Arkaroola region prevailed by virtue of its unique combination of logistical convenience, international scientific reputation and Mars-like geology.

Specific Mars analogue research already carried out in the region has been three-fold, focusing on aeolian landforms, extremophiles (mircroorganisms that thrive in extreme environments), and remote sensing. Studies of aeolian landforms compared Martian dunes at Nili Petra with terrestrial dunes at Gurra Gurra Waterhole in the Strzelecki Desert (Bishop, 1999; 2001). The extremophile work found radiation-resistant thermophiles (microorganisms that thrive at high temperatures) in the Paralana hot spring (Figure 2d), which is characterised by high levels of radon gas (Trott *et al*,. 2001). The area has been used in remote sensing experiments comparing hyperspectral imagery from the alteration halo surrounding the Mount Painter fossil hydrothermal system with ground truth from a hand-held spectrometer (Thomas, 2000; 2001). This last study is particularly relevant to detecting the presence of such systems on Mars, which are believed to be good localities to search for microfossils. Potential Mars analogue geoscience research in the area may include palaeontology, geomorphology and regolith studies. The Proterozoic sediments of the area are known to host silicified microfossils and the sinters of the Mount Gee fossil hydrothermal system show potential for microfossil preservation. The evolution of the alluvial fans on the eastern flank of the Flinders Ranges, the nature of the mound springs of Lake Frome, and landscape evolution of the northern Flinders Ranges (where uplift has led to partial exhumation and dissection of ancient land surfaces buried beneath Cretaceous cover) are some of the more important regolith and geomorphological research projects that might be conducted during future MSA field seasons.

An ideal site for MAR-OZ was found on the gravel plains to the east of the Arkaroola zone's central point, between the eastern side of the northern Flinders Ranges and Lake Frome. This will allow easy access to sites in the Flinders Ranges proper and on the plains that surround Lake Frome, and also simplify research station logistics through proximity to a well-maintained, unsealed road that runs up the eastern margin of the ranges, joining the Strzelecki Track to the north and the Barrier Highway to the south. The exact coordinates will be decided upon during a further expedition after discussion with the landholders.

As a result of the expedition, 15 new entries were made in the Jarntimarra database (accessible online at http://www.marssociety.org.au). More are expected to be made during forthcoming field seasons. The selection methodology developed by the MSA identified six sites at the centre of 200 km diameter exploration zones suitable for the MARS-OZ. Of these the area east of Arkaroola is the most attractive, at least for the first few field seasons. It is possible that the station will be moved to other sites of interest in future years.

Further baseline geology, biology, engineering and human factors studies of the Arkaroola region will be conducted by the MSA and overseas collaborators during 2004. This work will pinpoint the exact location at which the MARS-OZ infrastructure will be established. This will provide a focus for more advanced Mars analogue research in future.

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