RELIEF INVERSION: AUSTRALIAN ANALOGS OF A COMMON FEATURE OF MARTIAN LANDSCAPE EVOLUTION. C. F. Pain[1] and J. D. A. Clarke[2] [1]Mars Society Australia Box 327 Clifton Hill, Victoria 3068, Australia colinpain@internode.on.net [2]Mars Society Australia/Australian Centre for Astrobiology, Biological Science Building, University of New South Wales, Kensington, NSW 2052, Australia jon.clarke@bigbpond.com.

Introduction: Relief inversion explains a wide range of sinuous and dendritic ridges on the martian surface as well as elevated craters [1]. The process occurs when former depressions become elevated because their fill is more resistant to erosion than the surrounding terrain. On Mars the most likely cementing agents for surface induration are iron oxides, opalline silica, sulfates and perhaps other salts. Possible cementation mechanisms include fluid mixing during regional groundwater flow, cooling of hydrothermal or basinal fluids as they near the surface, and evaporation and sublimation of near surface water. Wind action appears the most common erosive process on Mars capable of the regional landscape lowering necessary for relief inversion to take place.

Figure 1: An example of inverted channels from the Eberswalde delta on Mars.

Formation of relief inversion: Terrestrial relief inversion occurs when former depressions become elevated because their fill is more resistant to erosion than the surrounding terrain [2]. The inverted relief will preserve relicts of former land surfaces and is therefore older than the surrounding terrain (Figure 1). Relief inversion can occur by a range of processes, including infill of depressions by intrinsically resistant material such as lava, selective secondary cementation via diagenesis and weathering, or surface armouring.

A variant of relief inversion occurs when exhumation of a sedimentary basin results in the exposure of paleochannels [3]. These may not have occupied valleys but, if more cemented than the surrounding sediments, can become inverted to form distinctive landscape ridges.

Significance: Inverted relief preserves relicts of former land surfaces and is therefore older than the surrounding terrain. On Mars, comparison of crater counts between the tops of inverted features and the surround plains allows estimates of the rates of landscape denudation to be made. The flanks of inverted relief features all can expose stratigraphic successions and relationships, providing useful targets for surface exploration [4].

Australian examples: The Australian continent is particularly favourable for the preservation of relief inversion because of the relatively stable intra-cratonic settings and the presence flat, or nearly flat lying sedimentary successions. Cementation has been by iron oxides, silica, and carbonate. Inversion of topography by lava flows is also common. Examples of inversion of impact craters are also known. Landscape lowering has been predominantly by fluvial action, although in arid regions eolian processes may also have been a factor. Following are several representative examples that offer potential as Mars analogs (Figure 2).

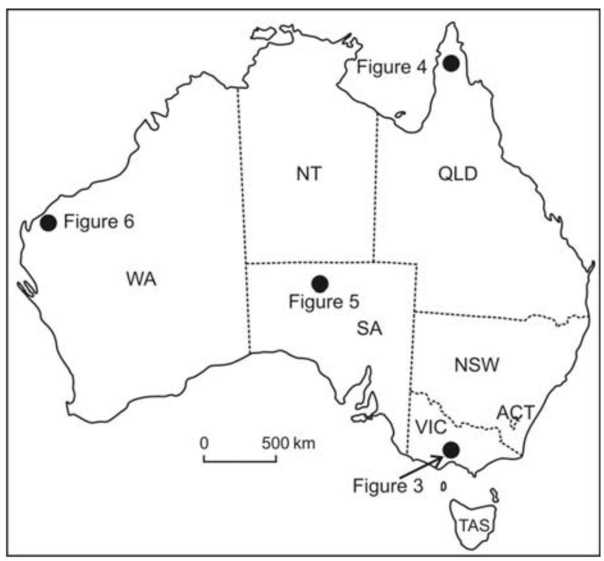

Figure 2: Australian occurrences of inverted relief mentioned in text.

Bullengarook. Late Miocene basalt flowed at least 20 km south down a paleovalley cut into Paleozoic siltstones and slates from a localized volcanic centre at Bullengarook in Victoria [2]. The basalt has been dated at 3.5 Ma, since when there has been a minimum of 75-126 m of lowering in the surrounding landscape, exposing basal conglomerates in the valley fill that were buried by the basalt (Figure 3).

Cape York. The Cape York region of northern Australia contains numerous examples of inverted relief [2]. It is an area of silica-rich sedimentary bedrock with common siliceous cementing of valley floor materials. This has resulted in inverted relief of various ages with up to 200 m lowering. (Figure 4).

Figure 3: Oblique Google Earth image (X3 vertical exaggeration) showing inverted lava flow at Bullengarook. Width of flow in foreground ~700 m.

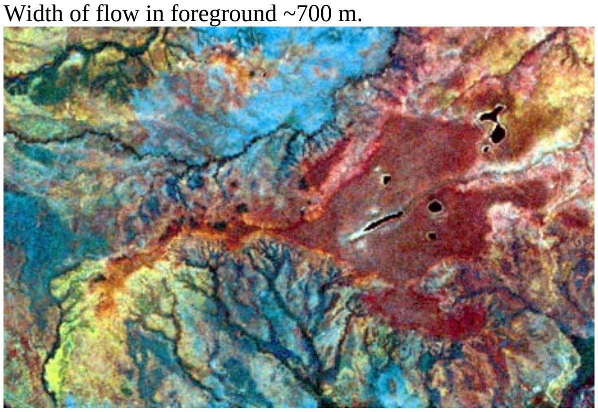

Figure 4: LANDSAT false color image of inverted fan (red), Cape York. Fan width ~25 km.

Mirackina. The Mirackina paleochannel is an inverted paleochannel of probable Miocene age in South Australia [5]. The iron and silica-cemented paleochannel has been extensively dissected and segmented by erosion which has lowered the landscape by 15-20 m. Original length was at least 140 km, channel width is typically 100 m (Figure 5).

Pilbara. Numerous segments of inverted paleovalley fills occur in the Pilbara region [6]. These are of Miocene age and composed of pisolithic hematitic ironstone. These have been extensively drilled in the course of exploration for iron ore, and several are being mined (Figure 6).

Value as Mars analogs: The Australian examples of inverted relief are valuable as Mars analogs because of the diversity of landscape contexts, infill, cementing agents, and age they illustrate. They are also ideal natural laboratories to study the paleoenvironmental history recorded in the sediments [7], and the history of groundwater flow and water-rock interaction contained by the diagenetic and weathering signatures. Those in arid environments have the potential to serve as testing grounds for exploration strategies that could be used on their martian counterparts.

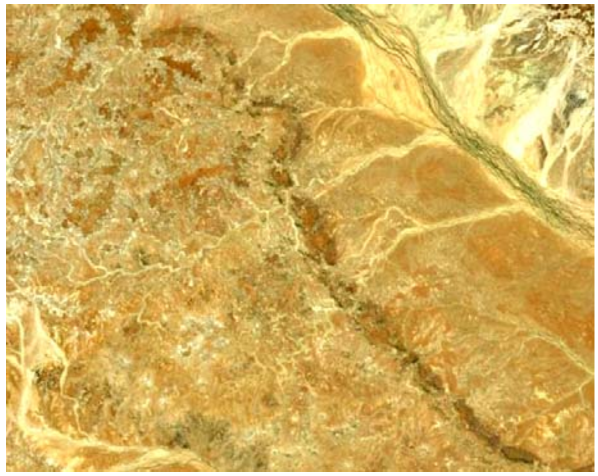

Figure 5: Vertical Google Earth image of Mirackina paleochannel, showing straight and meandering segments. Channel width ~100 m.

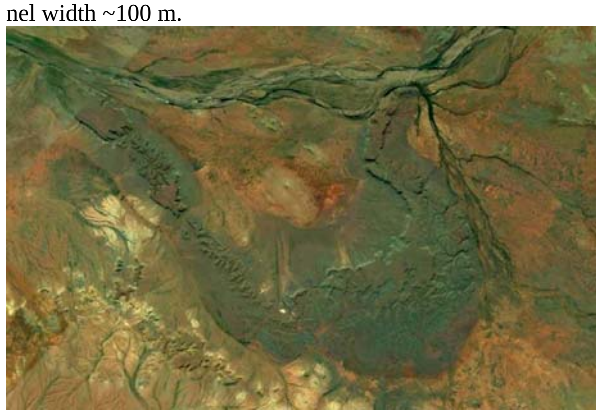

Figure 6: Meander loop of inverted paleochannel composed of pisolithic ironstone in the Pilbara. Paleochannel width ~200 m.

References: [1] Pain C. F. (2007) *Icarus* 190 478–491. [2] Pain, C.F. and C. D. Ollier (1995) *Geomorphology* 12, 151–165. [3] Williams R. M. E. et al. (2008) *Utah Geol. Ass. Pub.* 36 220-235 [4] Newsom H.E. (2009) *Icarus* 199 (in press). [5] McNally G.H and I. R. Wilson (1995) *AGSO J. Austr. Geol. Geophys*. 16, 295–301. [6] Morris R.C. and I.R. Ramanaidou (2007) *Aust. J. Earth Sci*. 54, 733-756. [7] Macphail M.K. And M.S. Stone (2004) *Aust. J. Earth Sci*. 51, 497-520.