Topographic Steering and Dune Morphology in a Polar Desert, Analogues for Mars from the McMurdo Dry Valleys of Antarctica

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Introduction: The McMurdo Dry Valleys of Antarctica are recognised as one of the best Earth analogues for the surface of the planet Mars due to the low temperatures, lack of liquid water and absence of vegetation. The Victoria Valley is the northernmost of the McMurdo Dry Valleys of Antarctica and contains three areas of sand dunes that demonstrate a strong topographic control on dune morphology and dune migration. The valley is aligned roughly East to West and the local wind regime, which is essentially bimodal, is topographically constrained [1]. Easterly winds blow up the valley from the Ross Sea while westerly föehn and katabatic winds blow down the valley from the polar icecap. The relative strength and duration of these winds, combined with topographic steering and shear against the valley wall, control aeolian sand transport, dune morphology and dune migration within the Lower Victoria Valley. Local changes in the wind regime within the valley are reflected in the dune morphology and the sedimentary structures preserved within the dunes.

Packard Dune Field

The Packard Dune Field is located on the northern side of the Lower Victoria Valley, beneath the Packard Glacier (Fig. 1). It is around 4km long and 0.5km wide covering an area of $2km^2$ [2]. The dunes which include barchans, transverse barchanoid, reversing dunes and climbing dunes are up to 13m high. The dune crests are aligned roughly Northeast-Southwest to North-South, with slipfaces facing west in response to the summer winds that blow up the valley from the East [3]. GPR profiles through the dunes shows that net migration is from east to west with many reactivation surfaces formed when the dune is reshaped by the reversing winds [1]. In addition, the reversing wind regime influences the dune morphology with the formation of flat-topped dunes. Optical dating of the Packard dunes indicates that they are up to 1,300 years old. The ages are used to calculate end-point migration rates that vary from 0.05 to 1.3 m/yr [1] but generally less than the rates derived from field measurements and from the analysis of aerial photographs [2].

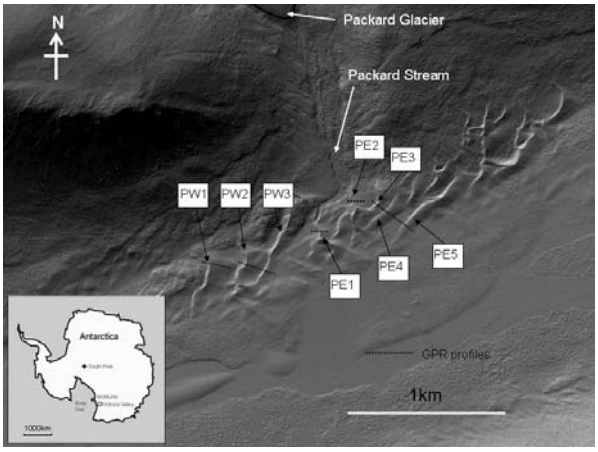

Figure 1. LiDAR image of the Packard dune field which included barchanoid, transverse, reversing and climbing dunes located along the north side of the Lower Victoria valley beneath the Packard Glacier.

Whaleback dunes

Whaleback dunes in the Victoria Valley lie on the valley floor and are aligned sub-parallel with the valley walls (Fig. 2). The dunes are aligned obliquely across the valley and although Selby et al. [3] suggest that their alignment and shape may be partly controlled by the underlying moraine it appears that the dunes are aeolian landforms and only locally influenced by the underlying fluvial and glacial topography [4]. The whaleback dunes are up to 1 ikm in length and around 100 m in width, and lack slipfaces. GPR profiles through one 800m long whaleback dune reveal low angle inclined reflections interpreted as dune bedding [4]. The bedding primarily dips towards the east indicating that the dune has extended from west to east in response to westerly winds. Bedding also dips towards the south indicating that the dune is expanding across the valley at the same time as extending along the valley.

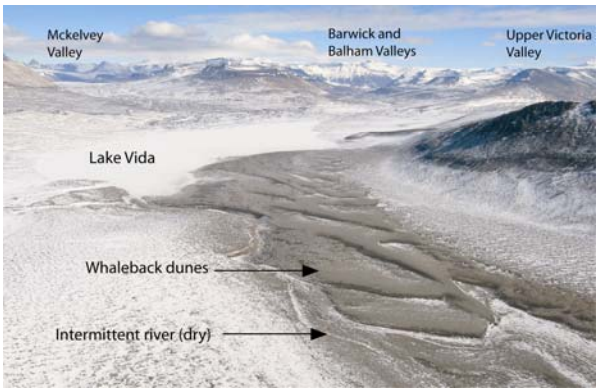

Figure 2. Oblique aerial photograph of whaleback dunes on the floor of the Lower Victoria Valley. View towards the west with Lake Vida and the McKelvey, Barwick and Balham valleys in the background. Westerly winds funnelled through the Lower Victoria Valley appear to control the orientation and migration of the whaleback dunes [4].

Lake Vida Dune

The Lake Vida dune stands on a debris lobe that projects south into the valley toward Lake Vida (Fig. 3a). The dune has a barchanoid morphology and is over 80m high, and over 800m wide, much higher and wider than any other dunes in the Victoria valley. GPR profiles across the dune show inclined reflections dipping towards the east (Fig. 3c), which indicates that the dune is migrating from west to east driven by westerly winds. This is the opposite direction to that which would be expected from the barchan like morphology. One possible explanation is that ice cement is stabilising the arms of the dune so that it is taking on a parabolic form. The depth of penetration by the GPR is greater than predicted for Quaternary sediments, most likely because of the absence of liquid water.

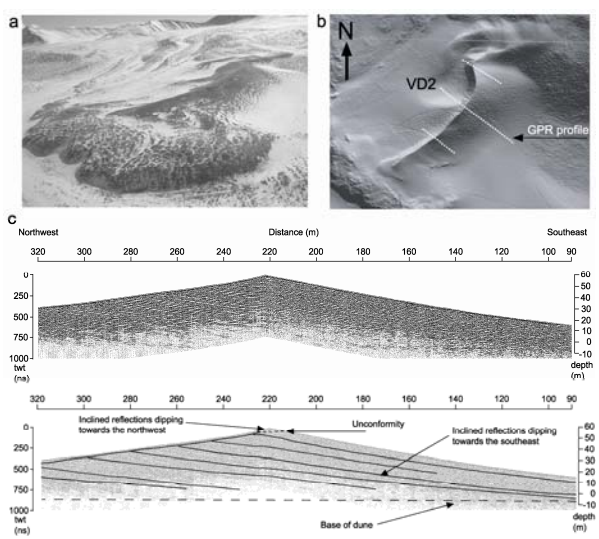

Figure 3. a, North facing oblique aerial view of Vida Dune standing on debris lobe. b, LIDAR image showing location of GPR profile, c, 100 MHz GPR profile across Vida Dune showing bedding dipping from left to right towards the east which indicates that the dune has been accreting towards the east.

The three areas of dunes in the Lower Victoria Valley show contrast in dune morphology and migration direction within a distance of 10km along the valley. Sedimentary structures revealed by GPR within two of the dunes, a whaleback dune and the Lake Vida dune indicate net migration towards the east. In contrast, GPR profiles across the Packard dunes indicate net migration towards the west (Fig. 4). Dune migration from east to west is driven by easterly winds that blow onshore from the Ross Sea. These sea-breezes are generated by solar radiation heating the valley floor and are therefore more common in the summer months. Dune migration from west to east is driven by westerly winds that are föehn and Katabatic winds that are more common and more powerful during the winter months.

The Lake Vida dune which stands on a debris flow lobe is elevated above the valley floor and exposed to the westerly winds. It is probably partially sheltered from the easterly winds due to the change in orientation of the Lower Victoria Valley as the valley opens out to the west.. The whaleback dunes lie on the valley floor and are exposed to both the easterly and westerly winds. This axial position and exposure to both winds has probably influenced the dune morphology which is elongate and lacks slipfaces. The dominance of east dipping strata within the dune indicates that the westerly winds are dominant dune forming winds in the middle of the valley. Sedimentary structures revealed by GPR profiles across the Packard dunes indicate net migration towards the west and thus in this area the easterly winds are the dominant dune forming wind. The Packard dune field lies along the northern edge of the valley beneath the Packard glacier and in this location the dunes are partially sheltered from the westerly winds. Thus the location of the dunes within the valley determines their morphology and migration direction due to their relative exposure to, or shelter from, the winds that are steered along the valley by the mountainous topography.

References:

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