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 2km² [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].

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 km 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.
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.

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