RECONSTRUCTION OF AEOLIAN PALAEOENVIRONMENTS AND PAST CLIMATE EVENTS AT THE GREENHEUGH PEDIMENT, AEOLIS MONS, MARS. S.G. Banham[1*], S. Gupta[1], A.B. Bryk[2], D.M. Rubin[3], K.S. Edgett[4], W.E. Dietrich[2], G. Caravaca[5], L.A. Edgar[6], C.C. Bedford[7] and A.R. Vasavada[8], [1]Imperial College London (s.banham@ic.ac.uk), [2]University of California Berkeley, [3]University of California Santa-Cruz, [4]Malin Space Science Systems, [5]University of Nantes, [6]USGS Flagstaff, [7]LPI, URSA, [8]JPL, Caltech.

Introduction: The signature of major and minor climate events can be recorded in the stratigraphic record of ancient aeolian dune fields. Sustained aridification may permit construction of dune fields and preservation of aeolian strata in areas previously characterized by strata deposited by water in humid conditions. Minor climate events may be manifest as episodic changes of the prevailing wind – such as direction reversal – can be encoded by changes to the stratigraphic architecture and facies preserved within an accumulating dune field's stratigraphic succession. By documenting the stratigraphic record and understanding how surface processes generate these strata, climate trends at different time scales can be deciphered, allowing more granular reconstruction of the ancient climates.

Between Sols 2600 and 2750, the MSL rover investigated the Stimson formation – which unconformably overlies the lacustrine Murray formation [1,2] – at the north edge of the Greenheugh pediment, to determine the depositional origin and processes which formed the capping unit. The pediment capping unit is interpreted to be an up-slope extension of the Stimson formation, and part of the Siccar point group [1,2,3], which are part of the broader "Mound skirting unit" seen across the lower northern flank of Aeolis Mons [4].

Sedimentary Texture: The MAHLI instrument was used to investigate 14 rock outcrops for grain size and textural properties, across the full vertical section of the pediment capping unit, from the basal unconformity to the top of the preserved succession. Grainsize measurements averaged across all targets, (n=1950) gave an average grainsize of 486 µm, with grains being well sorted, (slightly bimodal).

Above the basal unconformity (target Hutton's Section), large (~2mm) light grey clasts were observed; these are visually similar to the underlying Murray formation bedrock. They are interpreted to be extra-formational Murray fm. clasts reworked into the base of the Stimson formation (similar clasts were seen at Marias pass [5]. Above Hutton, at Chinglebraes target, laterally-persistent uniform-thickness parallel laminae are observed, these are interpreted as pinstripe or windripple strata. At Assynt-Window, a planform cross-section through several wind ripple laminae were imaged. These laminae are characterized by a lower finer-grained section, which is overlaid by a coarse-grained (~700 µm) upper section. This inverse grading is a common characteristic of windripple strata [6].

Sedimentary Facies: Mastcam observations of the pediment-capping unit revealed several key facies. In the area where the rover traversed onto the pediment, wind ripple strata are observed at the Enard Bay target. Here, laminations of 2-4 mm thickness are persistent for distances of >1 m and exhibit uniform thickness along their length. There were no examples in which such laminations pinched out or were truncated by other laminations. The laminae have recessive and protruding layers, giving them a pinstripe appearance. Such facies are commonly preserved where the airflow is predominantly oblique to a dune lee face.

At the Edinburgh section (Figure 1), avalanche (grainflow) strata were observed, interstratified with wind ripple strata. Wind-ripple strata formed prominent weathering-resistant thin laminations which are juxtaposed against thicker sections of weathering recessive sandstones. Careful inspection of these sandstones revealed "whispy", indistinct and faint wedge-shaped bodies. This texture along with the pinch-outs is a common feature of dune avalanche strata. Avalanches form distinctive tongues of sand that can amalgamate to form these distinctive facies in section.

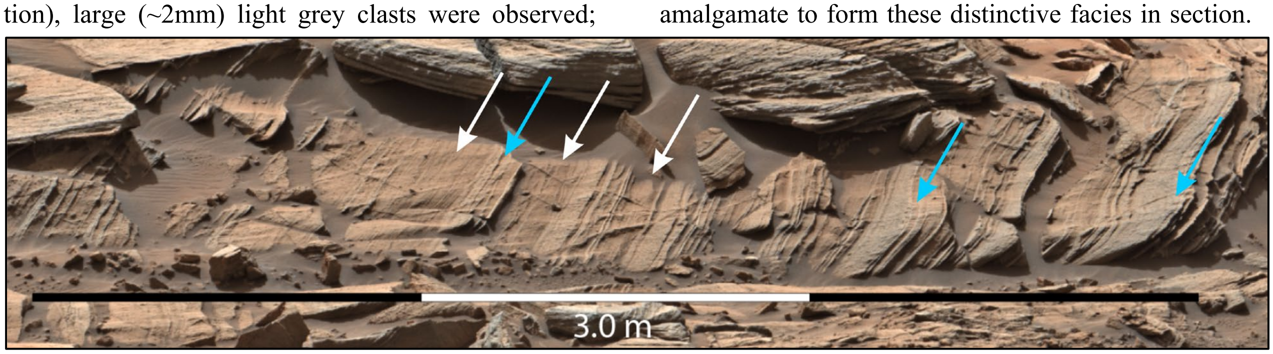

Figure 1: Edinburgh section, a planar cross set containing avalanche strata (white arrows) and wind ripple strata (blue arrows).

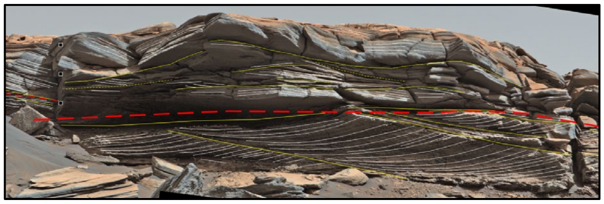

Figure 2: Boundary between Type 1 and Type 2 compound cross sets at Moray Firth outcrop.

These facies are common on dunes where sediment transport is perpendicular to the crest line [6].

Both of these facies are typically found within cross bed sets. Cross sets are bounded by an upper and lower bounding surface and contain cross laminations – normally wind-ripple strata. Wind-ripple strata dip asymptotically onto the lower bounding surface. In sections parallel to the transport direction, sets can appear trough-shaped or planar. Cross-sets are interpreted to record the preserved lower section of straight and sinuous-crested aeolian dunes.

Sedimentary architecture: Two stratigraphically and architecturally distinct types of compound cross-strata were observed in the study area:

Type 1 elements, characterized by an angular divergence between the cross-laminations and their subset bounding surface [7] were observed at Tower butte. Here, cross-laminations in sets 0.3-0.8m thick dip toward the northeast. These sets are bounded by subset-surfaces that dip toward the northwest. One coset ~2 m thick is identified here. This architectural arrangement suggests these compound cross-sets were generated by oblique compound dunes. The architectural arrangements of the cross-laminations and bounding surfaces indicate sediment transport was toward the north.

Type 2 elements, characterized by planar cross-sets parallel to their subset-bounding surfaces [7] were observed at Ogre Hill, and the Edinburgh section. At the Edinburgh section, a planform cut through the cross-set was observed, where cross-laminations are straight and can be traced for between 5-10 m across the outcrop without truncation. At Ogre Hill, planar cross-sets were observed containing subset-bounding surfaces with concordant cross laminations. The dip direction of both cross laminations and bounding surfaces are apparently to the south. Because these cross sets are in close association with the Edinburgh section, these are interpreted to be cyclic cross bedding associated with fluctuating flows: subset-bounding surfaces are interpreted to be reactivation surfaces [7].

Type 1 cross-sets are distributed lower in the stratigraphy, with Type 2 cross sets overlaying them. This relationship is best observed at the Moray Firth outcrop (figure 2) where oblique compound cross-sets with dips toward the north are overlain by planar cross-sets with southward dips. The boundary can be traced across the margin of the pediment. This boundary may record an intraformational unconformity, known as a supersurfaces [8].

Interpretation of major and minor climate events: The superposition of the aeolian Stimson formation overlying the lacustrine Murray formation indicates a long-term climate trend, in which the climate became sufficiently arid to permit the formation and preservation of a dune field where a lake once existed.

Short-term climate events can be inferred from changes of stratigraphic architecture and sediment transport direction within the Stimson formation. The juxtaposition of cross-sets indicating northward sediment transport at Tower butte, and southward sediment transport direction at Ogre Hill and the Edinburgh sections indicates a prolonged reversal of sediment transport (figure 3). The prevailing wind would need to reverse for some period to allow dunes to reform with their lee slopes oriented south, and for sufficient dune migration to occur for their cross-sets to be recorded in the stratigraphy. Finally, interstratification of windripple and avalanche strata (Figure 1) could indicate very short-duration climate events, such as daily to annual fluctuations of wind direction.

References: [1] Banham, et al. (2018) Sedimentology 12469. [2] Banham et al. (2020) LPSC 51, #2337. [3] Bedford et al (2020) Icarus [4] Anderson & Bell (2010) Mars V, 76-128. [5] Newsom et al (2016) LPSC 47, 2397. [6] Hunter (1977) J.Sed.Petrol, **47**, 697-706. [7] Hunter & Rubin (1983) Developments in sedimentology 38. [8] Havholm & Kocurek (1994) Sedimentology, 41, 913-924.

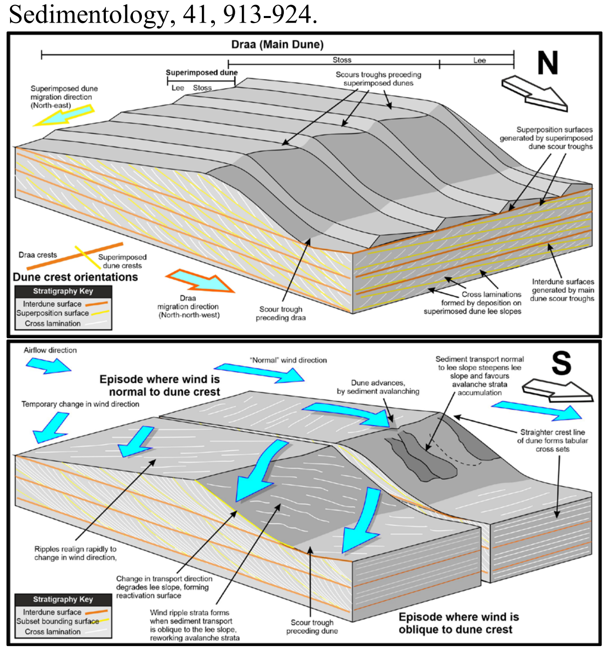

Figure 3: Conceptual models dunes which generated Type 1 and Type 2 compound cross strata