Giant Linear Dunes as the Formation Pathway to Megabarchan Chains : Titan and the Rub 'Al Khali.

Ralph D. Lorenz[1] and Jani Radebaugh[2]. [1] Space Exploration Sector, JHU Applied Physics Laboratory, Laurel, MD 20723, USA. (Ralph.lorenz@jhuapl.edu) [2] Dept. Geological Sciences, Brigham Young University, Provo, UT, USA.

Introduction: The term megabarchans, referring to large crescentic forms, might be thought to suggest a link to common barchans. However, the spatial arrangement of megabarchans, such as those at Liwa in the United Arab Emirates (fig.1) is quite distinct from that found in barchan corridors, and the mechanism by which winds in a unidirectional regime might accumulate to such large sizes is not at all obvious.

Instead, we suggest that the accumulation to large size, and the regular arrangement of megabarchans, results from their prior formation as large linear dunes in a bidirectional wind regime, where the frequency or intensity of one of the wind directions has diminished.

In the case of the Liwa dunes, the growth as linears (which are seen to the west) results from the North-Westerly Shamal wind and the southerly monsoon. During the Last Glacial Maximum, the monsoon is thought to have penetrated further north than it presently does, so the central areas of the Arabian desert would have seen bimodal winds, whereas now they are more predominantly exposed to the Shamal. This more unidirectional flow results in the formation of slip faces on the southern flanks of the dunes, and a slow advance to the south.

We suggest [1,2] a similar evolution may be taking place on Titan where megabarchan forms have been noted [3] amid the equatorial sand seas of linear dunes.

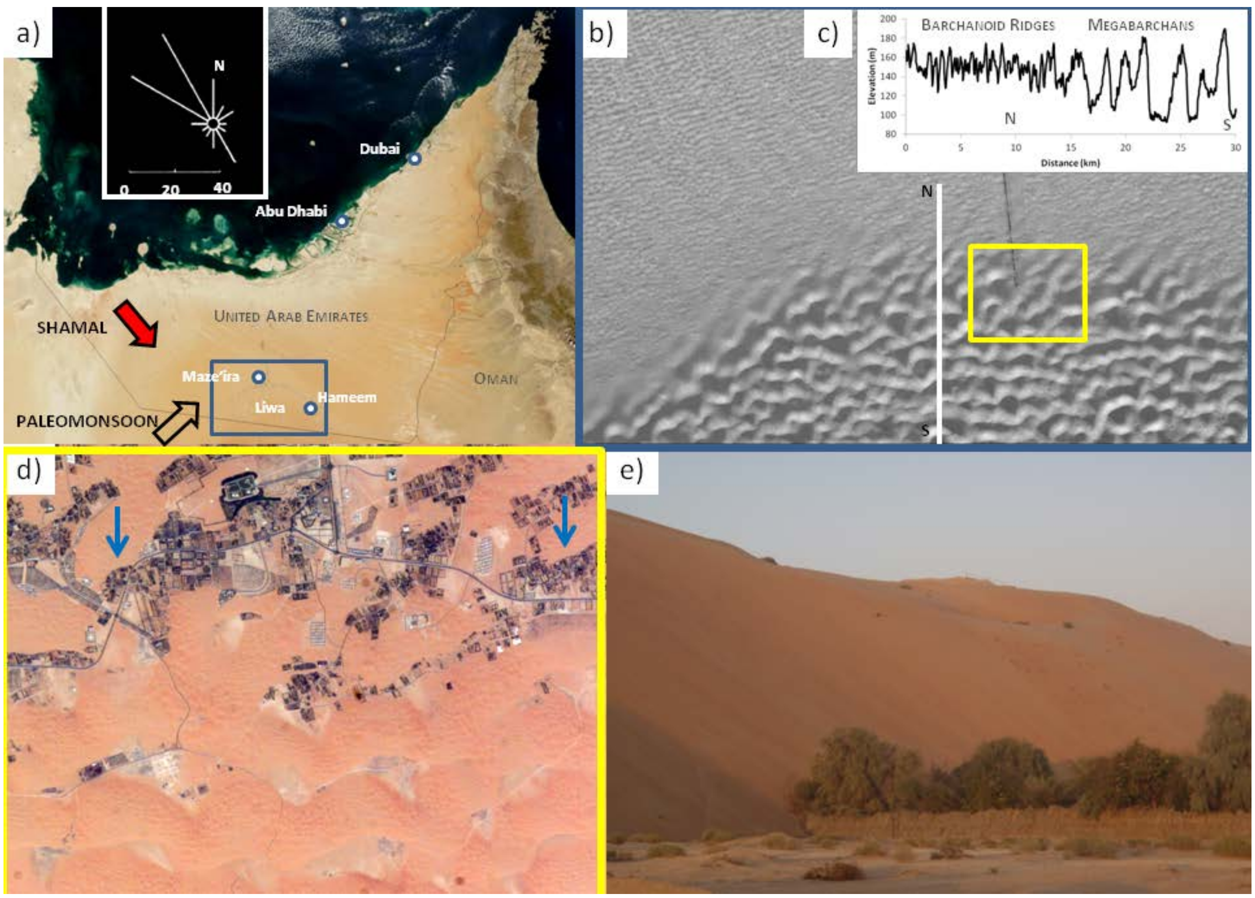

Figure 1. (a) Regional satellite image (MODIS) of the UAE : the oasis arc is visible inside the blue box which defines area in fig. 1b. Red arrow shows dominant Shamal winds which lead to observed Abu Dhabi wind rose in yellow box [Bristow]; open arrow denotes possible monsoon winds which were likely necessary to allow the Liwa megadunes to grow. (b) Enlarged area with ASTER topography showing the abrupt morphological transition from small ridges in the north to megabarchans in the south. (c) North-South ASTER profile (at white line in fig. 1b) showing transition and dune height. (d) Astronaut digital image of Mezeira region (yellow box in fig.1b) showing megabarchan geometry with sabkhas and oasis plantations between. Note the superposed small barchanoid forms, and the sharp edges of the plantations defined by the advancing dune slip faces (blue arrows). (e) ~20m megabarchan slipface (dune apex is rather higher but hidden here) advancing onto trees near Mez'eira.

2. Titan While linears are by far the predominant detectable duneform [1,2], recent denoised Cassini radar images [3, fig 2] show what appear to large crescentic dunes arranged in a linear trend, consistent with the E-W trend in the dunes overall [4]. This has been interpreted to indicate a change in wind regime. Morphologically these appear very similar to the Liwa megabarchans, which are also of a similar size.

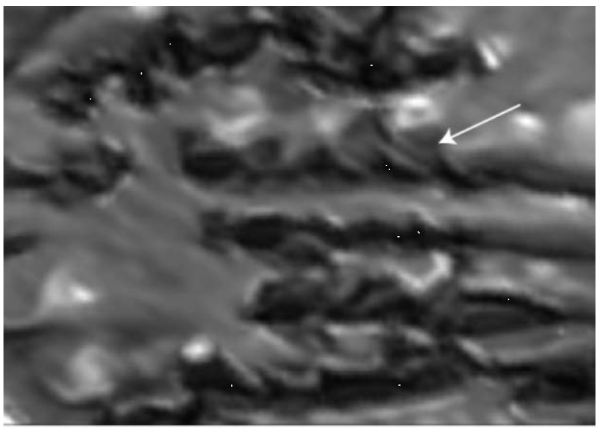

Figure 2. Crescent dunes on Titan (arrowed) from [3]. Dunes are 2-3km apart, a rather similar scale to those at Liwa

3. Morphodynamics at Liwa

To our knowledge, no estimate of the migration rate of the Liwa dunes has been published : since the dunes are large, they would be expected to be slow-moving. Even on high-resolution satellite images, movement is rather small and difficult to quantify, but field observation [1] suggests, from the overrunning of healthy date palms (fig. 1e), that a rate of~0.1 meter per year is about right. Given the ~50m slip face height (fig.1c), such a migration rate implies a sand transport rate of ~5 m3/m/yr (fig.3), somewhat consistent with estimates from the Resultant Drift Potential computed from wind data [1]. The transport is furthermore consistent with the migration of small dome and barchan dunes near the horns of the megabarchans [1.5]. It is perhaps not coincidental that the re-orientation timescale (~wavelength/migration rate) of 10-20,000 yrs coincides with the time since the wind regime may have changed.

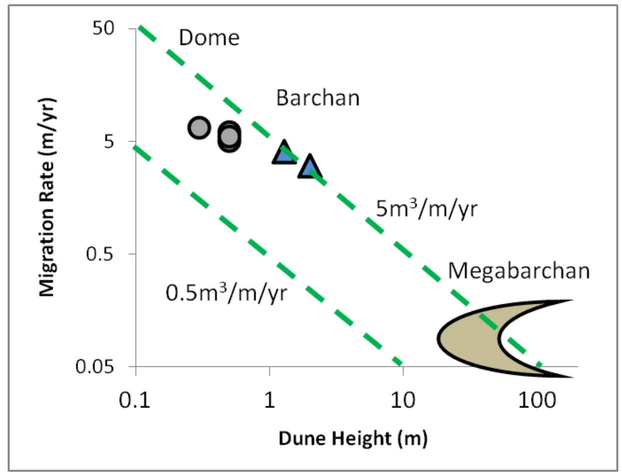

Figure 3. Migration rates of megabarchans and small dome and barchans at Liwa [1,5]

4. Implications

The availability of readily-studied analogs to Titan dunes allows these remarkable landforms to be better-understood. Not only do they serve to calibrate paleoclimate interpretations of Titan dune morphology, but the paradigm suggested here (that megabarchans are merely evolved linears) may have application on Earth. A worthwhile next step would be the exploration of this growth/re-orientation process with numerical models.

References :[1] Lorenz, R. and J. Radebaugh, Morphodynamics of the Liwa Megabarchans : Reworking of Giant Linear Dunes by Unidirectional Winds, GeoResJ, submitted [2] Radebaugh, J., R. Lorenz, T. Farr, P. Paillou, C. Savage, C. Spencer, Linear Dunes on Titan and Earth: Initial Remote Sensing Comparisons, Geomorphology, 121, 122-132, 2010 [3] Ewing, R., A. Hayes and A. Lucas, Sand Dune patterns on Titan controlled by long-term climate cycles, Nature Geoscience, DOI: 10.1038/NGEO2323 [4] Lorenz, R. D. and J. Radebaugh, Global Pattern of Titan's Dunes : Radar Survey from the Cassini Prime Mission, Geophysical Research Letters, 36, L03202 [5] Lorenz, R. and J. Zimbelman, Dune Worlds, Springer 2014

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