MEGAFANS AS HYDROUS ENVIRONMENTS.

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Introduction: The mesoscale sedimentary environment known as the *megafan*, is a low-angle, partial cone of fluvial sediment generated where a river enters an unconfined basin where it begins the process of avulsing over wide areas. In shifting to different positions, the river lays down a partial cone of sediment and establishes a characteristic radial pattern of paleo courses. Fan radii reach several hundred km [1]. In a global study, provoked by features encountered worldwide in astronaut handheld imagery, more than 150 megafans (defined as >100 km in length, some exceeding 600 km) have been identified on Earth [1, 2]. Megafans are generated by processes different from those responsible for classic, small alluvial fans and deltas [1]. Nested megafans cover areas of 10^5 km^2 in Africa [1]. We argue elsewhere [3] that megafans ought to be common throughout the geologic history of Mars; and should therefore provide a viable model for some martian mesoscale fluvial sediment bodies.

The megafan model is parsimonious in the sense that it explains large, flat plains of low slope without the presence of a waterbody—despite the commonly expressed assumption that waterbodies are necessary for the formation of such plains (e.g. [4]).

Cubango Megafan, Kalahari Desert: The central and northern parts of the arid Kalahari basin of southern Africa are underlain by a suite of nested megafans [2]. The location of the largest (320 km radius) was successfully predicted [2] based on patterns apparent in a global survey. A source river and convex-downhill topographic contours confirmed the feature as a large fluvial cone (fig. 1). The finding was corroborated by surface geology and borehole data describing water-table slope, subsurface flow directions, and isotopic water-age trends [5]. Recognition of the feature had been hampered by its relict character (due to abandonment by the formative and now-incised Okavango R.), overprinting by linear dunes, flooding of distal slopes by the neighboring Cuvelai R., and by the smooth, flat topography (slope 0.02°).

The subsurface data show that groundwater is directed to the lower slopes of the fan, coinciding with a "major transboundary aquifer system" mapped along the Namibia–Angola border [6]. Subsurface flow is probably directed by an internal architecture of radial channel sands embedded within sheetlike bodies.

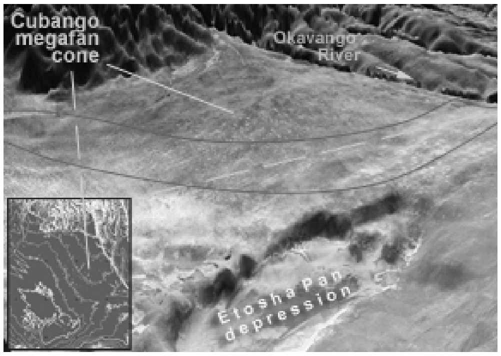

Fig. 1 Cubango megafan—north-looking oblique digital elevation model (DEM) with draped Landsat image overlay. Megafan, 320 km long (apex to Etosha depression), generated by the Okavango R., hosts a major, distal, subsurface water body (within curved lines). Namibia–Angola border—dashed line. Vertical exaggeration 1000x. (False color Landsat image, rendered as grayscale, draped on Shuttle Radar Topgraphy Mapping DEM.). *Inset:* SRTM-based contour lines (20 m) show partial cone morphology.

Possible Analogs on Mars: The apparent paucity of sedimentary bodies obviously tied to martian outflow channels may also relate to the difficulty of recognition due to their sheer size and featurelessness. However, the existence of megafans on Mars is being examined now that their ubiquity and characteristics on Earth are better understood. Accordingly we suggest two likely candidates on Mars.

We note that moderate water equivalent hydrogen (WEH) levels are recorded over both features [7].

Maja Valles fluvial cone (22–35N 150–175W). Mapped as a fluvial sediment body (unit $HNCc_1$ [8]) with a length of >100 km, the feature is described as a "broad, low cone of alluvial material" [9], and a "low relief, dissected fan" [10]. Generated apparently by sediments carried down Maja Valles, the fan apex is tied to the point where the Maja gorge cuts Xanthe Montes (fig. 2). Evidence of repeated flow in Maja Valles [e.g. 11], despite phases of incision, suggests that water has accumulated within the lower sediment body (fig. 2) where possible obstacles to distal fan development are noted.

Amazonis Planitia fluvial sedimentary bodies (17–19.5N 52–54W). Sourced from Martes Valles, a young Amazonis Planitia sediment mass (unit AAa_{2n} [8]) is here interpreted as a thin megafan. A diverging pattern of channels is mapped, extending hundreds of km from the end of Martes Valles, spreading across areas on the order of 10^5 km^2 in the central planitia [12] (provisional unit (Achp) in [12])(fig. 3).

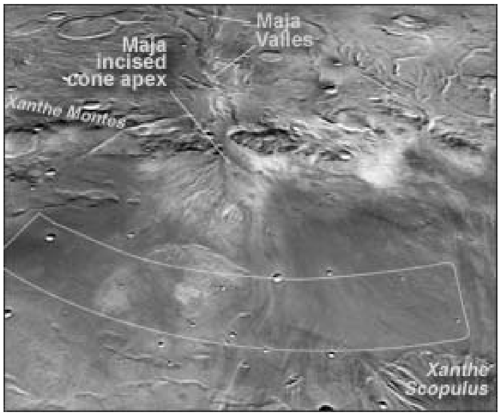

Fig. 2 Maja Valles incised fan feature occupies the center of this west-looking oblique image (THEMIS daytime IR mosaic). Fan apexed where Maja Valles gorge cuts through Xanthe Montes. Distal putative hydrous zone—within curved lines. Fan apex to Xanthe Scopulus is 107 km.

The topographic roughness algorithm that has been applied to Mars MOLA data [13, 14] was applied to Earth SRTM data for the Kalahari region [2] and more recently to most of the Earth (60N-60S)[15]. This study shows that all large areas of smoothest, low-slope topography on Earth's continents are almost exclusively megafan surfaces. The well-known extreme flatness of the martian planitia [12, 13, 14] accords with roughness signatures of terrestrial megafans, and suggests fluvial emplacement of young Amazonis units as argued in [12].

Two cryptic examples from Amazonis Planitia may be important for understanding subsurface hydrous accumulation. For at least some of its history, discharges from Mangala Valles likely resulted in megafans (in those scenarios when distal lakes/oceans were not synchronous with fluvial discharges [12]). Distances from the end of Mangala Valles to the northern (low) margin of the planitia are very large, a fact that has suggested that fluvial emplacement was unlikely [12]. However, the megafan model shows that long megafan radii are indeed feasible. It has been suggested further that discharge from Labou Vallis (8.5S 154.5W) must have led to fluvial sedimentation in the planitia [12]. We suggest that during locally non-lacustrine/ocean phases, this sedimentation would have occurred in the form of megafans.

Megafans emanating from Marte, Mangala and Labou valles have probably contributed to hydrous near-subsurface environments in their distal reaches—i.e. along the northern, eastern and southeastern margins of Amazonis Planitia at various times.

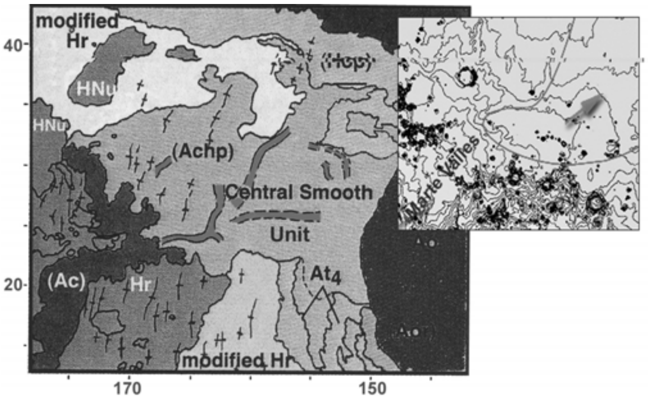

Fig. 3 Amazonis Planitia—Diverging drainage lines (dark sinuous features) on Central Smooth Unit (unit (Achp) in [12], AAa_{2n} in [8]). Marte Valles fills (Ac). Olympus Mons—black unit far right. Adapted from [12]. *Inset*: Martes Valles megafan apex zone: MOLA-based contour patterns (25 m). Confined Marte Valles opens onto unconfined plains of southwest Amazonis Planitia. Contours convex to fluid-flow directions (arrow) indicate partial cone morphology hundreds of km in extent (enclosed area top right).

Conclusion: Following a new terrestrial analog, we conclude groundwater has at times accumulated preferentially beneath distal slopes of the Maja Valles feature, and along the northern, eastern and southeastern margins of Amazonis Planitia.

References: [1] Wilkinson M. J. et al. (2006) *Jour. S. Amer. Earth Sciences 21*, 151-172. [2] Wilkinson M. J. & Kreslavsky M. A. (2008) 3rd Southern Deserts Conf. (Oxford U.), Molopo Lodge, Northern Cape, South Africa. [3] Wilkinson M. J. et al. (2008) *LPS XXVII*, Abstract #1392. [4] de Hon R. A. (1988) *LPS XIX*, Abstract #1134. [5] Miller, R. McG. (2008) *The Geology of Namibia*, *v. 3, ch. 24,* 24-1–24-76. [6] Struckmeier W. F. et al. (2006) Groundwater Resources of the World. Transboundary Aquifer Systems. *Fourth World Water Forum, Mexico City, March 2006.* [7] Berman D. C. et al. (2009) *LPS XL*, Abstract #1333. [8] Tanaka K. L. et al. (2005) *USGS Atlas of Mars, Sci. Investig. Map 2888 and Pamphlet.* [9] Rice J. W. et al. (1988) *LPS XIX*, Abstract #1494. [10] de Hon R. A. (1993) *LPS XXIV,* Abstract #1196. [11] Chapman M. G. et al. (2003) *JGR*, *108 (E10),* 5113. [12] Fuller E. R. & Head J. W. (2002) *JGR, 107 no. E10*, 24 pp. [13] Kreslavsky M. A. & Head J. W. (1999) *JGR*, *104*, 21,911-21,924. [14] Kreslavsky M. A. & Head J. W. (2002) *JGR*, *105*, 26.695-26,712. [15] Wilkinson M. J. & Kreslavsky M. A. (2009) unpublished observations.