LARGE WELL-EXPOSED ALLUVIAL FANS IN DEEP LATE-NOACHIAN CRATERS. J. M. Moore[1] and A. D. Howard[2], [1] NASA Ames Research Center, MS 245-3, Moffett Field, CA, 94035, jeff.moore@nasa.gov, [2] Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22904, alanh@virginia.edu.

Introduction: Large, fresh-appearing alluvial fans (typically > 10 km long) have been identified during a systematic search of 100 m/pixel low-sun daylight THEMIS IR imaging in deep late-Noachian or early-Hesperian craters. Our study of these fans was augmented with MOLA-derived topography and high-resolution MOC and THEMIS VIS images where available. The influence of alluvial fan deposition on the topography of crater floors has been recognized in previous topographic studies [1]. Recent *Mars Odyssey*-era studies [2,3] have also identified and described in detail a fluvial delta or fan of approximately the same age as the alluvial fans of this study. Our results, at the time of this writing, indicate that these fans are only found in < 5% of all craters ≥ 70 km in diameter within a large study region. In every case the fan-containing craters were restricted to a latitude belt between 20°S and 30°S. All of which had significant topographic relief and appeared morphologically younger [4] than typical mid-Noachian craters in the size range. However, large fans were not found in the most pristine (and presumably youngest) craters in this size range. Most Martian fans have morphologies consistent with terrestrial debris-flow-dominated fans.

Abundance and Location: We inspected all THEMIS IR daylight coverage of craters ≥ 70 km in diameter available as of Oct 2003 in a latitude range between the equator and 30°S. Heavily cratered terrain in the Northern Hemisphere was avoided because of the pervasive mantling in Arabia (e.g., [5]). Likewise terrain southward of 30°S was not examined because of the onset of the pervasive Amazonian mantle (e.g., [6]). Of the 218 craters identified in the *Catalog of Large Martian Impact Craters* [7] that met the size and location criteria, 138 of them were sufficiently imaged to characterize at least portions of their rims and floors. The vast majority of these craters show some degree of gullying and alcove formation on their rims, but their floors are generally featureless plains, and their overall relief is significantly less than that of fresher-looking craters of the same size. Many appear infilled, mantled, and moderately-to-heavily cratered. Five craters have very pristine morphologies including the preservation of small features in the ejecta and floor. These fresh craters have terraced rims with, at most, minor talus. Oudemans is the largest example of these pristine craters. Only 4 craters (Holden, Bakhuysen, and two unnamed craters at 22°S, 39°W and 27°S, 277°W exhibit well-defined prominent alluvial fans (though many craters have much smaller talus cones). All four fan-containing craters exhibit relatively steep relief, few superposed craters, and an overall morphologic freshness relative to the vast majority of those examined. In addition to being found only between 20° and 30°S, they also all occur at around ±1 km of the MOLA-defined Martian datum. A cursory examination of $^1/_{128}$° MOLA DTMs of the study region indicated that perhaps there are an additional ~10 fan-containing craters for which public domain THEMIS coverage is not yet available.

Setting and Description of Fans: All fans in this study head out of steep-walled scalloped alcoves and rarely is there evidence for drainage into alcove heads, indicating the fans are usually composed of the material eroded to form the alcove, and the alcove *is* the catchment. A typical example of a fan in this study is shown in Figure 1. In this example, the alcove is ~10 km long downslope and ~15 km wide across its spur-and-gullied back walls. These back walls have ~1 km relief and typically slope ~15°. Several Martian fanheads are channelized, with a main fanhead trench that that branches into a network of distributory channels (e.g., Fig. 2). Other fans, (e.g., Fig. 1) exhibit very long, narrow low-relief ridges radially oriented down-slope are possibly channel levees or debris flow lobes, often branching at their distal ends. Nighttime THEMIS IR images of the fan in Figure 1 indicate that these ridges have a relatively higher thermal inertia than their surroundings, implying that they are composed of coarser material as are levees and lobes on terrestrial midfans. Smooth areas are seen between ridges and channels on the outer fan probably the surfaces of sheet flows. A longitudinal profile of the fan in Figure 1 over a downslope distance of ~40 km shows that its surface forms a constant slope of 2°, most closely consistent with terrestrial debris-flow-dominated fans [8] such as those in the Mojave Desert. As these fans form on inward-facing crater rim walls, they inevitably nearly all coalesce to form uneven bajadas. A number of the fans in Holden have trimmed toes, presumably by the water passing through Holden from Uzboi Vallis and then out a breach in the eastern wall. The formation of prominent fan head entrenchment on the Holden fans may be the response to removal of material along their peripheries [9].

Implications and Speculation: The most striking aspect of these well exposed Martian alluvial fans is their rarity. While alluviation is inferred at many places in the cratered highlands from topography and used as evidence for precipitation and runoff in Noachian time (e.g., [1]), the scarcity of fresh fans must imply something about the conditions or timing of their formation. One possibility is that these fans formed at the latest time that the Martian climate permitted their formation. If this is so, then the presence of well-exposed fans on only a few, relatively fresh craters with steep, high relief rim walls implies that their absence on older shallower craters may be due to older craters lack of relief. The absence of fans in the 5 most pristine craters may be due to their formation after the last era of a "warmer, wetter" Mars. The latitudinal restriction of fans may imply that they could only form where a narrow zonal climate transported enough precipitation and/or encouraged snowmelt and runoff to form them. Also, fans may have formed only where there was an abundance of loose sediment susceptible to infiltration and transportation by water. Thus the rims of large craters formed just prior to this putative final episode of a "warmer, wetter" Mars would be ideal locations. Though statistics are small, there may be a tendency for mainly larger craters (>100 km in diameter) to host fans. If this is so, since most fresh craters on Mars > 40 km will have similar local relief, the tendency for fans to form in large craters may be the result of the ability of these craters to create their own local climate. The absence of fans found in an intermediate state of exposure supports the possibility put forth in [10] that an episode of terrain mantling with very little runoff immediately preceded the time of fan formation (and possibly simultaneous with the time of delta formation [2,3,10]), and thus occurred during the last "warmer, wetter" climate optima.

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Fig. 1. Pristine alluvial fan in an unnamed 100 km-diameter crater at 22°S, 39°W, colorized (both) and marked with 50 m interval contour lines (right) with MOLA-derived topography. This fan exhibits very long, narrow low-relief ridges radially oriented down-slope which are possibly channel levees or debris flow lobes, often branching at their distal ends. (I03360002)

Fig. 2. THEMIS VIS image of channelized fan heads branching into a network of distributory channels on Fans in Holden crater. (V01762003)

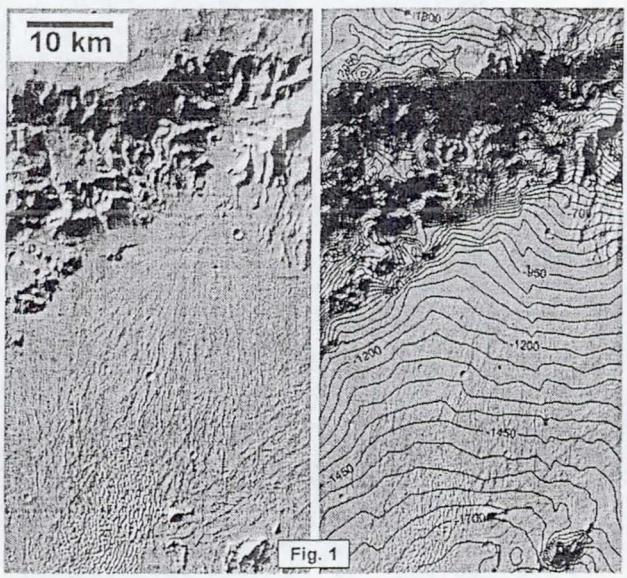

Fig. 1

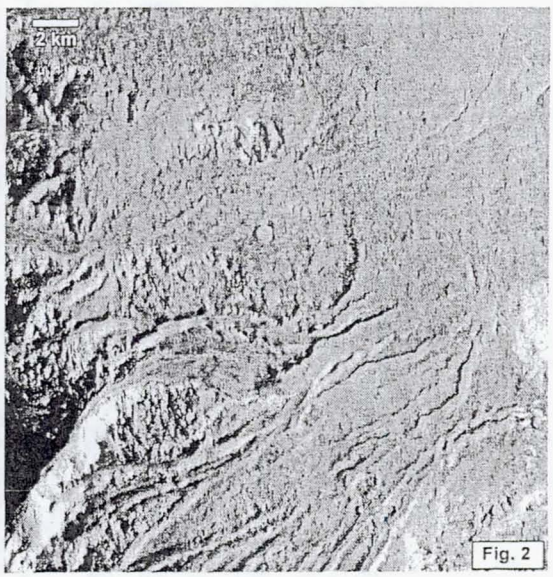

Fig. 2