NOACHIAN-HESPERIAN TRANSITION AND A POSSIBLE CLIMATIC OPTIMUM: EVIDENCE FROM LANDFORMS.

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Introduction: *A climatic optimum?* The often strong contrast between the 'pristine' and degraded Noachian channels and craters noted in [e.g. 1] might be due to a gradual climatic change superimposed upon an episode of mantling associated with early Hesperian volcanism. On the other hand, one or more episodes of volcanism or large impacts could have induced global warming [2,3] and produced a relatively short-lived optimum for precipitation and runoff. The rapid cutoff of fluvial activity following the development of the later 'pristine' fluvial features is consistent with this scenario. We discuss the changing style of erosion in the highlands during the Noachian and early Hesperian in a companion abstract to this workshop. Here we review the some of the morphologic evidence for a possible Noachian-Hesperian (N-H) climate optimum.

Late Noachian – Early Hesperian landforms:

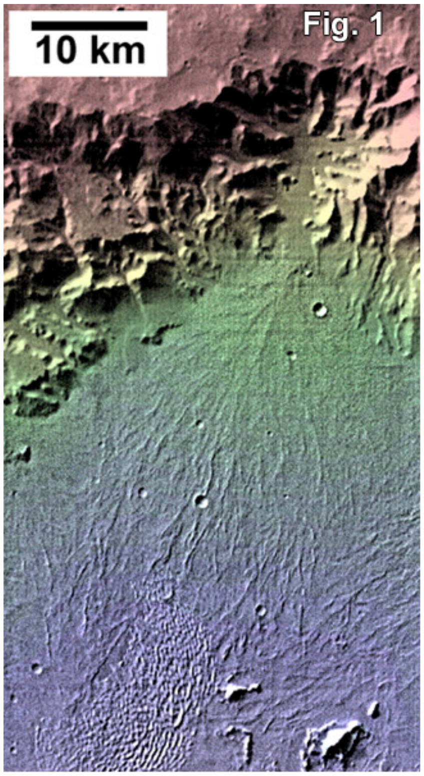
Alluvial Fans and Deltas: Large**,** fresh-appearing alluvial fans (typically > 10 km long) have been identified during a systematic search of daylight THEMIS IR imaging in deep late-Noachian or early-Hesperian craters. Our results, at the time of this writing, indicate that these fans are only found in ~6% of all craters ≥ 70 km in diameter within a large study region. All fans in this study [4] head in 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. Fans exhibit very long, narrow low-relief ridges oriented down-slope, which are possibly channel levees or debris flow lobes, often branching at their distal ends. Smooth areas seen between ridges and channels on the outer fan are probably the surfaces of sheet flows. A longitudinal profile of the fan in Figure 1 over a down-slope distance of ~40 km shows that its surface forms a constant slope of 2° as do many of the fans in our study, most closely consistent with terrestrial debris-flow-dominated fans such as those in the Mojave Desert.

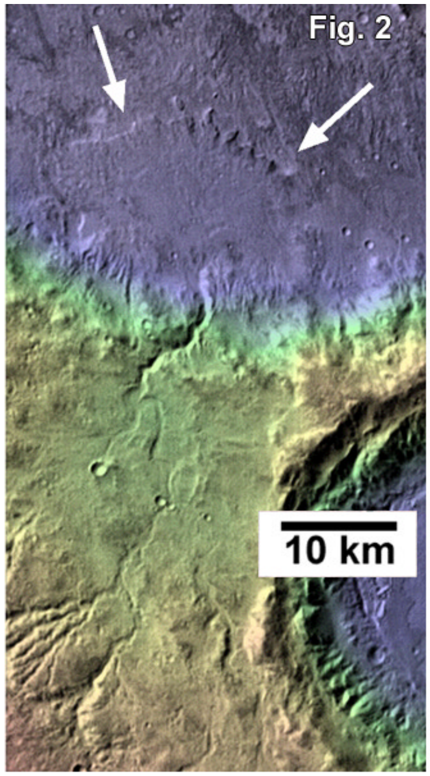
A fan-shaped 10 by 12 km outcrop interpreted to be an exhumed and differentially eroded fluvial delta or fluvial fan (located at 24.1°S, 33.9°W) lies at the mouth of an upland "drainage" basin of about ~70 by 60 km [5,6] superposed on late Noachian materials. The fan-shaped outcrop itself appears nearly planar, with an abrupt drop-off of 100-200 m at a feathered or digitate periphery along the north and east. The delta is composed of many low, flat-topped and often-sinuous ridges, which converge at the apparent fan apex. Ridges are often stacked upon one another, exhibiting crosscutting and superposition. One ridge forms a well-defined loop with distinct, successive scroll-bar recording the progressive growth of the meander, and eventually its cutoff, identical to that seen on terrestrial floodplains. The digitate periphery in detail is scarp-like, where individual ridge flanks and termini exhibit alternating steep slopes and ledges forming up to on order of a dozen steps, each ~10 m high interpreted to discrete layers of indurated material. To date only one other feature similar to (but less well presented) this delta has been found, also on N-H materials (Fig. 2). In both cases the volume of the contributing late stage incised valleys appears to be commensurate with the delta volume.

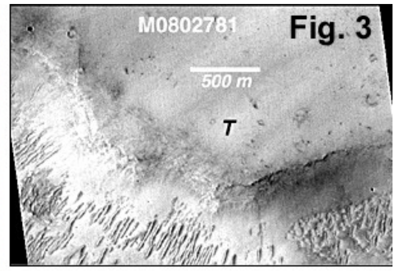
Hard Pans: MOC NA and THEMIS IR imaging of the incised 'pristine' N-H valleys commonly reveals a light-colored, high thermal inertia (TI) layer that caps the tops of the valley walls bordering the incised valleys (Fig. 3). The high TI implies that either that layer is composed of coarse lag gravels or an indurated crust. The sharp or ragged edges of many of these outcrops may indicate at least partial induration. Some of these high TI areas slope inward from surrounding uplands, making lava deposition an unlikely explanation. A few MOC NA images show textures that might be weak bedding below the capping unit. A plausible interpretation is that the crust or lag developed in Noachian basin sediments prior to the N-H incision, implying a possible hiatus between the two episodes. Resistance of the capping unit may also have contributed to limiting the areal extent of the late incision.

Northern Hellas Rim Sedimentological Style Transition and the Pits of Noachis. A number of unusual features on the northern rim of Hellas date from N-H time. Most conspicuous are large irregular depressions, such as can be seen in and around Terby (Fig 4), which themselves cut lobate flows with textures and morphologies consistent with plastic deformation such as is associated with warm ice (glaciers). A number of these "pits and glaciers" form a "zone" along the Hellas rim of roughly constant elevation, which occurs just below another zone in which a number of craters possess alluvial fans (but not the "pits or glaciers"). Above the alluvial fan "zone" the surface exhibits negligible N-H era fluvial or "glacial" activity. The origin of the pits is not understood. One possibility is that they are locations formerly occupied by massive ice blocks. The walls of the pits often exhibit enormous stacks of layers, which is difficult to reconcile with the massive ice hypothesis unless the pits were erosionally widened after the disappearance of the ice. It is probably significant that there is no post-pit "glacial" activity. The "zones" may the consequence of a strong topographic control over climate and water supply. Elsewhere, there are several large rimless pits in Noachis Terra, mostly in basins, which resemble the Hellas features except that they are devoid of adjacent "glaciers" or any other N-H era water-related activity (though some have "modern" small gullies).

Taken together the features discussed here fit into a hypothesis in which a climate optimum occurred around the N-H boundary imposing the last great act of large-scale Martian fluvial activity.







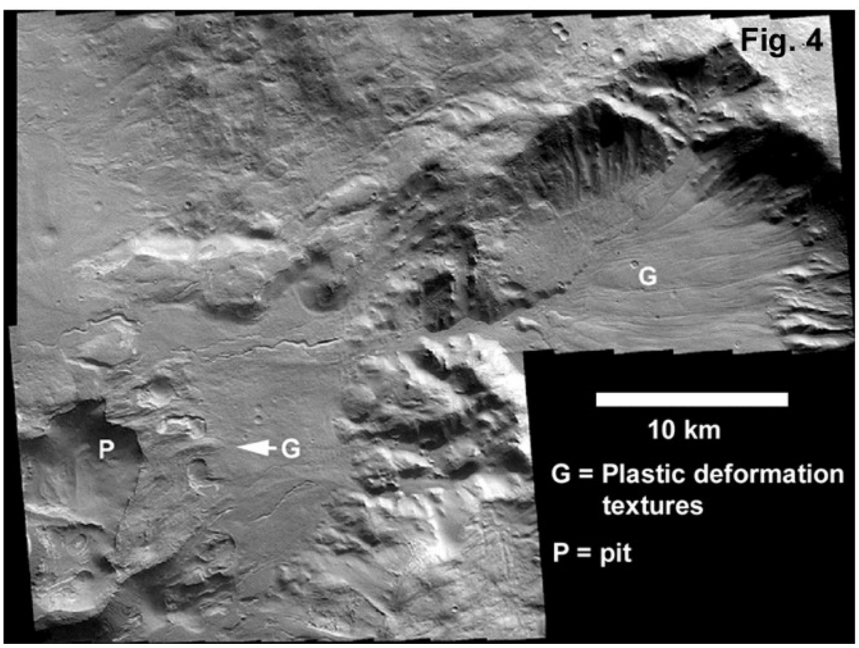


Fig. 1. Large alluvial fan in an unnamed 100 km-diameter crater at 22°S, 39°W, colorized with MOLA-derived topography. This fan exhibits very long, narrow low-relief ridges radially oriented down-slope, which are possibly channel levees or debris flow lobes, often branching at their distal ends.

Fig. 2. Fluvial Fan or Delta Deposit (arrows) and its associate up-basin network of incised valleys at 28°S, 277°W, colorized with MOLA-derived topography.

Fig. 3. High TI layer capping the top (T) of valley walls bordering incised valley. The high TI implies that either that layer is composed of coarse lag gravels or an indurated crust. This MOC NA image shows textures that might be weak bedding below the capping unit.

Fig. 4. Large irregular depressions (P) in and around Terby, which themselves cut lobate flows (G) with textures and morphologies consistent with plastic deformation such as is associated with warm ice (glaciers).

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