TERRESTRIAL LANDSCAPE RESPONSE TO CLIMATIC CYCLING AND MARTIAN PARADIGMS; *Ted A. Maxwell*, Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560

Over the past 20 years of martian geologic investigations, paradigms for the origin of dendritic highland channels have altered between surface runoff and subsurface release with consequent headward erosion via sapping. Even the highest resolution Viking images have been unable to provide a definitive suite of geomorphic relations, primarily because of limited coverage, but also because of varied relations between drainage channels and their superposed materials. In light of the continuing difficulties for a unique solution to highland channel formation, and as a result of new field investigations of terrestrial paleochannels in the northeastern Sahara, it seems opportune to re-evaluate some of the basic principles by which martian channels are interpreted. Some of the terrestrial observations were made in the late 1970's by McCauley, Breed, and El-Baz, but these concentrated on the Viking lander observations and analogous terrestrial aeolian features. The past 20 years have seen a great increase in knowledge of the timing of climatic change in the northeast Sahara, as well as new field investigations of areas not visited before by scientists familiar with the problems of martian geomorphology. Following a brief summary of the late Tertiary history of the now hyperarid desert of northern Sudan and southern Egypt, I list four commonly stated (or tacitly assumed) guiding principles for martian channel interpretation and discuss the merits of applying these guides to channels on both Earth and Mars.

By the late Eocene, the shallow seas that had occupied all of present-day Egypt and the northern Sudan to latitude 18° North had started to recede northward, leaving behind a thick (~300 m) sequence of limestone capped by fluvial sandstones and conglomerates now present in a belt parallel to the Mediterranean up to 150 km south of the shoreline. Because of this belt of fluvial deposits, it is thought that the earliest subaerial denudation of southern Egypt was by Miocene and early Pliocene northward drainage, direct evidence for such channels has long disappeared. By the middle Pliocene, a time of climate wet enough to support swamps and extensive fluvial deposits from tributaries to the early Nile, several factors contributed to more complicated drainage. Isolated basalt plugs in southern Egypt attest to the structural disruption of the once continuous limestone deposits, perhaps related to the initial rifting of the Red Sea. Also about this time, major SW-NE channels were formed near the Egypt-Sudan border. These 10-20 km wide channels are inset in the Nubian sequence; their direction of drainage varies by interpreter. The latest Pliocene and Pleistocene brought severe changes in both climate and drainage to the northeast Sahara. The long-lasting humid climate gave way to alternation periods of hyperarid greater than the pluvials. Our knowledge of drainage systems associated with those pluvials is less constrained than the dating of humid conditions for a variety of reasons. By the middle of the Pleistocene, channels in the core of desert became less integrated and activity during wet conditions consisted of reactivation of prior channels rather than continued integration of drainage and increase headward erosion. In addition, the amount of rainfall during the late Pleistocene pluvials did not exceed 500 mm/yr, enough to support a savannah environment, but not enough to excavate major new drainage channels. Finally, and perhaps most importantly, the evidence by which we interpret the fluvial history is fragmentary and in some cases inferential--much like the status of martian paleochannel interpretations.

<u>1. The lack of small tributaries is indicative of a subsurface origin for drainage.</u> As initially hypothesized by R.F. Peel, the blunt-nosed, amphitheater-like upstream ends of drainage channels in the Gilf Kebir plateau were thought to represent channel enlargement through sapping. Viewed at orbital resolution down to 30 m/pixel, these canyons share both scale and morphology with several martian counterparts, yet the

origin of the canyons themselves should be kept distinct for their modification over Pleistocene and Holocene time. The orientation of these canyons do not appear to be structurally controlled; their congruence with relict drainage divides outside the plateau and their overall linear planform both suggest an origin by surface runoff rather than sapping, which no doubt later modified the valley hears. Several other channels in southern Egypt also lack tributaries. Wadi Mareed, a 60-km long bedrock channel incised into the (Eocene) limestone plateau just west of the Nile has only a few blunt tributaries a few hundred meters long that gently slope up to the limestone caprock. Here, sapping has not played a role in modifying the shape of either the primary channel or the stubby tributaries. Instead, removal of surrounding alluvium and first-order channels was the result of climatic cycling. The initial Pliocene (or earlier) drainage formation involves an integrated network, only to have the overburden stripped during the past million years of repeated climate change. Finally, even the buried channels revealed by Shuttle Imaging Radar experiments lack tributaries, leading to disagreement over which way they drained. The relict interfluves are now only low ridges in the sand sheet, where accumulation and deflation of Pleistocene and recent sediments is keeping pace with erosion of resistant ridges. Thus, the geomorphic evidence of several types of Mars-analog channels is entirely consistent with erosion by surface water; it took only the past million years to modify the initial fluvial landscape into one characterized by sapping and aeolian denudation.

2. Airfall blanketing is a major process in aeolian modification of the landscape. Although pyroclastic airfall deposits may indeed form a resistant blanket surrounding volcanic centers, thick aeolian deposits formed of airborne detritus are not present in the arid core of the Sahara. Perhaps the closest analogy would be the sand sheet, which does obscure pre-existing topography, but results from a dynamic environment in which subtle albedo and topographic variations can be used to infer a prior landscape. More importantly, extensive sand sheet environments are relatively rare (at least on this planet), and possible occurrences of Mars could easily be interpreted as low viscosity basalt flows. Even in the sand sheet, however, the "blanket" does not stay still. Sedimentation and erosion occur at a rapid rate, keeping pace with erosion of high points on the sand plain.

3. Martian highland channels can be described by a unique origin. As shown by the above description of the disparate channel types, even paleochannels within a few hundred km's of each other have varied origins and ages separated by 10's of millions of years, but the common effects of regional aeolian denudation are efficient at removing all evidence of former tributary patterns. Add to this varying lithologies, the effect of local slopes, and geographic dispersion of volcanic influences, and it is highly unlikely that a single surface or subsurface origin can (or should) be uniquely ascribed.

4. A solution to the origin of martian paleochannels can be determined from high resolution images. Based on the use of remote sensing data ranging from 80 m/pixel to airphoto scales, the determination of channel origin is extremely difficult in a climatic regime that has undergone radical shifts. In southern Egypt, only short, deeply incised channel segments remain in the open sand plains, and even here, their flow direction is indeterminate because of the low gradients. At the resolution of air photography, aeolian erosion and deposition masks tributaries, leading to erroneous interpretations of the subsurface outflow. Thus, conflicting interpretations of martian highland drainage are likely to continue until detailed stratigraphic relations can be obtained in the field.

[Terrestrial research reported here is supported by NASA Solid Earth Sciences grant NAGW-3711 and planetary work by NAGW-3920.]