MORPHOLOGIC AND MORPHOMETRIC ANALYSES OF FLUVIAL SYSTEMS IN THE SOUTHERN HIGHLANDS OF MARS. S.C. Mest[1,2], and D.A. Crown[1,3], [1]Dept. of Geology and Planetary Science, Univ. of Pittsburgh, Pittsburgh, PA 15260, [2]Geodynamics, NASA Goddard Space Flight Center, Greenbelt, MD, 20771, mest@kasei.gsfc.nasa.gov, [3]Planetary Science Institute, 1700 E. Ft. Lowell Rd., Suite 106, Tucson, AZ 85719.

Introduction: Geologic mapping and geomorphic analyses have revealed the effects of fluvial processes within the Terra Tyrrhena (13°-30°S, 265°-280°W) [1-3], Promethei Terra (27.5°-47.5°S, 245°-270°W) [4-7], and Libya Montes (5°N-5°S, 265°-280°W) [8,9] regions. High-resolution MOC, THEMIS, and Viking Orbiter images and MOLA topographic data are being used to qualitatively and quantitatively characterize highland fluvial systems and analyze the role of water in the evolution of highland terrains. Fluvial features in these areas range from widespread, well-integrated valley networks to small isolated networks and single channels, as well as gullies incised along the rims of impact craters [1-9]. Characterization of these features and the geologic units in which they occur is necessary to fully understand the nature of Martian fluvial activity and the history of Mars' climate.

The three study areas are located adjacent to the Hellas (Terra Tyrrhena and Promethei Terra) and Isidis (Libya Montes) impact basins. The impact events forming these basins established regional slopes and structural patterns that have influenced the geologic histories of the terrains being studied. However, differences in the morphology and scale of fluvial features produced in these areas are observed. This abstract discusses the differences and similarities between fluvial systems in the three study areas.

Fluvial Systems: Highland materials within Terra Tyrrhena, Promethei Terra and Libya Montes are dissected by a series of well-integrated valley networks. The networks differ in scale and planform morphology, which make them ideal for comparison, as well as for relating the underlying geology to possible mechanisms of valley formation and network evolution. Valleys in Terra Tyrrhena are located within widespread Noachian-aged intercrater plains and crater rim and ejecta materials [3]. The Promethei Terra study area contains an array of geologic materials and geomorphic features formed or altered by fluvial processes [4-7]. The primary valley networks studied here are found within isolated deposits of intermontane basin fill (Late Noachian to Early Hesperian), which consists of sedimentary material eroded from highland massifs. A series of Late Noachian- to Early Amazonian-aged sedimentary plains units embay highland terrains and also record the effects of fluvial activity in the forms of narrow, sinuous channels and low-relief scarps that dissect their surfaces. Valley networks in Libya Montes are generally found within intermontane plains, such as the valley network plains, but also extend into adjacent highland massifs [8.9].

The morphologies of impact craters and their interior deposits are similar in the three study areas. Many craters have highly eroded rims (or are rimless), interior and exterior gullies that head near crater rims, dissected or a complete lack of ejecta blankets, and smooth floors [3-9]. The occurrence of gullies along crater walls, as well as dissected ejecta blankets, suggests fluvial processes dominated much of their erosion. Crater interior deposits are believed to have a variety of sources/origins, including material eroded from interior crater walls by fluvial processes, material from the surrounding terrain in cases where a crater is breached by a valley, lacustrine deposits, coalesced debris aprons, and eolian deposits [3-9].

Watershed Scale: The largest watershed observed in the three study areas is Vichada Valles in Terra Tyrrhena, which is composed of eleven sub-basins that drained an area of ~300,000 km^2; the sub-basins range in area from 271 to 177,000 km^2 (average=27,000 km^2). MOLA data (128 pixels/degree) indicates that Vichada Valles is a 4th order (Strahler system) network [10,11]; other smaller networks in the area tend to be 1st to 3rd order. By contrast, 84 watersheds in Promethei Terra and 93 watersheds in Libya Montes have been modeled and generally drain smaller areas, ranging from 100 to 8,078 km^2 (avg.=1,254 km^2) and 100 to 44,900 km^2 (avg=3,010 km^2), respectively. Stream orders of the Promethei Terra and Libya Montes networks however, are similar to Terra Tyrrhena, ranging from 1st to 6th order [10,11].

Morphology: Each study area displays dendritic, sub(parallel), and rectilinear network patterns [5-11]. Vichada Valles displays a mostly dendritic pattern; slopes across the local plains are relatively low (<0.3°) and few structures are visible at the surface, but sections of valleys appear to have angular reaches suggesting underlying structure may in part have influenced valley formation. Several smaller networks in Terra Tyrrhena are found on steeper slopes, such as on impact craters, and therefore show parallel patterns. Networks in Promethei Terra and Libya Montes occur mostly on slightly steeper terrain within isolated sedimentary deposits resulting in dendritic to sub(parallel) patterns; in addition to following possible structural trends the tributaries of some networks also follow notches in adjacent highland materials giving the networks rectilinear patterns.

The valleys differ morphologically in medium- to high-resolution Viking Orbiter (<45 m/pixel), MOC, and THEMIS images. Valleys in Terra Tyrrhena appear to be the most degraded [3]; they tend to have rounded banks, sediments on their floors that form dunes, and several small craters (D<500 m; visible in MOC) buried by or superposing the infilling sediments. Valleys in Promethei Terra and Libya Montes show little detail on their floors and it is observed in MOC images that their walls appear steeper and more pristine than in Terra Tyrrhena [5-9]. Topographic profiles (generated using the Interactive Data Language (IDL) application GRIDVIEW [12]) across valleys show widths range from a few 100's of meters in all three areas to almost 10 km in Terra Tyrrhena. Valley depths also differ between the three areas, being a few 10's of meters in Promethei Terra and Libya Montes to almost 200 m in Terra Tyrrhena. Profiles across valleys in all the three areas show v-shaped cross-sections.

Hydrologic Analyses of Drainage Basins and Valley Networks: High-resolution (128 pix/deg) MOLA DEMs are being used with the ArcInfo Geographical Information System (including GRID, ARCPLOT, and ArcView) and GRIDVIEW to quantitatively characterize the surface hydrology of Terra Tyrrhena, Promethei Terra, and Libya Montes [10,11].

Drainage basin divides and valley networks are modeled at different scales dependent on the depth to which pixel sinks are filled ("sinkfill depth"). Modeled drainage basins are irregular or circular in shape due to the distribution of highland materials and abundance of crater rims. Part of the modeling technique has been to determine the appropriate sinkfill depth to model drainage basins at a scale adequate to approximate basins identified from mapped valley distributions. Model results show that as sinkfill depth is increased, fewer basins are generated and their areas increase. Trunk channel segments increase in length as basin divides are removed and networks are combined, and the numbers of tributaries decreases.

Modeling yielded 11 sub-basins composing Vichada Valles in Terra Tyrrhena, 84 basins encompass the small isolated highland networks in Promethei Terra, and 93 basins in Libya Montes. Although the valley networks differ greatly in scale between the three study areas, drainage densities were found to be relatively similar, ranging from 0.011 to 0.086 km^{-1} (average=0.067 km^{-1}). These densities are consistent with values for Margaritifer Sinus (0.03-0.07 km^{-1}) [13,14] and higher than Martian global averages (0.001-0.01 km^{-1}) [15], and values for Noachian units (0.0032 km^{-1}), Hesperian units (0.00047 km^{-1}), and Amazonian units (0.00007 km^{-1}) [16]. These densities are much lower than most terrestrial values (>2 km^{-1}) [17-21], but are comparable to values reported for the central United States (0.079 km^{-1}; 1:1M scale) [16].

Conclusions: The highlands of Terra Tyrrhena, Promethei Terra and Libya Montes exhibit well-integrated valley networks and channels incised within intercrater plains, isolated sedimentary deposits, and impact craters. The valleys that compose these networks display degraded and pristine morphologies and a variety of cross-cutting and superposition relationships with impact craters. From morphologic observations, crater/valley relationships, and determination of impact crater distributions [3,5-9], it has been determined that valley ages differ among the study areas. Valleys in Terra Tyrrhena are significantly older, most likely Noachian in age [3], than valleys in Promethei Terra and Libya Montes, which are believed to be Hesperian-aged [5-9]. Gully formation, common to all three study areas, may represent some of the youngest activity, possibly as young as Early Amazonian [3-9]. The morphologies of valleys and networks, the relationships of valleys to the underlying geology and topography, and the fact that many gullies head at or near crater rims suggests that a significant part of valley formation involved surface runoff, although some component of groundwater sapping can not be ruled out.

Hydrologic modeling results suggest that large areas of apparently undissected terrain [15] may have been influenced by fluvial processes. Compared to mapped networks, models of the larger-scale valley systems in Terra Tyrrhena accurately represent the locations of valleys down to at least second order. Although some modeled first-order valleys are not visible in Viking or MOC images, other researchers have suggested up to a meter or more of dust may mantle the highlands and therefore may obscure smaller tributaries [22]; the dune-covered floors of Vichada Valles support this. Models of the smaller-scale systems in Promethei Terra and Libya Montes also represent the approximate locations of higher order valleys, but first- and second-order tributaries are less accurate. Rigorous comparison of the model results to image data can help to produce accurate maps of martian drainage basins and their associated valley networks, which provide critical constraints for valley formation mechanisms and climate history.

Acknowledgements: This research is supported by the NASA Graduate Student Research Program and the Planetary Geology and Geophysics Program.

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