STYLES AND TIMING OF VOLATILE-DRIVEN ACTIVITY IN THE EASTERN HELLAS REGION OF MARS.

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Introduction. Hellas basin, the largest well-preserved impact structure on the Martian surface, is Mars' deepest depositional sink and has long been recognized as a source for global dust storms. The basin and surrounding highlands span a wide range in latitude and elevation, exhibit landforms shaped by a diversity of geologic processes, and preserve exposures of Noachian, Hesperian, and Amazonian units. Geologically contemporaneous volcanism and volatile-driven activity in the circum-Hellas highlands provide resources for potential Martian life. Hellas is a geologically significant region for evaluating volatile abundance, distribution and cycling and changes in surface conditions on Mars. Current work integrates geologic studies of the basin floor and east rim using Viking Orbiter, Mars Global Surveyor, and Mars Odyssey datasets to provide a synthesis of the history of volatiles in the region.

Previous Work. Eastern Hellas includes highland terrains of Tyrrhena Terra and Promethei Terra, extensive ridged plains of Hesperia Planum, highland volcanoes Tyrrhena and Hadriaca Paterae, Dao, Harmakhis, and Reull Valles canyon systems, and basin floor deposits of Hellas Planitia. Geologic mapping studies and geomorphic analyses have examined highland degradation styles and regional stratigraphy [1-5], explosive volcanism at highland paterae [6-8], emplacement of Tyrrhena Patera lava flows [6, 9-10], development of fluvial systems [2, 11], formation of valles and associated sedimentary plains [2, 12-16], geomorphology of lobate debris aprons [17], and characteristics of impact craters [18-19]. Recent climate modeling studies indicate that eastern Hellas is a volatile accumulation zone [20]; previous studies proposed that Hellas was the site of lacustrine and glacial activity [21-22].

Cratered Highlands. The Noachian Period included formation of Hellas basin and surrounding cratered highlands, as well as eruptive activity at highland paterae. Cratered terrain and intercrater plains surfaces, crater rims, and paterae flanks exhibit valley systems attributed to a combination of groundwater sapping and surface runoff. Integrated valley networks with sub-parallel, rectilinear, or dendritic patterns are observed within Tyrrhena and Promethei Terra. Drainage basins in Promethei Terra are significantly smaller but more numerous than those in Tyrrhena Terra, reflecting differences in highland topography. Mapping studies suggest that Tyrrhena Terra fluvial systems are ancient, whereas those in Promethei Terra were active in the Hesperian Period and dissect an intermontane basin unit that accumulated in low-lying highland regions. This apparent age difference is consistent with the more pronounced and long-lived presence of volatile-driven activity near Promethei Terra.

Highland paterae exhibit radial valley systems dissecting their flank materials. Deeply incised valleys within wide, flat-floored troughs along the flanks of Hadriaca Patera suggest a greater component of surface runoff than at Tyrrhena Patera. THEMIS images show fine-scale parallel troughs perpendicular to the larger radial valleys, consistent with friable pyroclastic deposits and sustained fluvial erosion in some locations. MOLA DEMs show significant and widespread modification of highland topography surrounding Hellas; in eastern Hellas, this occurred prior to paterae formation and emplacement of Hesperia Planum. Ridged plains partially fill a former low-lying region but remain at elevations below surrounding highland surfaces.

Vallis Systems. Three prominent canyon systems extend through cratered highlands and Hesperian sedimentary plains of eastern Hellas toward Hellas Planitia. Dao and Harmakhis Valles are characterized by relatively steep-walled depressions, zones of subsided plains, and prominent central canyons whose walls display gullies with associated depositional aprons that cover parts of canyon floors. Reull Vallis' distal regions are similar, but its upper reaches exhibit streamlined islands, scour marks, narrow, sinuous channels, and lateral terraces or benches, all evidence for a fluvial stage or zone. The emplacement and erosion of a sequence of plains adjacent to Reull Vallis may be directly tied to flooding associated with this canyon system. Recent studies suggest that the lateral and vertical growth of Dao and Harmakhis Valles are dominated by collapse and sapping [23-25]. Surface runoff may only have occurred locally or in stages now erased by subsequent collapse.

Hellas Planitia. It has been suggested that Hellas basin contained ice-covered lakes from observations in MOC images, primarily of the deepest parts (below -6900m) of western Hellas Planitia [22]. Here, layered sediments and polygonal cavities were attributed to a lacustrine environment; Viking and MOLA data were used to propose additional shorelines at -5800m and -3100m [22]. After identifying intricate patterns of finely layered deposits located where Dao Vallis enters Hellas Planitia, we systematically searched MOC images to examine the distribution of these layered outcrops in eastern Hellas. Layered outcrops are concentrated along the scarp defining the eastern edge of the basin near Dao and Harmakhis Valles. The layered outcrops are exposed in locally high-standing mesas, knobs, and surfaces, typically near -5700m in elevation. MOLA topographic contours are deflected toward the basin interior in precisely the area exhibiting the layered outcrops, delineating a substantial depositional shelf in eastern Hellas. This shelf could be a preferential accumulation zone for atmospheric volatiles and/or the edge of a volatile-rich deposit associated with the basin interior.

Numerous, typically singular channels extend toward Hellas Planitia from the NE both adjacent to the valles and to the north, suggesting significant drainage into Hellas along the depositional shelf. It is possible that Dao and Harmakhis Valles once were similar to these narrow, elongate channels and grew by collapse of volatile-rich shelf sediments. The upper reaches of Dao and Harmakhis Valles as well as the larger segment of Reull Vallis (i.e., the "non-fluvial" segment that meets Harmakhis Vallis) all appear to be bounded by the -1800m elevation contour. Over the -1800 to -5800m interval, the topographic expression of the highlands changes significantly; below -5800m large impact craters are not apparent, between -5800 and -1800m large craters are present but are degraded, and above -1800m typical cratered terrain surrounds the basin. Topographic data, cratered terrain preservation, valles morphology, and the distribution of layered outcrops are all consistent with ancient lakes in Hellas, perhaps to a larger extent than envisioned previously. Although obscured by Hesperian and Amazonian units, an even larger fluvial/lacustrine system may have once connected Hellas basin with the ancient depression in Hesperia Planum. This may explain the location of Reull Vallis' upper reaches in Hesperia Planum as well as other recently identified channels extending south from Hesperia Planum [26].

Recent Ice-related Features. The eastern Hellas region is overprinted with a suite of geologically recent features indicative of contained ice, melting of ice, or its release to the atmosphere. Lobate debris aprons extend from canyon walls, highland massifs, and crater rims and may be analogous to rock glaciers or debris-covered glaciers. A variety of smaller ice-rich flow features have also been recognized in similar settings, often in association with the ice-cemented mantling deposits characteristic of Martian mid-latitudes and prominent gully systems [27-30].

Conclusions. Eastern Hellas is characterized by an extensive history of volatile-driven activity, although the style, spatial extent, and magnitude may have varied considerably over time. The general progression from widespread valley development across the region in the Noachian Period to concentrated activity associated with large canyons in the Hesperian Period and finally to smaller-scale, localized flow features in the Amazonian Period may represent a transition from a water- to ice-dominated surface environment. Periods of significant lacustrine activity in Hellas basin may have preceded or been concurrent with valley network formation. With continued analyses, large volumes of lacustrine sediments may be identified on the basin floor. Sedimentary plains and layered deposits in east Hellas may have been deposited in or at the margins of large, ancient standing bodies of water. Remobilization of volatiles may account for the distribution and form of younger collapse-dominated canyon segments and ice-rich flow features.

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