REGIONAL EMPLACEMENT HISTORY OF THE UTOPIA AND ELYSIUM PLAINS DEPOSITS, MARS. J. A. Skinner, Jr.1,2, K. L. Tanaka3,4, U.S. Geological Survey Flagstaff Field Center, 2255 North Gemini Drive, Flagstaff, AZ, 86001; 3Department of Geology, Northern Arizona University, Flagstaff, AZ, 86011; jskinner@usgs.gov

Introduction: Using a basin-analysis approach to interpret depositional styles and sequences, we have re-characterized the geologic and geomorphic boundaries of the channelized interior plains material within Utopia and Elysium Planitiae. Rendering Mars Orbiter Laser Altimeter (MOLA) datasets through a GIS environment has revealed inter-relationships of these deposits not recognized in imagery. These materials have been variously interpreted as paleolake [1], marine [2,3], volcaniclastic [4], and laharic [5] in origin. Here, we review a new stratigraphic framework and regional emplacement history of these channelized deposits that suggests: 1) the deposits are a sequence of variably fluidized debris flows, 2) represent temporally and spatially varied outpourings from Elysium Fossae, and 3) are younger than previously recognized. These efforts elucidate the formational processes of the channelized materials, better constrain the timing of emplacement, and point to the existence of subsurface reservoirs of volatiles.

Geologic Setting: The Utopia/Elysium deposits extend >1500 km from the base of Elysium Mons, forming a lobate tongue of relatively smooth and flat channelized materials [4] and covering an area of 1.45x10^6 km^2. The deposits overrun and partially infill the Utopia impact basin, a large (3300-km-diameter) subdued circular depression interpreted as an ancient impact basin [6] centered at ~350°W/45°N. The channelized materials extend >1000 km, are roughly symmetrical in cross-sectional profile, and have a down gradient axis striking at ~N55°W. Abruptly contrasting the slopes of Elysium Mons and the Elysium rise to the southeast (5.5° and 0.7° respectively) the interior deposits display almost no regional slope (>0.005°) from the base of the Elysium rise to the most distal reaches of the deposition. The deposits generally lie below ~3080 m and display a mean elevation of ~4950 m. These materials rest unconformably on Late Hesperian ridged, grooved, and knobby terrains [4]. Although the Utopia/Elysium deposits are interpreted as volcanic and sedimentary materials originating along flank fissures and troughs of Elysium Fossae [4-5, 8], the depositional sequences dominating lowland deposition have not been addressed in detail on a regional scale.

Geologic Mapping: We have mapped 14 Elysium plains units (excluding crater materials) within the study area at 1:5M scale. These units are divided into undivided materials, channel-system materials, and a Utopia/Elysium interior plains assemblage consisting of proximal, medial, and distal facies. The undivided material consists of relatively high-standing, patchy outcrops of rugged material that underlies all channelized materials. Narrow and deep braided channel networks sometimes dissect these units. Channel-system materials are mappable throughout the Elysium deposits and include continuous to discontinuous channel networks displaying nested systems, flood-plain deposits, and dissected and undissected terminal fans. The Elysium interior plains assemblage consists of continuous to discontinuous, expansive plains deposits of variable topography and origin. Proximal facies are lobate deposits adjacent to the Elysium rise that form subdued dissected and undissected terminal fan deposits at the mouths of Elysium Fossae. Medial facies consist of expansive, relatively featureless, medium-albedo deposits underlain by discontinuous sinuous channels visible only in digital elevation models (DEM’s). Distal facies lie within the lowest portions of Utopia impact basin, are areally expansive and show indications of widespread secondary erosion.

Depositional Sequences: We have attempted to reconstruct the depositional history of the channelized plains deposits. Even though we interpret the formation of these deposits to have occurred over a short period of time, the depositional events are divided into stages for clarity.

Pre-Utopia/Elysium deposits. The Vastitas Borealis Formation covered the majority of the pre-existing terrain prior to the emplacement of the Utopia/Elysium deposits [6]. These Late Hesperian materials were deformed by wrinkle-ridge assemblages oriented at ~N25E and ~N40W. This deformational event produced subdued linear features that were later embayed and covered by volcanic and sedimentary sequences associated with construction of the Elysium shield volcanoes.

Stage 1. Initial outpourings of material occurred along the southern portion of the Elysium rise, forming a broad debris fan. These fan deposits include sequences of volcanic debris and/or lava flows with irregular lobate fronts. These materials are interpreted to have been poorly fluidized due to the overall lack of channels associated with primary deposition. The eruptive sequence emplaced high-standing, rugged material onto and southward of a major structural ridge that trends northwest (termed S1) for nearly 500 km. The sources of these deposits were possible flank fissures along the lower portions of Elysium rise that were subsequently buried. These fan materials embay patchy outcrops of the slightly older grooved terrain of unknown origin; both terrains collectively comprise the mapped undivided material.

Stage 2. Continued outpourings along the Elysium rise produced highly mobilized flows and channel networks (Granicus Valles). These flows dissected the previous rugged debris apron into small channel networks. Outpourings were likely punctuated, in which individual flows overran previous flows producing a vertical sequence of stacked, thin debris flows. These flows began producing the medial plains facies largely made up of overbank materials. As coarser material was transported short distances away from the source regions and deposited, fine particles remained entrained and moved into the low regions of Utopia basin, where the flows stagnated and ponded. The distal facies likely includes interlayered overbank channel deposits, quiescent water-lain finer particles, and aeolian material. As the volatile component was removed due to evaporation and infiltration, fine particles may have been reworked into dune fields and loess deposits.
Flank eruptions along the northern portion of the Elysium rise produced morphologies and materials similar to those of the south (Aspus Valles). These outpourings migrated along the northern boundary of the deposits, and could have interfered with southern eruptions at certain locations, though subdued high-standing terrains and underlying structures mostly separated them.

The northern and southern flows could have interfered with the medial portions of the deposit, though subdued topographic boundaries might have kept the flows separated until reaching distal regions in Utopia basin. These deposits are of local extent and bury stage 2 deposits in the north.

Stage 3. Eruptions continued along the Elysium rise. Southern flows sculpted initial fan materials (stage 1) along the northern edge of the $S_1$ topographic boundary. Erosion within this region produced a large channel network (Thinjar Valles) while leaving elevated, abandoned channels. Eruptions occurred along Galaxias Fossae, supplying fluidized material into medial regions of the Utopia/Elysium deposits. These flows are of local extent and bury stage 2 deposits in the north.

Stage 4. The latest flows were volcanic debris and lava flows that originated in the central portion of Elysium rise. They include moderately dissected debris aprons at the terminal reaches of flank fissures. These outpourings cover previous channel networks and potential source depressions within the northern portions of the Elysium rise.

Discussion: Mapping efforts and interpretations have revealed a diverse suite of materials and morphologies previously unrecognized within the Elysium lowland deposits. These deposits indicate temporal and spatially variable outpourings of fluidized volcaniclastic material and volcanic flows from Elysium Fossae. The classical definition of a sedimentary basin is a region that has experienced continual infilling as a result of prolonged subsidence. Although Utopia basin is not presumed to have been actively subsiding during deposition of the channelized materials in question, we can use the techniques of basin analysis to infer a depositional sequence. MOLA provides high-resolution topographic data allowing reasonable estimation of the volumes of source regions, deposit thickness, and regional slopes, channel morphometry, and the topographic nature of geologic/geomorphologic contacts required for reconstruction of emplacement history.

We recognize many new stratigraphic relationships in the channelized materials of Utopia/Elysium deposits. It is likely that the resulting deposits were emplaced in a short period of time as eruptions moved back and forth over the Elysium rise. Digital elevation models created from MOLA datasets reveal several buried channel networks within the deposits, demonstrating that earlier features were buried by the latest outpourings. It is possible that the major extant channels were preferential conduits that migrated back and forth within a flood plain. Large outpourings produced medial and distal channel deposits, depending on degree of fluidization. Proximal sequences likely include the interfinger of expansive lava flows related to shield construction, thick debris aprons, and channelized deposits. Medial sequences include the interfinger of broad channel networks, overbank deposits, and debris flows. Distal sequences include thinly layered deposits, channel networks, overbank, and aeolian material. Secondary modification of the deposits occurred following emplacement to produce the terrains that are exposed today. These processes include terrain softening [8], eolian scour and deposition, and mass-wasting.

Crater morphologies and distributions indicate that the deposits are younger than previously recognized. Ejecta blankets interpreted at various scales [4, 6] as superposing the Utopia/Elysium deposits are actually dissected by channel networks. We observe ejecta blankets that are excavated at their boundary, are dissected or embayed by channelized material, or have been partially smoothed by fluvial action. Additionally, DEM’s indicate multiple craters buried within or beneath the deposit. Based on crater-rim diameter/height relationships and ejecta blanket estimations, the Utopia/Elysium deposits are not of sufficient thickness to cover these features. These relationships open the possibility that many of the craters previously used to date the surface were mistakenly considered to superpose the deposit.

Conclusions: Using new datasets, a GIS environment, and a classical basin analysis approach, we are able to make inferences on the regional depositional sequence of materials in the northern plains, assess the influence of the topographic controls on basin morphology and evolution, and test existing formational hypotheses. We feel that the regional emplacement processes were dominated by variably fluidized debris flows as a result of volcano-ice interactions along the northwest flanks of Elysium Mons similar to the lahar depositional style as first proposed by [5]. We conclude that the environment of deposition within Utopia/Elysium plains deposits can be characterized as dominantly volcanic debris and lava flows proximal to the shield and aeolian-fluvio-lit from within the deep portions of Utopia basin. These materials were catastrophically to passively erupted from Elysium Fossae due to the interaction of volcanism and reservoirs of subsurface volatiles along the lower flanks of Elysium Mons and Elysium rise. We have identified no evidence to suggest that the flows that emanated from Elysium Fossae flowed into a central sink causing widespread lacustrine deposits. Similarly, we have no identified evidence to suggest the existence of large-scale ice deposits during or subsequent to the emplacement of these channelized materials were emplaced.