NO-RAINFALL ORIGIN OF MELAS CHASMA VALLEY NETWORKS BY SALT DEHYDRATION: NUMERICAL THERMAL MODEL. J.S. Kargel[1], R. Furfaro[2], J.A.P. Rodriguez[3], P. Candelaria,[2] O. Prieto-Ballesteros[4], G.M. Marion[5], J. Crowley[6], and S. Hook[7], [1]Department of Hydrology & Water Resources, University of Arizona, Kargel@hwr.arizona.edu, [2]Deprtment of Aerospace & Mechanical Engineering, University of Arizona, [3]Planetary Science Institute, Tucson, AZ, [4]CAB-INTA-CSIC, Madrid, [5]Desert Research Institute, Reno, Nevada, [6]U.S. Geological Survey, Reston, VA, [7]Jet Propulsion Laboratory, Pasadena, CA.

Introduction: Light-toned layered sedimentary sequences, typically from one to several kilometers thick, were deposited in basins within the Valles Marineris. In Melas Chasma these sequences include mainly kieserite and polyhydrated sulfates [1]; the deposits locally are marked by dendritic valley networks, reworked sediment fans, and features appearing to mark a former lake [2]. The features have been linked to a possible episode of rainfall driven erosion [2]. We show through numerical thermal modeling simulations that self-insulation of low-conductivity salt hydrates [3,4] in Melas Chasma can induce dewatering, volume loss, and brine emission; these predicted responses potentially can explain the geological observations, including formation of valley networks without involvement of rainfall, if brines could erupt from shallow depths or if subsurface brine channels can be eroded (potentially just a couple hundred meters beneath the surface). Ordinary heat flow could sustain warm, wet conditions suitable for life at depths that are comparatively easy for exploratory drilling.

Observations of Melas Chasma deposits. HiRISE imagery shows details of the valley networks best explained by production and emission of fluids from within the deposits, erosion and collapse over shallow subsurface drainage routes, and sediment deposition at the valley termini (Figure 2). OMEGA and CRISM data have both indicated the presence of salts, especialy kieserite and polyhydrated sulfates, in much of the region of Melas Chasma shown in Figure 1. The salts are located particularly in areas where light toned layered deposits and the valley networks exist. THEMIS thermal inertia mapping shows physically distinct materials corresponding to major outcrops of light toned layers. In sum, available data indicate that the layered sequences in Melas Chasma are mineralogically distinct from the canyon walls, the plateau surface, and the chasmata floor materials where light-toned layers are absent. Although we cannot be sure that the salts dominate the rock sequence in the light-toned layered deposits, this certainly is a possibility. Our modeling so far has assumed dominance of one or another type of thermally insulating hydrate.

Thermal numerical model setup. Due to the physical chemical properties of hyrated salts, the inclusion of large quantities of these materials in the deposits causes depressed melting temperatures and sharply elevated upper crustal temperatures sufficient to have driven dehydration. Chloride salts would induce large freezing point depressions and thus substantially affecting melting temperatures. Sulfate salts generally have more modest depressions of eutectic temperatures, but the thermal insulation due to these materials' low thermal conductivity induce huge thermal anomalies even for ordinary background geothermal fluxes. We have examined the cases of sediment infill composed alternatively of gypsum, epsomite, and phyllosilicates. Even current background global average heat flow on Mars (estimated as 0.03 W m^{-2}) can produce large enough thermal anomalies in thick sediment piles to cause dewatering. Our model results shown below are for higher ancient heat flux of 0.12 W m^{-2}, corresponding to a global average heat flow about 3 billion years ago. We imposed a slope-variable surface temperature and uniform heat flow at the base of the model domain. Temperature-dependent thermal conductivity values appropriate for basalt, epsomite, gypsum, and anhydrite were used (for kieserite, whose conductivity data are lacking, we substituted values for anhydrite). The models were then iterated after it was assessed that the temperature of the hydrate domain exceeded the dehydration condition. For gypsum, dehydration occurs to anhydrite at 313 K, and for epsomite we approximated the multi-step dehydration as a single step to kieserite at 341 K.

Thermal modeling simulation results and interpretation. The thermal models (e.g., Fig. 3) reveal large positive thermal anomalies within and beneath the hydrate-rich sedimentary wedge. Heat flow is locally refracted by zones of reduced thermal conductivity (in the highly hydrated zones) and elevated thermal conductivity (in the dehydrated zones). Heat flow anomalies project up to the surface. High-temperature zones are especially evident along the fault-bounded sides of the sedimentary wedge. Due to the physical/lithological/structural discontinuity and due to the high thermal gradient, these sites at the edge of the deposit would be likely sites of brine eruption.

Dewatering of hydrated sulfates can explain the valley networks in Melas Chasma without resorting to rainfall episodes. Numerical modeling of heat transport indicates that dehydration temperatures easily could have been reached in these layered deposits if they contained large amounts of salt hydrates. Kieserite and anhydrite are expected products of dewatering. Volume loss by dehydration explains not only the valleys but also slumping and faulting in the deposits. This new thermal modeling alleviates a need to have conditions allowing rainfall in subsequent times.

Origin of the Primary Salt Deposits. From this hypothesis and model it may be inferred that the present hydration states of the observed minerals might not be entirely primary. Metamorphic dehydration or dissociation due to incongruent melting might have changed hydration states and redistributed salts. The original deposition of the salt deposits remains to be explained and requires an ancient eposide of high aqueous activity to have caused the chemical weathering of silicates and sulfides and to mobilize and redeposit the salts in thick sedimentary sequences. Chemical evaporitic reef type conditions are one possible original depositional paleoenvironment. This period might have been related to pervasive hydrogeologic activity across Mars, but may instead have involved subsurface aqueous chemical weathering and saline groundwater discharge, basin filling from those sources, and precipitation in basins. Primary precipitation might have been caused by either freeze-driven crystallization in colder parts of the basin or by evaporation-driven crystallization in warmer and drier parts of the basin; either way, circulation of lake brine over the sites of crystallization may have built layered sequences in a manner analogous to evaporitic reefs on Earth (either with or without attendant biological mediation of precipitation). The topographic configuration of Melas Chasma's salt

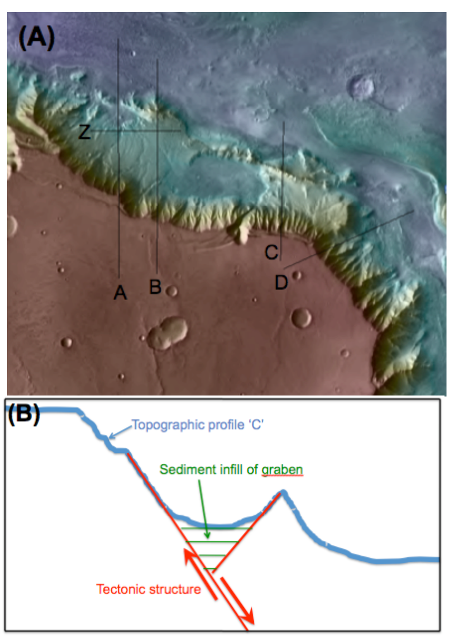

Figure 1. (A) MOLA DEM (blue is low, red is high) superposed over THEMIS mosaic of a portion of Melas Chasma. (B) Topographic profile and interpreted structure along profile line 'C'.

deposits suggests that a graben provided both a perched basin at the edge of the chasma and a structural/topographic barrier to lakewater circulation between the barred basin and the deeper lake. This condition may have facilitated evaporite deposition.

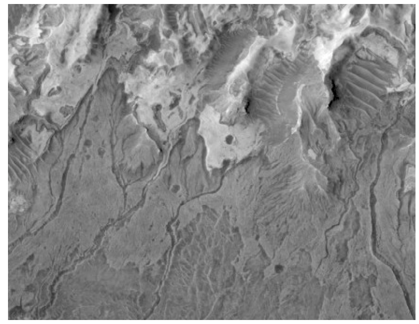

Figure 2. Portion of HiRISE image PSP 005452_1700 showing valley networks emanating from light-toned, hydrated deposits in Melas Chasma.

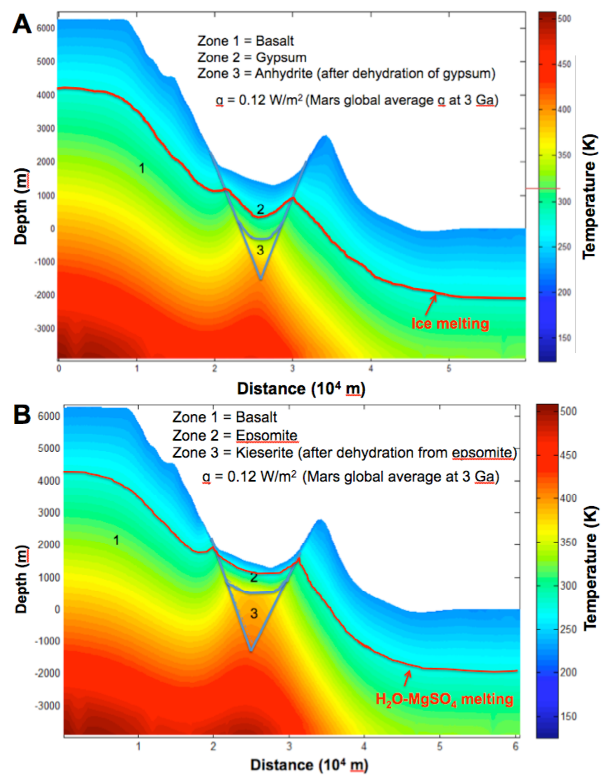

Figure 3. Thermal perturbations and melting and dehydration conditions in Melas Chasma for a sediment wedge initially dominated by (A) gypsum and (B) epsomite. In each panel, zone 3 represents dehydrated salts and zone 2 the original hydrated salts. These panels do not represent volume changes that would occur, but in the presentation we will present and discuss such modeling results.

References. [1] A. Gendrin and 10 others, 2005, Science 307, 1587-1591. [2] C. Quantin and 4 others, 2005, Jour. Geophys. Res. 110, E12S19. [3] O. Prieto-Ballesteros and J. Kargel, 2005, Icarus 173, 212-221. [4] J. Kargel and 7 others, Geology 35 (11), 975-978.