EPISODIC ENDOGENETIC-DRIVEN ATMOSPHERIC AND HYDROLOGIC CYCLES AND THEIR INFLUENCE ON THE GEOLOGIC RECORDS OF THE NORTHERN AND SOUTHERN HEMISPHERES, MARS

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Diverse evidence shows a direct correlation between episodic endogenetic events of the Tharsis magmatic complex (TMC)/Superplume [1], flood inundations in the northern plains [2], and glacial/lacustrine/ice sheet activity in the south polar region, which includes Hellas and Argyre impact basins (**Fig. 1**) [3-5], corroborating the MEGAOUTFLO hypothesis [6,7]. The TMC encompasses a total surface area of approximately 2 X 10^7 km^2, which is slightly larger than the estimated size of the Southern Pacific Superplume [8]. These hydrologic events include (1) a Noachian to possibly Early Hesperian oceanic epoch and related atmospheric and environmental change (a water body covering about 1/3 of the planet's surface area [9]) related to the incipient development of Tharsis Superplume and the northwestern sloping valleys (NSVs) [10,11] and possibly early circum-Chryse development [12-14], the northwest and northeast watersheds of Tharsis, respectively, (2) a smaller ocean [6-7; 15-17] inset within the former larger ocean related to extensive Late Hesperian to Early Amazonian effusive volcanism at Tharsis [18] and Elysium [19-20] and incisement of the circum-Chryse outflow system [e.g.,12-13]. During this time, magmatic/plume-driven tectonic activity transitioned into more centralized volcanism [4,21]. This Late Hesperian water body may have simply diminished into smaller seas and/or lakes [22] during the Amazonian Period, or renewed activity at Tharsis [21] and Elysium [20,23] resulted in brief perturbations from the prevailing cold and dry climatic conditions to later form minor seas or lakes [2]. All of the hydrologic phases transitioned into extensive periods of quiescence [1,2].

Dynamic, pulse-like, magmatic activity, especially at Tharsis [10] is partly the result of a stagnant-lid lithospheric regime where the internal heat of the planet builds over time to catastrophically erupt magmas and volatiles at the martian surface [1,6,7]. This is not to be unexpected, as pulses of activity are also documented for the Southern Pacific Superplume on Earth where present plate tectonism is recorded [8]. On Mars, the primary releases of the stored-up internal heat of the planet occur at dominant vent regions such as at Tharsis and Elysium and along pre-existing zones of weaknesses related to earlier magmatism and tectonism. This may include both impact events and plate tectonism during the earlier stages of planetary development [1,24]. Persistent periods of quiescence transpired between these violent outbursts sending the planet back into a dormant deep freeze [1,25], with the exception of areas where elevated geotherms persist and local hydrologic activity occurs.

Following a persistent deep freeze and ever thickening cryosphere, an Ontong Java-sized event on Mars (especially considering it is unvegetated and less than half the size of Earth, allowing a far greater impact to the climatic system) would trigger enhanced atmospheric conditions and hydrologic dynamics. A prime example of this process is observed during the Late Noachian/Early Hesperian; a time when magmatic-driven activity included the emplacement of older wrinkle ridged materials in the Thaumasia Planum region, the formation of the Thaumasia plateau, and major development of the primary centers of activity, Syria and central Valles (Stage 2 of Tharsis Superplume evolution; see [4,10-11,21]).

Though variation in the orbital parameters of Mars must be considered as a contributing influence on environmental change [26], a direct correlation between endogenic activity at Tharsis (and to a lesser extent Elysium) and global aqueous activity on Mars is observed in the geologic and paleohydrologic records of Mars (schematically portrayed in **Fig. 1**), including: (1) inundations in the northern plains and relatively short-lived climatic perturbations [1,2,6-7,25], (2) growth and retreat of the south polar ice sheet [5], (3) glacial and lacustrine activity in and partly surrounding Hellas [27] and Argyre [3-4], (4) outflow channel activity at NSVs [10-11] and circum-Chryse [e.g.,12-13], (5) formation of the Tharsis Montes aureole deposits [28], and development of impact crater lakes [29,30]. As such, any theoretic modelling of martian atmospheric or surface conditions must take into account endogenetic-driven activity as distinctly expressed in the geologic record.

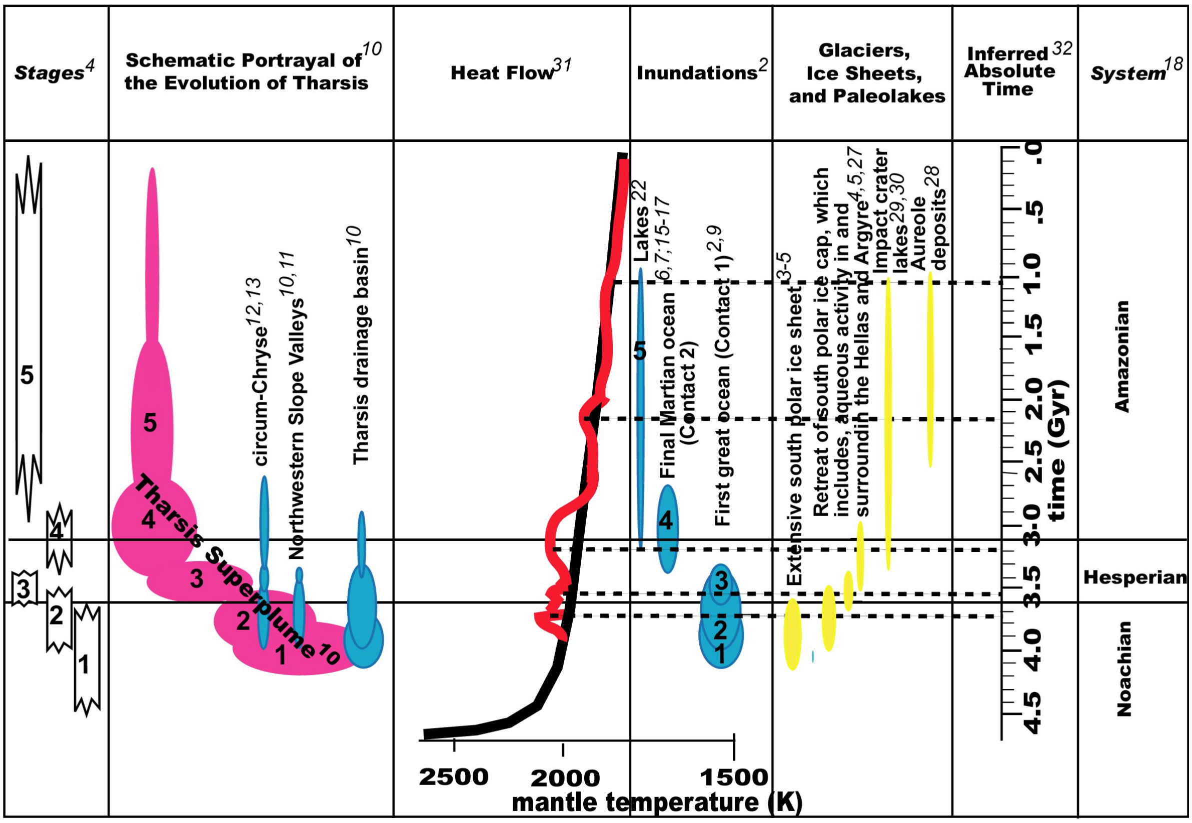

Figure 1. Schematic diagram portraying the spatial and temporal occurrence of major geologic and hydrologic events in martian history.

References. [1] Baker, V.R., *et al.* (2002). A theory for the geological evolution of Mars and related synthesis (GEOMARS). *Lunar Planet. Sci. Conf.*, XXXIII, #1586 (abstract) [CD-ROM]. [2] Fairén, A.G., et al. (2003). Episodic flood inundations of the northern plains of Mars. *Icarus*, in press. [3] Kargel, J.S., and Strom, R.G. (1992). Ancient glaciation on Mars. *Geology*, 20, 3-7. [4] Dohm, J.M., et al., (2001a). Geologic, paleotectonic, and paleoerosional maps of the Thaumasia region of Mars: USGS Misc. Inv. Ser. Map I-2650, scale 1:5,000,000. [5] Milkovich, S.M., et al. (2002). Meltback of Hesperian-aged ice-rich deposits near the south pole of Mars: evidence for drainage channels and lakes. *J. Geophys. Res.*, 107, 2001JE001802. [6] Baker, V.R., *et al.* (1991). Ancient oceans, ice sheets and the hydrological cycle on Mars. *Nature*, 352, 589-594. [7] Baker, V.R., *et al.* (2000). Mars' Oceanus Borealis, ancient glaciers, and the MEGAOUTFLO hypothesis. *Lunar Planet. Sci. Conf.*, XXXI, #1863 (abstract) [CD-ROM]. [8] Maruyama, Shigenori, 1994. Plume tectonics, J. Geol. Soc. of Japan, 100, 24-49. [9] Clifford, S. M., and Parker, T. J. (2001). The evolution of the Martian hydrosphere: Implications for the fate of a primordial ocean and the current state of the northern plains. *Icarus*, 154, 40–79. [10] Dohm, J.M., *et al.* (2001b). Ancient drainage basin of the Tharsis region, Mars: Potential source for outflow channel systems and putative oceans or paleolakes. *J. Geophys. Res.*, 106, 32,943-32,958. [11] Dohm, J.M., *et al.* (2001c). Latent outflow activity for western Tharsis, Mars: Significant flood record exposed. *J. Geophys. Res.*, 106, 12,301-12,314. [12] Rotto, S.L., and Tanaka K.L. (1995). Geologic/geomorphologic map of the Chryse Planitia region of Mars. *U.S. Geol. Surv. Misc. Invest. Ser.* Map I-2441. [13] Nelson, D. M., and Greeley, R. (1999). Geology of Xanthe Terra outflow channels and the Mars Pathfinder landing site. *J. Geophys. Res.*, 104, 8653-8669. [14] Zuber, M.T., et al. (2000). Internal structure and early thermal evolution of Mars from Mars Global Surveyor topography and gravity. *Science*, 287, 1788-1793. [15] Parker, T. J., *et al.* (1987). Geomorphic evidence for ancient seas on Mars. In *Symposium on Mars: Evolution of its Climate and Atmosphere, LPI Tech. Rept. 87-01*, 96-98, 1987. [16] Parker, T.J., *et al.* (1993). Coastal geomorphology of the Martian northern plains. *J. Geophys. Res.*, 98, 11061-11078. [17] Head, J.W., *et al.* (1999). Possible ancient oceans on Mars: Evidence from Mars Orbiter laser altimeter data. *Science*, 286, 2134-2137. [18] Scott, D.H., and Tanaka, K.L. 1986. Geologic map of the western equatorial region of Mars, *USGS Misc. Inv. Ser. Map I-1802-A (1:15,000,000)*. [19] Greeley, R, and Guest, J. E. 1987. Geologic map of the eastern equatorial region of Mars, *USGS Misc. Inv. Ser. Map I-1802B (1:15,000,000)*. [20] Tanaka, K.L., et al. (2003). Resurfacing history of the northern plains of Mars based on geologic mapping of Mars Global Surveyor data. *J. Geophys. Res.*, 108, 8043, doi: 10.1029/2002JE001908. [21] Anderson, R.C., *et al.* (2001). Primary centers and secondary concentrations of tectonic activity through time in western hemisphere of Mars. *J. Geophys. Res.,* **106**, 20,563-20,585. [22] Scott, D.H., *et al.* (1995). Map of Mars showing channels and possible paleolake basins. U.S. Geol. Surv. Misc. Invest. Ser. MAP I-2461. [23] Skinner, J. A., and Tanaka, K. L. (2001). Long-lived hydrovolcanism of Elysium. *Eos. Trans. AGU* ***82***, Fall Meet. Suppl., Abstract P31B-07. [24] Fairén, A.G., et al. (2002). An origin for the linear magnetic anomalies on Mars through accretion of terranes: implications for dynamo timing. *Icarus*, 160, 220-223. [25] Baker, VR. (2001). Water and the Martian landscape. *Nature*, 412, 228-236. [26] Touma, J., and Wisdom, J. 1993. The chaotic obliquity of Mars. *Science*, 259, 1294-1296. [27] Moore, J. M., and Wilhelms, D. E. 2001. Hellas as a possible site of ancient ice-covered lakes on Mars. *Icarus*, 154, 258-276. [28] Scott, D.H., et al. (1998). Geologic map of the Pavonis Mons volcano, Mars: *USGS Misc. Inv. Ser. Map I-2561* (1;2,000,000 scale). [29] Cabrol, N. A., and Grin, E. A. (1999). Distribution, classification and ages of Martian impact crater lakes. *Icarus*, 142, 160-172. [30] Cabrol, N. A., and Grin, E. A. (2001). The evolution of lacustrine environments on Mars: is Mars only hydrologically dormant? *Icarus*, 149, 291-328. [31] Schubert, G., and Spohn, T. 1990. Thermal history of Mars and the sulfur content of its core. *J. Geophys. Res.* 95, 14,095-14,104. [32] Hartmann, W. K., and Neukum, G. 2001. Cratering chronology and the evolution of Mars. *Space Sci. Rew.*, 96, 165-194.