THERMAL EFFECTS OF BOMBARDMENTS IN THE EARLY SOLAR SYSTEM. S.J. Mojzsis[1] N.M. Kelly[1], R. Brasser[2], and O. Abramov[3], [1]CRiO, Department of Geological Sciences, 2200 Colorado Avenue, University of Colorado, Boulder, CO 80309, USA (mojzsis@colorado.edu), [2]ELSI, Tokyo Institute of Technology, Ookayama, Meguro-ku, Tokyo 152-8550, Japan (brasser_astro@yahoo.com), [3]Planetary Science Institute, 1700 East Fort Lowell Road, Suite 106, Tucson, AZ 85719, USA (abramov@psi.edu).

Introduction: The most heavily cratered landscapes in the inner solar system are preserved in the ancient highlands of the Moon, Mars and Mercury. Intense early cratering affected all inner solar system bodies by melting and fracturing crusts, draping large areas in impact ejectae, generating regional-scale hydrothermal systems (i.e. on Earth, Mars' cryosphere, very early Venus), and increasing atmospheric pressure (and thereby, temperature) to modulate climate.

Bombardment scenarios: Post primary-accretionary bombardment scenarios that shaped the worlds of the inner solar system can be imagined in several ways (**Figure 1**): either as a simple exponential decay with an approximately 100 Myr half-life, or as a "sawtooth" timeline characterized by both faster-than-exponential decay from primary accretion and relatively lower total delivered mass, followed by a second, short and intense bombardment epoch. Indications are that the "late" bombardment spike was superposed on an otherwise broadly monotonic decline subsequent to primary accretion, of which two sub-types will be investigated: a classical (albeit, an idea that is now out of favor) "cataclysm" peak of impactors centered at ca. 3900 Ma that lasted 100 Myr, and a protracted bombardment typified by a sudden increase in impactor flux at ca. 4100-4300 Ma with a correspondingly longer decay time (~400 Myr).

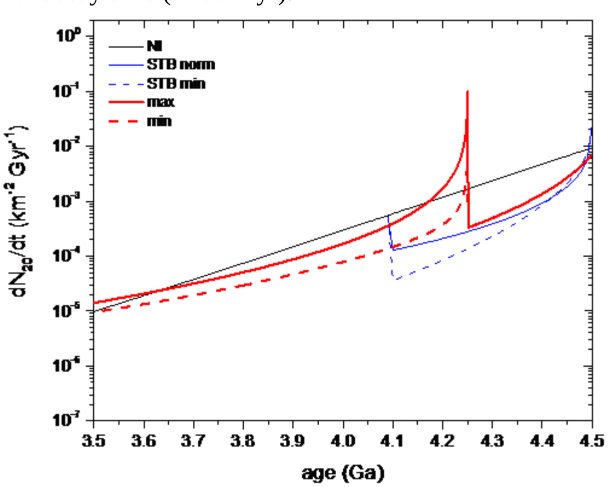

Figure 1. *Differential number of lunar craters > 20 km (N20) as a function of time and per unit surface for scenarios considered herein. These are used to compute the terrestrial impactor flux. The different scenarios range from a* ***monotonic decay*** *of the flux (no LHB; black curve of [ref.1]), a* ***sawtooth bombardment*** *(STB) with a moderate increase of the flux during the LHB arbitrarily set at 4.15 Gy ago (blue curve from [ref. 2]), and a red curve with a rapid rise in impacts at 4.25 Ga.*

We report new 3-D analytical thermal models for each of the scenarios cited above to (i) explore how silicate crusts (and in the case of Mercury, its mantle) thermally responded to bombardment with abundant liquid water (Earth, very early Venus, early Mars), or in a cryosphere (Mars), or under completely dry conditions (Mercury, late Venus, Moon); and (ii) provide detailed dynamical models [e.g. ref. 3,4] of solar system evolution to explain these bombardments.

Results: Our preliminary work has shown that depending on the chosen scenario, other physical effects of impacts were at least as important as impact melt generation. For example, between 10 and 100% of the Hadean Earth and Noachian Mars surface was covered by impact craters and blanketed in resultant (hot) ejecta [5,6,7]. In the case of the habitability of early Mars – a generally arid and cold planet that was always at the edge of the solar system's habitable zone [8] – heating from impacts punctuated an otherwise cold, arid surface state by intermittently destabilizing the near-subsurface cryosphere to generate regional-scale hydrothermal systems.

We assess using new dynamical studies of solar system evolution whether impacts were deleterious to the proclivity of the inner solar system to host emergent biospheres (at least on Earth). Specifically, we show how impacts affect the volume and duration of the surface/subsurface geophysical habitable zones, including an evaluation of the habitable potential of Venus in the first hundred million years.

References: [1] Neukum G. and Ivanov B.A. (1994) *Hazards due to Comets and Asteroids (Gehrels, G. eds), University of Arizona Press, Tucson*, 359–416. [2] Morbidelli et al. (2012) *EPSL, 355-356*, 144-151. [3] Brasser, R. et al. (2016) *EPSL, 455*, 85-93. [4] Brasser R. and Mojzsis S.J. *GRL, 44, doi:10.1002/2017GL074002*. [5] Abramov, O. and Mojzsis, S.J. (2009) *Nature, 459*, 419-422. [6] Abramov, O. et al. (2013) *Chemie der Erde, 73*, 227-248. [7] Abramov, O. and Mojzsis, S.J. (2016) *EPSL, 442*, 108-120. [8] Brasser, R. et al. (2017) *EPSL, 468*, 85-93.

Acknowledgements: The John Templeton Foundation-FfAME Origins program in support of CRiO.