SCALING RELATIONSHIPS FOR IMPACT BASINS ON MARS. K. Miljković[1], M.A. Wieczorek[2], A.-C. Plesa[3], G.S. Collins[4], I.J. Daubar[5], A. Lagain[1], G.K. Benedix[1], [1]Space Science and Technology Centre, School of Earth and Planetary Science, Curtin University, Perth, Australia, [2]Observatoire de la Côte d'Azur, Nice, France, [3]German Aerospace Center (DLR), Berlin, Germany, [4]Imperial College London, UK [5]Brown University, Providence, RI, USA (katarina.miljkovic@curtin.edu.au).

Introduction: Impact basins can be used as a tool to investigate planetary evolution and interior structure. We present a family of model-based scaling relationships for a range of possible crustal conditions for Mars, namely different thicknesses and thermal gradients. This is to investigate the sensitivity of the basin size to impact and target conditions and compare with standard impact scaling laws.

On Mars, the smallest identified peak ring basin is 101 km in rim-to-rim diameter [1]. Previous survey [2] suggested a transition from peak-ring to multi-ring-like basin to be at the Argyre basin size (1860 km in diameter). In this work, we investigate the peak-ring basin morphology only. The few basins that are of Argyre size and larger will be subject to further investigation.

Methodology: To form the majority of impact basins observed on Mars, we used impactors that were 20, 40, 60, 80, 100, 150 and 200 km in diameter, hitting the surface of Mars at the average impact speeds of 5 and 12 km/s [3]. These impact conditions produced impact craters with diameters from 100 to 1300 km, measured at the pre-impact surface level.

We use the iSALE-2D finite-difference shock physics code developed to simulate behaviour of geologic materials under impact conditions [4]. We used the 2D version of the code to be able to employ high computational resolution and perform a large number of runs. All impacts have been modelled as head-on collisions, because the code uses cylindrical symmetry.

We tested both basalt and granite ANEOS as the equation of state for the crust, and we used the dunite ANEOS for the mantle and projectile materials [5]. Up to 20% difference in the transient and final crater diameter was observed between these materials for the crust. In simulations, the bulk porosity of the crust was not included, however, the crust was assumed to be damaged rock. The final basin morphology significantly depends on the choice of the parameters controlling acoustic fluidisation process during crater modification phase [6]. In this work, we used the same values for the acoustic fluidisation that were used for simulating the formation of lunar impact basins [5].

Thermal profiles with depth (Figure 1) and the respective crustal thickness were taken from a set of thermal evolution simulations for Mars [7]. Three profiles were adopted in the impact simulations: a) the 30 km thick crust, where Mars cools the fastest (shown in blue), b) the 62 km thick crust that represents an intermediate model (red), and c) the 87 km thick crust, where Mars cools the slowest (green), over geologic timescales. Each thermal case was taken at 3.7 and 4.4 Ga, to cover the beginning and end of the large impact bombardment history, making the total of 6 thermal profiles used in this study.

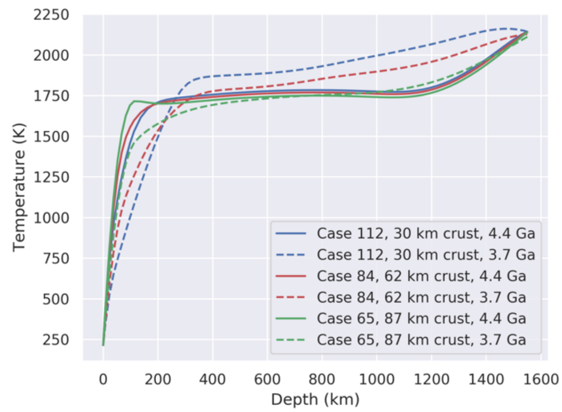

Figure 1. Six thermal profiles used in the suite of impact simulations for the formation of Mars basins.

Results: For the same thermal case, but different geologic epochs (solid vs. dashed lines in Figure 1), the final basin morphology did not significantly change; The final basin diameter was <5% different in simulations where the crustal thickness was the same, for the same impact conditions. This suggested insensitivity of the final basin diameter on the selected range of thermal crustal conditions.

The difference in the final basin diameter, as well as the diameter of the transient crater (observed when the excavation volume was the largest) was noticeable when different crustal thicknesses were applied (Figures 2-4). The relative difference in the final basin diameters was up to ~10% larger in the case when the crustal thickness was largest (data shown in green) compared to when it was smallest (data shown in blue), indicating that the impact basins forming in a thicker crust could have formed slightly larger than in the case of a basin forming in a thinner crust on Mars, for the same impact conditions. This discrepancy is even more prominent once the fitting equations were applied.

Figure 2 shows the relationship between the final crater diameter and the coupling parameter, C, defined as the product of the impactor diameter, L, and impact speed to an exponent. Here we used, $C=LV^{0.58}$, which was also applied in our lunar impact basin scaling study in the past [8]. These relationships show a direct link between impact conditions and basin size, and account for any typical impact conditions on Mars.

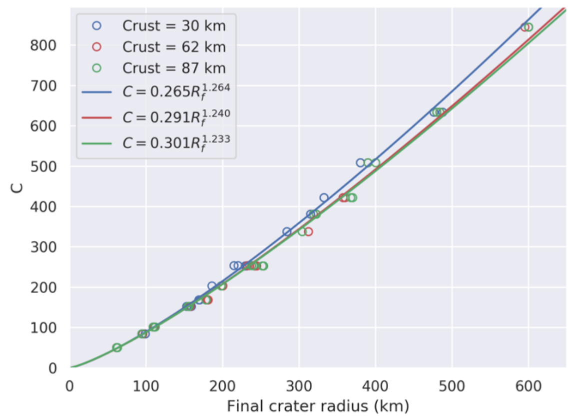

Figure 2. Relationship between the final crater radius and the coupling parameter, C, defined as $C=dV^{0.58}$ for three different crustal conditions (cold Mars with 30 km thick crust shown in blue, average Mars with 62 km thick crust shown in red, and hot Mars with 87 km thick crust shown in green).

Similarly to Figure 2, Figure 3 shows the relationship between the final basin diameter and the transient crater diameter. Comparison with the standard impact scaling law for a body of Mars' gravity is applied (black line) [9-10]. The standard scaling differs from our numerically derived scaling relationships such that the standard scaling underestimates basins smaller than ~200 km in diameter, but overestimated final basin diameters if larger than ~200 km.

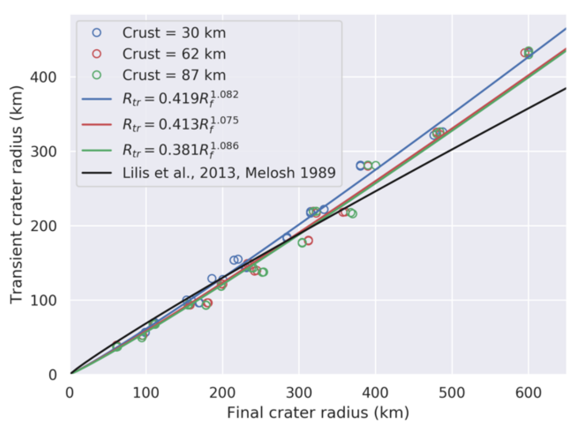

Figure 3. Relationship between the final crater radius and the transient crater radius (both measured at surface level) for the three abovementioned crustal conditions. Black line represents the standard scaling law for Mars craters.

Crater database: Figure 4 shows the relationships from Figure 2 applied to the Mars impact basins catalogued from [11]. Our scaling relationship suggested that if basins formed in a thin and cold crust (blue line), they would have formed smaller than in the case of thicker and warmer crust. However, there is almost negligible difference between the average crust and the thick crust cases.

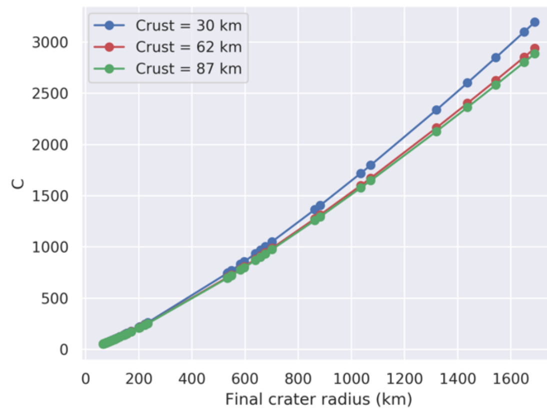

Figure 4. Relationships in Figure 2 applied to the basin database from [11] assuming the 3 global target conditions.

Conclusions: The impact scaling relationship derived from numerical simulations investigated dependence of basin diameters on a range of Martian crustal conditions (thickness and thermal gradient) suspected for the basin-forming epoch. While significant deviation from the standard scaling law is demonstrated, there is a small, yet significant, difference in final basin sizes between a cold and thin crust compared to the intermediate or hot thicker crust on Mars.

Further work will include new findings from the NASA InSight seismic and thermal observations that will help constrain the interior model of Mars, including the thickness of the crust and its thermal evolution.

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References: [1] Baker, D.M.H. (2016) *47th LPSC*, LPI contribution No. 3046. [2] Schultz, R.A. and H.V. Frey (1990) *J. Geophys. Res*, 95(B9), 14175–14189. [3] Daubar, I. *et al.* (2018) *Space Sci. Rev.* 214:132. [4] https://isale-code.github.io/ [5] Miljković, K. *et al.* (2013) *Science* 342, 724. [6] Melosh, H.J. (1996) *Nature* 379, 601–606. [7] Plesa, A.-C., *et al.* (2018) *Geophys. Res. Lett.*, 45, 12,198–12,209. [8] Miljković, K. *et al.* (2016) *J. Geophys. Res.*, 121. [9] Melosh, H.J. (1989) *Oxford Monographs, Geology and Geophys*. [10] Lilis, R.J. *et al.* (2013) *J. Geophys. Res.* 118, 1488–1511. [11] Robbins, S.J. *et al.* (2012) *J. Geophys. Res.* 117 (E06001), 21.