Impact-induced crustal dichotomy on Mars: from SPH to long-term mantle convection models

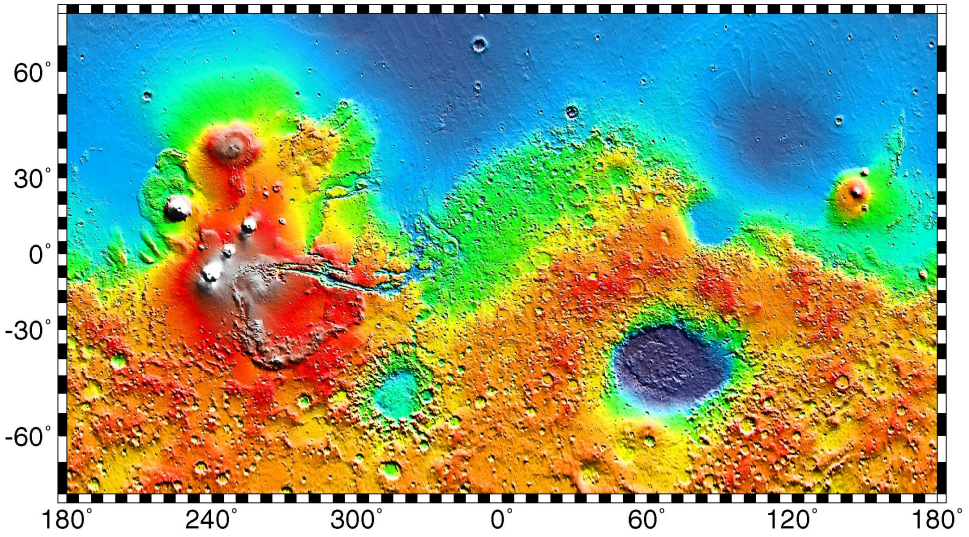
Kar Wai Cheng[1], Harry Ballantyne[2], Antoine Rozel[1], Gregor Golabek[3], Martin Jutzi[2], Paul Tackley[1]
[1] ETH Zürich, Switzerland [2] University of Bern, Switzerland [3] University of Bayreuth, Germany

Kar Wai Cheng
Doctorate student

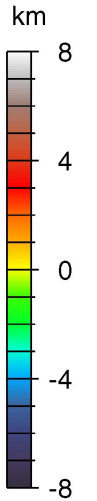
Geophysical Fluid Dynamics Group, ETH Zürich

Email:
karwai.cheng@erdw.ethz.ch

Research Interest:
Mantle convection modelling in planetary applications, including Mars, Venus, etc.

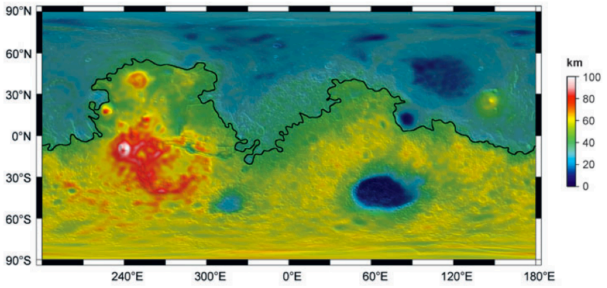


MOLA Topography (Smith et al 2001)



The Martian crustal dichotomy is an ancient feature that formed in the first ~100s Myr.

Crustal thickness *(Neumann 2004)*



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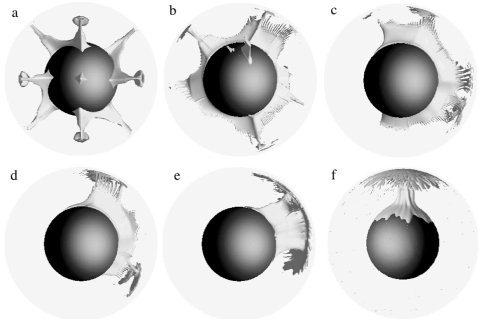
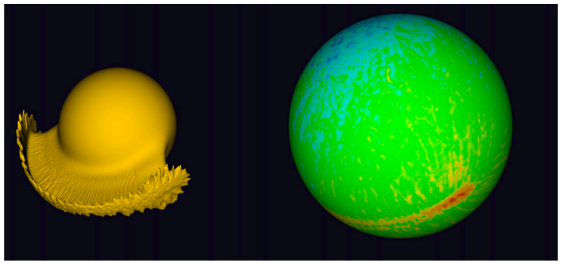
Introduction
Origin of Martian crustal dichotomy?

There are several classes of hypotheses, this study looks into the scenario involving a giant impact and subsequent mantle convection.

Endogenic origin (mantle plume)

Robert & Zhong (2006)

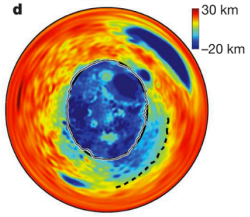




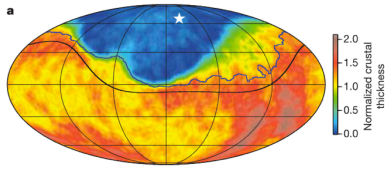
Keller & Tackley (2009)

Exothermic origin (giant impact)

Andrews-Hanna et al. (2008)
Inverting isostatic crustal root from topography and gravity data

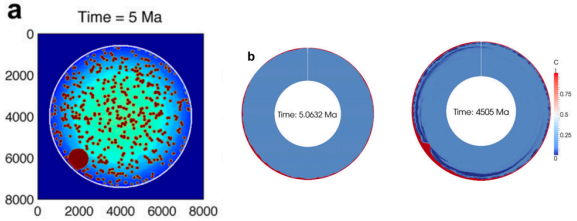


Marinova et al. (2008)
SPH simulations of northern impact

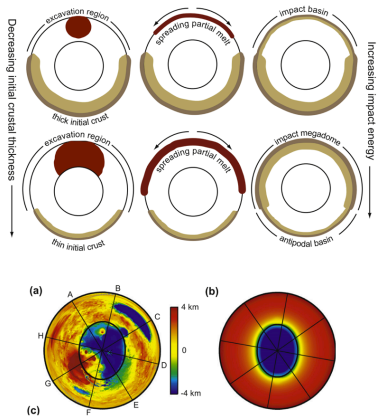


Hybrid origin (a mix of both)

Golabek et al. (2011)
Preferential crust production subsequent to impact-induced runaway core formation



Reese & Solomatov (2011)
Impact basin vs. impact megadome



Methodology and Preliminary Results
Using results from SPH model on mantle convection model

The reason to use both SPH and mantle convection models:

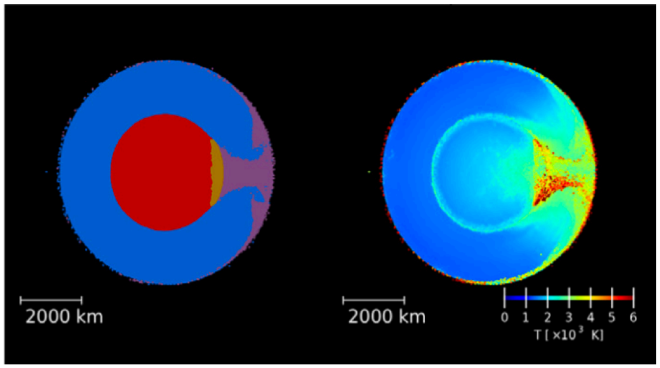
1. SPH models can provide a more realistic impact scenario compared with parametrized impacts commonly used in mantle convection models, considering e.g. different impact angles and re-impacted ejectiles.

2. The high temperature from a giant impact can generate a large amount of melt, which can potentially create a lot of crust (with this mechanism, even on the impact side).

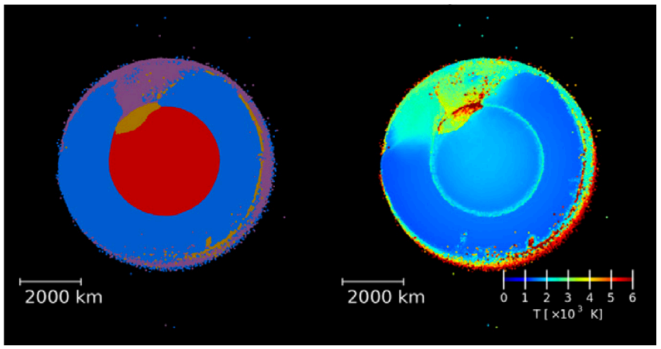
   We use mantle convection model StagYY (Tackley, 2008) to simulate the crust production and the long term evolution in the Martian mantle.

SPH models showing different impact scenarios:

Head on collision (0 deg)

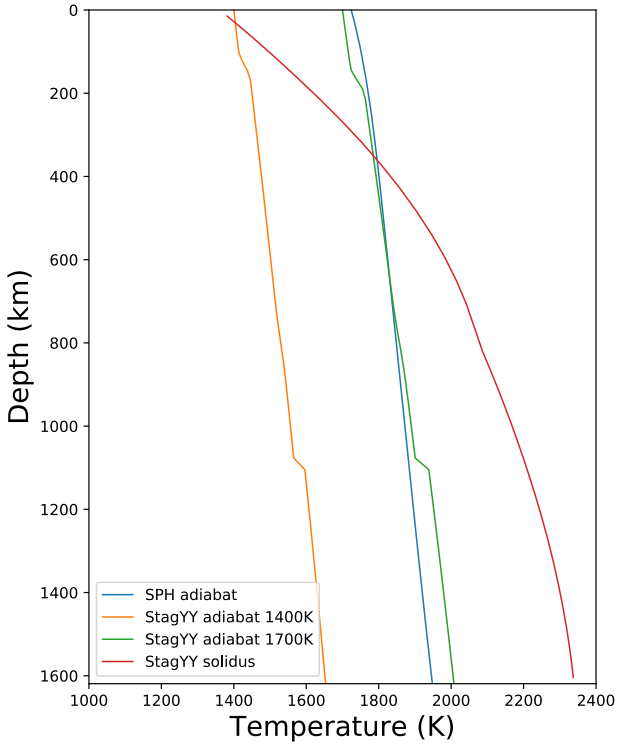


Grazing collision (45 deg)



Golabek et al. (2018)

Methodology and Preliminary Results
Using results from SPH model on mantle convection model



Care needs to be taken when using the resultant temperature field from SPH models:

- The shape of adiabatic temperature curve in SPH models and StagYY are different.
- Depending on the thermal state of Mars prior to the impact, a different adiabat could be more suitable, affecting the impact-induced melt in the interior of the planet.
- SPH to StagYY transfer time.

Methodology and Preliminary Results
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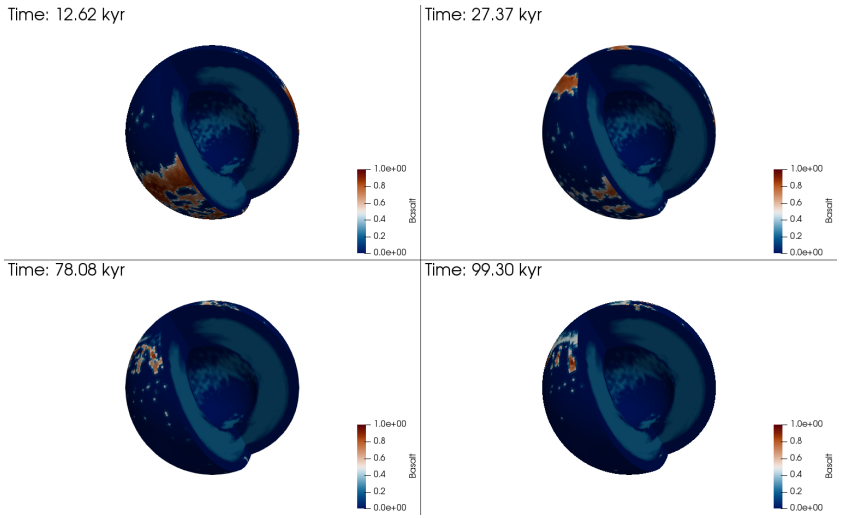
Set-up: Posing a temperature cutoff above which silicate is vaporized?

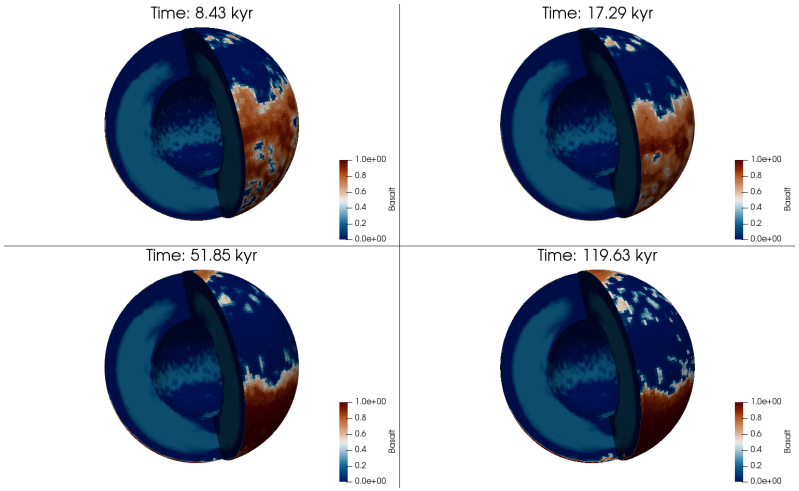
- Without a cutoff: T field is naturally higher -> ‘remelt’ crust faster
- With a cutoff: crust on non-impact side remains after ~100 kyr

No T cutoff



Crust re-melting due to the high temperature from surrounding

T cutoff at 4000K



Crust remains on the non-impact side

Next steps…

- Fine tune treatments for melt pond within solid mantle!
- Run models for longer!
- Include more different impact scenarios
- Compute observable quantities and compare with data

References

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