Author : Romain VIDAL [DLR] , Adrien BROQUET [DLR]

Objectiv:

Mars, a single-plate planet, has never experienced plate tectonics, so its surface has preserved intact traces of internal deformation for 4.5 billion years. Studying crustal thickness therefore gives access to the planet's geodynamic history, from past magmatism to the thermal evolution of the mantle and core. The problem is that gravity and topography data alone cannot uniquely determine crustal thickness and density, the inverse problem is underdetermined, and InSight seismology provides only one local anchor point, insufficient at a global scale. The objective of this work is to break this ambiguity by using surface deformation derived from tectonic structures as an additional independent constraint, injected into a joint inversion to obtain more realistic models of the Martian crust.

DATA

Data / Parameter	Value	Source
Gravity (GMM3)	A(l_m)=90	Genova et al. 2016 [1]
Topography	MOLA_shape	Smith et al. 2001[2]
Fault catalog	8,500 structures	Knapmeyer et al. 2006 [3]
crustalthickness	65 km	InSight [4]
Elastic -tHICKNESS	100 km	Wieczorek 2004 [5]
Crustal density	2,900 kg/m³	Wieczorek 2022 [6]
Mantle density	3,500 kg/m³	Khan et al. 2021 [7]

Modeling of the Martian lithosphere : contribution of vertical tectonic deformation the gravity-topography inversion

Methods

Fault catalogue

Extension

$$\varepsilon_e = \frac{\cos\theta_e \cdot \gamma_e}{A_r} \sum_k L_{f,k}^2$$

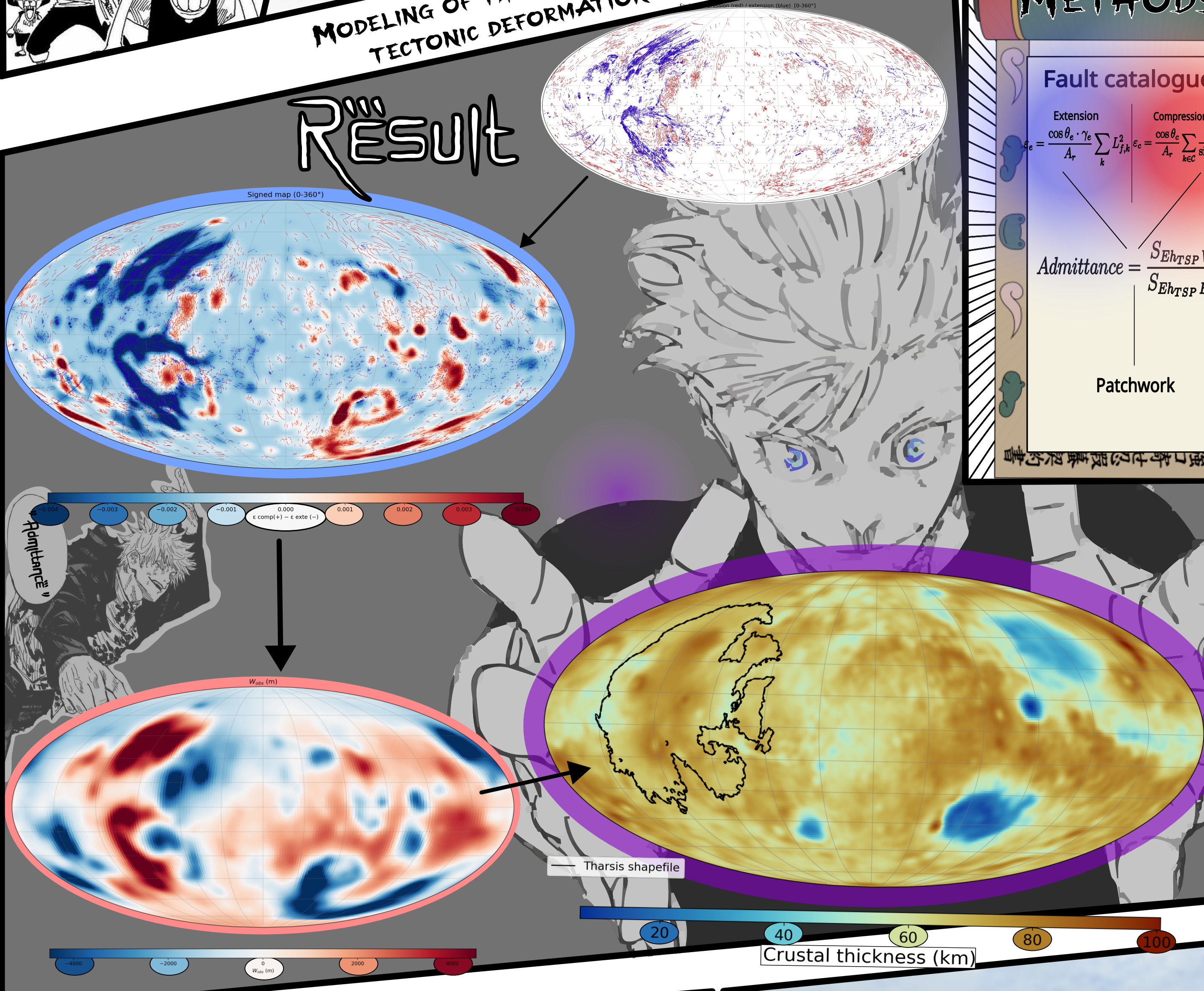
Compression

$$\varepsilon_c = \frac{\cos\theta_c}{A_r} \sum_{k \in C} \frac{h_k}{\sin\theta_c} L_{f,k}$$

$$Admittance = \frac{S_{Eh_{TSP}W_{TSP}}}{S_{Eh_{TSP}Eh_{TSP}}}$$

Patchwork

Result



Conclusion:

We introduce vertical surface deformation from tectonic faults as a new geophysical observable to constrain Mars' internal structure. Converting a fault catalog into a vertical displacement field and incorporating it into a joint gravity–topography (G, H) inversion breaks the classical non-uniqueness between crustal density and Moho depth.

Key finding: When incorporating surface faulting, the expression of the hemispheric dichotomy in the crustal thickness map is noticeably attenuated compared to classical G–H inversions.

Implication: This suggests that the dichotomy is not rooted in the crust itself (no Moho signature), pointing to a non-extrusive origin for the Martian crust, rather than differentiated crustal emplacement between hemispheres.

Perspective:

Spectral Extrapolation: Enables continuous modeling of Martian gravity up to l_max = 240, following Kaula's rule (beta = 1,5 . 10^{-4}) beyond observational limits.

Geodynamic Value: Produces self-consistent high-resolution gravity fields to better constrain localized flexure and density anomalies.

[1] Genova, A., et al. (2016). Seasonal reflections on Mars's gravity field. Icarus, 272, 228-245.
[2] Khan, A., et al. (2021). Upper mantle structure of Mars from InSight seismic data. Science, 373(6553), 434-438.
[3] Knapmeyer, M., et al. (2006). Working models for spatial distribution of marsequakes. Journal of Geophysical Research: Planets, 111(E11).
[4] Knapmeyer-Endrun, B., et al. (2021). Thickness and structure of the Martian crust from InSight seismic data. Science, 373(6553), 438-443.
[5] Smith, D. E., et al. (2001). Mars Orbiter Laser Altimeter: Experiment summary after the primary mission. Journal of Geophysical Research: Planets,
[6] Wieczorek, M. A. (2004). Gravity and topography of the terrestrial planets. Treatise on Geophysics
[7] Wieczorek, M. A., et al. (2022). InSight constraints on the global thickness and density of the Martian crust. Journal of Geophysical Research: Planets