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Modeling the internal architecture of Mars Polar Layered Deposits by HCA method

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Abstract

The polar layered deposits (PLD) of the Martian ice caps reveal an architecture analogue to the internal layering of the East Antarctic Ice Sheet (EAIS). The Hybrid Cellular Automata (HCA) modeling of the internal layering of the EAIS allowed to highlight the interaction between the active bedrock tectonics and the ice sheet dynamics. The HCA numerical approach allowed to kinematically simulate the internal architecture of the layered deposits from both the north and the south Martian ice caps and revealed the role played by tectonic movements on the present-day Martian ice cap stratigraphy.

1. Introduction

The polar layered deposits (PLD) of Mars constitute the water ice stratigraphy of polar spiral troughs up to several miles thick [1,2]. The PLD cross section profiles, based on data from the Shallow Subsurface Radar (SHARAD) instrument on NASA's Mars Reconnaissance Orbiter, showed discontinuities within these layers [3,4]. The PLD have been recognized as stratigraphic evidence for migration caused by wind transport and erosion [1]. Nevertheless, their internal stratigraphic architecture strongly resembles the layered geometries evidenced by radargram from radio echo-soundings of the East Antarctic Ice Sheet (EAIS). The important role played by tectonics in the present-day EAIS stratigraphy was proposed by [5,6]. In this way the mechanisms responsible for layered deposits of Mars are still an open issue [7] and this work represents a contribution to the debate.

2. Methodology

Layered ice is simulated by a mesh of cells piled up. Three major types of link exist among adjacent cells: 1. intralayer relations link cells belonging to the same layer and consist of rigid relationships derived from average volume and surface preservation conditions, physical boundary conditions, and rock rheology. 2. Inter-layer relations regulate the relationships among adjacent layers. These relations take into account the weaker rheologies of interlayer material, physical boundary conditions, and volume preservation conditions, while partial freedom is given to surface variations. 3. Discontinuity relations correspond to the presence of ruptures such as faults. No kinematic links exists across them, but physical boundary conditions and slip-induced stresses [8]. The combination of the FEM and CA approaches allows to replicate the natural material anisotropies, such as rocks and ice sheet internal layering, and to simulate complex tectonic evolutionary paths [9,10]. The Hybrid Cellular Automata (HCA) modeling of the internal layering of the EAIS allowed to highlight the interaction between the active bedrock tectonics and the ice sheet dynamics (including ice flow, erosion, and sedimentation) and showed the important role played by the recent-to-active tectonics on the present-day ice sheet stratigraphy.

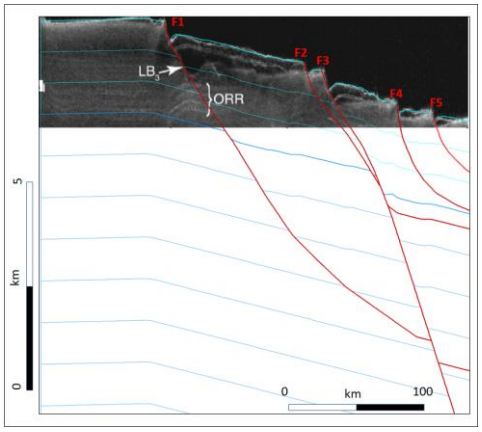

Figure 1: HCA numerical model of the ice layered deposits from Mars south polar region. Subset of the SHARAD radargram 5968-01 (from [2])

3. Summary and Conclusions

The HCA numerical approach allowed to kinematically simulate the internal architecture of the layered deposits from both the north and the south Martian ice caps. In particular the observed stratigraphy (geometries and thickness of the ice layers) was replicated as resulting from the relative, normal movement among blocks separated by shear discontinuities with listric shape (normal faults). In some places the fit between the internal layering revealed from the radar data and the geometries from the numerical model was achieved with minor fault inversions.

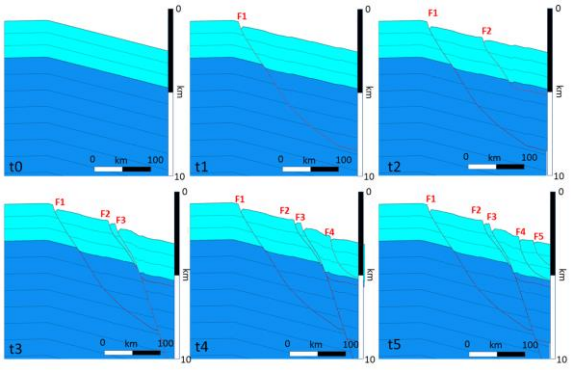

Figure 2: Evolution of the layered deposits from Mars south polar region as derived by HCA modeling. Computed fault displacements are: F1: 4000m; F2: 2000m; F3: 5000m; F4: 1000m and F5: 1000m

Acknowledgements

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References

[1] Smith, I. B., and Holt, J. W. Spiral trough diversity on the north pole of Mars, as seen by Shallow Radar (SHARAD). Journal of Geophysical Research: Planets, 120(3), 362-387, 2015. https://doi.org/10.1002/2014JE004720

[2] Phillips, R. J., Davis, B. J., Tanaka, K. L., Byrne, S., Mellon, M. T., Putzig, N. E., *et al*. Massive CO2 ice deposits sequestered in the south polar layered deposits of Mars, Science, 332(6031), 838-841, 2011. doi:10.1126/science.1203091

[3] Foss, F. J., Putzig, N. E., Campbell, B. A., and Phillips, R. J. 3D imaging of Mars' polar ice caps using orbital radar data. The Leading Edge, 36(1), 43-57. 2017. https://doi.org/10.1190/tle36010043.1.

[4] Putzig, N. E., Smith, I. B., Perry, M. R., Foss II, F. J., Campbell, B. A., Phillips, R. J., and Seu, R. Three-dimensional radar imaging of structures and craters in the Martian polar caps, Icarus, 308, 138-147,2017. https://doi.org/10.1016/j.icarus.2017.09.023

[5] Cianfarra P. and Salvini F. Modelling ice flow kinematics and deformation by HCA numerical method (poster presentation), Seventh International Symposium on Antarctic Glaciology (ISAG 7), Milano, Italy, 25-29, 2003.

[6] Cianfarra P. The tectonic origin of the Antarctic Subglacial lakes in the Vostok-Dome C region, East Antarctic craton. PhD Thesis, Roma Tre University, Rome, Italy, 2006.

[7] Guallini, L., Rossi, A. P., Forget, F., Marinangeli, L., Lauro, S. E., Pettinelli, E., Seu, R., Thomas, N. Regional stratigraphy of the south polar layered deposits (Promethei Lingula, Mars): "Discontinuity-bounded" units in images and radargrams, Icarus, 2017. http://dx.doi.org/10.1016/j.icarus.2017.08.030

[8] Salvini F. and Storti F. Active-hinge-folding-related Deformation and its Role in Hydrocarbon Exploration and Development—Insights from HCA Modeling. AAPG Mem. 82, p. 453-472, 2004.

[9] Cianfarra P. and Salvini F. Origin of the Adventure Subglacial Trench linked to Cenozoic extension in the East Antarctic Craton. Tectonophysics, 670, 30-37. 2016. http://dx.doi.org/10.1016/j.tecto.2015.12.011

[10] Cianfarra P. and Maggi M. Cenozoic extension along the reactivated Aurora Fault System in the East Antarctic Craton, Tectonophysics, 703, 135-143, 2017. doi: 10.1016/j.tecto.2017.02.019