

EXPERIMENTAL INVESTIGATION OF EUROPA ICY LITHOSPHERE THANKS TO DEM RECONSTRUCTION C. Mergny^{1,2}, A. Davaille², F. Schmidt¹, H. Massol¹, ¹Université Paris-Saclay, CNRS, GEOPS, 91405, Orsay, France (cyril.mergny@universite-paris-saclay.fr) ²Laboratoire FAST, Bat. 530-Pascal, Rue Andre Riviere, 91405 Orsay, France

Introduction: Jupiter's moon Europa presents on its icy surface linear structures [1], [2] which may form by accretion during extensional deformation of the ice shell. Here, we conduct analog experiments using Ludox®, a colloidal suspension, to investigate the dynamic of Europa's ice shell and the formation processes of these structures. Thanks to the implementation of a numerical tool using photogrammetry, we were able to perform quantitative analyzes on the solidified topography. Our measurements of the ridges geometry will, with further work, help constrain the ice shell properties and provide us a better understanding of Europa's geologic activity.

Analog Experiment: Due to its unique mechanical properties, Ludox was notably used as an analog to mantle rocks on Earth [3]. In contact with a saline solution, the liquid Ludox forms a skin almost instantaneously if

the salt concentration is above a critical value C_c . In addition, salt diffusion through this skin generates a slower solidification under the skin. This is analog to thermal diffusion through the lithosphere on a planet, and for a certain range of spreading velocities, the process of skin formation recovers well what is observed on mid-ocean ridges on Earth [3]. Moreover, preliminary experiments at lower spreading velocities had suggested the formation of double-ridges, which might be relevant to the formation of Europa's crust.

Our analog experiment consist of a Plexiglas reservoir of dimensions 230×330 mm filled with liquid Ludox up to $H = 20$ mm (see Figure 1). Partially immersed in the liquid gel, two solid plates, about one centimeter thick each, are attached to a motor (not shown in figure) and can move horizontally. Initially, these plates almost touch each other. On top of these plates

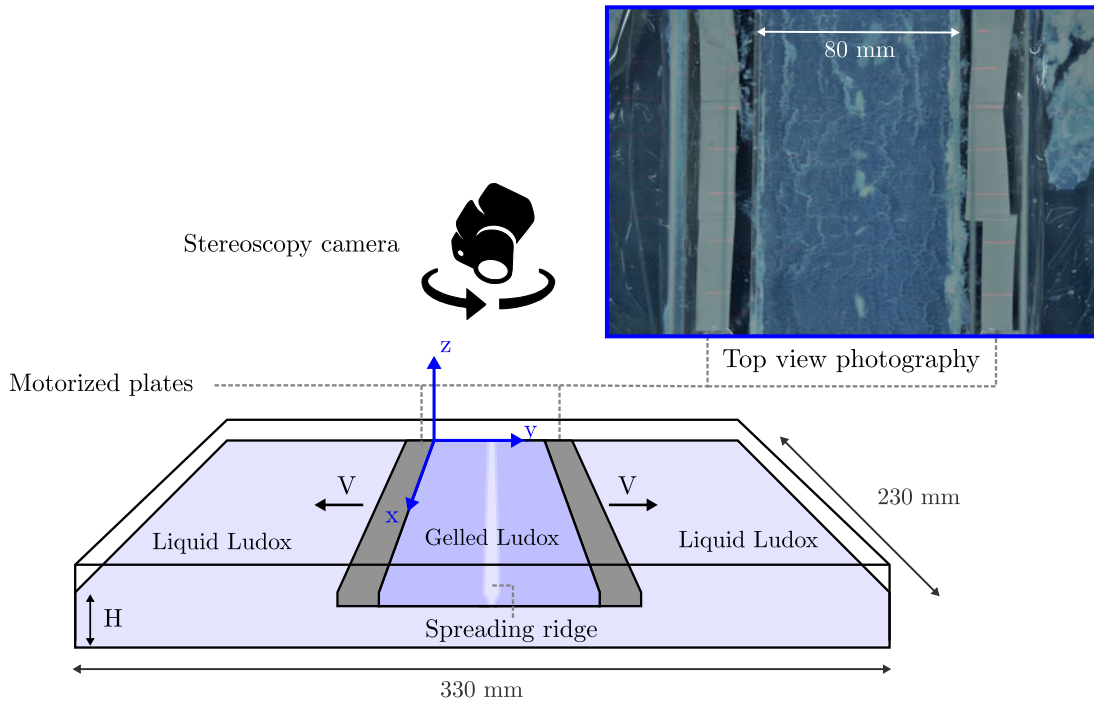


Figure 1: Experimental setup of our analog experiments. A glass tank is filled with liquid Ludox that can solidified by contact and/or diffusion with the saline water solution above it (not represented here). Two motorized plates initially at the center of the tank, spread horizontally at velocity V . A top view camera takes multiple images of the experiment for stereoscopy reconstruction while an other camera records the experiment evolution. *Top Right:* Top view photography an experiment with spreading velocity $V = 30 \text{ mm} \cdot \text{min}^{-1}$ at the end of the extension process. Due to a high spreading velocity, double ridges do not appear here.

and the liquid Ludox, we inject about 200 to 400 mL of saline water (H_2O , NaCl) of initial concentration C_0 (not represented in figure). *Outside the plates*, a thin plastic film protects the liquid Ludox from being in contact with the saline water. *In-between the plates*, liquid Ludox and saline water are in contact and form a gellified Ludox plate. During the experiment, the plates spread apart from each other at a velocity V ranging from $0.25 \text{ mm} \cdot \text{min}^{-1}$ to $40 \text{ mm} \cdot \text{min}^{-1}$. In most cases, we stop the spreading process when the plates are 80 mm apart.

Digital Elevation Model: To conduct a 3D reconstruction, we used the open source photogrammetric software Micmac developed by the French National Geographic Institute [4]. Stereoscopy allowed us to reproduce precisely the gelled Ludox skins of our experiments as a three dimensional point cloud. Original pictures of the experiments have a resolution of $0.45 \text{ mm} \cdot \text{pix}^{-1}$. Here, DEM are produced with a zoom factor of 2, meaning that our 3D objects have a resolution of $0.90 \text{ mm} \cdot \text{pix}^{-1}$, with noise adding uncertainties of about $\pm 1 \text{ mm}$. The total computation to produce a DEM from a set of four to five images is approximately five minutes on a Intel Core i7 CPU. Considering the transparency of the colloidal suspension and the reflectance of the saline solution, our numerical results are surprisingly precise and complete, and provided us a useful tool to perform quantitative analysis of our experiments.

Results: Experiments with low initial saline water concentration $C_0(\text{NaCl}) = 250 \text{ g} \cdot \text{L}^{-1}$ and a very slow spreading velocity $V = 0.25 \text{ mm} \cdot \text{min}^{-1}$, resulted with the formation of ridges and double ridges like structures (see Figure 2).

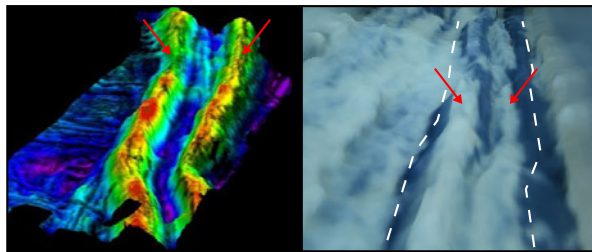


Figure 2: Two representations of double ridges (located by red arrows). *Left*: 3D view of double ridges on Europa computed from satellite imagery ; source: NASA. *Right*: 3D reconstruction of our experiment. For clarity, white lines delimit the region bounded by the double ridge.

After smoothing the point cloud topography, we were able to measure the heights of two neighbored ridges as shown in Figure 3. The peak of tallest ridge is situated at

height $h_1 = 11.3 \pm 0.5 \text{ mm}$ above the surrounding terrain, while the smaller ridge height is $h_2 = 7.38 \pm 0.5 \text{ mm}$. These ridges are measured to be between 12.8 to 14.4 mm away from each other. Moreover, measurements of the local slope angles of the biggest ridge $\theta_1 = 71^\circ \pm 1^\circ$ and $\theta_2 = 47^\circ \pm 1^\circ$ reveal an asymmetry in the double ridge structures, that may also be seen in Europa [2].

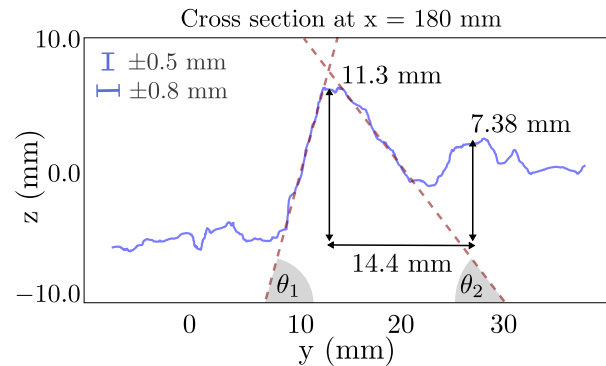


Figure 3: Heights and lateral distance measurements from the cross section of an experiment. Vertical and horizontal measurement uncertainties are given at the top left corner.

Conclusion: Analog experiments [3], [5], [6] are a promising way to advance in understanding icy moons, where *in situ* analysis are not possible and satellite imaging are scarce. In this preliminary study we examine accretion as a plausible mechanism for double ridges formation. While for earlier experiments the analysis of the topography was the limitant factor, here we implemented a method using photogrammetry to perform a complete and precise analysis of the colloid topography. Thanks to the generated three dimensional point cloud, we were able to conduct a quantitative analysis of the experiment structures by measuring ridges geometry precisely. This new method leads the way to further experimental work and could be compared to the ridges geometry on Europa, with the right scaling laws.

References

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