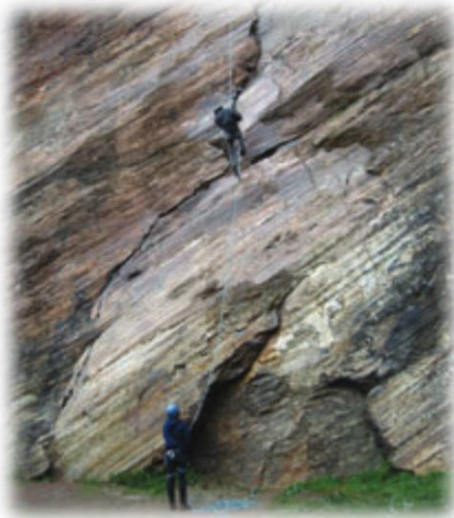


## Frictional anisotropy in 3D-printed faults

05/05/2020



Tom Vincent-Dospital<sup>1</sup>, Alain Steyer<sup>1</sup>, Aldo Mellado Aguilar<sup>1</sup>, François Renard<sup>2,3</sup>, Renaud Toussaint<sup>1</sup>

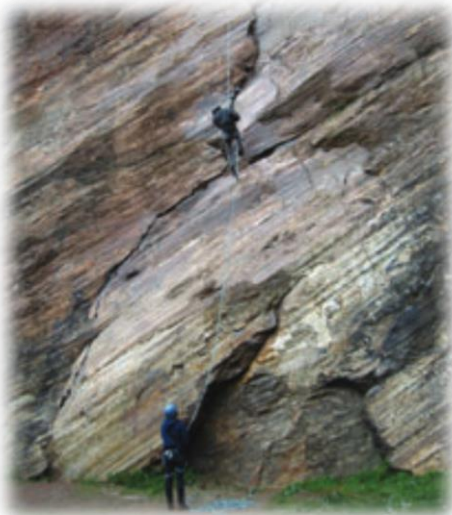
(1) Université de Strasbourg, Institut de Physique du Globe de Strasbourg - EOST, CNRS UMR 7516

(2) University of Oslo, The Njord Centre, Department of Geosciences

(3) Université Grenoble Alpes, Université Savoie Mont Blanc, CNRS, IRD, IFSTTAR, ISTerre

[vincentdospital@unistra.fr](mailto:vincentdospital@unistra.fr),

[renaud.toussaint@unistra.fr](mailto:renaud.toussaint@unistra.fr)



Corona Heights fault  
San Francisco, California

Chert rocks

From *Candela et al. 2011*

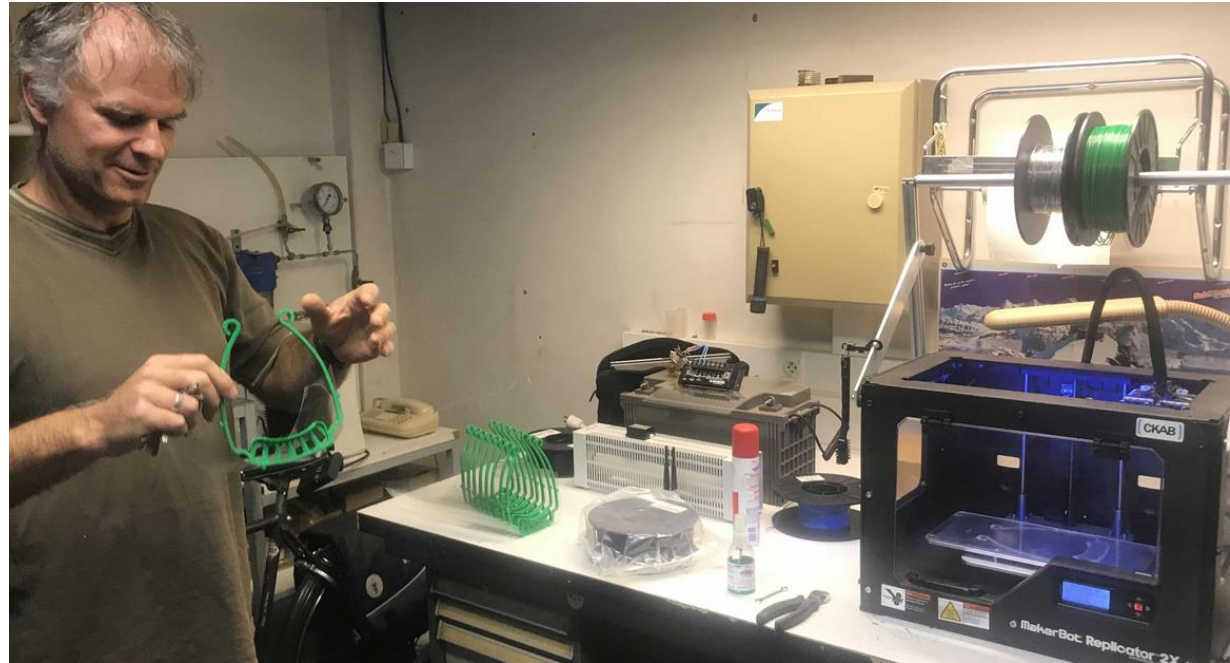


4 cm in the lab  
2 m in the field

3D print  
of a portion of the same fault

PLA plastic

## But first, a word on the versatility of 3D printing



- Renaud Toussaint and Alain Steyer (Université de Strasbourg) printing face shields in the current epidemic context.
- Have a 3D-printer?  
<https://prusa3d.com/covid19/>

## Back to frictional anisotropy

It has been studied in many fields

- The motion of animals.

e.g.: *Filippov and Gorb, 2013*      *Zheng et al., 2007*



- The hydration of plants.

e.g.: *Roth-Nebelsick et al., 2012*

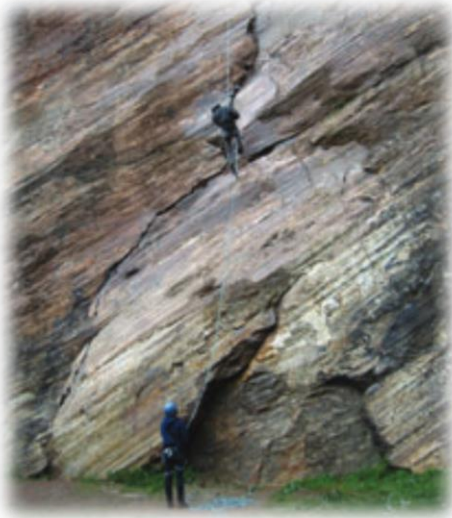


- Advance adhesives and water condensation.

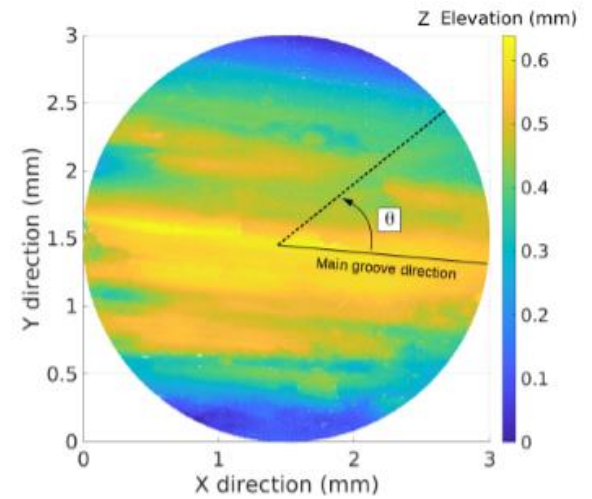
e.g.: *Jin et al., 2012*      *Pionnier et al. 2018*



## When it comes to faults, there is indeed a strong directional anisotropy



*Candela et al. 2011*



*Roughness of the Corona Heights fault on the metric and millimetric scales.  
From LIDAR and white light interferometry measurements*

## Such anisotropy is multi-scale

- **Microscopic at the mineral level**

*Campione and Capitani, 2013*

- **Mesoscopic and macroscopic, mainly from slip-induced wear**

e.g.: Candela et al., 2012      *Candela and Brodsky., 2016*

## How to characterize the frictional anisotropy?

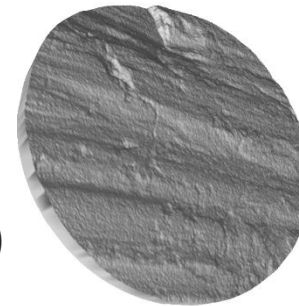
### 1. Measure the topography of a fault.

A database for such topographies can notably found [here](https://www.isterre.fr/french/recherche-observation/equipes/mecanique-des-failles/moyens-et-outils/article/donnees.html).



<https://www.isterre.fr/french/recherche-observation/equipes/mecanique-des-failles/moyens-et-outils/article/donnees.html>

(Additions to this database are welcome.)

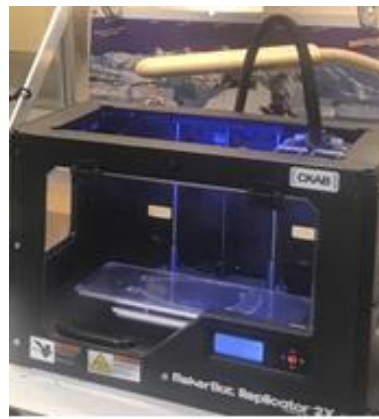


### 2. Transform it into a printable object.

(for instance into a .STL file as shown here)

### 3. Use a 3D printer.

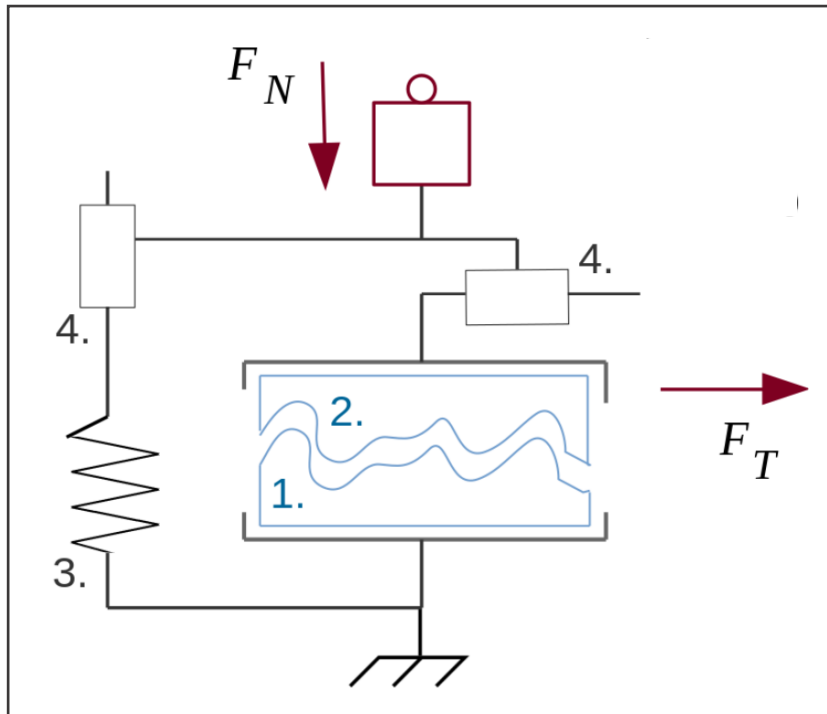
(here a MakerBot Replicator 2X)



### 4. Use the 3D-prints as moulds and cast the faults into plaster to have them in a mineral like material.



And then... Make it slide in various direction !

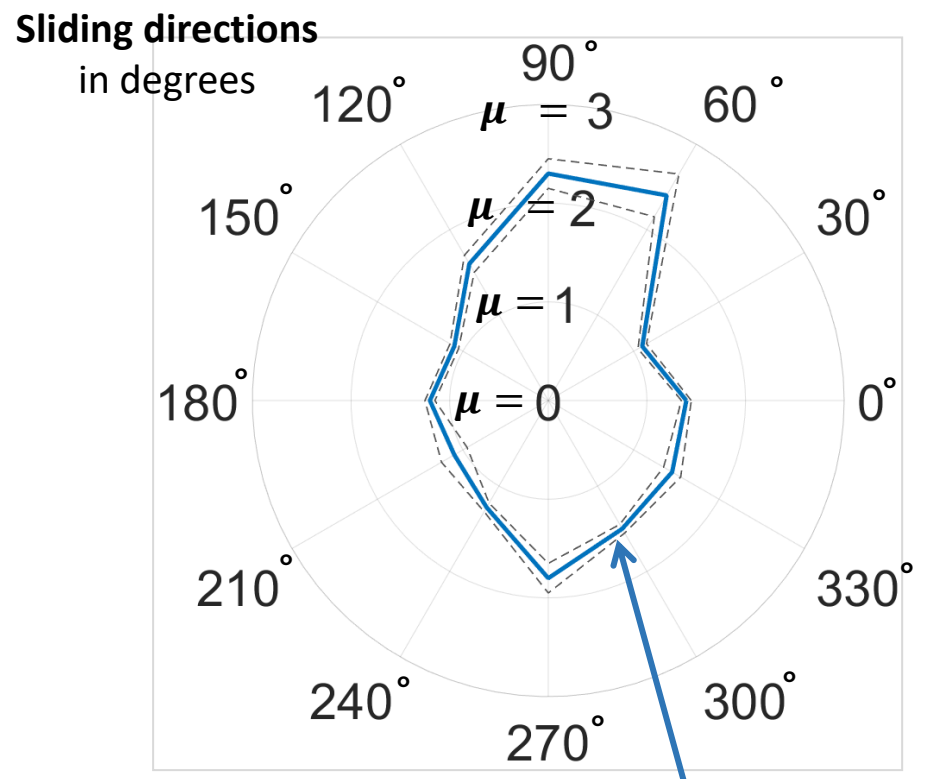
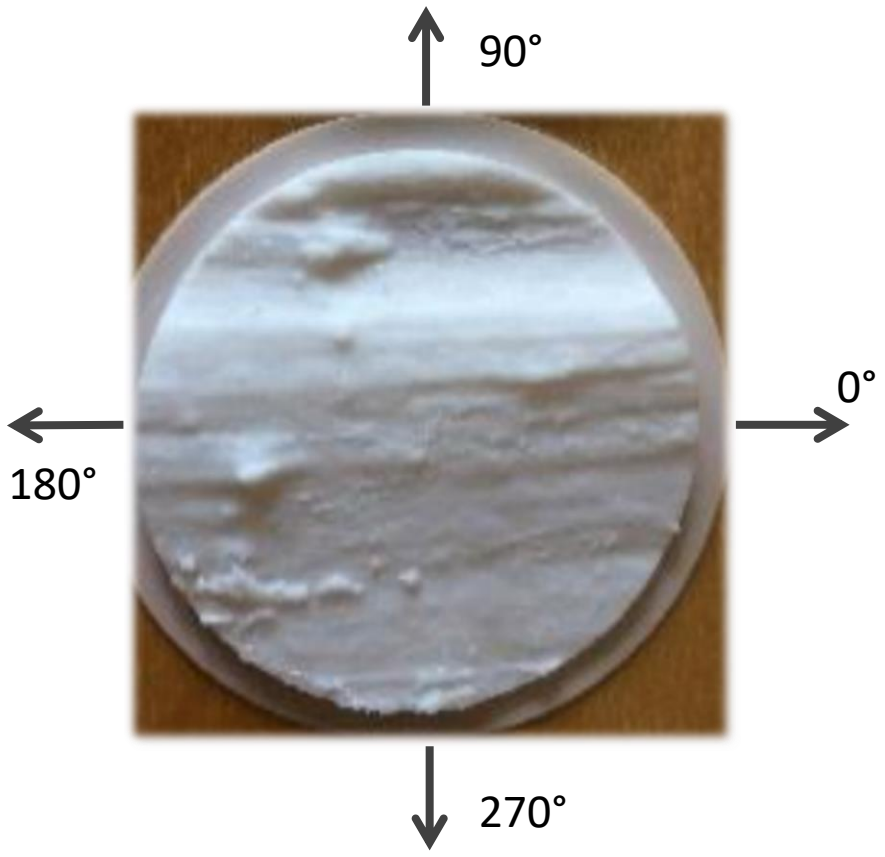


1. Plaster fault
2. Complementary surface  
(that was also printed and moulded)
3. Spring
4. Mechanical sliders

*A schematic of our set-up*

*$F_N$  is a normal applied force,  $F_T$  the tangential one,  
that is applied in a given direction of the fault plane.*

### Some results of frictional anisotropy



3D-print of the Nojima fault (Japan).  
The arrows correspond to given sliding directions during the friction tests, for which the coefficient of friction is summarized in the neighboring figure.

Coefficient of static friction  $\mu$  (blue) with error estimation (black)

## Take home ideas

- The **3D-printing of faults can help** to better characterize them.
- **Slip is easier to obtain along the direction of the main grooves.**  
(i.e., along the historical sliding direction of the fault)
- But **slip is possible in the other directions as well.**  
Thus, the next direction of rupture not only depends on the regional stress state, but also on the frictional anisotropy.
- Although we have here looked at the static coefficient of friction, such anisotropy might also impact the slip dynamics.

Thank you for reading

## References

Thibault Candela, François Renard, Yann Klinger, Karen Mair, Jean Schmittbuhl, and Emily E. Brodsky. Roughness of fault surfaces over nine decades of length scales. *Journal of Geophysical Research: Solid Earth*, 117 (B8), 2012. doi:10.1029/2011JB009041.

Thibault Candela, François Renard, Jean Schmittbuhl, Michel Bouchon, and Emily E. Brodsky. Fault slip distribution and fault roughness. *Geophysical Journal International*, 187(2):959–968, 11 2011. ISSN 0956-540X. doi:10.1111/j.1365-246X.2011.05189.x.

Thibault Candela and Emily E. Brodsky. The minimum scale of grooving on faults. *Geology*, 44(8):603–606, 08 2016. ISSN 0091-7613. doi:10.1130/G37934.1.

Marcello Campione and Gian Carlo Capitani. Subduction-zone earthquake complexity related to frictional anisotropy in antigorite. *Nature Geoscience*, 6: 847, 2013. ISSN 1752-0908. doi:10.1038/ngeo1905.

A. E. Filippov, G. Westhoff, A. Kovalev, and S. N. Gorb. Numerical model of the slithering snake locomotion based on the friction anisotropy of the ventral skin. *Tribology Letters*, 2018. ISSN 1023-8883. doi:0.1007/s11249-018-1072-4.

Yongmei Zheng, Xuefeng Gao, and Lei Jiang. Directional adhesion of superhydrophobic butterfly wings. *Soft Matter*, 3:178–182, 2007. doi:10.1039/B612667G.

A. Roth-Nebelsick, M. Ebner, T. Miranda, V. Gottschalk, D. Voigt, S. Gorb, T. Stegmaier, J. Sarsour, M. Linke, and W. Konrad. Leaf surface structures enable the endemic namib desert grass *Stipagrostis Sabulicola* to irrigate itself with fog water. *Journal of The Royal Society Interface*, 9(73):1965–1974, 2012. doi:10.1098/rsif.2011.0847.

Kejia Jin, Yu Tian, Jeffrey S. Erickson, Jonathan Puthoff, Kellar Autumn, and Noshir S. Pesika. Design and fabrication of gecko-inspired adhesives. *Langmuir*, 28:5737–5742, 2012. ISSN 0743-7463. doi: 10.1021/la204040p.

Nicolas Pionnier, Julie Vera, Elise Contraires, Stéphane Benayoun, Rémi Berger, and Stéphane Valette. The effect of the orientation and the height of periodic sub-micrometric texturing on dropwise condensation. *Journal of Colloid and Interface Science*, 526:184 – 193, 2018. ISSN 0021-9797. doi: https://doi.org/10.1016/j.jcis.2018.04.043.