Mechanics and physics of geological folds *via* sheet compression

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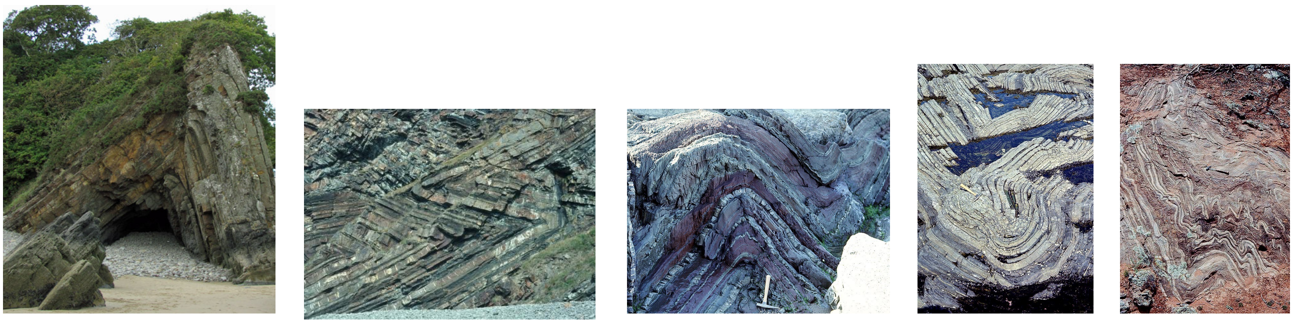
Summary

Typical length-scales of geological folds are widely distributed (from centimeters to kilometers) and their morphology is diverse. We will use mechanical and physical experiments to gain a better understanding of the formation of geological folds and figure out the elementary mechanisms that create them. Our approach is based on elastic plates as model systems, taking advantage of our past knowledge of slender structures. We will focus on a layer and/or multi-layers, immersed or not in a fluid, under compression and/or bending.



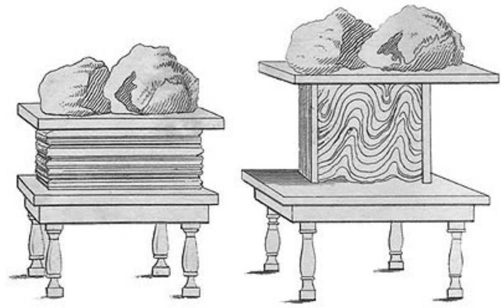
a) b) c) d) e)

Fig. 1 : Geological folds of different shapes and sizes in different regions [J. Talbot, www, 2014] : a-b) Great Britain. c-d) Quebec, Canada. e) Australia.

What complexity lies behind the variety of geological folds observed in nature (Fig. 1)? Does the wide distribution of scales typical of geological folds (kilometer, meter, centimeter) indicate the existence of different formation mechanisms? What are the minimum ingredients required to produce folds on all scales of the earth's soil and subsoil? Do tectonic stresses have to be multi-scale, characterized by spatial or temporal fluctuations, or do layers must have different or heterogeneous properties? Is the rheology of geological strata crucial to the morphogenesis of folds? What about geometry? Would the single constraint of non-interpenetrability of stacked layers, combined with an energy minimization criterion explain these phenomena?

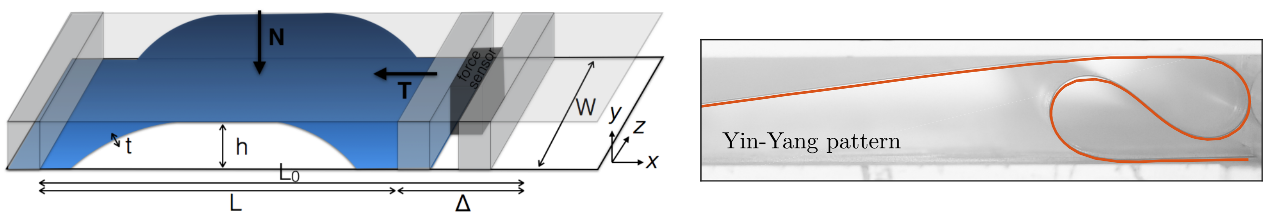
The first laboratory studies (Fig. 2) of geological folding date back to the early 19th century [Hall 1815, Ranalli 2001, Graveleau et al 2012, Nabavi and Fossen 2021]. James Hall was one of the first laboratory experimenters in the Earth Sciences, who used fabrics as a model system. However, the elementary physics and mechanics underlying the phenomena he studied have received little attention. Other studies have focused on the longitudinal compression of a single layer of material. More often than not, the materials involved are fluids, and the rheology of the layer is modified: viscous, plastic, granular, as well as certain combinations of the above (visco-plastic, elasto-viscous, elasto-plastic). However, the elastic or geometric contribution has not been studied, nor the case of a stack of layers [Hunt 2011, Badr et al 2021, Chai and Moshkovitz 2022, Guerra et al 2023].

Fig. 2 : J. Hall's first experiment in 1815 using fabric pieces [Hall 1815].



The internship will focus on the compaction of thin plates in a uniaxial compression device (Fig. 3a). The existing experimental set-up, which can be improved, has enabled us to demonstrate spontaneous plate instability and localization of deformations in the form of a Yin-Yang pattern (Fig. 3b) [Deboeuf et al 2023], after a finite number of more classical buckling instabilities in the form of quasi-periodic patterns [Roman and Pocheau 1999]. We will explore the regime of large and very large compressions, measure the forces developed and characterize the different morphologies observed, for which statistical physics can be used to quantify the disorder in the system [Deboeuf et al 2009, Adda-Bedia et al 2010].

As the internship progresses, we will gradually introduce additional ingredients, such as multi-layers and the presence of a fluid. Depending on the trainee's skills, we will be able to balance the role of experimentation and theoretical or numerical modeling. Several fields of physics and mechanics will be covered in this internship at the interface with earth sciences. The internship may be extended by a PhD thesis, for which the candidate will be able to apply for a doctoral contract from the doctoral school (ED SMAER).



a) b)

Fig. 3 : a) Scheme of experimental uniaxial compression of a plate under confinement [Deboeuf et al 2023]. b) Yin-Yang pattern obtained at moderate compression [Deboeuf et al 2023].