IMA9 - 9th Conference of the International Marangoni Association
August 31 – September 5, 2018
Guilin, China

Cohesion of natural cave sediments in the presence of thin liquid films

Perrine Freydier [1], Frédéric Doumenc [1, 2], Jérôme Martin [1], Béatrice Guerrier [1], Pierre-Yves Jeannin [3]

[1] Lab. FAST, Université Paris-Sud, CNRS, Université Paris-Saclay,
Bâtiment 502, Campus Universitaire, F-91405, Orsay France
perrine.freydier@u-psud.fr
[2] Sorbonne Universités, UPMC Univ. Paris 06, UFR919
F-75005, Paris, France
[3] Swiss Institute for Speleology and Karstology (SISKA)
La Chaux-de-Fonds, CH-2301, Switzerland

Vermiculations are small aggregates (a few centimetres long typically) made of particles (clay, calcite, minerals, organic matter, prehistoric paintings…) present at the surface of cave walls. When particles agglomerate, due to mechanisms that we seek to understand, pigments of prehistoric paintings may be dragged with them, deteriorating irremediably these remains of the past (see Figure 1). Vermiculations have been observed in caves by speleologist community for 60 years. The related literature mainly reports descriptive studies based on field observations (Bini at al. 1978). Most authors mention the presence of thin liquid films at the walls, originating from percolation or condensation water, which can lead to mobilization, displacement and aggregation of particles forming vermiculations.

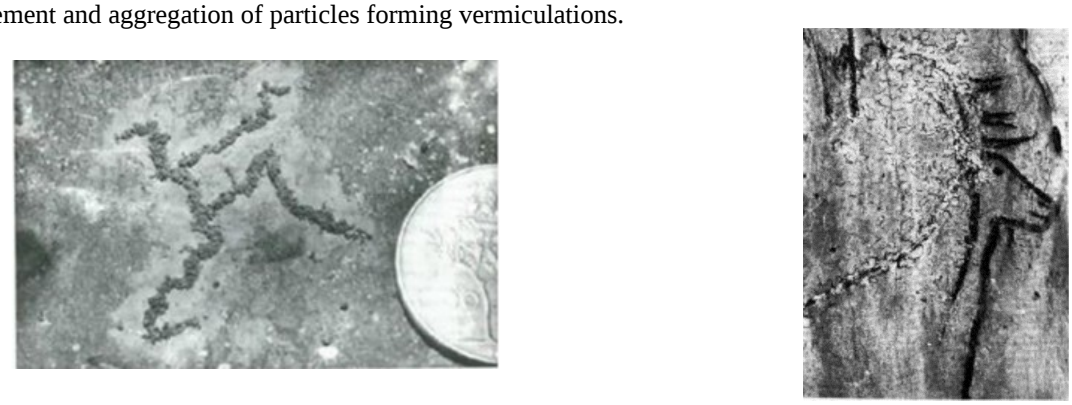

Figure 1: Example of vermiculations. Left: “Ramified vermiculation” (Bini et al. 1978); Right: Degradation of wall paintings in the cave of Niaux (Clottes, 1981).

To further assess and prevent the degradation of paintings due to vermiculations, a better insight into their mechanisms of formation is now needed. To date, no controlled experimental study tackled this issue. The aim of the present study is to find out the conditions required to mobilize sediments and form vermiculations, through experimental investigations coupled with field observations.

For our experiments, we use typical natural sediments collected in caves. Rheometrical analyses, performed with a rough-plate rheometer, show that these wet sediments exhibit a stress threshold, called yield stress, above which they flow as viscous fluids and below which they present a solid-like behavior. As a decrease of the yield stress of these sediments will lead to an easier mobilization by external forces (gravity, viscous friction due to water flow…), we believe that such a yield stress decrease is needed to form vermiculations. Our experiments consist in measuring the evolution of yield stress of typical cave sediments depending on conditions that sediments are expected to encounter in a cave environment. Sediments are immersed from 20 min to several weeks in pure water representing the condensation water, calcium carbonate saturated water representing the percolating water, or different chemical composition to test the influence of the ions in solution. Carbon dioxide partial pressure (pCO_2) is varied from 300 ppm to 10%, as in cave conditions, to study the influence of pH and dissolution of calcium carbonate on sediment cohesion. In a second experiment, a continuous and controlled flow of water is applied over the sediment. It aims at evaluating the cohesion decrease induced by the water renewal and at characterizing the effect of an additional hydrodynamic stress to the mobilization. These experiments provide an interesting dataset highlighting the evolution of cohesion of natural sediments through different water composition and pCO_2. Furthermore, the reproduction of vermiculations in laboratory is awaited to help qualifying degradation factors of cave paintings.

References

Bini A., Cavalli Gori M., Gori S. A critical review of the hypotheses on the origin of vermiculations. International Journal of Speleology 10 (1978), 11-33.

Clottes, J. Midi-Pyrénées. Gallia préhistoire 24 (1981), 525-570.