In situ optical measurements of water film thickness on caves walls and speleothems

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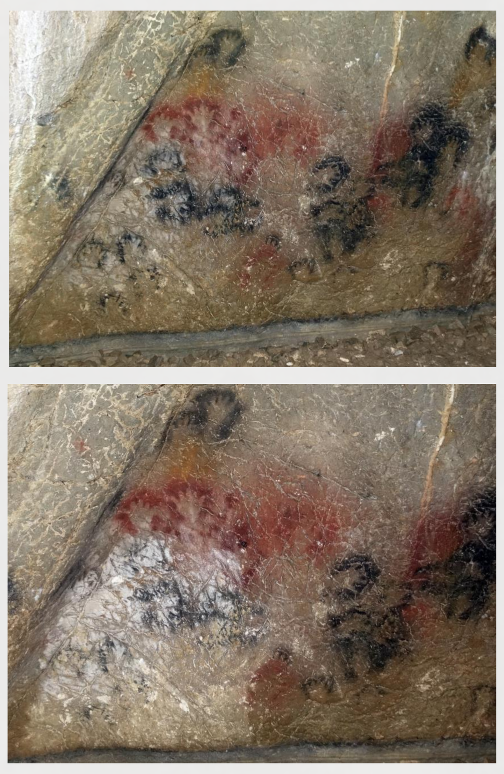
Background



- The risks of deterioration caused by climate change on cultural heritage sites are increasingly evident.
- Thermal disparities modify the internal aerology of a cave (Lacanette et al. 2009).
- A seasonal water film affects the wall conditions.
- To date, only very few tests of water film thickness measurements have been performed by weighing soaked blotting papers (J. Parmentier et al., 2019).

Figure.1| Seasonal formation of the white spots that partially cover the negative hands in the Gargas cave after the water film has dried.

Under these conditions, the film of water covering the rock paintings can either dry out or grow by condensation depending on the humidity of the cave air and the relative temperatures of the cave wall and the humid air. When the thin film of water evaporates, a carbonate precipitate is deposited on the wall. As the water film thickens, the pigments in the paint can be resuspended in the water and the paint undergoes a process of vermiculation, and may even be erased in extreme cases.

Caves sites

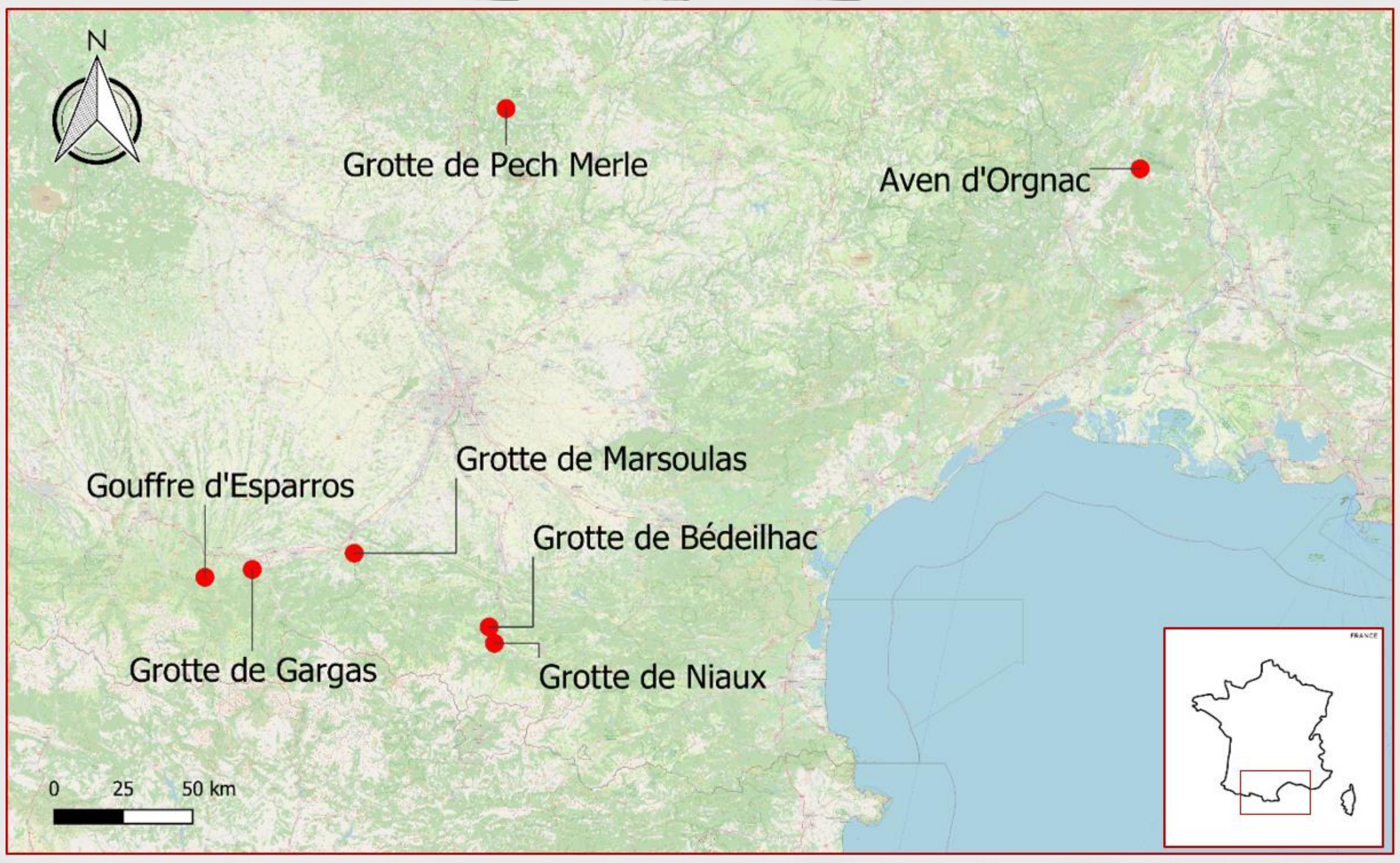


Figure.2| Map of the location of the sites studied for the measurement of water film.

Origin and interaction of water films in cave

On a cave wall, the water present can have several origins (**fig.3**). 1) Percolation through the fissural network of the karst and the porosity of the wall. 2) Condensation due to the thermo-hygrometric conditions of the underground air at the interface (humidity : 95 and 100%). To this must be added runoff from upstream, groundwater and capillary rise and spray (aerosols).

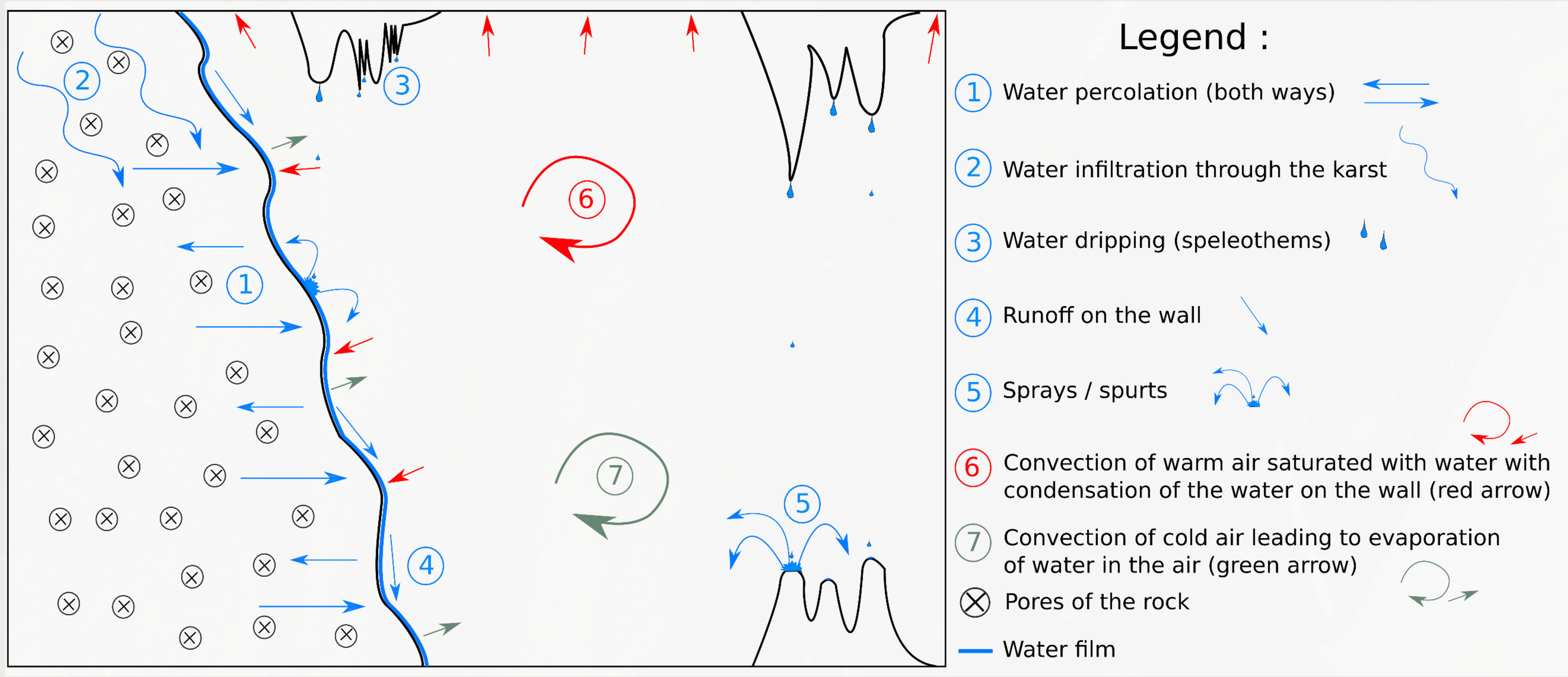


Figure.3| Diagram of the origins and interactions of water related to the film and associated microclimate

Methods

- First we need to choose a sensor capable to measure the water film thickness.
- The measurement required a list of specification :
  - Don't touch the wall
  - No modification of the natural condition
  - Dynamical measurement
  - Autonomous and transportable
- A contactless optical sensor, commercialized by Micro-epsilon was selected as the most suitable device.
- Resolution levels of 1 µm and a measuring range of 0 to 300 µm

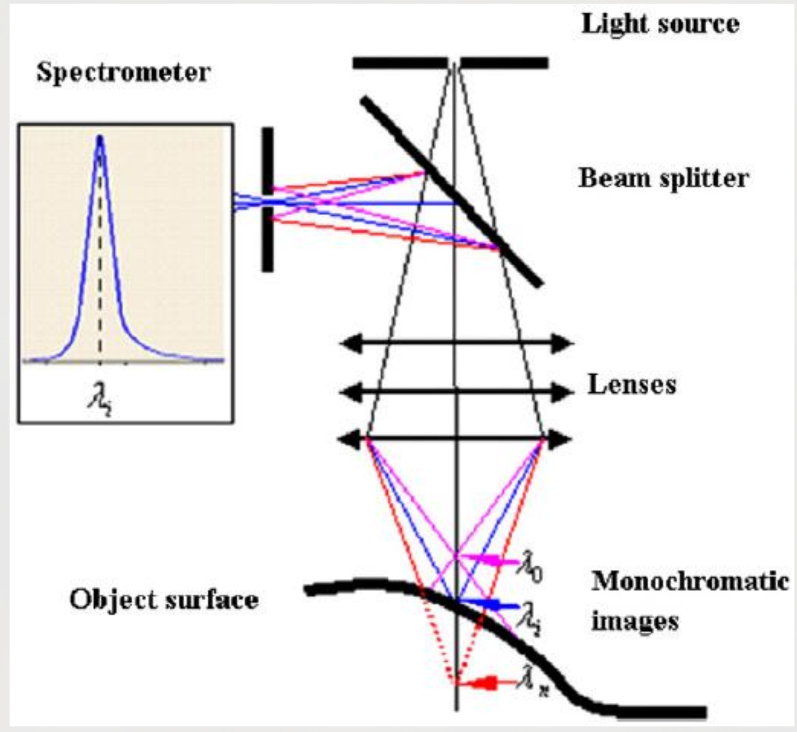


Figure.4| Confocal optical sensor measurement principle (Gong et al., 2011).

Preliminary laboratory tests performed on natural limestone surfaces, gave a range of measurable thicknesses from 25 to 220 µm (thickness sensor range begin at 15 µm; uncertainties of <±0.3 µm).

Wall painting results

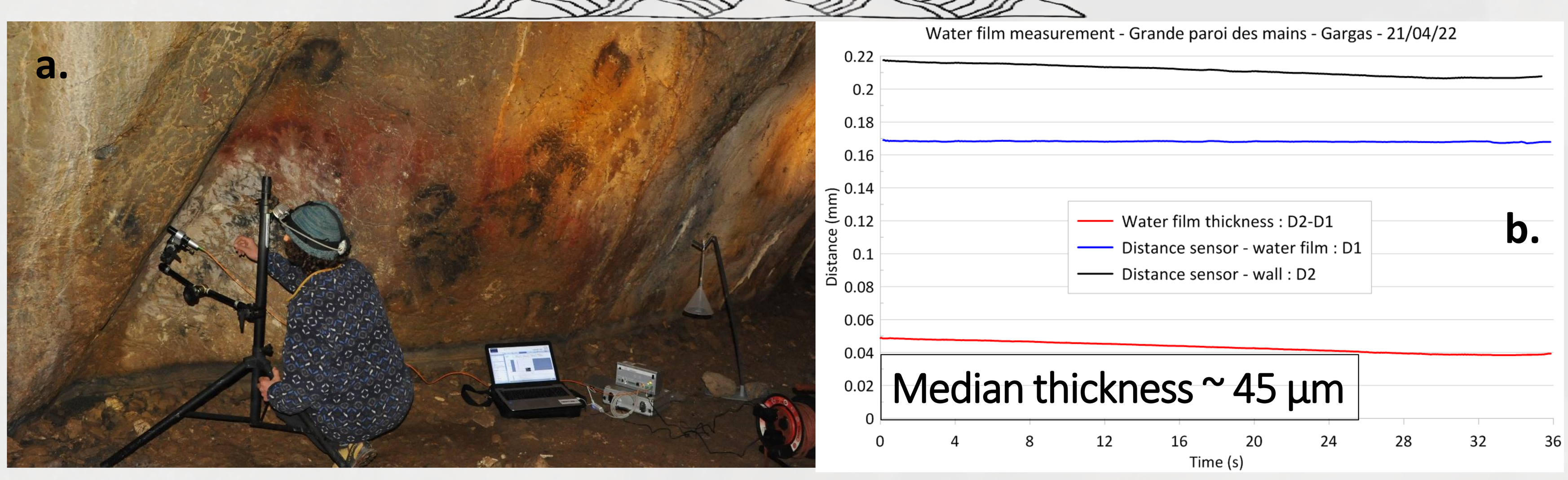


Figure.5 | Photo **a**. Device used to measure the water film on the "Grande paroi des mains". The different elements of the setup can be recognized here, the control unit, the computer and the sensor (from right to left). On the right, a piche evaporometer. **b**. Graph showing the profile of the distance data recording with calculation of the deduced thickness during 36 s at the wet area in the upper right corner of the white spot.

The measurement of the water film on the wall painting is a success. On the "Grande parois des mains" in Gargas cave, we were able to confirm the presence of the water film in the wet area and its absence in the white zone (**fig.5a**).

Speleothems results

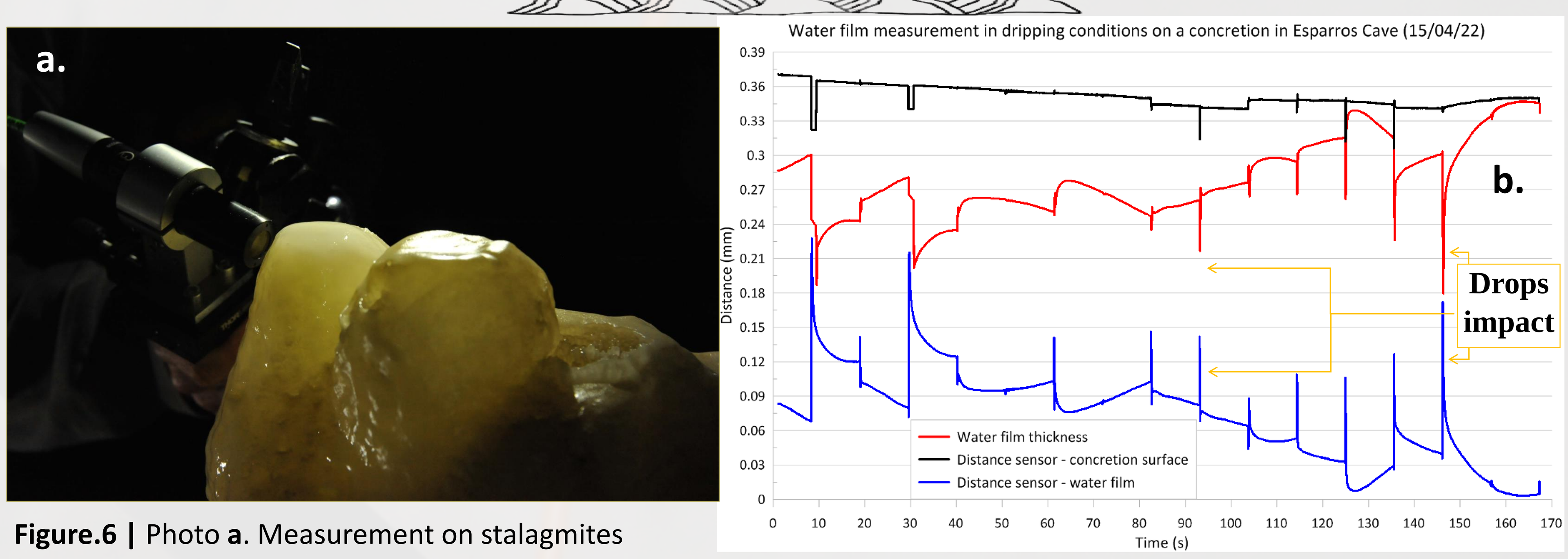


Figure.6 | Photo **a**. Measurement on stalagmites (Esparros cave), the shiny water film on the calcite can be seen. **b**. Graph showing the profile of the distance data record with calculation of the deduced thickness during 170 s. The yellow arrows show the drops impacts on the record.

An innovative experiment was carried out in the Esparros cave : the dynamic measurement of a drip on a speleothem. This proves that it is possible to record the ripples and impacts created by the drip above. It also confirms that the impact zone of the drops is large (**fig.6**).

Keys results

Table.1 | Water film measurements in decorated and concretionary caves in Occitanie

_	Pech Merle	Gargas	Esparros	Niaux	Marsoulas	Orgnac	Bédéilhac
Median water film thickness	~ 60 µm : calcite film	~ 45 µm & ~ 75 µm	~ 25 µm	~ 56 µm	~ 28 µm	~ 40 µm	~ 40 µm
Nature of the wall	Calcite on Limestone	Limestone	Limestone and calcite	Limestone	Limestone	Calcite	Limestone
Measurement stability	+	+ & +	- & +	-	=	=	-
Origin of water?	Cond.	Cond.	Cond. & Egt	Egt & Rlt	Cond.	Egt & Rlt	Cond. & Rlt

In spite of the variety of environments and supports (rock quality, variable wall conditions, alterations, calcite coverings, functioning concretions, active condensation), the measurement of water films was nevertheless generally possible on the cave walls. The results obtained show a certain homogeneity on the different sites with water film thicknesses between 30 and 50 µm for most of them (**Table.1**).

Perspectives

- The water film will become a new dynamically measurable parameter of caves environment.
- This experimentation may lead to the implementation of a new environmental monitoring tool for the conservation of the remains.
- The physics of the film that determines the water film opens up new paths of reflection.
- The application on speleothems and calcite film is also relevant.

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