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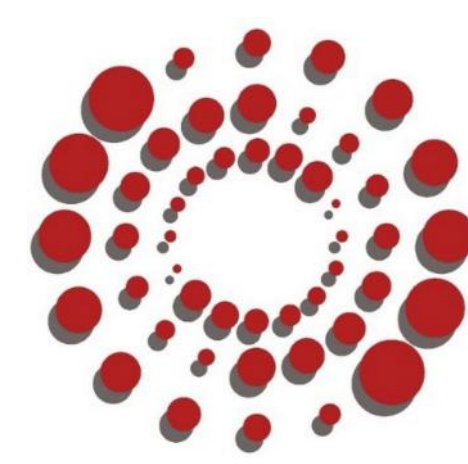
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La Venta Esplorazioni  
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# Late stage condensation-corrosion in high mountain marble cave (Val di Scerscen, Bernina Massif, Valtellina, Italy)

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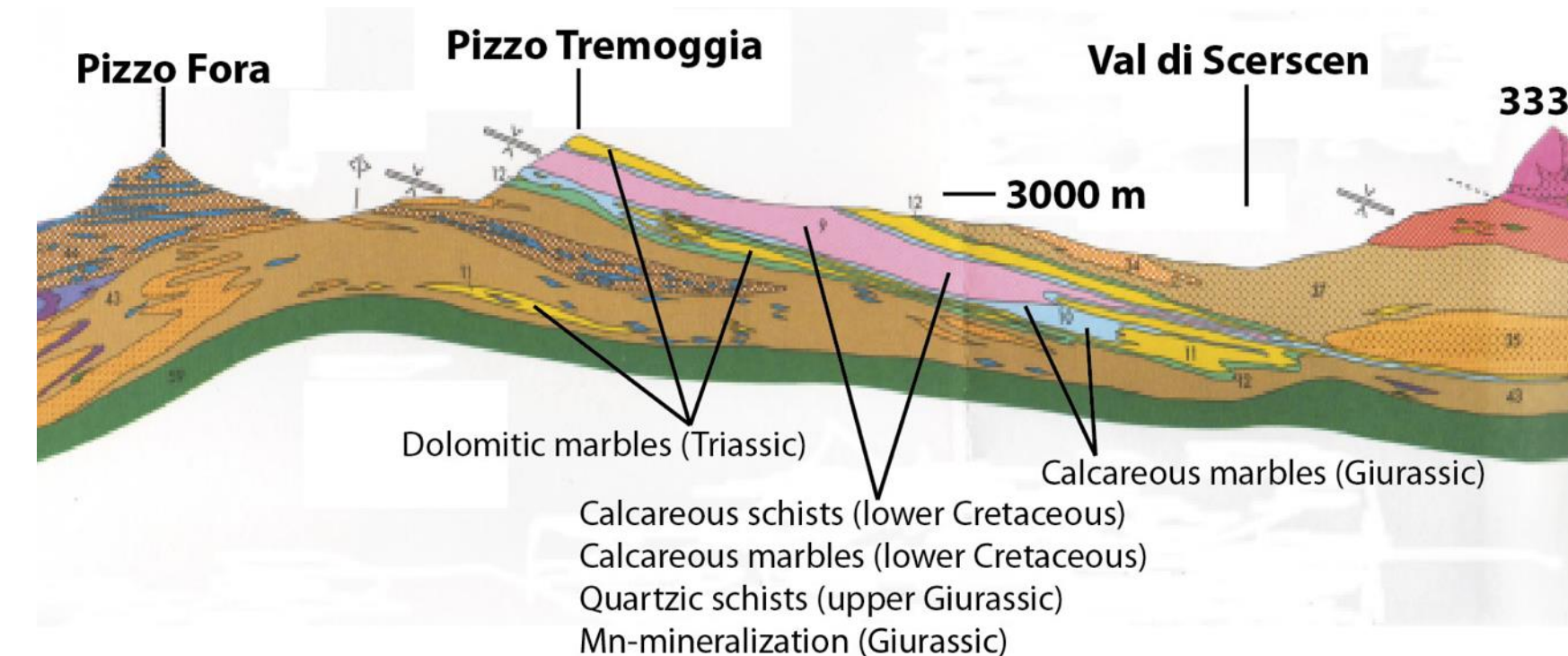
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## INTRODUCTION

Val di Scerscen is located in the Central Italian Alps (Northern Lombardy), in the scenic setting of Valmalenco. This area is not very rich in caves, especially due to the abundant presence of oceanic metamorphic rocks, which were uplifted during the Alpine orogenesis, dominate the terrains. A thin lens of whitish dolomitic marbles belonging to the Austroalpine Margna Nappe (on the geological sketch represented by pink, light blue, and yellow colors) hosts a few short caves, right at the end of the tongue of the Scerscen glacier, on the southern slopes of Bernina Piz. This glacier and its meltwater probably strongly contributed to the cave evolution. The most important caves, opening at about 2600 m asl, are: Veronica cave (length: 638 m), Morgana cave (348 m), and Tana dei Marsooi (77 m). These are typical epiphreatic caves with juvenile pattern and with adjustment to the water table (Audra and Palmer, 2013), according to the glacier evolution and to the valley incision. With the important retreat of the glacier during the Holocene, the processes of cave evolution have changed. The runoff provided by the glacier became less and less important and the drainage changed with the migration of the tongue of the ice cover. Today, the groundwater flow is mainly active during spring due to snow melting on a restricted catchment. The underground climate is characteristic of alpine caves, with a low mean temperature.



Veronica, Morgana and Tana dei Marsooi caves open along the Insubric line of the central portion of Alpine chain, in Val di Scerscen, Bernina Massif, Valmalenco, Italy.

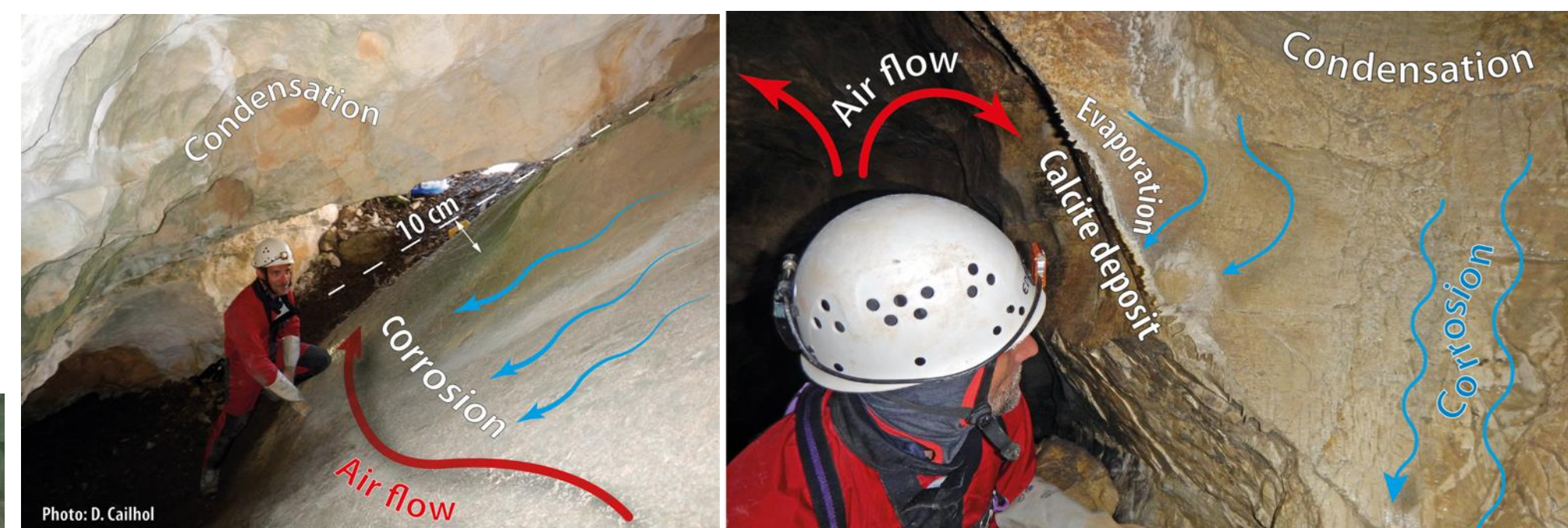


## GEOMORPHOLOGICAL OBSERVATION



Panoramic view of Bernina Massif (photo Didier Cahiol)

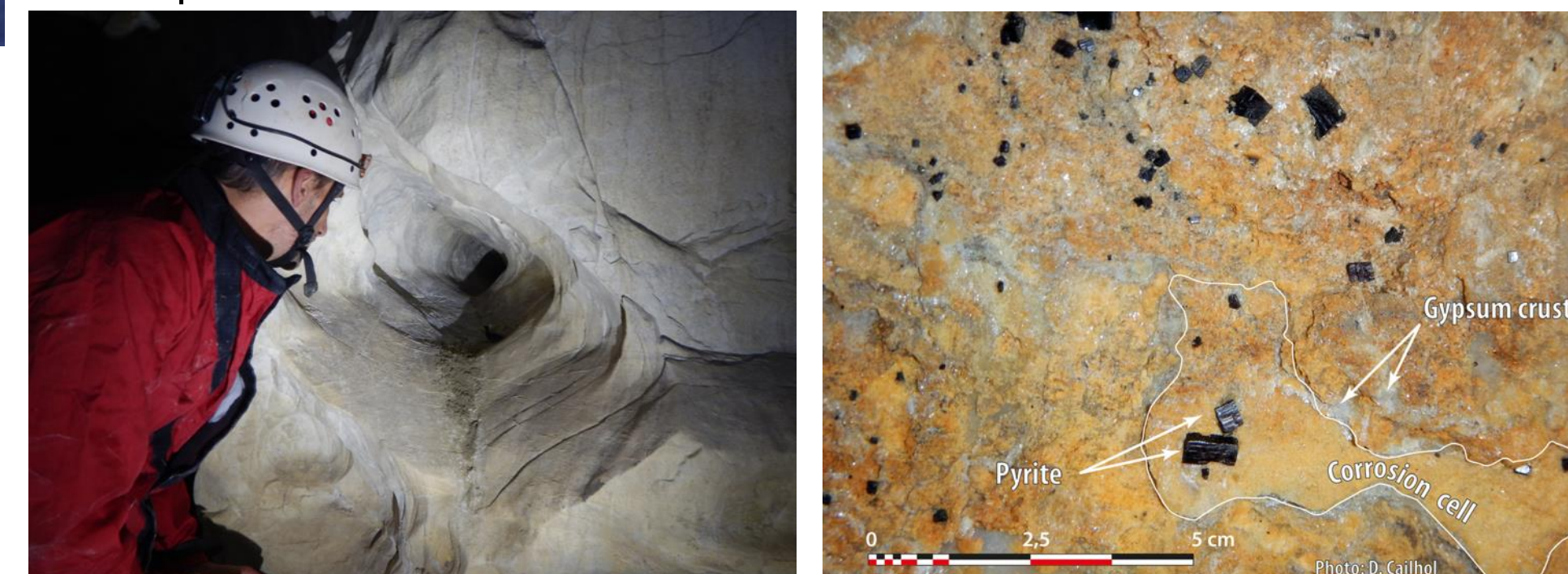
Condensation-corrosion processes (James, 2013) presently have a major control on the morphology of the cave passages. The shape of walls and ceilings has changed with the aerosol circulations according to the gradient of temperature between the cave and the exterior. Consequently, condensing waters carved smooth reliefs, notches and bell holes.



Condensation-corrosion features well-visible in Veronica Cave (photos Didier Cahiol).

The air circulation in Veronica Cave is driven by exchanges with the underground and surface through the epikarst. Air flows are important especially during winter and summer due to the temperature differences between cave and surface. During the spring and summer, the rate of humidity is high, due to snow melting in altitude, whereas during the winter time, the presence of snow cover and the surficial cold temperature cave atmosphere becomes dryer (Badino, 1995, Lismonde, 2002). In such a high-altitude karst, condensation-corrosion processes have a major impact on the cave morphology. Condensation is possible only if the temperature of the cave walls is below the dew point of the air (Gabrovšek et al., 2010).

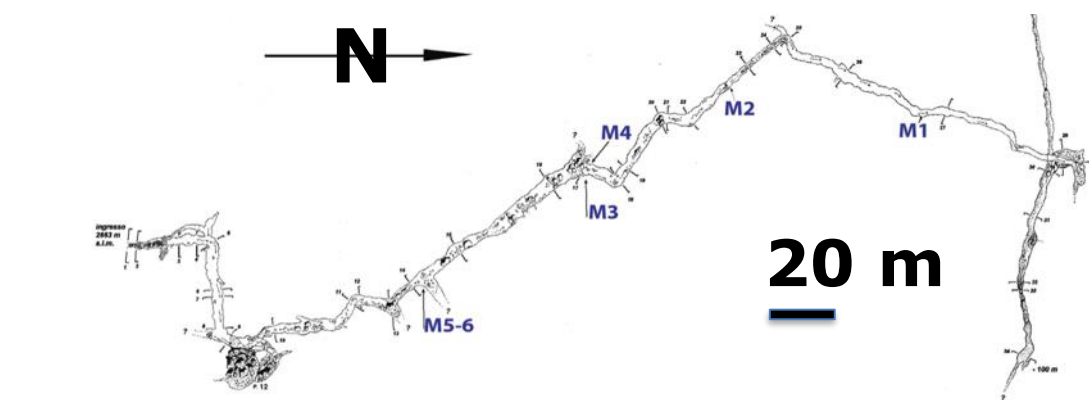
With the retreat of the ice cover of the Scerscen glacier, the cave evolution is now dominated by the condensation-corrosion (CC) dynamic as shown in the pictures above.



Left: circular conduit due to condensation-corrosion processes in Veronica Cave (Photo Didier Cahiol). Right: Cubic pyrite crystals, gypsum crusts and condensation-corrosion structures (Photo Didier Cahiol)

## VERMICULATION DEPOSITS AND SAMPLING

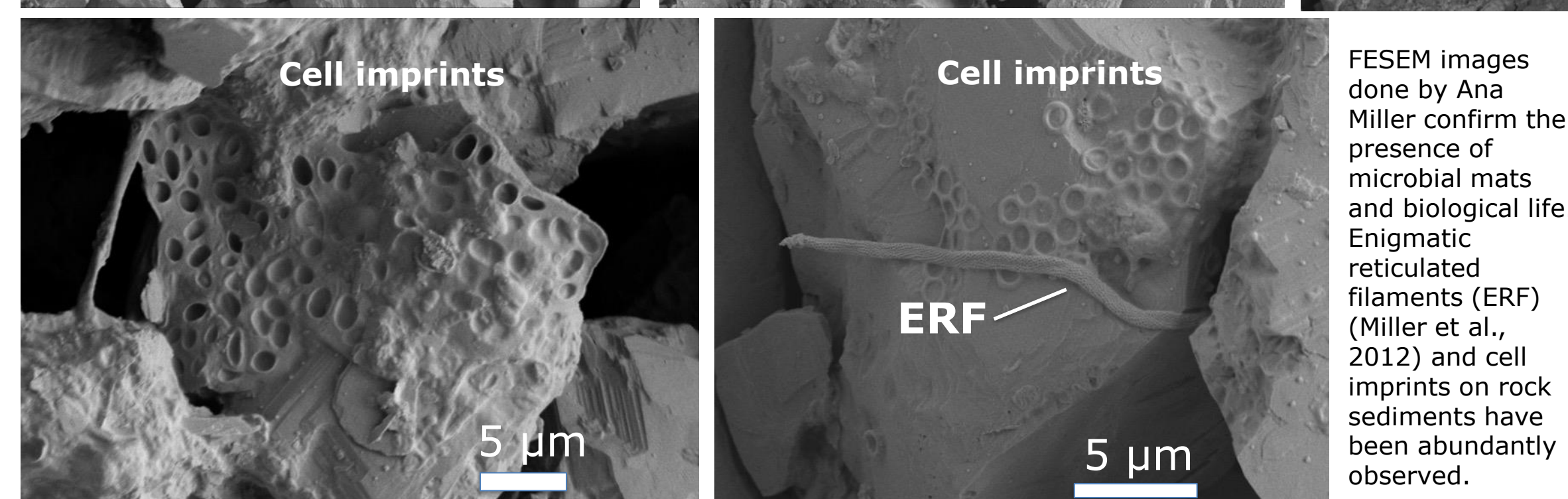
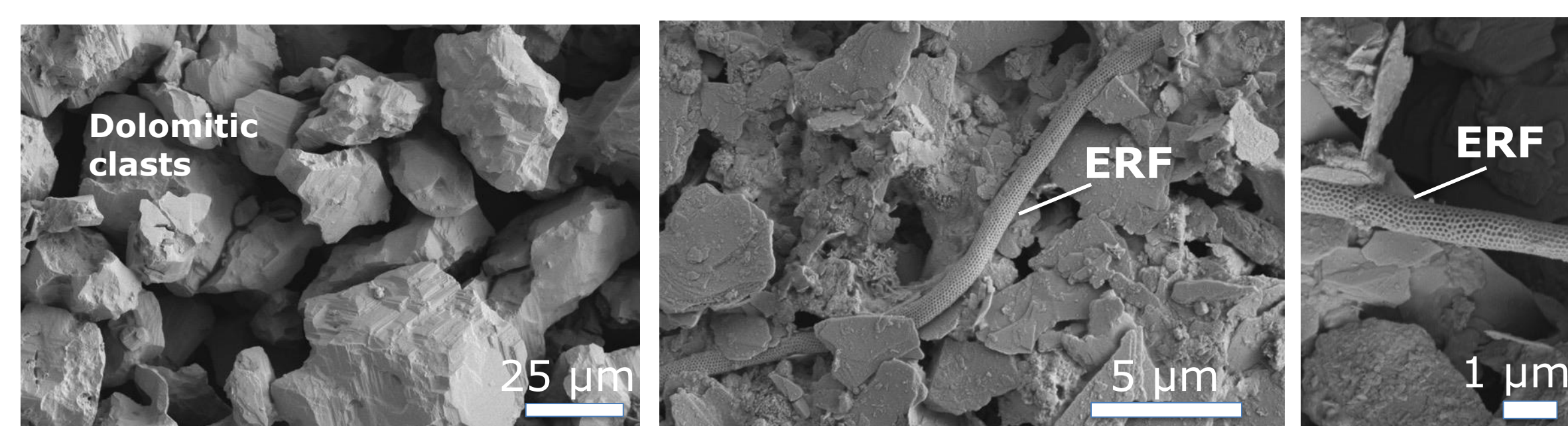
Vermiculations are thin, irregular and discontinuous deposits of incoherent particles, commonly found on the walls and ceilings of natural or artificial underground environments. Generally, they exhibit several kinds of morphologies (*i.e.* dots, dendritic, hieroglyphic...), colors (red, brown, grey, white) and dimensions (D'Angeli et al., 2017; Parenzan, 1961; Hedges, 1993; Bini et al., 1978). Vermiculations have been described in different caves around the world and are thought to be indigenous materials of underground environments. However, their genesis is still uncertain, but various theories have been proposed. They were collected in different sites of Morgana Cave (from the innermost part M1 towards the outermost zone of the cave in M5-6) and studied by DNA-based molecular biological analysis and field emission scanning electron microscopy at the IRNAS-CSIC (Seville, Spain). All the samples are dominated by dolomite clasts, whereas clay minerals are abundant only for the greyish and brownish vermiculation deposits



On the left is shown the survey of Morgana Cave made by Paola Tognini, Gruppo Grotte Milano. The six sampling sites from the innermost M1 to the outermost zone M5-M6 have been indicated on the survey.



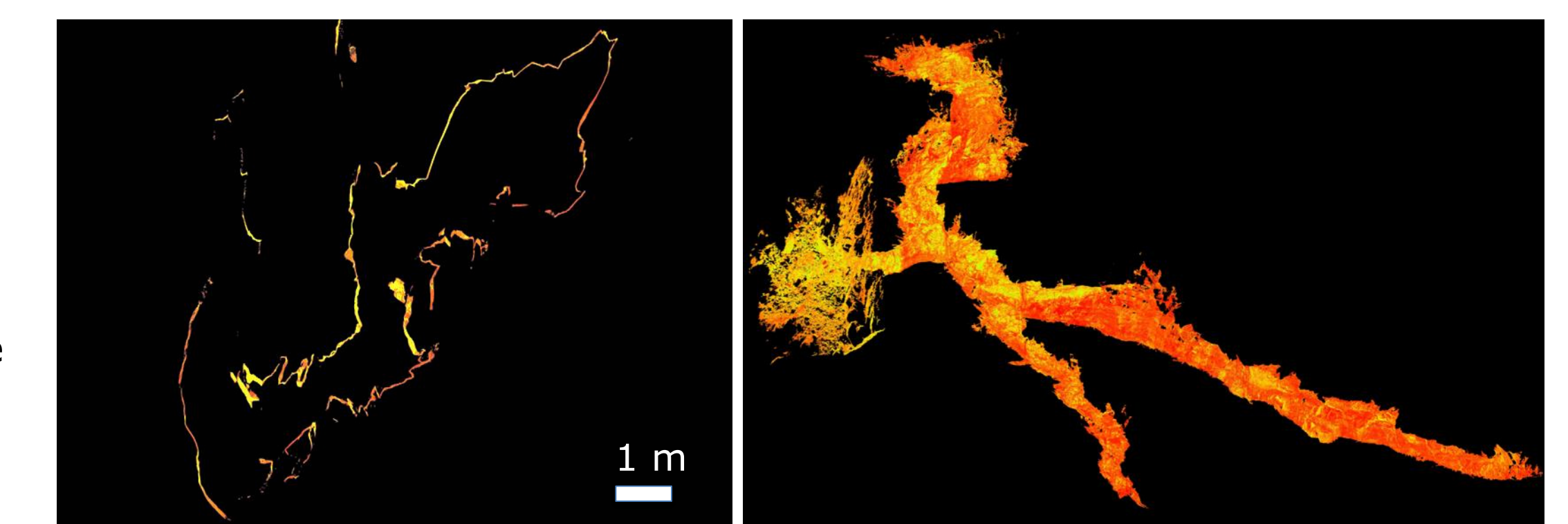
Vermiculation deposits collected from the walls of Morgana Cave (photos Mauro Inglese). They present different shapes and colors such as whitish, brown, and greyish.



FESEM images done by Ana Miller confirm the presence of microbial mats and biological life. Enigmatic reticulated filaments (ERF) (Miller et al., 2012) and cell imprints on rock sediments have been abundantly observed.

## CONCLUSION

Thanks to the collaboration with Leica Geosystems Italy, it has been possible to test, for the first time in a cave, two new 3D mapping instruments: the "BLK360" laser scanner, the smallest and lightest of its kind weighing only 1 kg, and the "Pegasus Backpack", a mobile mapping system which allows making a 3D scan of the environment by simply walking around. The data allowed creating 3D models of the Veronica cave which can be used both for morphological analysis and for virtual tours with educational purposes.



Left: A representative cross section from Veronica Cave. Right: Three-dimensional model of Veronica Cave. The images have been obtained using Leica BLK360 (credits Marco Formentini).



Left: Phreatic conduit in the lower part of Morgana cave, actually cut by a small stream (photo Mauro Inglese). Right: Photogrammetric reconstruction of the phreatic conduit showed in the picture on the left

Val di Scerscen caves are amazing underground environments located in an amazing setting, considered of difficult access for tourists, which, indeed, contributes to promote still pristine and uncontaminated conditions. Veronica, Morgana, and Marsooi caves represent very interesting systems from both pure geological-geomorphological and microbiological standpoints. All the observation carried out during the field, allowed us to clarify their speleogenesis, that before was uncertain. As a matter of fact, they were thought to be hypogene caves (De Waele et al., 2014). Geomorphological features confirmed the last stage of cave formation to be due to condensation-corrosion processes, related to air flows.

Ongoing studies are focused on: (i) long term processes (U/Th dating on calcite crusts, cosmonucleide dating on quartz pebbles); (ii) current physical processes of condensation-corrosion, comprising microclimatic monitoring and in situ exposure of limestone tablets, (iii) sequencing of microbial communities from vermiculation deposits, (iv) assessment of microbially mediated corrosion.

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