

An ecological investigation on lichens and other lithobionts colonizing rock art in Valcamonica (UNESCO WHS n. 94) addresses preventive conservation strategies

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Supplementary materials

Figures S1-S4

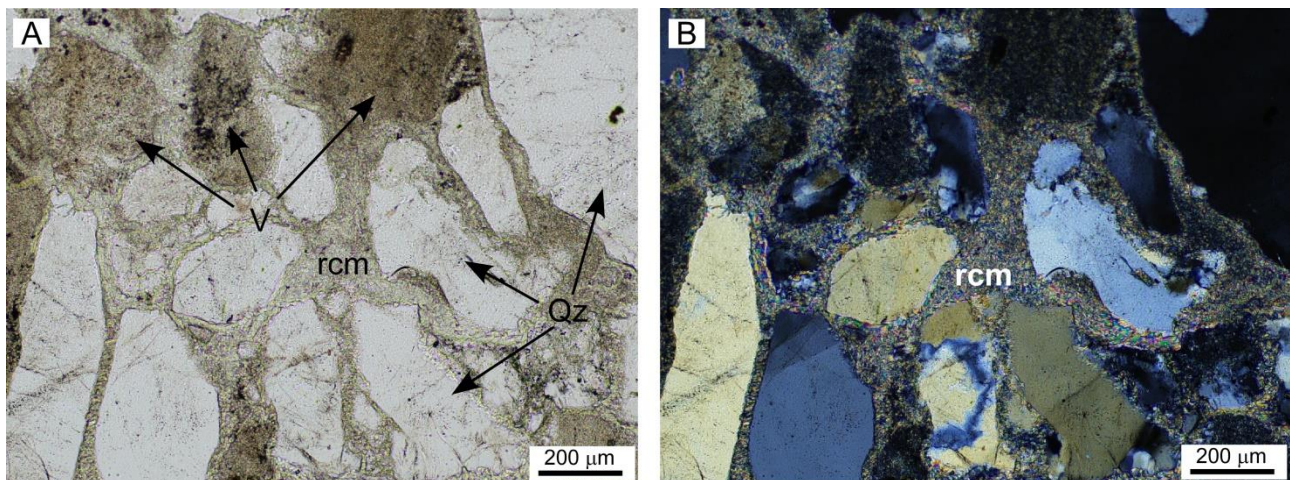


Fig. S1. Photomicrographs in plane polarized, transmitted light (a) and crossed polars (b) of a sample of a medium to coarse grained sandstone of the Verrucano Formation at Naquane. Limpid grains consist of mono- and polycrystalline quartz (Qz) whereas turbid grains are fragments of volcanic rocks (V). The original intergranular clay matrix is clearly recrystallized (rcm). Note the absence of porosity which, together with the recrystallization of the clay matrix, gives a great compactness to the rock.



Fig. S2. Lithobiontic colonization on Rock 70* (A) in November 2017, three years after the cleaning intervention in 2014, (B) in October 2019, three months after the last cleaning intervention, at the time of the construction of the protective wall, (C) in March 2021, 20 months after the last cleaning intervention, and (D) in November 2022, 40 months after the last cleaning intervention, when a surface darkening is visible in the right, unprotected side of the outcrop, while the left side, protected by the wall (renewed in Summer 2022), still maintains a clean condition.

*Rock 70 is one of the most famous of the Park because of the engraving of Celtic god Cernunnos, is approx. 4.5m × 3.3m; the smooth, west-facing surface shows inclination in the range of (20)-30-(40)°. Three restoration interventions were documented from 1980s to 2017: the first one was carried out in the period 1984-1986 and included the removal of lichens and mosses with a scalpel and the application of the biocide Lito3 (fluometuron; Ciba-Geigy); the second was conducted in 2005 and included the mechanical removal of lichens and mosses, the application of the benzalkonium chloride based biocide Preventol R80 (3%), the cleaning of the microbial biofilm with the benzalkonium chloride containing detergent NewDes (5%) and the final application of the water repellent, fluorinated polymer Akeogard CO. A last cleaning was performed in 2014, using low-pressured water and the biocide Preventol R80.

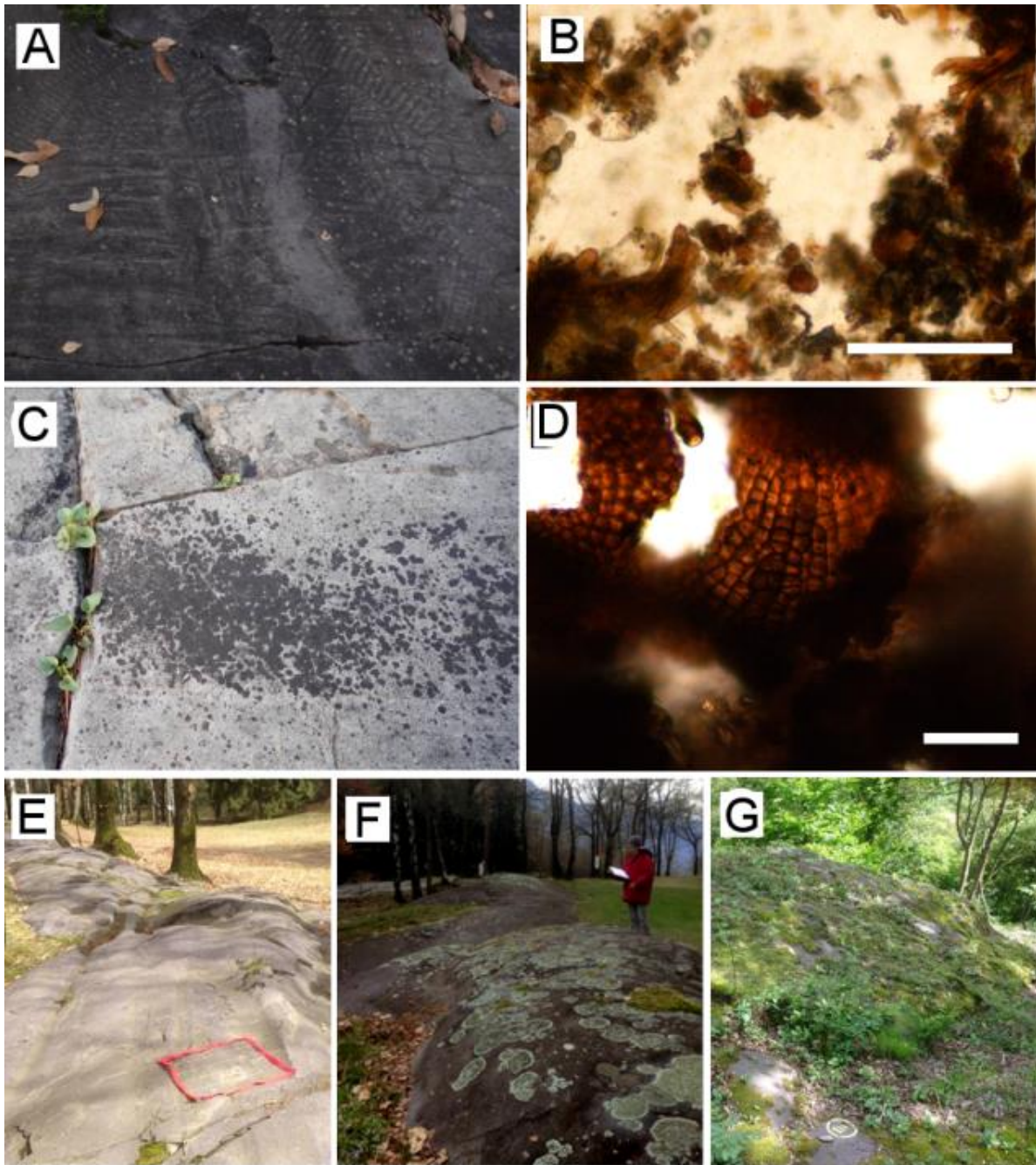


Fig. S3. Lithobiontic communities on the sandstone outcrops of the Rock Engravings National park of Naquane*. (A) Blackish biofilm dominated by filamentous and coccoid cyanobacteria (microscopic image in B, scale bar: 100 μm), with sparse thalli of *Fuscidea lygaea* (white dots) [3YC Rock 73 in 2017, last cleaned in 2014]; (C) meristematic fungi forming a macroscopic community (microscopic image in D, scale bar: 20 μm), not successfully removed in a recent cleaning intervention [3YC Rock 1 in 2017, last cleaned in 2015]; (E) greenish biofilm dominated by green algae [3YC Rock 99 in 2019, last cleaned in 2015]; (F) lichen and (G) moss dominated communities on rocks not cleaned (at least) after early 1980s.

*Lithobiontic colonization on the engraved rock outcrops in the site of Naquane was early mentioned as a disfiguring factor after the modern discovery of the Camunian rock art at the beginning of 20th century, specifying the widespread occurrence of cyanobacterial biofilms and the dominance of filamentous cyanobacterial forms (Battaglia 1934). Treatments which were once or repeatedly performed to limit lithobiontic presence on engraved surfaces and improve their legibility were not

registered until 1980s. Nevertheless, the widespread application of mechanical treatments combined with the use of common detergents (e.g. Spic and Span, Procter & Gamble), and/or followed by the application of techniques to highlight the engravings, is reported (Tratebas 2004 with refs. therein) and generally remembered in the Valley (Claudio Vaira, Direzione regionale Musei della Lombardia, personal communication).

Battaglia R (1934) *Indagini etnografiche sui petroglifi della cerchia alpina. Studi Etruschi 8, 11-48.*

Tratebas AM (2004) Biodeterioration of Prehistoric rock art and issues in site preservation. In: Seaward MRD and St. Clair LL (eds), *Biodeterioration of stone surfaces*. Dordrecht: Springer, pp. 195-228.

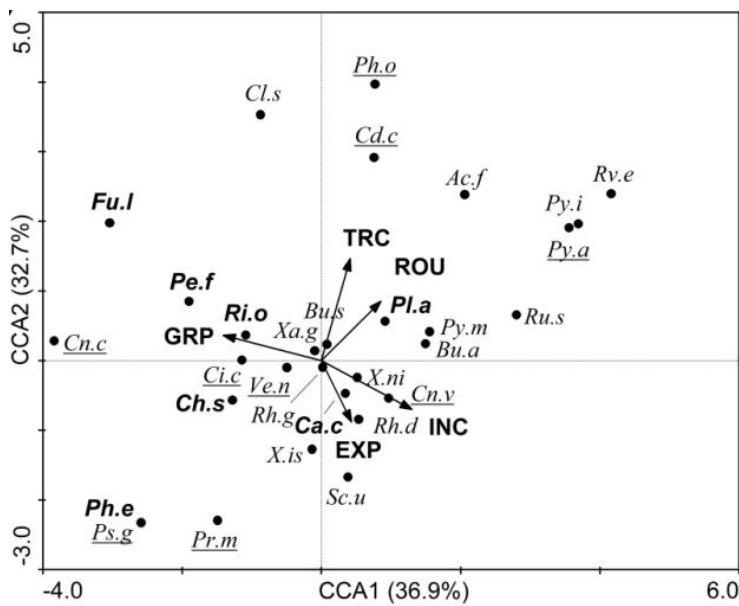


Fig. S4. CCA-II: contributions of lichen species to the plot ordination in Fig. 4B. Species Abbreviations of species and environmental factors in Table 1 and Fig. 4, respectively; nitrophytic species underlined, meso-hygrophytic species in bold.