

***Interactive comment on* “The origin and role of biological rock crusts in rocky desert weathering” by Nimrod Wieler et al.**

Nimrod Wieler et al.

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Dear Editor,

Please find attached a revised version of the manuscript, titled “The origin and role of biological rock crusts in rocky desert weathering”. We thank you and the anonymous reviewer for the constructive comments and appreciate the time you have invested in improving this manuscript. The changes to the manuscript include text changes that address the points raised by the reviewer. Thank you for the efficient review process. We will be glad to answer any further questions.

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Sincerely,

Roey Angel on behalf of all co-authors

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Comments by reviewer:

R: The origin and role of biological rock crust in rocky desert weathering“ by Wieler et al. is focused on the origin and role of rock biofilms in cavernous weathering in arid and hyperarid climate. Authors use multiple techniques to reveal the origin of biocrust and its effect on evaporation rate and thus weathering. Manuscript contains valuable information and its worth of publication.

The answer to questions 1-15 in review instruction is positive, except the critical comments mentioned below. Please take into account that I am not expert on DNA techniques nor on statistical processing of such data, so I can not reliably review chapters 2.6, 2.7 and 3.3 from biological point of view in required depth. These chapters seems to be however clear and makes sense to person from other scientific branch.

A: Thank you, we appreciate this feedback.

R: Page 1 line 12: It is unclear which portions of honeycombs or tafoni surfaces were sampled for biogenic rock crust (BRC). Was it the outer surfaces or hollows (cavities)?

R: Page 2 line 5: It seems that just outer surfaces are covered by BRC, but it is not clearly stated. It should be spelled our more clearly if BRC is missing in caverns or if it covers whole surface of tafoni.

A: Thank you for bringing this up. We sampled the outer surfaces of the cavities. The BRC is missing in the caverns since the caverns are the weathering fronts. The text was corrected in page 1 line 12: “We studied the origin and role of rock biofilms covering rock surfaces in geomorphic processes of limestone and dolomitic rocks that feature comparable weathering morphologies though originating from arid and hyperarid environments, respectively”. Correction was also done at page 2 lines 4-6: “Following the cementation processes, typical honeycomb features are formed on the exposed parent

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rock, typified by pits separated by thin walls that are coated by the calcrete or dolocrete and are absent in pits cavities”.

R:Page 1 line 32: Reference at the end of sentence is needed

A: Thank you, a reference for the ventifacts exists at line 33.

R: Page 2 line 26: Fungi and algae are reported as common constituent of BRC by Slavik et al (2017)-cited in document.

A: The reference was added to the manuscript.

R: Page 3 line 1: There should be few more sentences given on characterization of limestone and dolomite: sedimentation settings, diagenesis, lithology, whether these rocks act as aquifer or aquitard, into which degree the water from rain infiltrates to them vs. surface runoff dominates

A: Thank you, we presented detailed description of the subjected lithologies at the supplementary information (Table S1).

R: Page 3 line 4: Rather than P/PET 0.05-0.005 you should write this ratio for both studied localities respectively (to show the difference between them). This ratio is in one of supplementary tables, but it should be also directly in the text.

A: Correction was made in the manuscript in page 3 lines 3-4: “The Negev Desert, Israel, maintains arid to hyperarid conditions since the Holocene and has an aridity index (P/PET) of 0.05 for the arid region and 0.005 for the hyper-arid region (Amit et al., 2010; Bruins, 2012)”.

R: Page 3 line 10: These samples were taken from 1) narrow walls of tafoni, 2) hollows of tafoni, 3) outer surfaces, which are not covered by tafoni or 4) inner material below tafoni hollows? This should be clear. Similarly for each method used is important which of these four types of material you used.

A: All rock samples were taken from outer surfaces that cover cavernous features.

Correction was made in the manuscript in page 3 line 9: “Twenty-four rock surface samples were collected along rocky slopes facing northward, comprising”.

R: Page 3 line 29: You mention measuring of porosity in direction normal and perpendicular to bedding. This is good idea, but please report also results from both measurements (table 1). Currently the direction is not distinguished there. Measured samples were without crust, with crust or crust itself? It should be more clearly spelled out in this (and also other) method(s), whether the underlying rock or crust was tested! If crust was not measured it will be valuable to measure the crust as well and compare it to underlying rock.

A: Thank you for bringing this up. The porosity was measured on rock cylinders without crust, correction was made in the text in page 3 lines 29-30: “twelve rock core cylinder samples that their BRC was mechanically removed using a diamond saw (Dremel, Racine, WI, USA) to a depth of 5 cm”. Crust porosity was not measured due to technical limitations. The porosity values of the normal and perpendicular directions showed no bigger difference, therefore we unified their results.

R: Page 3 line 30: It is generally recommended to do about 20 readings by Schmidt hammer per single obtained value. Your 20 measurements per lithology means 20 readings (1 value) or 20 sites measured each by ?20? readings? Please specify. Also in further text you use “elasticity” (P5 L23), “surface penetration resistance”(Table 1). This cannot be measured by Schmidt hammer, but it could be possibly derived by some formula. Did you measure it by other device? (Please characterize the device) or did you calculated that from rebound value of Schmidt hammer (then please provide the formula and reference). The terms “penetration resistance” elasticity of material should be uniññed in text and tables, if they describe the same measured parameter.

A: The Schmidt hammer measurements contained 20 readings per single site, correction in the text is in page 3 line 34: “Twenty measurements were carried out for each

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site bearing different lithology”.

The values mentioned are the elastic rebound (R) measured by the Schmidt hammer. The terms were unified in the text as elastic rebound and corrected in the text in page 5 line 25-27: “To study the possible differences between these sites, we performed geological characterisation of 10 limestone and dolomite rocks collected from the arid and hyperarid sites, respectively, testing for mineral content, porosity, permeability and elastic rebound” and in table 1.

R: Page 4 line 4 and 6: really it was $\delta^{18}\text{O}$ in H_2O ? I would expect O in CO_2 gas not H_2O vapor. The sample is carbonate not water. Please check

R: Page 4 line 7 and 8: Really SMOW was used? All values seems to be referenced to PDB standard to me (Fig. 2). Please check.

A: Thank you, we checked it again, and corrected the in page 4 lines 6-11: ” Measurements (in duplicate) of $\delta^{18}\text{O}$ -calcite and $\delta^{13}\text{C}$ -DIC were performed on gas source isotope ratio mass spectrometer (GS-IRMS; Thermo Fisher Scientific, Waltham, MA, USA) coupled to a Gas Bench II interface (Thermo) after CO_2 equilibration or CO_2 extraction by acidification for $\delta^{18}\text{O}$ -calcite and $\delta^{13}\text{C}$ -DIC, respectively. The samples were calibrated against internal laboratory standards: carbonate standard NBS19. $\delta^{13}\text{C}$ values were referenced relative to Vienna PeeDee Belemnite (VPDB) standard as previously described (Uemura et al., 2016) with SD of 0.1‰. All values are reported in per-mil (‰”.

R: Page 4 line 17: What do you mean by “incubated”? bacteria were introduced to rock?

A: The Desiccation experiment included rock cylinders with and without BRC. No bacteria were introduced. The cylinders were simply dried at 44 °C (low temperature was used to protect the BRC). The term “incubated” is indeed misleading and was removed.

R: Page 5 line 16: “crusts were restricted to atmospherically exposed...” please

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change “atmospherically exposed” to more proper description. Do you mean that crust was missing in bottom of hollows? Or deeper below surface? This should be more clear.

A: Correction was made in the text in page 5 lines 18-19”: The weathering and presence of the crusts were restricted to the upper parts of the rocks (i.e., rock parts that are exposed to the atmosphere)”.

R: Page 5 line 17 vs line 19: Statement is not consistent. In first sentence you speak about weathering MORPHOLOGY in second you speak about weathering RATES. So if morphology is the same, this does not necessarily mean their rates are the same as well. I am afraid that this in fact not challenges the model.

A: Thank you for pointing this out. The manuscript aims to explain the presence of the same weathering morphology across different lithologies and different climates in comparison to common model that suggest different parameters which may affect weathering rates that leads to weathering morphology. The sentence was changed to “The presence of an identical weathering morphology and its prevalence in different climates and lithologies challenges the current model, which assumes that surface permeability, moisture and the presence of salts as primary factors control the weathering type and rates” in order to resolve this inconsistency.

R: Page 5 line 29-32: Text is unclear, please rewrite.

A: In lines 29-32 we note that the honeycomb weathering features results from the protective effect by the presence of the BRC and not from different mineral composition, as was previously suggested. The text was corrected in page 5 lines 34-39: “Presence of thin septa between the weathering pits was previously suggested to result of different mineralised networks or case hardening (McBride and Picard, 2004), however, detecting calcretes and dolocretes on limestone and dolomite, respectively, on the rocks’ surface reject this hypothesis.. In fact, the detection of mature calcretes and dolocretes could serve as an indication of atmospheric exposure but was also suggested to result

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from biogenic activity (Alonso-Zarza and Wright, 2010; Goudie, 1996).”

R: Page 6 line 35: “clogging the pores on the surface of the rock and thereby minimizing capillary rise”. This statement is confusing. In fact the smaller the pores, the higher the capillary rise. The reason why biota affects capillary water is not the diminishing the size of pores but the presence hydrophobic organic matter. So please mention rather hydrophobicity here as explanation.

A: We mention clogging effect as a result of the EPS originated by the biota. The desiccation experiment along with the different characteristics of the BRC note that small concentrations of EPS in the BRC are suggested to have a strong retarding effect on rock pores, thus effecting water movement through the rock. As a result the BRC mitigate crystallization of dissolved salts.

R: Page 6 line 42: Slavik et al 2017 reports DECREASE of hydraulic conductivity and capillary water absorption by 15-300 times and 2-33 times, respectively. So cited statement that BRC does NOT affects water transport rates is wrong. Only diffusion of water vapor was not effected by crust based on Slavik et al 2017. But in your case it could be the same situation: lowered evaporation is not necessarily due to low diffusion of vapor (only few if any well designed studies indicated that biocrust is capable even to affect vapor transport). Far more probably the decreased evaporation rate (which you observe on crust) is due to fact that capillary front is pushed below surface due to hydrophobic organic matter and thus diffusion occurs via more thick dry surface layer in case of BRC sample compare to bare rock core (longer diffusion path means far lower evaporation rate). Until the vapor diffusion is measured via BRC and bare rock and both rates are compared on your samples (e.g. by wet cup technique) it is impossible to say if evaporation rate is lowered by(i)lower diffusion rate or(ii)due to different geometry of capillary front. This will be very valuable to test.

A: Thank you for mentioning this, the text was corrected at page 7 lines 4-5: “Moreover,

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the obtained results performed on temperate sandy stones showed decrease effect of BRC on water transport rates (Slavík et al., 2017).”

R: Page 7 line 13: From which depth the samples were taken?

A: Soil samples were collected beneath the soil crust, at a depth of 5 centimeter. Correction was made at page 3 line 13: “Concomitantly, six soil samples (ca. 500 g each) were collected at a depth of 5 cm beneath surface, half from the arid (named: SBSoil 1-3) and a half from the hyperarid (named: UVSoil 1-3)site”.

R: Page 8 line 28 and 29: Sentence not clear. “...composition and function.” of what?

A: Correction was made in the text in page 8 lines 28- 33: “The two BRCs did differ in their bacterial communities at the OTU and higher taxonomical levels, demonstrating a discrepancy between microbial communities composition and function”.

R: Page 9 line 4: please specify which “microscale conditions”

A: Correction was made in the text in page 9 line 10: “The results presented here suggest that in arid environments, microscale climatic conditions determine the magnitude of weathering that shape the landscape”.

Technical corrections:

R: Page 1 line 13: replace “hard lime” by “limestone”

A: Correction was made in page 1 line 13: “We studied the origin and role of rock biofilms covering rock surfaces in geomorphic processes of limestone and dolomitic rocks”.

R: Page 3 line 12: if UVSoil had 3 samples, there should not be “UVSoil 1-12” but rather“1-3”

A: Correction was made in page 3 line 14: “half from the arid (named: SBSoil 1-3) and

a half from the hyperarid (named: UVSoil 1-3)".

R: Page 4 line 10: Use rather “Evaporation experiment” then “Desiccation experiment”

A: We used the term desiccation because the term evaporation does not include heating from an outer source as was conducted in this experiment.

R: Page 5 line 12: replace “weathering features” by “Cavernous weathering features” to be clear which weathering features you mean

A: We specify the cavernous weathering features out of many other weathering features found in rocky desert outcrops.

R: Page 6 line 8: please replace 2.5 Ga by 2.5 Ma

A: Correction was made in page 6 line 11:” The low ratio detected here (Fig 2A) and by Vaks et al. (2010) suggest that the Negev region has been able to support only limited vegetation for at least 2.5 Ma”.

R: Page 6 line 14: there should be rather “In” then“ between”. The sentence is not much clear (it is unclear if values are concerning BRC, underlying rock, or both; but clearly not the boundary between them - Fig 2).

A: Thank you, the text was corrected at page 6 line 21.

R: Fig. 2: please add PDB standard to horizontal axis of $\delta^{13}C_{org}$.

A: Thank you, the figure was corrected.

R: Fig. 3: please replace “desiccation” by “drying”

A: Thank you, the figure and the text was corrected.

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