MICROSTRUCTURAL INVESTIGATIONS OF SOILING PROCESSES IN DESERT LOCATIONS

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PV-Days 2017

Halle, 2017/10/25

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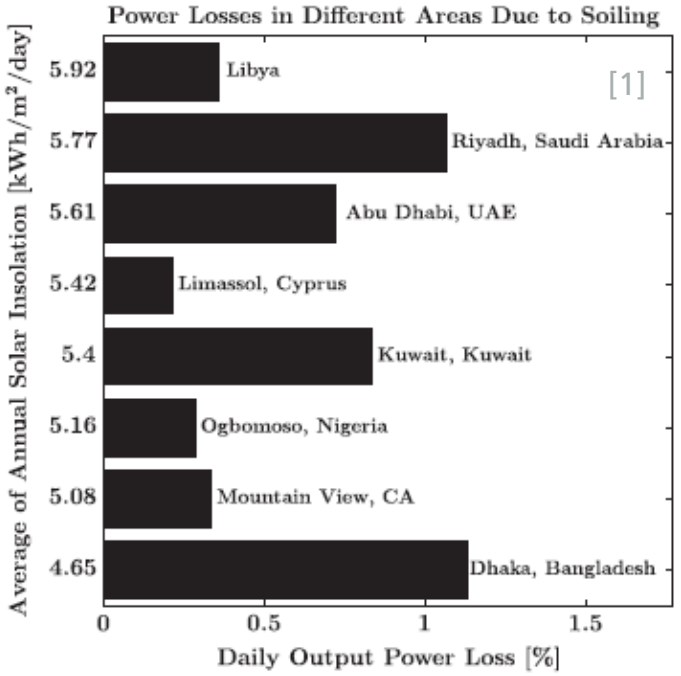
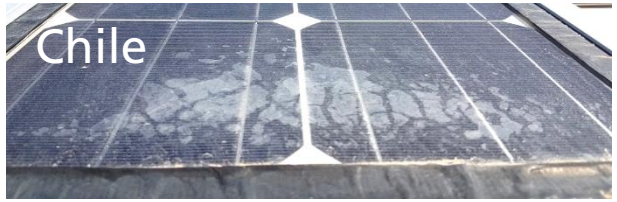
Motivation

- Large differences in soiling rates for different locations [1]
  - Main influencing factor: airborne dust concentration [2]
    - → hardly influenceable
- For optimization of mitigation strategies also type of soiling & cementation important factors
  - Cleaning methods (wet/dry)
  - Anti-Soiling-Coatings (surface chemistry, structure)

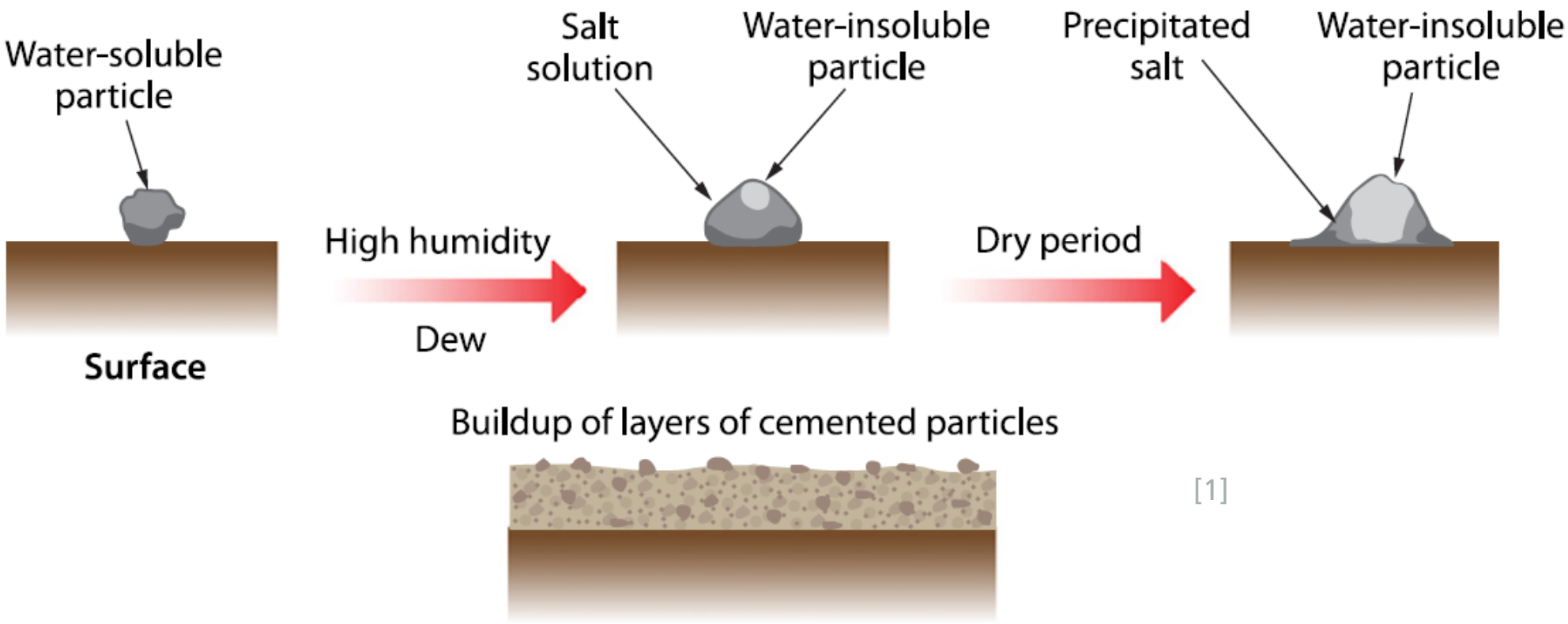
Understanding of soiling and cementation needed on a microstructural level





[1] Sayyah et. al. (2014): "Energy yield loss caused by dust deposition on photovoltaic panels" Solar Energy 107, p. 576–604.
[2] Micheli, Muller (2017) "An investigation of the key parameters for predicting PV soiling losses" Prog. Photovolt: Res. Appl. 25, 4, p. 291–307

Cementation process
Model



[1]

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[1] Sarver at al. (2013): *Renewable and Sustainable Energy Reviews* 22, S. 698–733. DOI: 10.1016/j.rser.2012.12.065.

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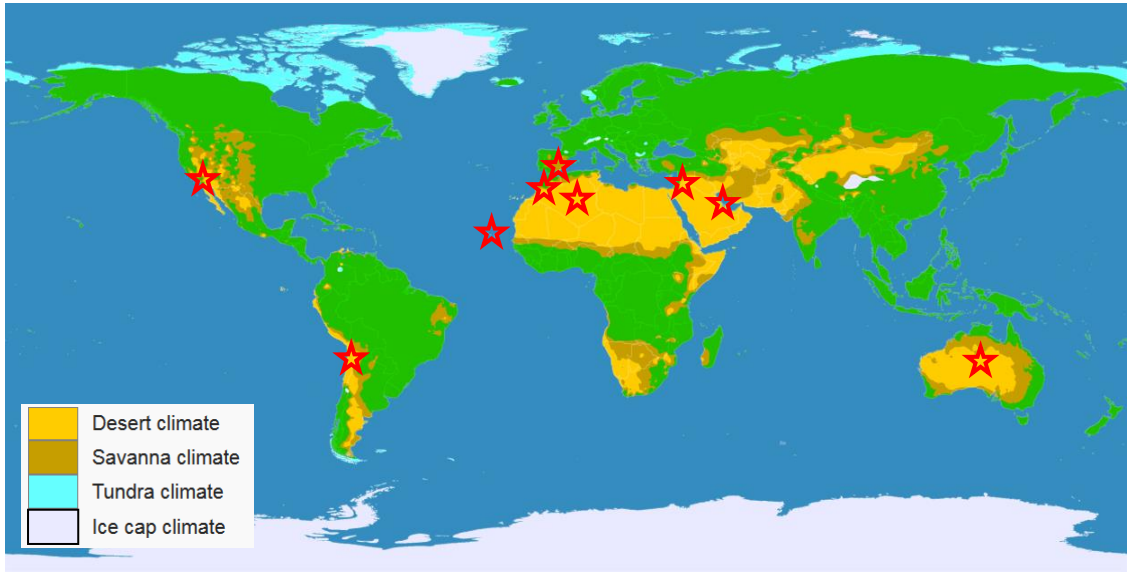
Experiment overview

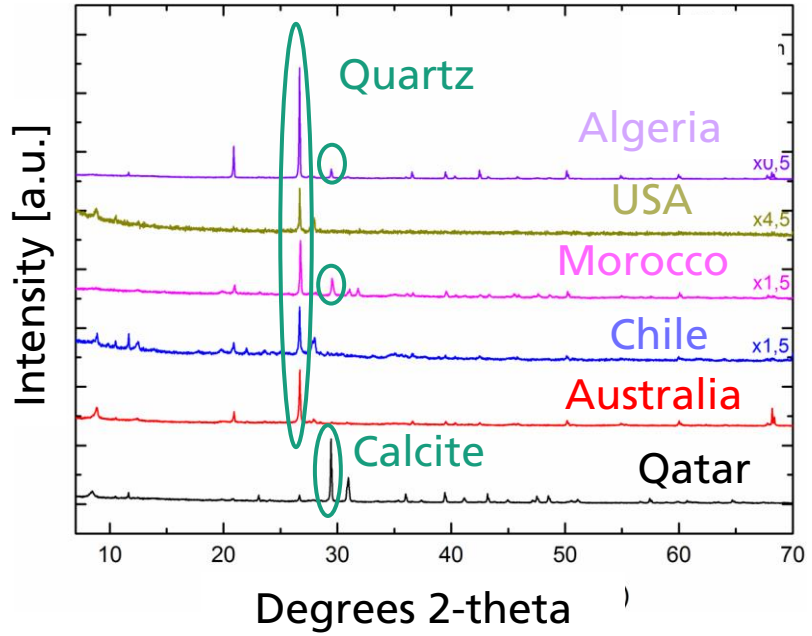
- **Aim**: comparative study of soiling and cementation processes for different desert regions
- Outdoor exposure of glass and plastic slides at 9 different desert areas
  - Fixed on PV modules → same temperature & tilt angle
  - Different periods of time (1, 3, 7, 14, 28 days)
  - Dust scraped off from PV modules
  - Detection of environmental parameters

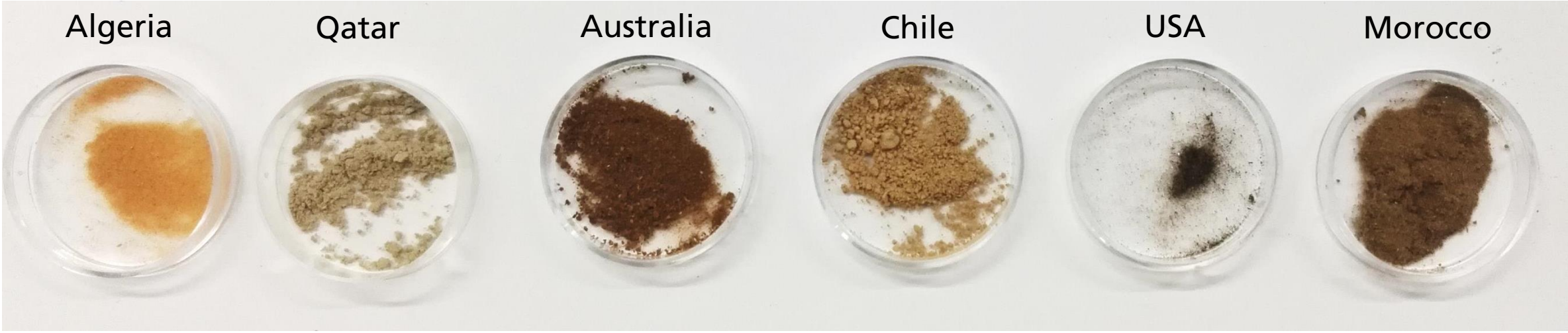


- Soiling rate/optical properties
- Microstructure of soiling
- Mineral composition
- Number of dew events

Dust samples scraped off PV modules
First impressions

- Huge variation in colour of dust from different regions
- Different mineral composition
- Good correlation between mineralogy of dust collected from PV module and reported dust mineralogy from ground [1]





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[1] Engelbrecht, Supplement of Atmos. Chem. Phys., 16, 10809–10830, 2016
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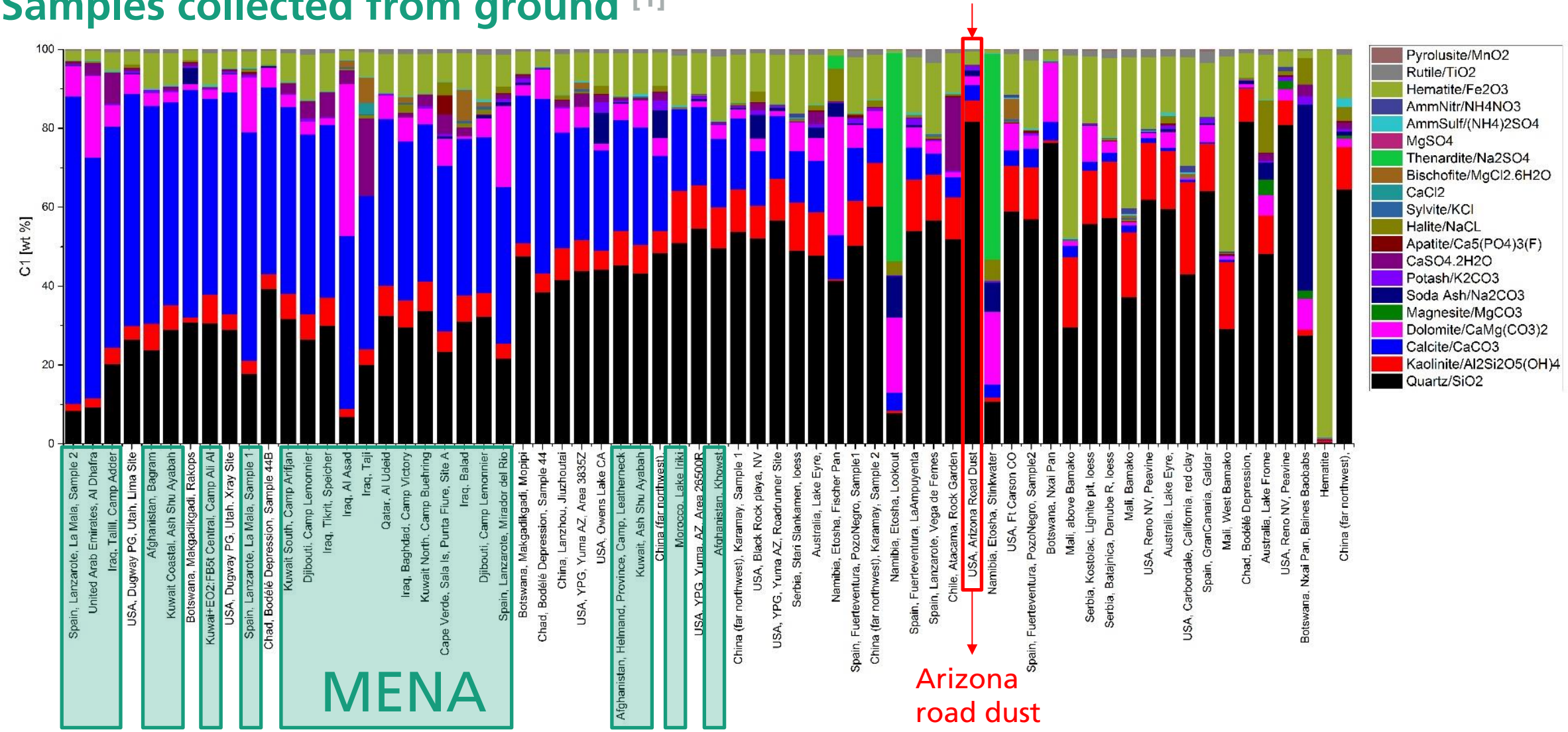
Dust composition from different locations throughout the world

Samples collected from ground [1]



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[1] Engelbrecht, Supplement of Atmos. Chem. Phys., 16, 10809–10830, 2016

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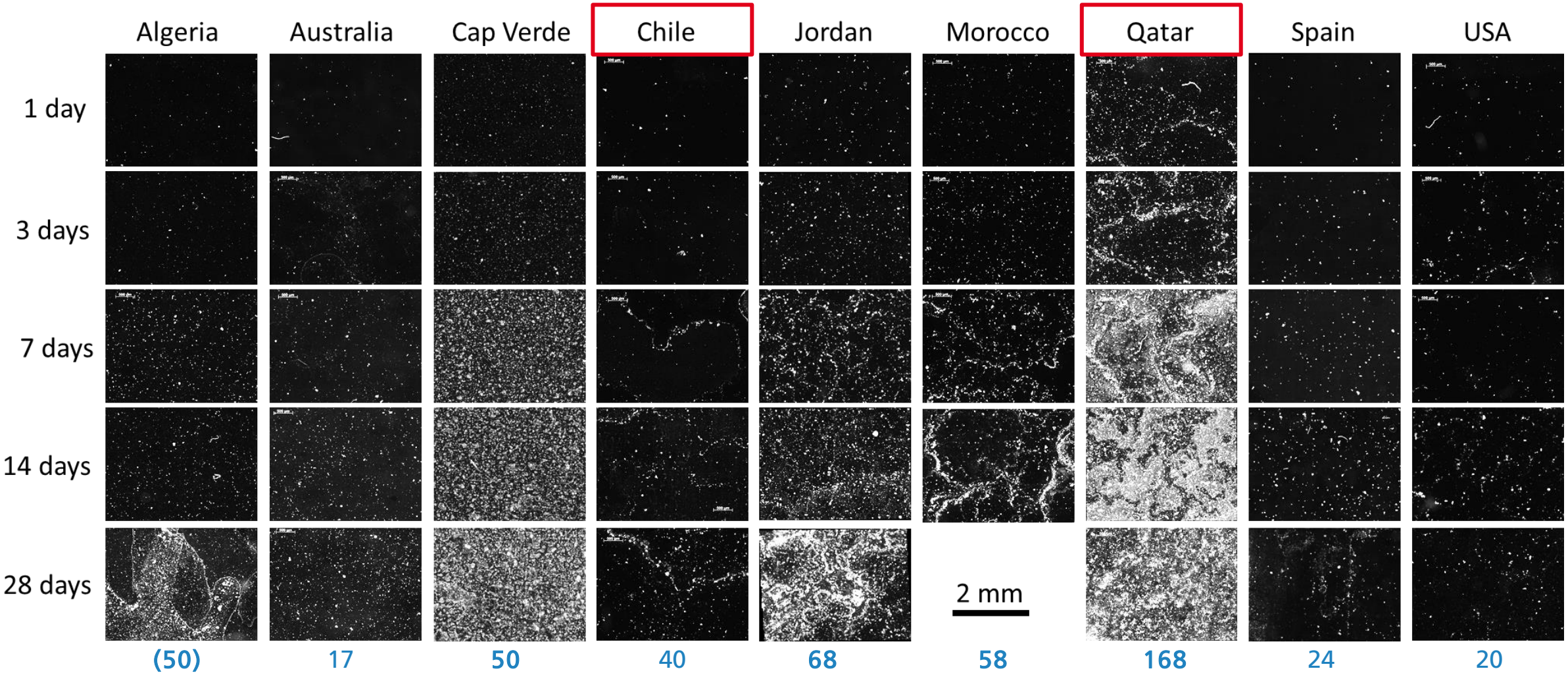
Outdoor exposure of glass slides

First impressions from light microscopy



Annual mean PM10 [µg/m³], WHO database

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Results of microstructural investigations

Surface morphology investigated by Scanning Electron Microscopy (SEM)

Qatar

Dew events on **22 / 28** days for

2016/10/16-2016/11/14

Following results shown for borosilicate glass samples, 1 day and 28 days outdoor exposure (October 2015, horizontal position) at Solar Test Facility in Doha, Qatar

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Ilse et al. "Microstructural analysis of the cementation process during soiling on glass surfaces in arid and semi-arid climates." *physica status solidi (RRL)-Rapid Research Letters* 10.7 (2016): 525-529.

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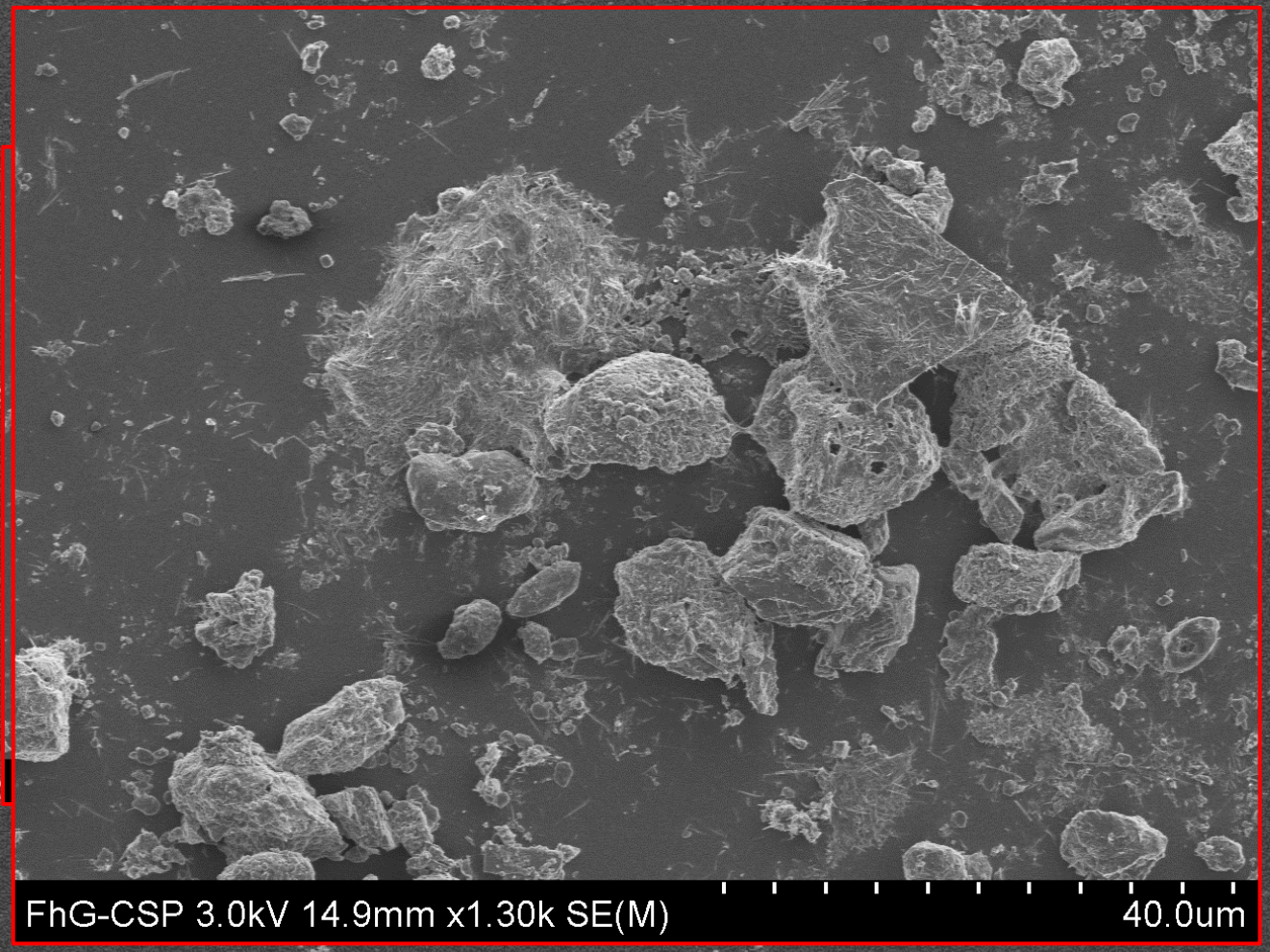
Qatar 1 day



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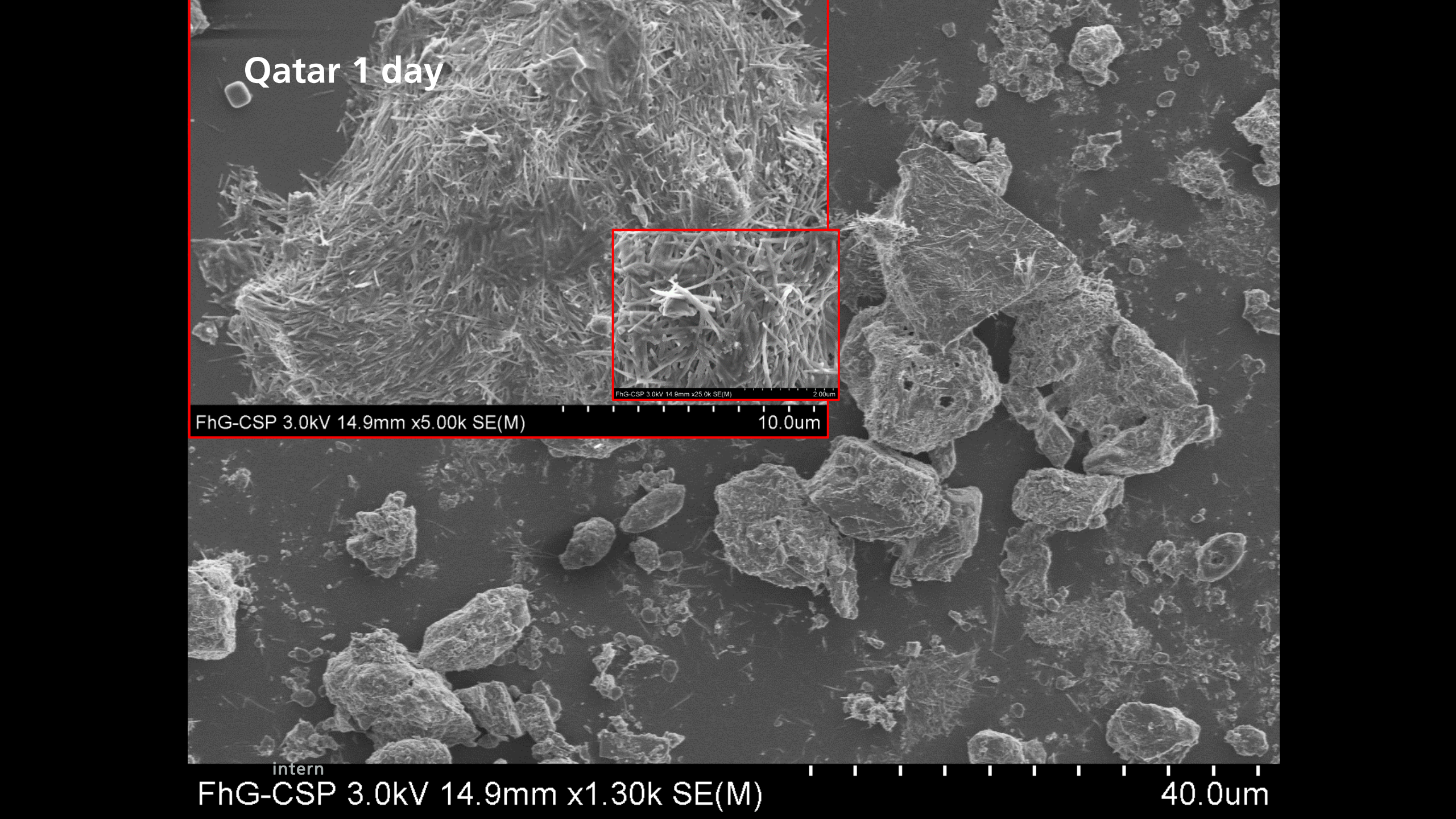
FhG-CSP 3.0kV 14.7mm x30 SE(M)

1.00mm


Qatar 1 day
FhG-CSP 3.0kV 14.9mm x5.00k SE(M)
10.0um
FhG-CSP 3.0kV 14.9mm x25.0k SE(M)
2.00um
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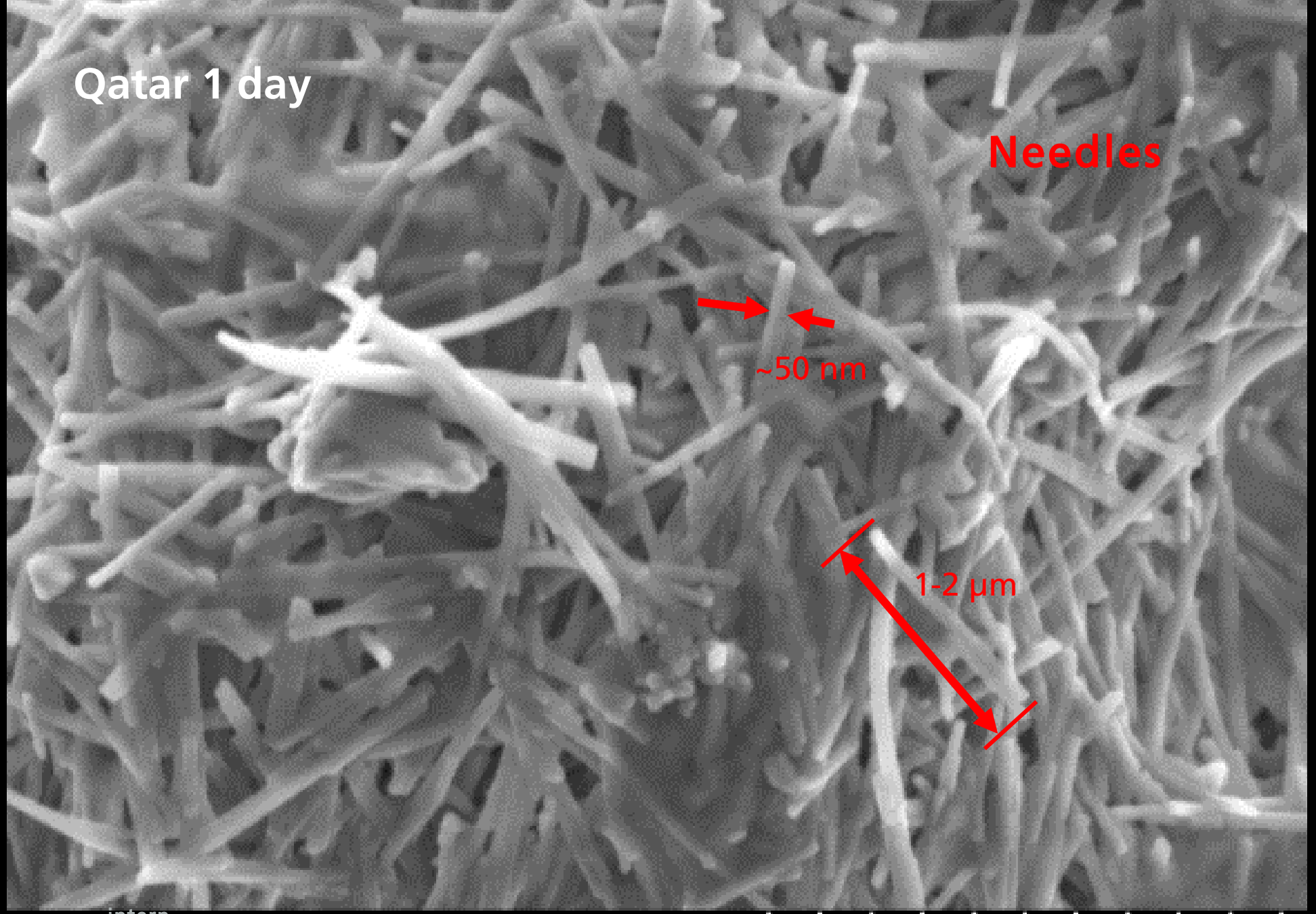
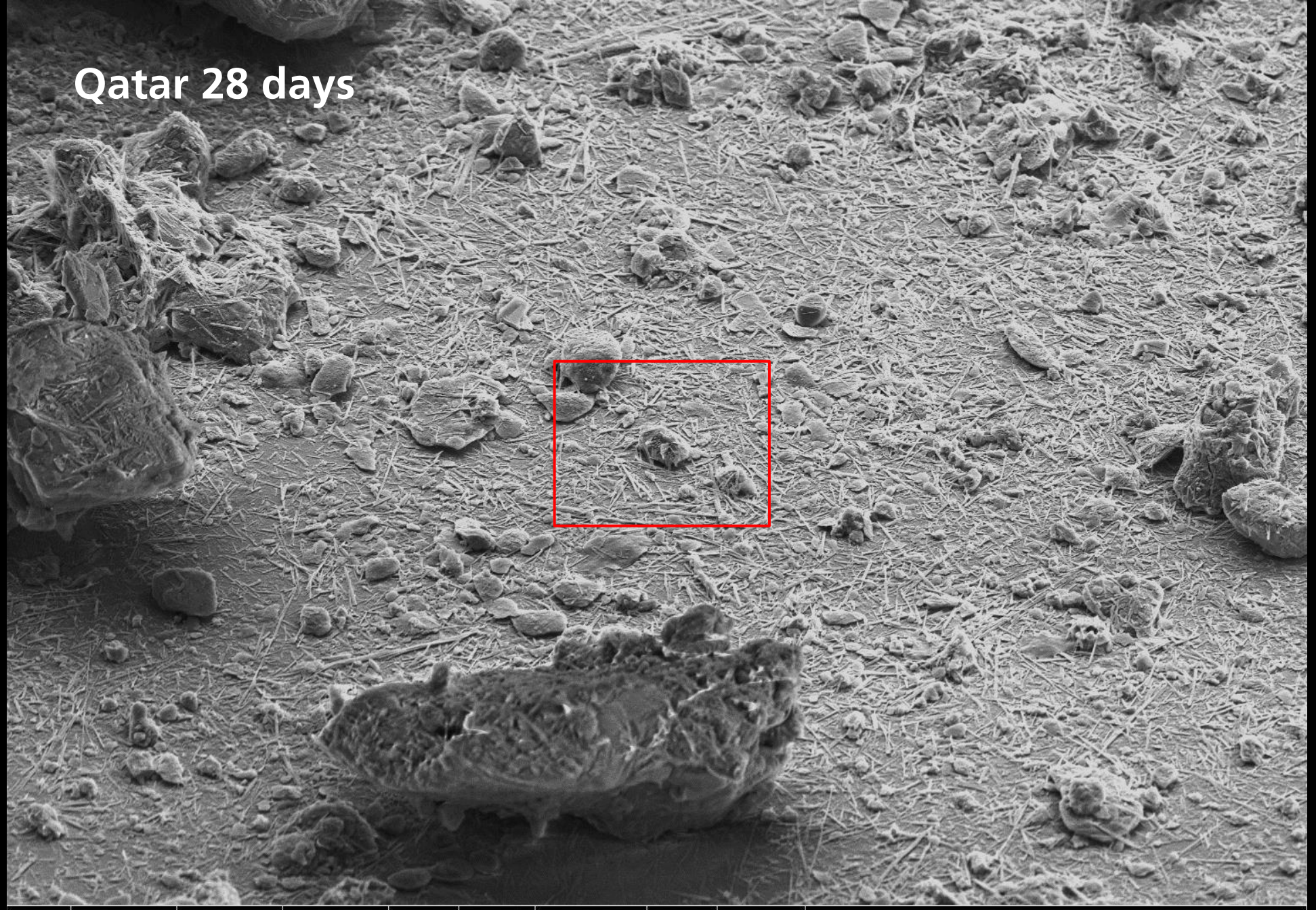
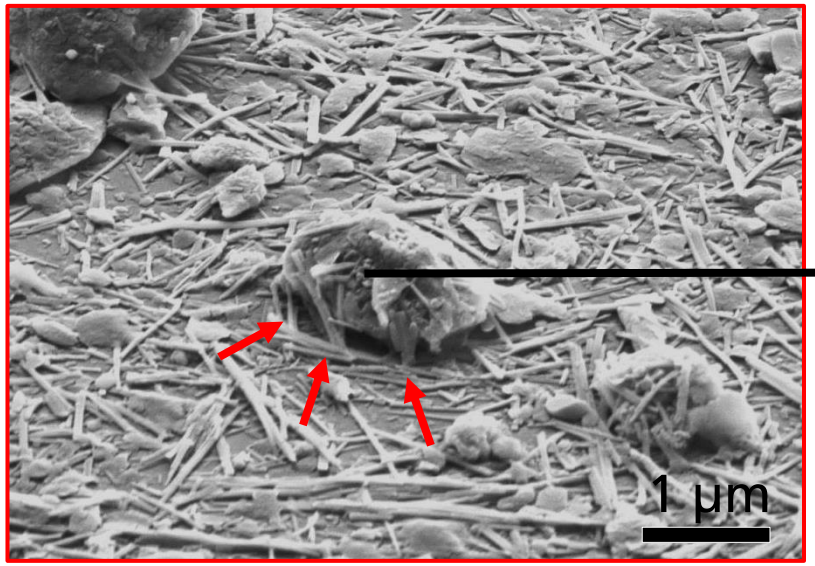
FhG-CSP 3.0kV 14.9mm x1.30k SE(M)
40.0um

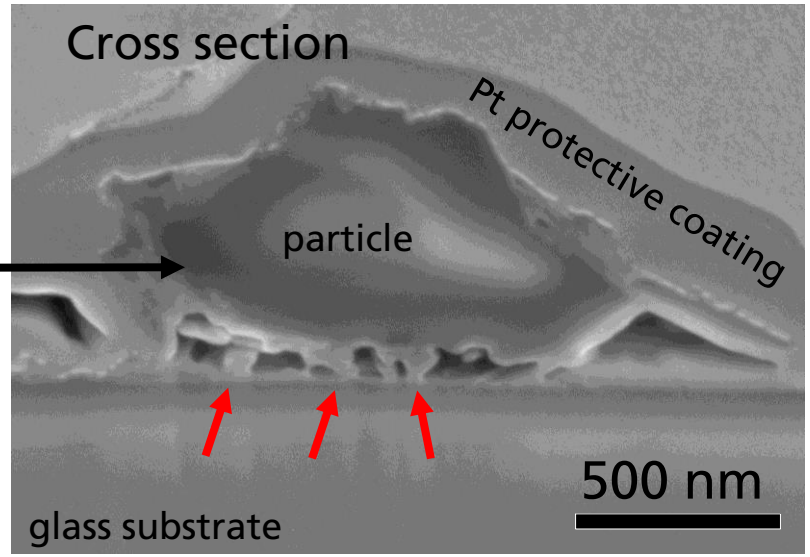

Qatar 1 day
Needles
~50 nm
1-2 µm
intern
FhG-CSP 3.0kV 14.9mm x25.0k SE(M)
2.00um

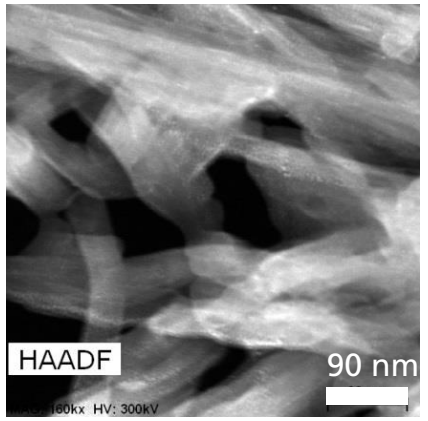

Qatar 28 days
HV
4.00 kV
WD
9.9 mm
mag
5 000 x
det
ETD
mode
SE
HFW
41.4 µm
tilt
52 °
curr
23 pA
10 µm

Results of microstructural investigations

Surface morphology investigated by SEM & FIB







- Nanoscopic needles promote adhesion of bigger dust particles
- Needles can be attributed to **Palygorskite** (clay mineral) [1] $(Mg,Al)_2Si_4O_{10}(OH) \cdot 4(H_2O)$
- Development via solution-precipitation processes during dew events → cementation

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[1] Ilse et al. "Microstructural analysis of the cementation process during soiling on glass surfaces in arid and semi-arid climates." *physica status solidi (RRL)-Rapid Research Letters* 10.7 (2016): 525-529.

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Results of microstructural investigations

Surface morphology investigated by Scanning Electron Microscopy (SEM)

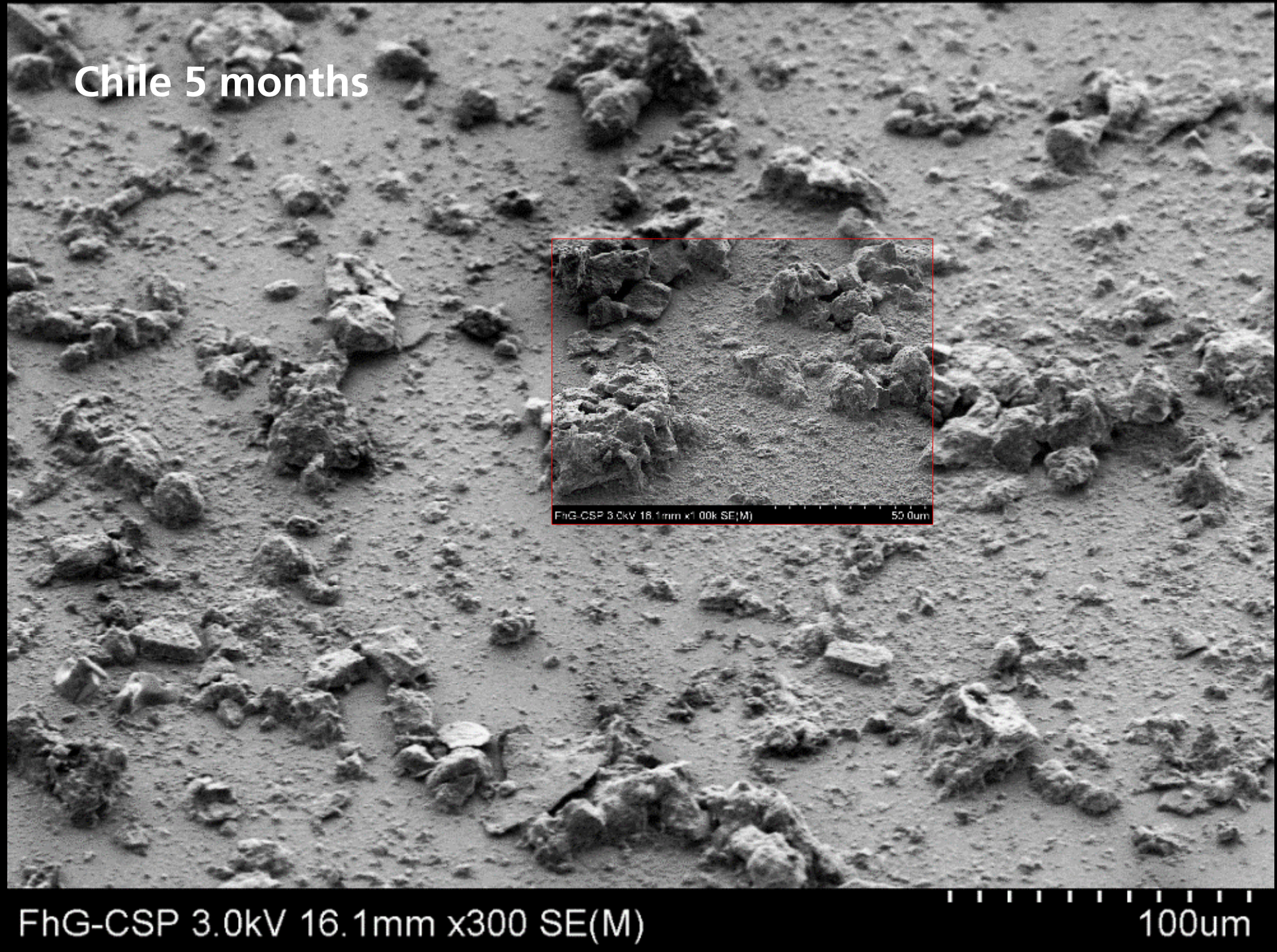
Chile

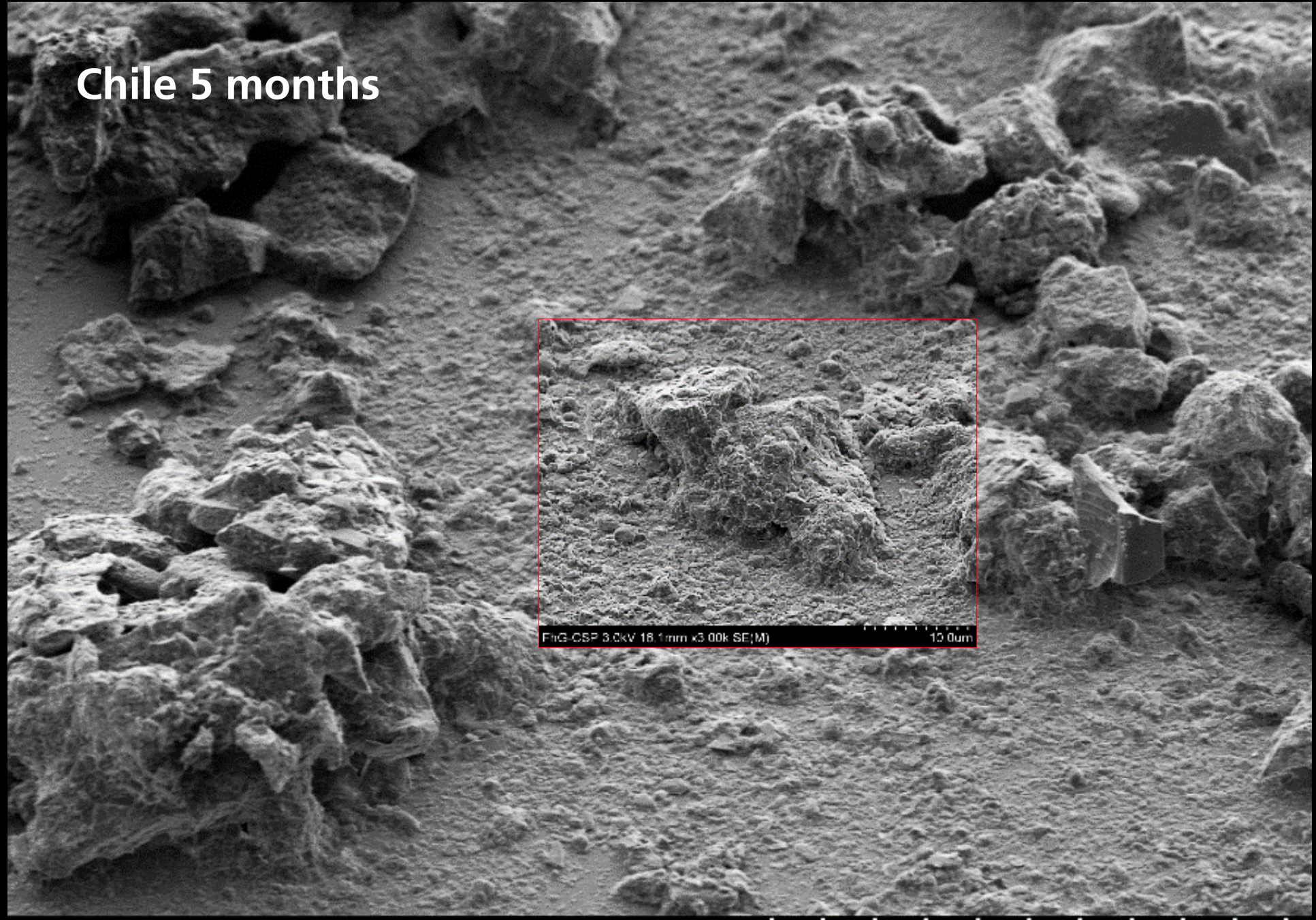
Dew events on **14 / 28** days for

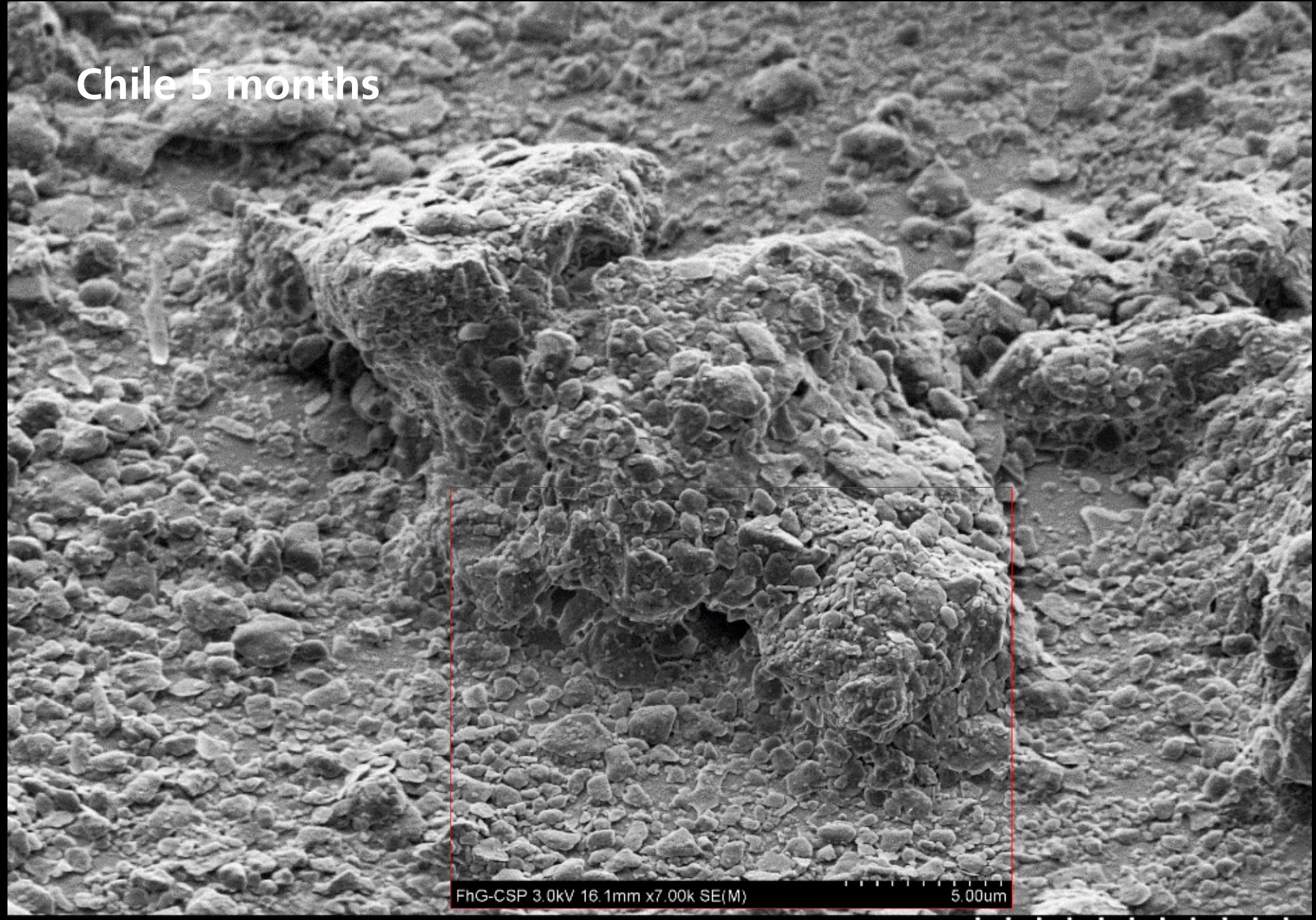
2017/03/21-2017/04/17

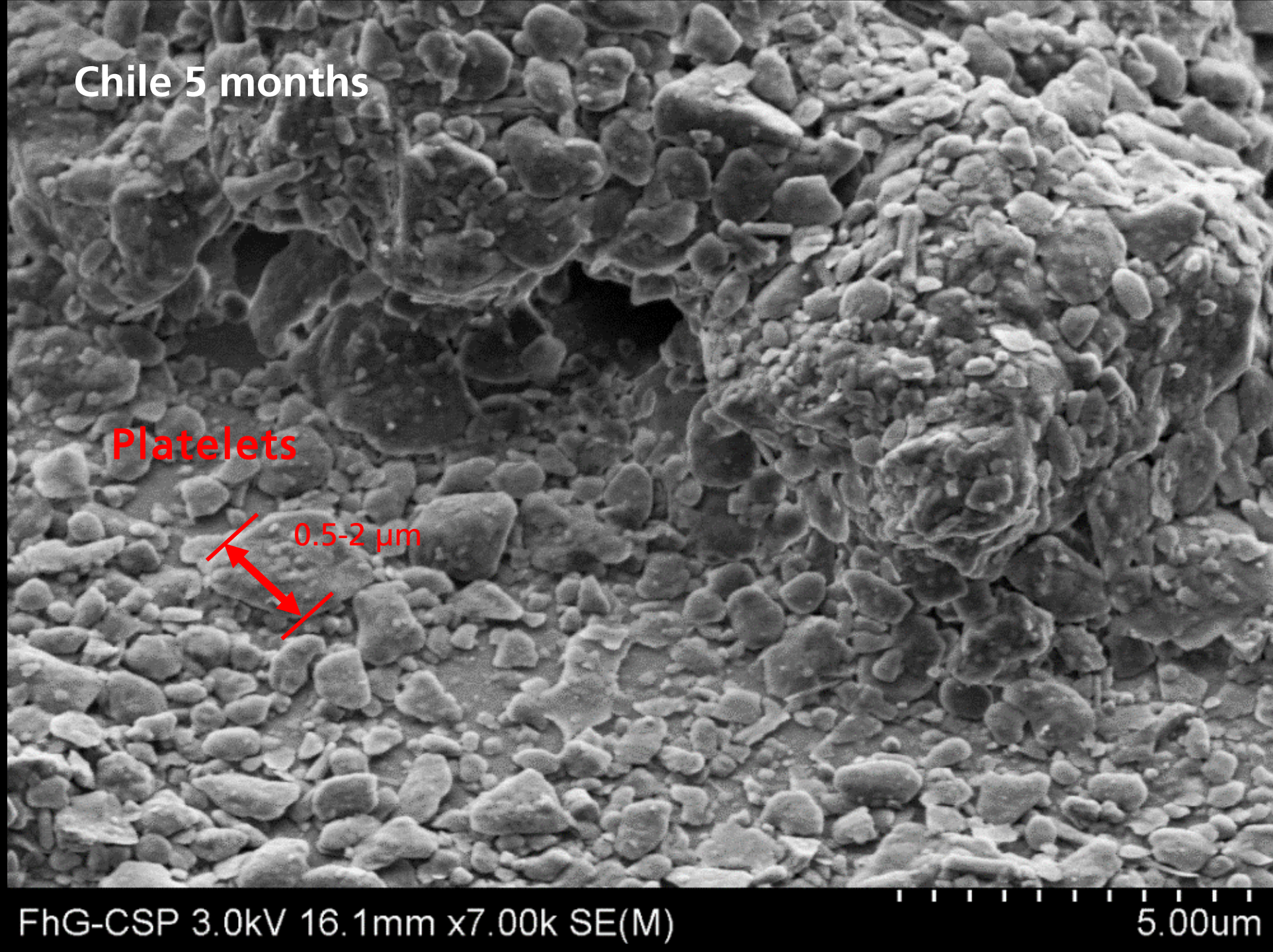
Following results shown for solar glass, ~ 5 months outdoor exposure (Jan-May 2016) at PSDA in Atacama Desert (managed by Center for Energy Development Antofagasta CDEA)

Ilse et al. "Comparing Indoor and Outdoor Soiling Experiments for Different Glass Coatings and Microstructural Analysis of Particle Caking Processes", IEEE-PVSC 2017, Washington


Chile 5 months
FhG-CSP 3.0kV 16.1mm x1.00k SE(M)
50.0um
FhG-CSP 3.0kV 16.1mm x300 SE(M)
100um

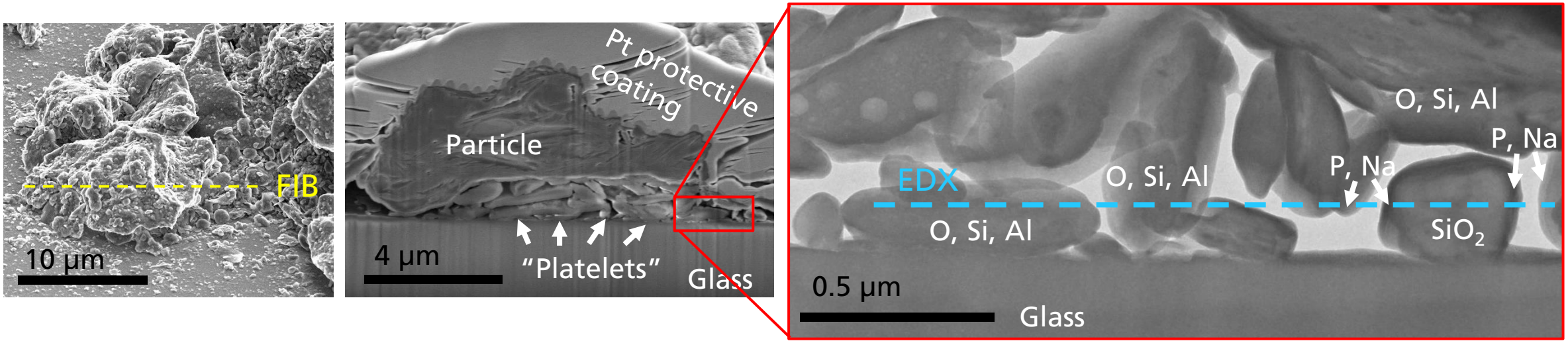

Chile 5 months
FhG-CSP 3.0kV 16.1mm x3.00k SE(M)
10.0um
FhG-CSP 3.0kV 16.1mm x1.00k SE(M)
50.0um


Chile 5 months
FhG-CSP 3.0kV 16.1mm x7.00k SE(M)
5.00um
FhG-CSP 3.0kV 16.1mm x3.00k SE(M)
10.0um


Chile 5 months
Platelets
0.5-2 µm
FhG-CSP 3.0kV 16.1mm x7.00k SE(M)
5.00um

Results of microstructural investigations

Surface morphology investigated by Scanning Electron Microscopy (SEM)

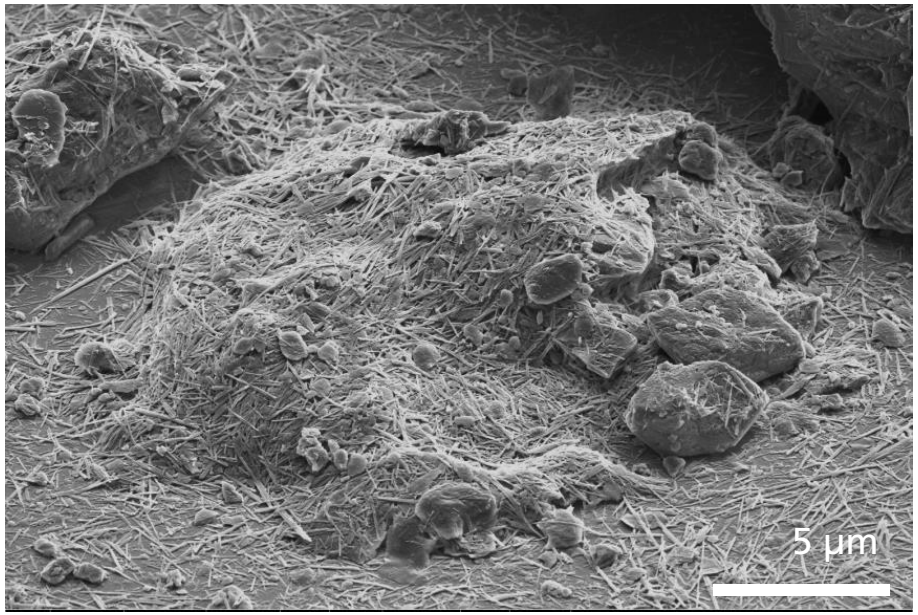


- Cross section confirms: small particles fill up holes and spaces → increased adhesion through increased contact area
- EDX: majority of small particles can be addressed to phyllosilicates on basis of Al and Si → **Kaolinite** ($Al_2Si_2O_5(OH)_4$) (most common clay mineral)
- Rearrangement of particles during dew events → caking

Ilse et al. "Comparing Indoor and Outdoor Soiling Experiments for Different Glass Coatings and Microstructural Analysis of Particle Caking Processes", IEEE-PVSC 2017, Washington

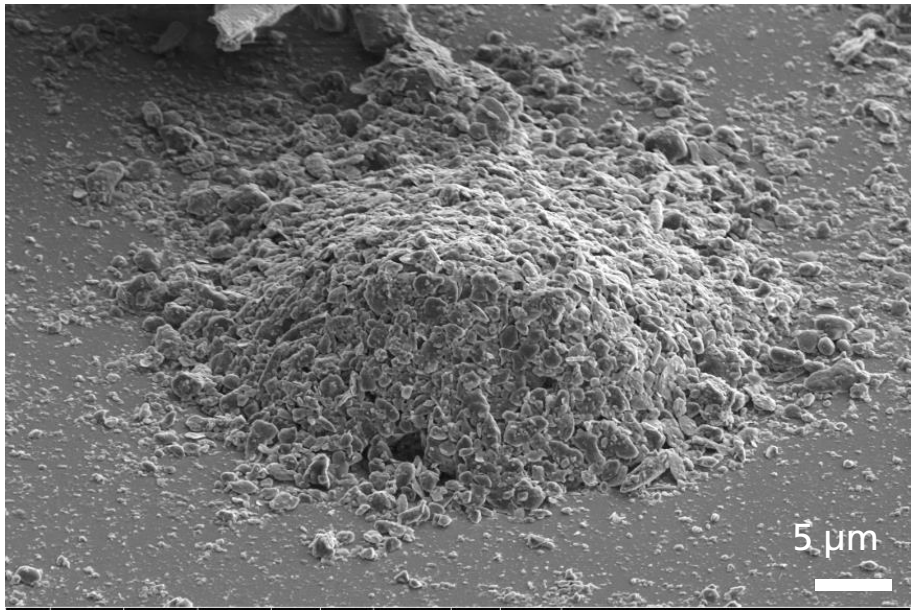
Summary

Qatar



- Needles → clay mineral palygorskite [1]
- Solution-precipitation → cementation

Chile



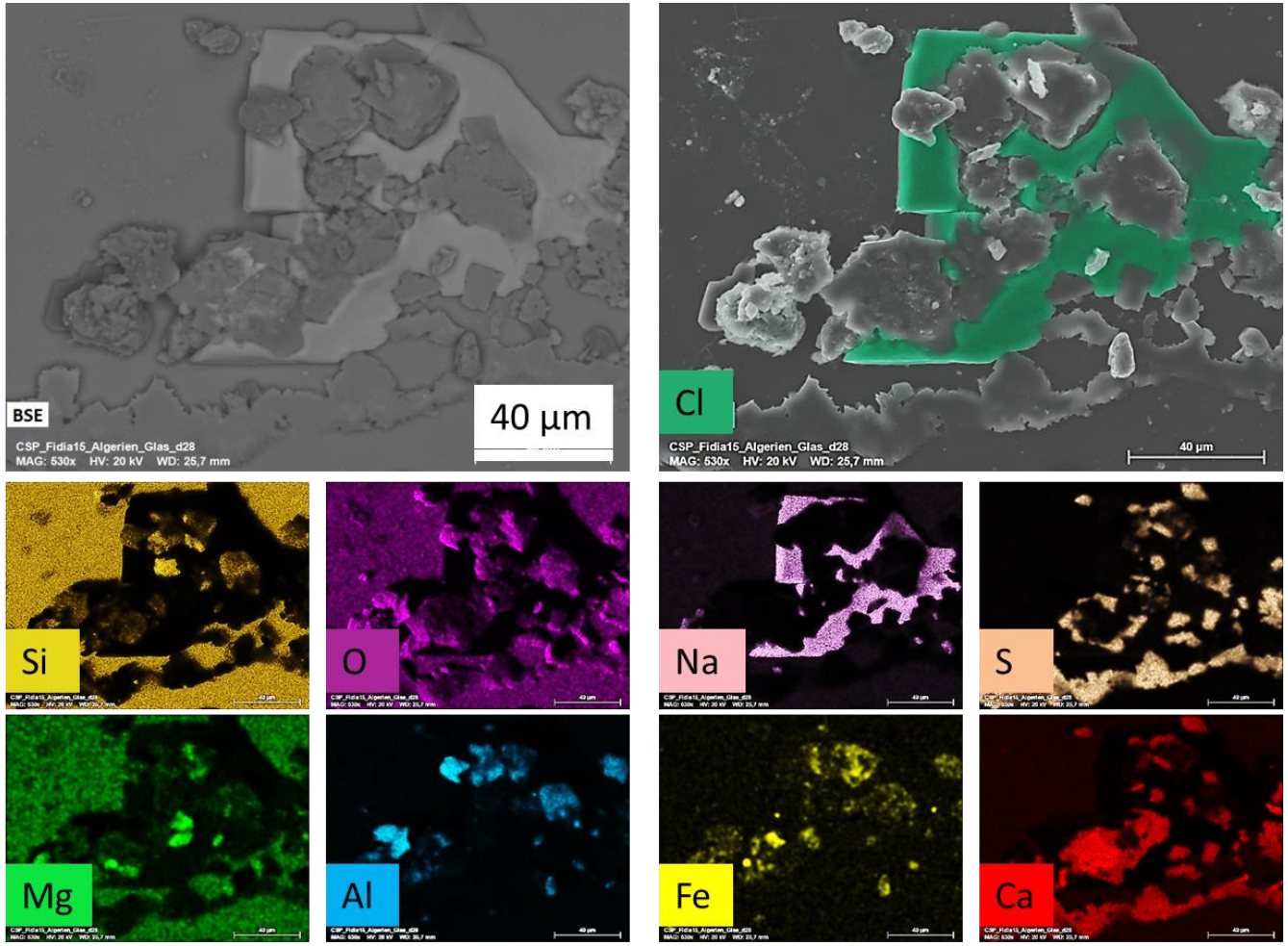
- Small platelets → clay mineral kaolinite
- Rearrangement → caking

Dust + clay mineral + dew ➡ Hardly removable by wind or rain

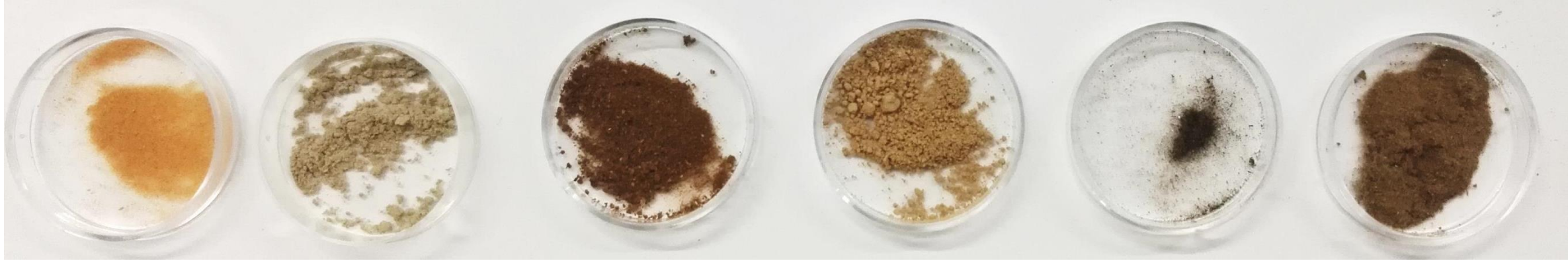
Outlook

- Further characterization of samples concerning microstructure of soiling, mineralogy, optical behavior
  - Example Algeria: Solution-precipitation of salt (NaCl) and gypsum ($CaSO_4$)

- Want to do comparable outdoor tests at your location? → Test kits available!



Thank you for your attention!



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Federal Ministry for Economic Affairs and Energy
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Thanks to our Partners!

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