

Environmental Significance of Holocene Dust Accumulation in Archaeological Hilltop Ruins in the Southern Levant

Joel Roskin (*University of Haifa, Geomorphology and Portable Luminescence Laboratory*)

Bernhard Lucke, Kim Vanselow, Rupert Bäumler (*FAU Erlangen-Nürnberg, Institute of Geography*)

Hendrik Bruins (*Ben-Gurion University of the Negev, Department of Man in the Desert*)

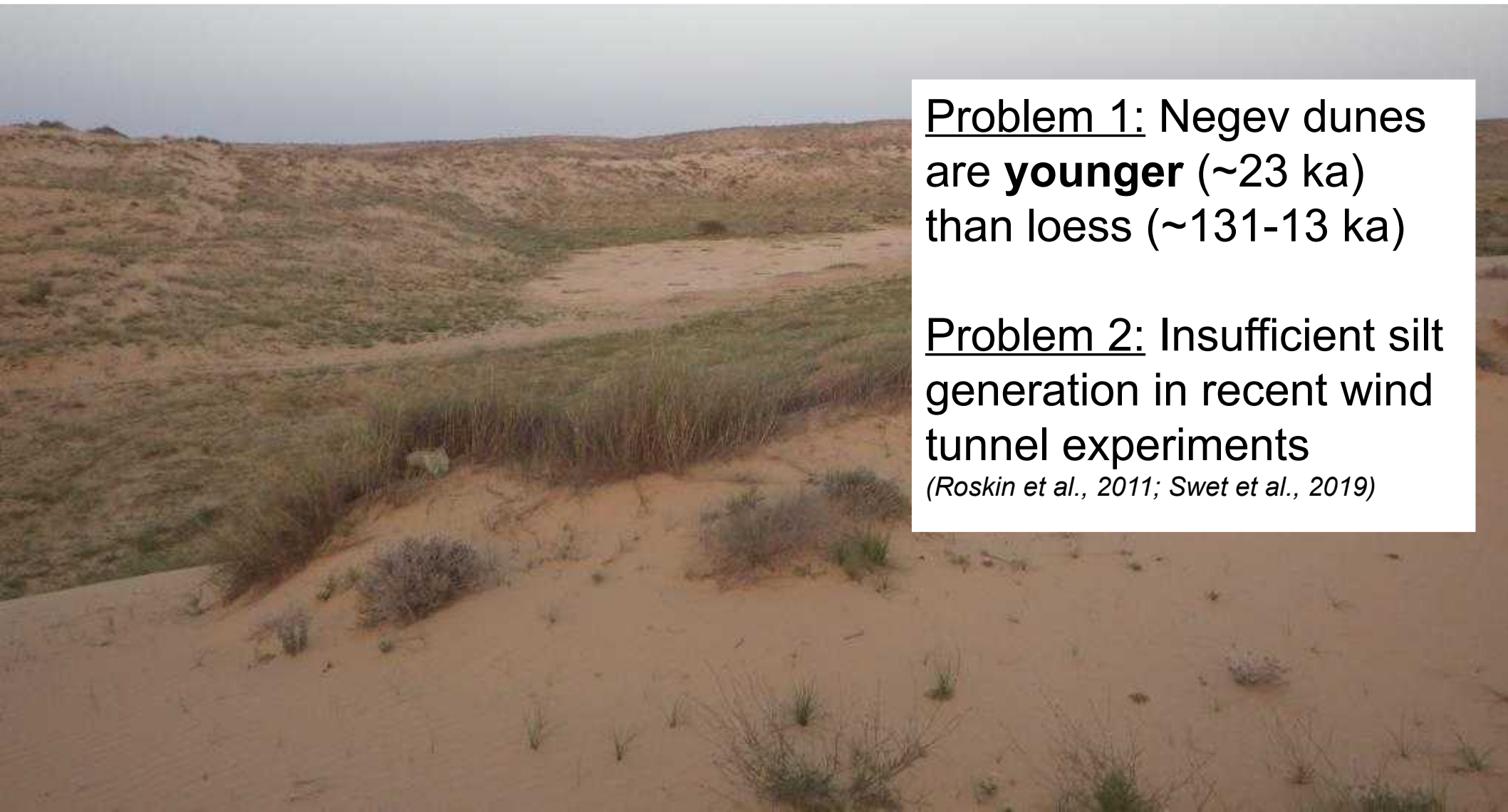
Nizar Abu-Jaber (*German Jordanian University, Natural Resources Engineering and Management*)

Naomi Porat (*Geological Survey of Israel*)



Loess in the Negev has been proposed to result from quartz abrasion in Negev-Sinai sand dunes – and Ergs in general as 'desert loess' sources.
(e.g. Crouvi et al., 2009, 2010)

Holocene loess seems **missing**: product of *dustier Pleistocene*, with *stronger winds* leading to abrasion of dune sands?



Problem 1: Negev dunes are **younger** (~23 ka) than loess (~131-13 ka)

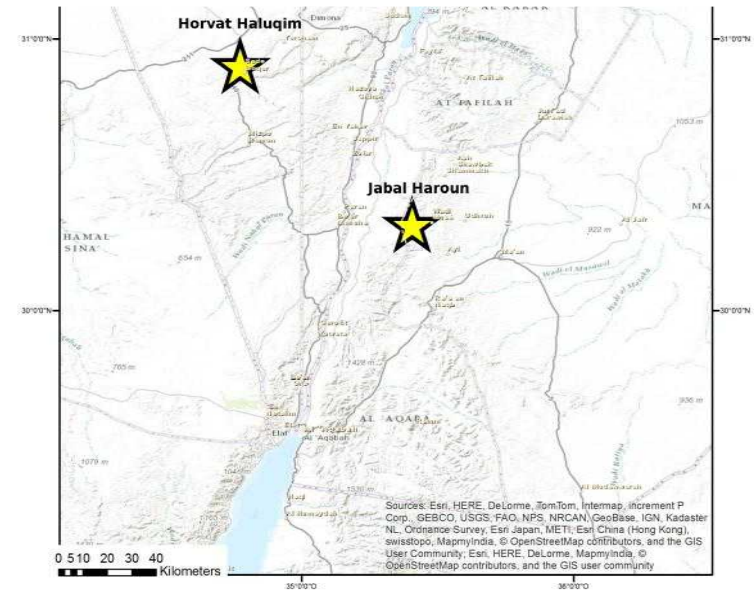
Problem 2: Insufficient silt generation in recent wind tunnel experiments
(Roskin et al., 2011; Swet et al., 2019)

Basic premise of earlier studies:

Settled dust = dust moving through the atmosphere

Approach of earlier studies: Identification of indicators of dust sources

Our approach: What about the sediments covering archaeological ruins?



Systematic comparison of sediments in arch. ruins in south Israel and Jordan

- (Partly) collapsed ruins usually covered by initial soils on debris
- Ruins likely acted as traps of **aeolian dust** → like current traps
- **Potential Holocene loess in the Levant** (missing link between studies of Pleistocene paleosols and modern dust from traps)

Including sampling the occasional current dust storms



Sampling sites in the Negev



Ruin
(on limestone ridge)



Reference samples
(loess apron with paleosol,
+ various rock outcrops)



Ruin
(on small loess apron/hill
overlooking wadi slope)

Sampling sites near Petra/Jabal Haroun



Ruin of Bronze Age site



Natural reference soil
on sandstone plateau



Limestone outcrop
+ various other rocks




Ruin of Byz. monastery

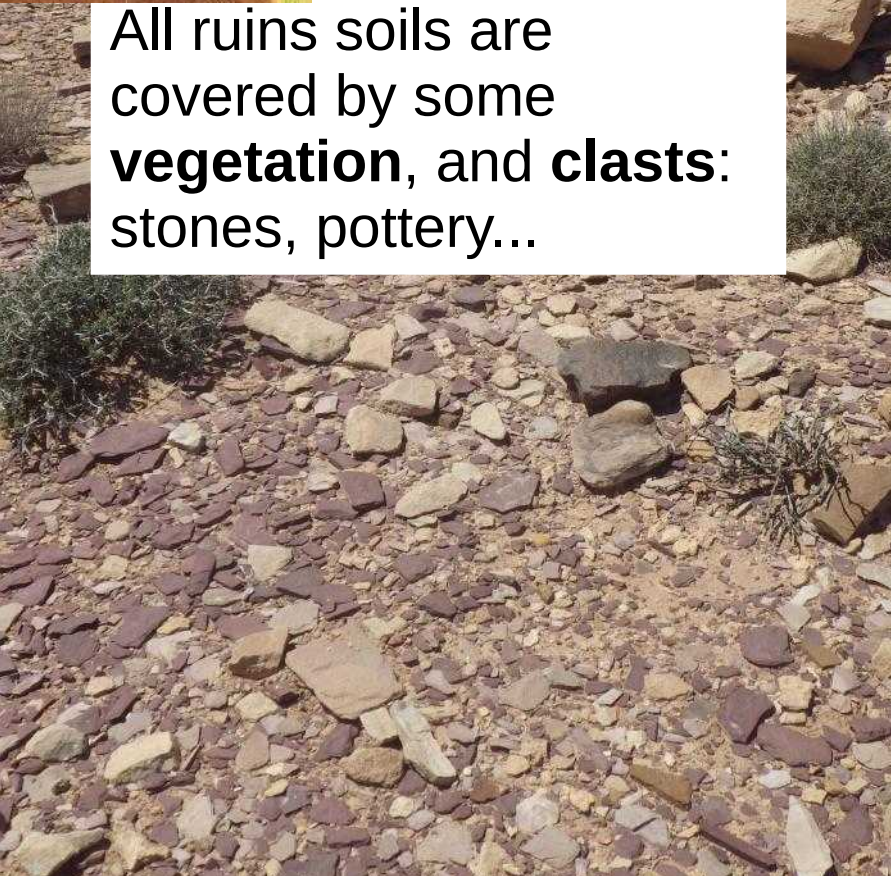
Hilltop triclinium




All hilltop ruins characterized by: V-horizons, clast pavements, surface crusts, some vegetation



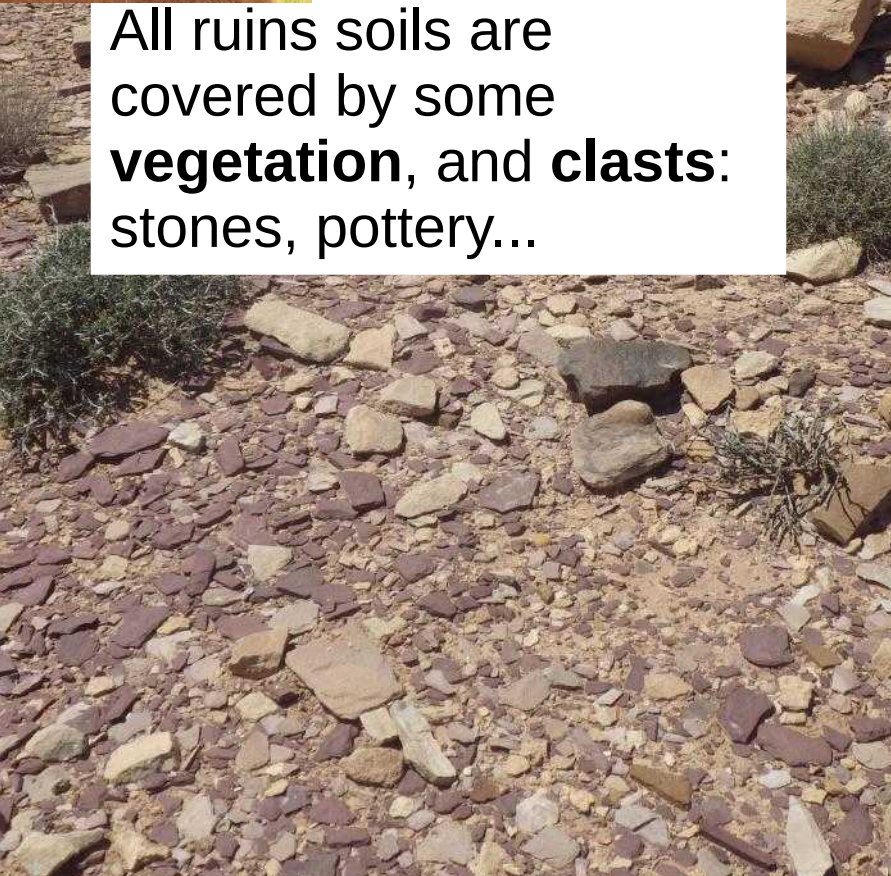
V-horizon
(Turk et al.,
2016)



All ruins soils are covered by some **vegetation**, and **clasts**: stones, pottery...



... clasts are connected with **crusts** below (physical or biological) → *similar to desert pavements...*



... **fixation of sediment** seems connected with water retention, clast cover, and crust formation!

Lucke, B., Roskin, J., Vanselow, K., Bruins, H., Abu-Jaber, N., Deckers, K., Lindauer, S., Porat, N., Reimer, P., Bäuml, R., Erickson-Gini, T., Kouki, P., 2019. Character, rates, and environmental significance of dust accumulation in archaeological hilltop ruins in the southern Levant. MDPI geosciences 9(190), 1-60.



Role of precipitation & snow:

- second highest dust amount (after dust devil) collected during **snow storm** at Petra
- snow leads to gentle water infiltration into the soil → minimum runoff, minimum erosion
- fosters vegetation and biocrust
- much higher silt content than dry dust samples → more similar to ruin soils!
- could explain why only a part of the current dust is fixed in the soil in the absence of precipitation

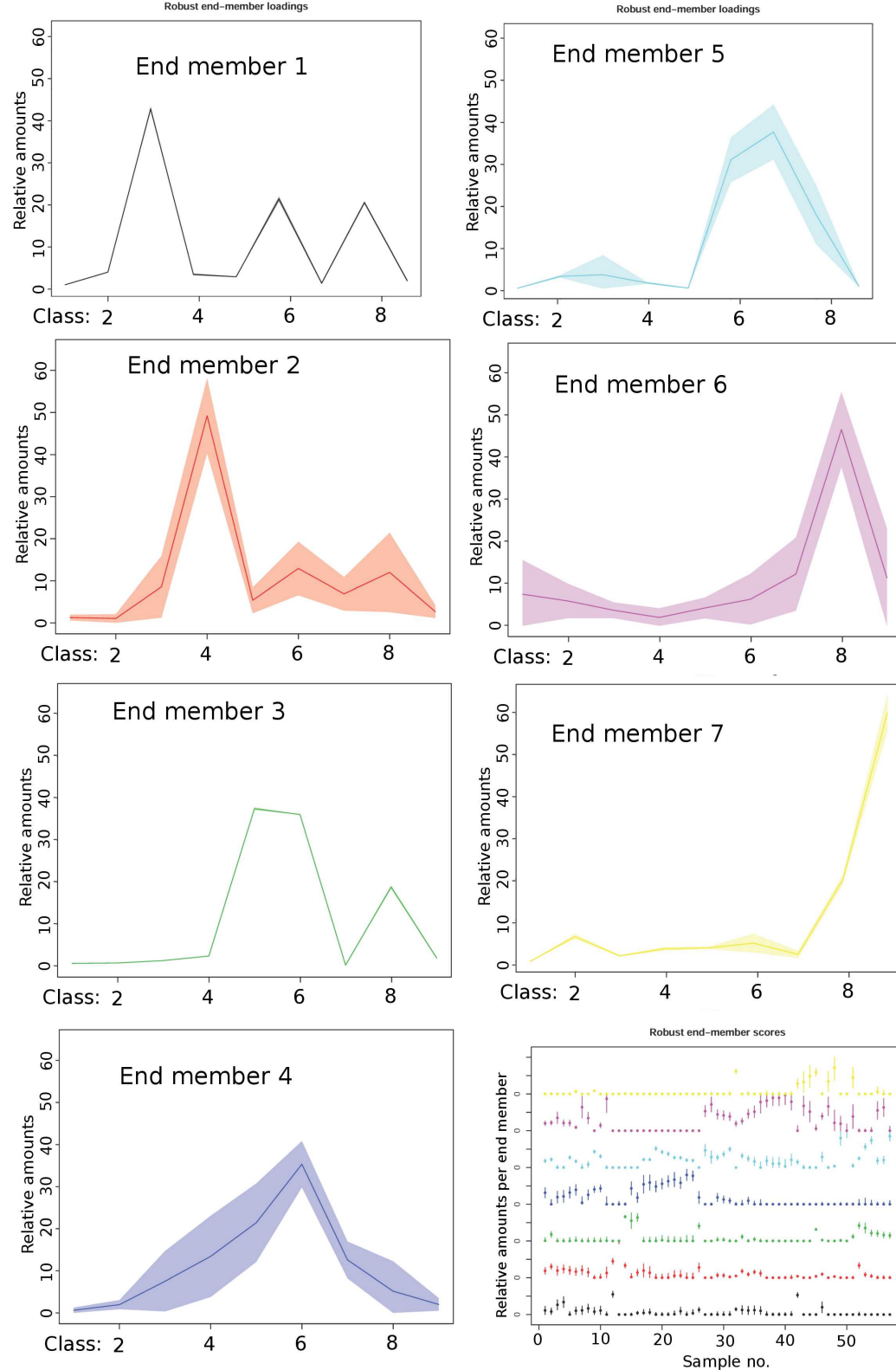


- 1) *Current dust Petra, mortar made from mud, sandstones, current soil and fans*
- 2) *Negev dust storms, Negev loess aprons, and snowstorm & rain near Petra*
- 3) ***Ruin soils*** in both investigation regions → *dissimilar from current storms!*



Group 2: silt contents

Group 3: sorting, clay contents



Statistical modeling with EMMA: 7 end-members (in Negev *and* Jordan)

| End-member no., % var. | Composition | Present in |
|------------------------|-------------------------|--------------------------|
| 1: 4.5 % | Coarse clay | Ruin soils, references |
| 2: 8.5 % | Fine silt | Ruin soils, dust storms |
| 3: 9 % | Medium-coarse silt | References, dust storms |
| 4: 19 % | Coarse silt | Ruins soils, dust storms |
| 5: 18 % | Coarse silt – fine sand | Ruin soils, dust storms |
| 6: 31 % | Medium sand | Ruin soils, Petra rocks |
| 7: 10 % | Coarse sand | Few dust storms, rocks |

Statistical modeling suggests similar deposition processes

Ruins soils in both areas can be **statistically modeled as one characteristic sediment type**

Negev Pleistocene*

~85 g/m² a⁻¹

Negev hilltop ruin

~150 g/m² a⁻¹

Current dust Negev

~150 g/m² a⁻¹

Petra isol. hilltop ruin

~125 g/m² a⁻¹

Petra ruin at cliff

~265 g/m² a⁻¹

Current dust Petra

~250 g/m² a⁻¹

Deposition rates indicate local sources

**figure from the literature*

Source problem or question of fixation?

- Occurrence of 'Desert loess' so far approached as "source problem"
- Dust in drylands is however omnipresent: multiple sources and very effective dust-producing processes
 - fluvial comminution*
 - aeolian abrasion
 - insolation weathering
 - salt weathering
 - frost shattering
 - volcanism

*Experimentally determined as most effective short-time silt-producing process (Wright et al., 1998; Wright, 2007)

- The question of desert loess might in fact be a "**dust fixation problem**"! → material is mostly not immobilized

Summary

- **Settled dust ≠ dust moving through the atmosphere** → settling connected with (probably site-specific!) fixation processes

Suspended dust: always present, very homogeneous

Moving dust: local & regional sources mix, may "harvest" remote dust

Settling dust: variable storms, partial (or selective?) fixation

- Archaeological hilltop ruins are effective dust traps, often still ongoing deposition due to:

wind shadow effects - protection against water erosion - fixation against wind erosion

- Hilltop ruins sedimentation rates match current dry marble collectors
- Sediment properties show clear role of rocks in Petra region and recycled nearby Paleosols in the Negev → local sources matter
- Precipitation plays important role: **snow** brought more material, but minimal runoff → could be a key issue to understand high dust deposition in the Negev during the Pleistocene!

Lucke, B.; Sandler, A.; Vanselow, K.A.; Bruins, H.J.; Abu-Jaber, N.; Bäuml, R.; Porat, N.; Kouki, P., 2019. Composition of Modern Dust and Holocene Aeolian Sediments in Archaeological Structures of the Southern Levant. MDPI Atmosphere 10, 1-84, doi: 10.3390/atmos10120762.

References

- Crouvi, O., Amit, R., Enzel, Y., Gillespie, A.R., McDonald, E.V. 2009. The significance of studying primary hilltop, aeolian loess: an example from the Negev desert, Israel. *Journal of Geophysical Research, Earth Surface*, 114, pp. 1–16.
- Crouvi, O., Amit, R., Enzel, Y. & Gillespie, A.R., 2010. Active sand seas and the formation of desert loess. *Quaternary Science Reviews* 29, 2087–2098.
- Lucke, B., Roskin, J., Vanselow, K., Bruins, H., Abu-Jaber, N., Deckers, K., Lindauer, S., Porat, N., Reimer, P., Bäumler, R., Erickson-Gini, T., Kouki, P., 2019. Character, rates, and environmental significance of dust accumulation in archaeological hilltop ruins in the southern Levant. *MDPI geosciences* 9(190), 1-60, doi:10.3390/geosciences9040190.
- Lucke, B.; Sandler, A.; Vanselow, K.A.; Bruins, H.J.; Abu-Jaber, N.; Bäumler, R.; Porat, N.; Kouki, P., 2019. Composition of Modern Dust and Holocene Aeolian Sediments in Archaeological Structures of the Southern Levant. *MDPI Atmosphere* 10, 1-84, doi: 10.3390/atmos10120762.
- Roskin, J., Porat, N., Tsoar, H., Blumberg, D. G., Zander, A. M. Age, origin and climatic controls on vegetated linear dunes in the northwestern Negev Desert (Israel). *Quaternary Science Reviews* 2011, 30(13-14), 1649-1674, doi: 10.1016/j.quascirev.2011.08.014.
- Swet, N., Elperin, T., Kok, J. F., Martin, R. L., Yizhaq, H., Katra, I. Can active sands generate dust particles by wind-induced processes? *Earth and Planetary Science Letters* 2019, 506, 371-380, doi: 10.1016/j.epsl.2018.11.013.
- Wright, J., Smith, B., Whalley, B. Mechanisms of loess-sized quartz silt production and their relative effectiveness: laboratory simulations. *Geomorphology* 1998, 23(1), 15-34.
- Wright, J. S. An overview of the role of weathering in the production of quartz silt. *Sedimentary Geology* 2007, 202(3), 337-351.

References

Crouvi, O., Amit, R., Enzel, Y., Gillespie, A.R., McDonald, E.V. 2009. The significance of studying primary hilltop, aeolian loess: an example from the Negev desert, Israel. *Journal of Geophysical Research, Earth Surface*, 114, pp. 1–16.

Crouvi, O., Amit, R., Enzel, Y. & Gillespie, A.R., 2010. Active sand seas and the formation of desert loess. *Quaternary Science Reviews* 29, 2087–2098.

Lucke, B., Roskin, J., Reimer, P., Bäumler, S., Porat, N., Environmental significance of dust. *MDPI geosciences* 9(190), 1-60, doi:10.3390/geosciences9190160

Lucke, B.; Sandler, A. Composition of Modern Southern Levant. *M*

Roskin, J., Porat, N. vegetated linear dur *ce Reviews* 2011, 30(13-14), 1649-167

Swet, N., Elperin, T., Ruk, G. I., Martin, R. E., Hznag, H., Katta, T. Can active sands generate dust particles by wind-induced processes? *Earth and Planetary Science Letters* 2019, 506, 371-380, doi: 10.1016/j.epsl.2018.11.013.

Wright, J., Smith, B., Whalley, B. Mechanisms of loess-sized quartz silt production and their relative effectiveness: laboratory simulations. *Geomorphology* 1998, 23(1), 15-34.

Wright, J. S. An overview of the role of weathering in the production of quartz silt. *Sedimentary Geology* 2007, 202(3), 337-351.

Thank you