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Water-induced drag and air-induced creep of clasts – revealing two unique earth surface processes by physical experiments and numerical modelling

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Earth surface processes, especially in arid environments, have received attention for several hundreds of years and most relief-shaping mechanisms have been investigated thoroughly by now. However, the current state of process knowledge allows not to consistently explain many properties of a surface type, covering up to 15 % of terrestrial surfaces worldwide: stone pavements and the associated vesicular horizons, fine-grained aeolian veneers with a distinct foamy structure. Throughout hot to cold deserts, from semi-arid to hyper-arid conditions, stone pavements usually show slope aspect-controlled bimodal alignment patterns of their clast length axes and are able to recover from disturbance by lateral processes.

Two yet disregarded earth surface processes play an essential role in both, recovery of disturbed sites and formation of the preferred clast alignment pattern. The vesicular horizon with its unique properties has fundamental control functions for the two processes. One process is unconcentrated overland flow, which supports rapid accumulation of clasts during the initial stages of recovery, given preconditions for sufficiently deep flows. The other process is clast creep due to air, escaping from the vesicular horizon upon rapid wetting. The latter process is unique in several aspects: it affects clasts but does not transport finer material and it is more effective the gentler the slope is. Both processes lead to clast rotation upon collision and thereby create the bimodal orientation pattern.

Both processes are described conceptionally, explored by physical-based numerical modelling and consistently validated by laboratory experiments. Water-induced drag and air-induced creep of clasts may represent two key mechanisms to explain unresolved challenges of many desert surfaces and underlying soil-sediment complexes regarding i) stability versus fragility, ii) dust sink versus dust source, and iii) the palaeoenvironmental archive function.