Gravity moves dry grains or blocks downhill in rockslides and rockfall. These mass movements can cause large boulders to saltate and impact with huge energies. Boulder impacts into bedrock surfaces should cause significant bedrock erosion, likely shaping the topography even in the absence of water. Examples of potential rockfall-driven bedrock landforms include bedrock gullies on steep hillslopes, so-called plinth surfaces on caprock-topped mesa escarpments, and steep impact-crater slopes on planetary surfaces. Although grain impact processes have been incorporated into mechanistic models for fluvial and debris-flow incision, similar models for dry rockfall erosion have yet to be developed.

To explore the potential for dry rockfall to erode bedrock and shape the topography, we set up a discrete, cellular D16 dry grain saltation trajectory model accounting for particle saltation dynamics and evolving topography. We calibrated the model variables (i.e., particle hop angles, distances and velocities) for different grain sizes and hillslope angles using laboratory experiments of dry gravel transport over a tilted foam bed that served as an erodible bedrock analogue. We then explored the calibrated model for a broad range of hillslope angles, grain sizes and bedrock erodibilities.

Both model and experiments predict significant erosion due to rockfall-driven impacts. As the topography develops, alcoves (shell-shaped hollows) form near the upslope end of the model domain. These alcoves eventually overdeepen and fill with talus, preventing further erosion. Farther downslope, topographic feedbacks drive rockfall into incipient channels, which cause those channels to incise resulting in gullies. Overall, our work suggests that dry rockfall can be a significant bedrock incision process, and can lead to gully formation, even for hillslope angles that are significantly less than the angle of repose.