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Evaluation of rockfall hazard and risk to a town within the Dead Sea fault zone (Qiryat-Shemona, northern Israel)

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Rockfalls are a typical slope-failure mode in steep hard rock slopes. Rock blocks of various sizes moving at speeds of up to tens of meters per second are hazardous to humans and property in mountainous areas. Rockfalls may be triggered by earthquakes or extreme weather conditions. We study rockfalls west of Qiryat-Shemona, a town in northern Israel situated within the Dead Sea Transform fault system, at the foot of the Ramim Escarpment. 40 m thick limestone outcrops provide the source material for rock blocks. Aerial photos dating 1946 show rock blocks of volumes 1 m^3 to 150 m^3 situated within the now built town premises. It is likely that these blocks have traveled to their present localities from the Ramim Cliff by rockfall mechanism. We aim at evaluating rockfall hazard and risk for Qiryat-Shemona.

Three questions are addressed in this study for complete hazard evaluation: (a) what is the origin of the rock blocks?; (b) what is the triggering mechanism?; (c) which are the feasible downhill trajectories of the blocks?

To answer these questions we mapped hundreds of rock-blocks both on the field and on aerial photos and analyzed their volume and spatial distributions; we simulated rockfall trajectories using a commercial simulation program (CRSP v4); we determined burial ages of soil samples from beneath large fallen blocks.

Results show that the probability density function (PDF) of block volume follows an exponential function of the form ax^b with $b$value -1.23. This volume distribution is used to determine most probable rock-block volumes for hazard evaluation. Field observed piles of rock-blocks show evidence for a catastrophic nature of the rockfalls, as opposed to a possible slow weathering mechanism. Preliminary OSL dating of 9 soil samples demonstrate clustering around specific dates, which coincide with known earthquakes found in historical and seismic catalogs, implying that rockfalls were triggered by earthquakes. We used maps of maximal downhill block travel distances combined with slope morphological analysis to suggest possible downhill historical block trajectories, along which we calibrated the simulation program variables (tangential and normal coefficients of the slope). We then used these variables and simulated possible downhill rockfall block trajectories towards the town premises. Simulation results were used to compile the rockfall hazard maps. Probable block volumes determined from the volume probability density function yielded risk evaluation for the area of Qiryat-Shemona. We found that at the south-westernmost part of town, life and property are at a present rockfall risk in particular areas, which we detailed on a map. Simulated results of block velocity and block bounce height along the slope can be used as parameters for a risk reduction engineering program for Qiryat-Shemona.