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Kinematic and dynamic rock fall modelling: the Soreq and Refaim valleys (Israel) and the Monte Salta rock fall (Italy)

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Rock falls are very fast mass movements that occur when a rock fragment (a block) is detached from a nearly-vertical cliff and travels down-slope by bouncing, flying and rolling. Rock falls represent a severe and constant hazard in mountain regions worldwide, and pose a severe threat to structures, infrastructures and the population. Investigators have long attempted empirical and mathematical modelling of rock falls, and estimates of the related hazards and risk. Software is available to simulate the behaviour of rock falls in 1-, 2- and 3-dimensions. In this work, we report on recent developments of STONE, a computer program for the 3D simulation of rock falls. The software was entirely re-engineered, and new functionalities were added, including the possibility to perform quasi-dynamic simulations of the rock fall process, and to produce improved statistical outputs. We have tested the software in two study areas, in Israel and Italy. The first test area is located along the Refaim and Soreq valleys (Israel), which extend for about 30 km from the Judean highlands, to the E, to the mountain-front, to the W. In the area, sequences of massive and layered dolomite, interbedded with marl, crop out. Elevation ranges from 400 to 750 meters above sea level, and terrain gradient ranges from moderate (25°-40°) to sub-vertical. Preliminary measurements of the size and shape of individual rock fall boulders were performed along the source and depositional areas of the rock falls, and were used in the analysis. The second test area is located along the southern slope of Monte Salta, in the Vajont Valley (NE Italy). The Monte Salta landslide is a large rock fall - rock

slide controlled by the presence of a regional thrust. Above the thrust zone, folded and highly fractured layered limestone dips steeply towards the slope free face, a geological and morphological condition prone to failure. Elevation in the area ranges from 750 to 1800 meters. Topography is characterized by a sub-vertical cliff, 300 m in height, located above a long, steep and complex talus and rock slope. For the two study areas, a DEM, geological maps, and geomorphological information, including information on the location of the rock fall source areas, of the size and shape of the individual rock boulders, on the type and pattern of the surface geology, and on the location of rock fall deposits, were available. We used the available information to perform kinematical (i.e., “lumped mass”) and quasi-dynamic simulations of the rock fall process. We exploited the improved output capabilities of software STONE to test and compare the obtained results.