Effect of overburden on pebble breakage in gravels

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Fractured pebbles from unconsolidated sediments were investigated in a gravel pit south of St. Margarethen (Burgenland, Austria). The outcrop is located in the Neogene Eisenstadt-Sopron Basin, which is a sub-basin on the SE border of the Vienna Basin. The sediments, which were deposited during the Sarmatian and Pannonian (12.7-7.2 Ma), represent a succession of deltaic gravels with intercalations of shallow-marine calcareous sandstones. Extensional tectonics in these sediments resulted in the generation of conjugate sets of predominately WNW- and subordinate ESE-dipping normal faults (shear deformation bands). These faults were primarily localized in meter-thick gravel layers and, with increasing displacement, eventually crosscut other lithologies (Figure 1).

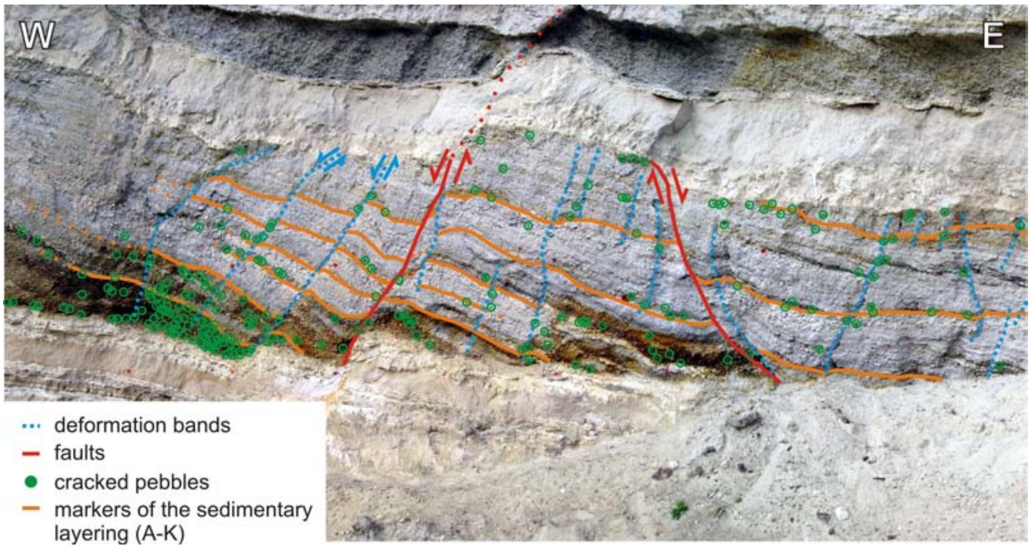

Figure 1. Photograph of the outcrop showing the sedimentary succession and the structural features.

The gravel layers contain a significant number of cracked pebbles (Figure 2). Detailed structural mapping of the distribution of cracked pebbles revealed their preferential occurrence in the vicinity of the normal faults and, in these, within zones of roughly uniform-sized pebbles (Figure 1).

Figure 2. Cracked pebbles in a close-up of the gravel layer.

The findings indicated a strong relation to the mechanics of faulting within the sediment. To find the controlling factors for the localization of pebble fracturing, point load tests were conducted and the grain-size distribution, shape and the number of point contacts of the pebbles were statistically measured. The results were then used as input parameters for numerical modelling.

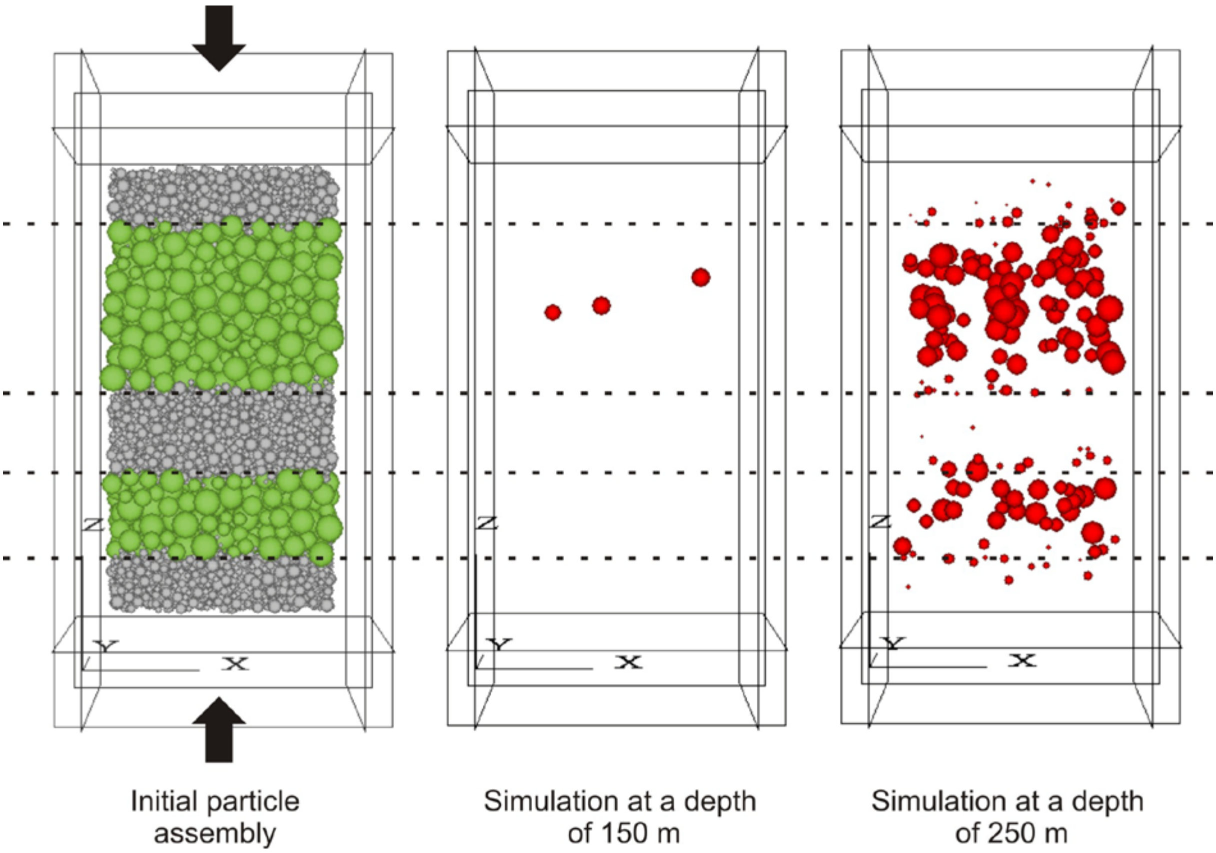

Figure 3. Different stages of the DEM model that simulates progressive pebble breakage in a gravel layer. Black arrows in the first picture indicate the loading direction (sidewalls are fixed). Only broken pebbles (red) are shown in the second and third picture.

The Discrete Element Method (DEM) was applied to simulate the effect of overburden on a certain volume of particles (i.e. the pebbles). The magnitude and the distribution of contact forces between the particles were observed and compared with the fracture resistance of natural pebbles, determined by point load testing in the laboratory.

Results from numerical modelling indicate that a maximum estimated overburden of a few tens of meters would not have been able to generate contact forces high enough to crack the significant number of pebbles that have been observed in some parts of the outcrop.

We therefore conclude that cracking was related to faulting by force jamming due to pebble reorganization and/or by contact force concentrations due to boundary effects of layering.