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Ruptured Pebbles – a coseismic and paleoseismic indicator?

Christopher Weismüller and Klaus Reicherter
Neotectonics and Natural Hazards, RWTH Aachen University, Germany (c.weismueller@nug.rwth-aachen.de)

To increase the understanding of paleo-earthquakes and deformation patterns, and the propagation of surface waves in the proximity of active faults, we use the mainly disregarded features of ruptured or broken pebbles within in a clayey matrix. Deformation of unconsolidated sediments (alluvium, colluvium) due to earthquake ruptures is a long investigated topic, including the degradation of the fault scarp. However, during many trenching studies aligned pebbles along the fault planes have been described, and attributed to coseismic deformation. Over the last decades, we have found many ruptured pebbles in trenches at active faults with historic earthquakes, but also aligned (rotated?) pebbles. Here, we describe ruptured pebbles from a Pleistocene debris flow near the coastline between the towns Carboneras and Mojácar (SE Spain), East of the Sierra Cabrera. The outcrop is on-fault at the transition of the active Carboneras and Palomares faults (major historical earthquakes with M $\sim$ 7 in 1518 and 1522), implying proximity to the earthquakes epicenters. The Carboneras (NE-SW), Gafarillos (E-W) and Palomares (NNE-SSW) faults form major faults in eastern Andalucia. The outcrop contains ruptured pebbles in an only slightly consolidated, Pleistocene debris flow with 50 % matrix content. Similar near-fault ruptured pebbles have already been observed in the Carrizales quarry near Baelo Claudia, S Spain, and many other sites (e.g., Italy, Greece, Russia), but always in the proximity of active faults.
We measured the fractures of 100 pebbles as planes, if possible, or trend, in case no measureable plane was accessible. Complementary 3D-models of the outcrop and each ruptured pebble were created using Structure from Motion, allowing us to further study the pebbles morphology and geometry. Mode II and conjugate fractures are prevailing in the pebbles and the lack of surface-loading such as striations and dissolution pits neglects clast-interaction. Un-cemented shear planes fostered the assumption that these pebbles must have been fractured in-situ in the matrix. During slow deformation in combination with the contrast in competence between pebble and matrix, the pebbles would rotate and realign along a shear plane within the matrix. We explain the observed shearing of pebbles in the debris flow to be the product of a temporary tensile stress induced by the propagation of a seismic wave through the sediment body. The quick deformation causes the pebbles and matrix to engage in a state of similar competence, enabling the shearing of the clasts in the matrix. Under the given circumstances, we conclude the near-fault presence of ruptured pebbles in a soft sediment body to indicate paleoseismic activity and coseismic deformation. In contrast to that we regard aligned pebbles as a slow deformation, probably caused by afterslip and post-seismic deformation.