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Characterization and Modeling of Compaction Damage from Shaped Charge Jet Penetration in Saturated Geomaterials

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In oil and gas wells, shaped charges are used to establish a connection between the wellbore and the formation rock. During the penetration event, a localized zone of damaged material is created around the perforated tunnel which plays a dominant role both in well stimulation and in the eventual production of oil from the reservoir. In recent injection flow experiments on perforated limestone cores we have systematically characterized the permeability of the damaged zone and shown that it depends on both the initial permeability of the rock and on pore fluid properties. The present study aims at understanding the basis for these trends through a combined experimental and numerical investigation. To this end, large-format thin sections are prepared at multiple cross sections along the perforation tunnel and are digitized with a petrographic microscope. Novel segmentation and image analysis algorithms reconstruct the spatial variation of pore-scale properties throughout the damaged zone. In limestone, we find that damage is dominated by collapse of the pore network resulting in a compacted region with strongly reduced porosity near the edge of the tunnel. The mechanisms of compaction damage are then explored in hydrocode simulations of planar impact on a 2-dimensional meso-scale model of limestone with a synthetic pore network. The simulations attempt to explicitly capture the process of pore collapse and clarify the influence of pore network and fluid properties on the resulting compaction pattern.