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The hydrodynamic response of the Sibillini Mts. carbonate hydrostructure before and after the Mw 6.5 Norcia earthquake (Central Italy): hints from numerical models

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Abstract

Apennine carbonate hydrostructures host important aquifers, leading to the storage of extensive amounts of groundwater and representing an important water resource for the Italian peninsula. The hydraulic properties of aquifers vary based on lithological heterogeneity, fracturing, and karst conduit development. Accordingly, the groundwater flow is further controlled by tectonic and structural elements.

During the 2016 Central Italy seismic sequence, the Mw 6.5 Norcia earthquake caused significant, long-lasting hydrogeological changes in the Sibillini Mts. carbonate hydrostructure. The seismic event, originating from the rupture of different segments of the Vettore-Bove normal fault system, resulted in important ground deformation with surface faulting. The mechanism of "aquifer fault rupture" (Mastrorillo *et al.*, 2020) has been invoked to explain the sustained discharge changes observed at springs and along the main drainage systems, suggesting a shift of the groundwater divide following the Vettore fault rupture. In this work, we aim to characterize the Sibillini hydrostructure and assess the hydrodynamic response to the coseismic dislocation of the Vettore fault by means of numerical approaches.

Following the concept of parsimony, we constructed a straightforward model representing the earthquake-related hydrodynamic changes of the Sibillini carbonate hydrostructure. We idealized the model as a simplified hydraulic system consisting of three volumes separated by faults (Vettore and Norcia faults). Given the regional-scale extent of the model, we assumed the Sibillini carbonate aquifer as an equivalent continuous and homogeneous medium, with an average permeability for the entire area. We implemented faults in the model (Vettore and Norcia faults) as horizontal flow barriers with different permeabilities than those of the aquifer. First, we simulate the groundwater flow before and after the Norcia earthquake. Then, we performed an automatic calibration of the model using observed spring discharge and hydraulic head data as target function. The modeling allowed us to define the hydraulic parameters characterizing the hydrogeological system at a regional scale. Groundwater modeling results are compared with the crustal volumetric changes obtained from the simulation

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of the Vettore fault rupture through a geomechanical numerical model. The comparison will contribute to enhancing the groundwater model by evaluating and refining permeability variations within the system, especially in post-seismic conditions.

Keywords: numerical modeling, groundwater, carbonate hydrostructure, Norcia earthquake

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