Hydrogeochemical response of karstic aquifers to strong earthquakes: The 2016-2017 Amatrice-Norcia sequence in central Italy

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Mechanisms driving co-seismic chemical changes in karstic aquifers remain unclear, but are important to understand in order to demonstrate that groundwater for human consumption is safe after earthquakes. One reason for unclear responses is the chemical and hydrologic variability between events and regions. We summarize hydrochemical effects throughout the 2016-17 central Italy seismic sequence, a shallow-crustal sequence with four mainshocks of Mw between 5.5 and 6.5 accompanied by normal faulting. This sequence is typical of the seismic style in the Central Apennines, and extensive environmental effects on the local large karstic aquifers have been documented during several strong earthquakes in the past.

We monitored 2 high-flow karst-sourced springs (S. Susanna and Peschiera) and 1 alluvial spring (Vicenna Riara) in the Rieti area, ∼30-50 km from the epicenters, and one karst-sourced spring within 5 km of the October mainshocks (Nerea spring). We measured physiochemical parameters (pH, temperature, electrical conductivity) and analyzed water samples for major, minor, and trace elements, as well as $\delta^{13}C_{DIC}$, $\delta^{18}O_{H20}$ and δ^2H_{H20}. Pre-earthquake chemical data exist from 2014-15 monitoring of Rieti basin springs, and from bottled samples from the Nerea SpA bottling plant.

Principal Component Analysis reveals two distinct elemental suites: one dominated by Ni, Cr, Pb, Cu, Al, and another including Ca and elements typically substituting in the carbonate crystal lattice (Mg, U, Sr, Rb). A transient increase in elemental concentrations was observed in both suites following the main shocks and then declined to pre-earthquake concentrations. Analysis of $\delta^{18}O_{H20}$ and δ^2H_{H20} reveals the same recharge source for any of the springs. There was a different response in $\delta^{13}C_{DIC}$ values between Nerea and the Rieti springs. The Rieti springs showed enrichment in $\delta^{13}C_{DIC}$ following the August 24th event, Nerea showed depletion. The $\delta^{13}C_{DIC}$ enrichment was not attributed to shaking effects but instead to dilation of specific fault conduits that overlie a deep CO_2 source not present at Nerea.

Transient increases in elemental concentrations can be explained by the release of longer residence time pore water stored in slow moving fractures or abandoned karstic flowpaths within the aquifer during shaking. These fluids were expelled into the main flow paths after an increase in pore pressure and hydraulic conductivity. Weaker response to the later earthquakes in the series is explained by progressive depletion of these high solute fluids, as earlier shocks flushed the stored fluids out of fractures. We exclude deep fluids interaction as a cause of metals release.

Additional monitoring efforts using an automated specific conductance (SC), temperature, and water level in a well at Foce di Montemonaco, which was affected by several shocks of Mw >3.5 within a radius of 20 km since April 2017. Changes in post-shock SC do not correlate with water level changes or rainfall, and may be co-seismic. Interestingly, no demonstrable precursory changes were noted in any of the data collected. Future efforts will focus on the implementation of a continuous monitoring network in the Apennines to better understand co-seismic aquifer processes at work.