Cross-correlation analysis of 2012-2014 seismic events in Central-Northern Italy: insights from the geochemical monitoring network of Tuscany

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Since late 2002, a geochemical monitoring network is operating in Tuscany, Central Italy, to collect data and possibly identify geochemical anomalies that characteristically occur before regionally significant (i.e. with magnitude > 3) seismic events. The network currently consists of 6 stations located in areas already investigated in detail for their geological setting, hydrogeological and geochemical background and boundary conditions. All these stations are equipped for remote, continuous monitoring of selected physicochemical parameters (temperature, pH, redox potential, electrical conductivity), and dissolved concentrations of CO_2 and CH4. Additional information are obtained through in situ discrete monitoring. Field surveys are periodically performed to guarantee maintenance and performance control of the sensors of the automatic stations, and to collect water samples for the determination of the chemical and stable isotope composition of all the springs investigated for seismic precursors.

Geochemical continuous signals are numerically processed to remove outliers, monitoring errors and aseismic effects from seasonal and climatic fluctuations. The elaboration of smoothed, long-term time series (more than 200000 data available today for each station) allows for a relatively accurate definition of geochemical background values. Geochemical values out of the two-sigma relative standard deviation domain are inspected as possible indicators of physicochemical changes related to regional seismic activity.

Starting on November 2011, four stations of the Tuscany network located in two separate mountainous areas of Northern Apennines separating Tuscany from Emilia-Romagna region (Equi Terme and Gallicano), and Tuscany from Emilia-Romagna and Umbria regions (Vicchio and Caprese Michelangelo), started to register anomalous values in pH and CO_2 partial pressure (PCO_2). Cross-correlation analysis indicates an apparent relationship between the most important seismic events (magnitude >3 up to 5.4) experienced in the Tuscany, Emilia-Romagna and Umbria regions during the period 2012-2014, and these geochemical anomalies. Changes in pH (decreasing) and PCO_2 (increasing) are generally observed from a few months to a few weeks before the main shock.

This trend has been recognized for the Parma quake of 27 January 2012 (M = 5.4), for the Pieve Fosciana quake of 13 January 2013 (M = 4.8), for the Garfagnana-Lunigiana seismic sequence started June 21, 2013 (Mmax = 5.2), for the Montefeltro seismic sequence started July 11, 2013 (Mmax = 3.9), for the Gubbio seismic sequences of July and December 2013 (Mmax = 3.9), for the Città di Castello seismic sequences of April 2013 and December 2013 (Mmax = 3.9), for the Casentino seismic sequence started October 17, 2014 (Mmax = 3.5), and for the Chianti seismic sequence started December 19, 2014 (Mmax = 4.1).

These features suggest that the selected mineral springs can be considered as appropriate sites for the search of geochemical earthquake precursors. Further investigations focused on in-depth analysis of signals are currently in progress.