Proposal of PhD Project (Re.Me.S.T. – University of Urbino Carlo Bo)

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Hydrogeochemical monitoring of the waters discharging in the Umbria-Marche Apennines (Central Italy) aimed at earthquake forecast and seismic precursors

Keywords: fluid geochemistry, isotope geochemistry, springs, water composition, dissolved gases in water, earthquakes, seismic precursors.

ERC: PE10 (Earth system science); PE10_11 Geochemistry, crystal chemistry, isotope geochemistry, thermodynamics; PE10_18 Hydrology, water and soil pollution.

1. Introduction

Among natural disasters, earthquakes are the most severe events in terms of both social and economic damage and human fatalities [1] and therefore, earthquake forecast should be highly reliable in terms of timing, location and intensity in order to take actions in advance and reduce the associated risk [2].

Recent studies have shown the promising potential of geochemical monitoring (focused on springs and wells) to earthquakes forecast in different geodynamic settings [3, 4 and references therein]. Changes in the chemical and isotopic composition of waters and dissolved gases [5] as well as variations in the groundwater systems and hydrology in a seismic prone area [6] may be related to the earthquake's preparation process and to the stress rate increase [5]. The most reliable and suitable parameters to be used as seismic tracers are strictly related to the structural geology, tectonic setting and hydrogeology [3, 4].

The study area is represented by the Mt. Nerone and Mt. Catria-Acuto and their surroundings (Umbria-Marche Apennines; Central Italy), characterized both in recent and past history by an intense seismic activity with events that reached a magnitude above 6 Mw, e.g. the 1781 "Cagli Earthquake". This latter had an estimated magnitude of ca. 6.4 Mw and intensity Io equal to 10 in the MCS Scale that caused about 300 fatalities [7]. The area is characterized by a complex tectonic setting with the presence of several extensional low angle normal faults (LANFs) whose activity has been held accountable for the recent seismic activity recorded all over the project area [8].

2. Research Objectives

The aim of this project is to characterize the chemistry of waters (spring and wells) discharging in the Umbria-Marche Apennines to define the main processes acting in the area and controlling the waters (and dissolved gases) composition (main cations, anions, trace elements and isotopes), since the scientific knowledge on this sector of central Apennine is not comprehensive and referred to relatively old literature data [9].

These results will represent the reference values for several geochemical parameters and subsequently, their periodical and/or continuous monitoring could highlight possible changes that can be interpreted as precursors

of earthquake's preparation processes and therefore indicating the possible occurrence of a seismic event. The geochemical monitoring is generally focused on deep wells and springs since they are less prone to be influenced by seasonal recharging or by pumping of nearby wells [5].

3. Methodology and Expected Results

The project will involve the periodical sampling and analysis of several springs and wells distributed all over the study area to determine their geochemical and isotopic composition, as it follows:

- water physiochemical parameters (i.e. T, pH, EC and Eh potential);
- major cations (i.e. Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (e.g. HCO_3^{-}, Cl^{-}, SO_4^{2-}, F^{-}, etc.);
- trace elements (e.g. Fe, Mn, Li, B, As, Sr and others that has proven to be reliable as seismic tracers in similar studies [2]);
- hydrogen ($\delta^{2}H$-H_2O) and oxygen ($\delta^{18}O$-H_2O) isotopic ratio:
- isotopes of B ($\delta^{11}B$), Sr ($^{87}Sr/^{86}Sr$), S ($\delta^{34}S$-SO_4) and C ($\delta^{13}C$-TDIC);
- major dissolved gases concentrations (e.g. N_2, O_2, Ar, He, CO_2 and CH_4);
- carbon isotopic ratio ($\delta^{13}C$) of dissolved CO_2 and CH_4;

Additionally, the monitoring of the hydrological parameters, i.e. springs flow rate and wells water level, will be performed, since several studies carried out in other seismic prone area in central-southern Italy has shown promising results [10]. The expected outcomes for this project are to: (a) define the main geochemical processes acting in the area, (b) define the hydrogeological pathway, (c) investigate the possible interplay between deep-originated fluids and shallow aquifers, and (d) evaluate the possible use of selected geochemical parameters as precursors of seismic activity. The geochemical analysis will be planned in different laboratories (mainly University of Urbino and Florence and CNR-Institute of Geosciences and Georesources of Pisa).

4. References

[1] Center for Research on the Epidemiology of Disaster (CRED), 2018, *The Human Cost of Natural Disasters: a global prospective*, CRED-IRSS-UNISRD, pp. 31.

[2] Claesson L et al., 2004, *Hydrogeochemical changes before and after major earthquake,* Geology, 32, 641-644.

[3] Wang C. W. & Manga M, 2010, *Earthquakes and water,* Springer, 225.

[4] Ingebritsen S. E. & Manga M, 2014, *Earthquakes: hydrogeochemical precursors,* Nature Science, 7, 697-698.

[5] Thomas D., 1988, *Geochemical precursors to seismic activity,* PAGEOPH, 126, 241-266.

[6] King C-Y et al., 1995, *In search of earthquake-related hydrologic and chemical changes along the Hayward Fault,* Applied Geochemistry, 9, 83-91.

[7] Guidoboni E et al., 2018, *CFT14: Catalogue of Strong Earthquakes in Italy (461 B.C.-1997) and Mediterranean Area (760 B.C.-1500),* INGV-SGI.

[8] Laurenzano G et al., 2008, *2D numerical simulation of earthquake ground motion: examples from the Marche Region, Italy,* J. Seismol., 12, 395-412.
[9] Capaccioni B. et al., 2001, *Hydrogeochemistry of groundwaters from carbonate formation with basal gypsiferous layers: an example from the Mt. Catria-Mt. Nerone ridge (Northern Apennines, Italy),* J. of Hydrology, 253, 14-26.
[10] Barberio M. et al., 2016, *Hydrogeological monitoring to assess possible pre-seismic correlations of groundwater changes with seismic activity in central Italy,* Rend. Online Soc. Geol. It., 41, 338-341.

5. Description of the research in the three-year period

I year: 1-6 m(s), detailed bibliographic research, take lessons of the ReMeST doctorate program, planning the sites for collecting water samples and do the analysis at different laboratories, starting the monitoring program of springs and wells; 7-12 m(s), monthly monitoring and analyses, planning type of springs to be continuously monitored for some physical and geochemical parameters.
II year: 13-18 m(s), two-time months monitoring and analysis; 19-22 m(s): monitoring and analysis every ten days; 23-24 m(s), 2-months experience in a foreign research laboratory, also addressed to specific courses in fluid geochemistry.
III year: 25-30 m(s), periodical monitoring and analysis according to the geochemical variations found in the two previous years and elaborating conceptual models on the origin of the waters and water-rock interaction; 31-33 m(s), 3-months foreign experience in a foreign research laboratory also testing different analytical methods; 34-36 m(s), writing the PhD Thesis.