Title: Development of geophysical and numerical modeling for studying time evolution of complex geological systems and delineating hazard scenarios

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Research program

Characterization of complex geological systems, such as active fault zones, subsidence areas, volcanic districts, in terms of volumetric distribution of geophysical parameters is essential for understanding the processes that govern their dynamics (e.g., fluid migration within fault damage zones, land-surface elevation lowering, magma or volcanic fluid uprising). On the other hand, the numerical modelling, together with field geophysical monitoring, is an indispensable tool to study the time evolution of such complex systems.

In this framework, the present research programme aims at developing geophysical models and methods for analyses of complex geological systems characterized by intense CO_2 degassing. Over last decade, geophysical methods have been successfully applied for detection of CO_2 degassing in both volcanic and non-volcanic areas (Byrdina et al., 2009; Pettinelli et al., 2010; Revil et al., 2011; Byrdina et al., 2014). In particular, geoelectrical investigations (i.e. self-potential and resistivity tomography surveys) are shown to be among the most appropriate methods for revealing spatial distributions of carbon dioxide, whose discharge in non-volcanic areas is essentially controlled by fractures, faults and/or structural highs of the carbonate reservoir (Rogie et al., 2000). Self-Potential (SP) measurements usually show a strong correlation between CO_2 degassing and negative SP anomalies in areas with focused release, while electrical resistivity tomograms identify zones of influence of gas vents as both conductive and resistive anomalies depending on the geological setting and the physical, chemical and biological soil environment of the investigated vents (Arts et al., 2009; Byrdina et al., 2009; Pettinelli et al., 2010). The combination of geophysical results with geological data allows to localize preferential migration pathways of CO_2, while time evolution of CO_2 fluxes and gas saturation degree can be simulated by using discrete dynamical models like cellular automata and/or software like Tough2, which uses a multi-phase approach to fluid and heat flow accounting for the movement of gaseous and liquid phases, their transport of latent and sensible heat, and phase transitions between liquid and vapor.

The research programme therefore aims to:

- examine data of different nature for an accurate characterization of the complex geological context;
- investigate the factors controlling the fluid uprising through in-situ measurements repeated over time;
- develop numerical modeling for simulating the time evolution of the investigated system and delineating possible hazard scenarios.

The study of the infiltration processes and uprising of fluids within the subsoil is fundamental for estimating the risks associated with subsidence in different geological contexts. Thus, the results of these studies could be of great help in predicting possible hazard scenarios by estimating variation in time and space of CO_2 fluxes and more probable areas for sinkhole occurrence.

Proposal for a PhD position

The research activity will be focused on the Ciorlano area of Matese Ridge (southern Apennines, Italy), which recent accurate geological and geochemical analyses classify as the area with the highest non-volcanic natural emissions of CO_2 ever measured on Earth (Ascione et al., 2018).

The proposal will follow the following schedule:

- identification of sources and analysis of the various factors that govern the CO_2 migration in the unsaturated zone;
- monitoring of CO_2 degassing through repeated geophysical measurements over time;
- simulations of time-evolution of the investigated area for the definition of possible future scenarios.

In particular, first an integrated interpretation of data from geological, geochemical and geophysical investigations will allow to reconstruct the 3D model of the examined complex geological system and to identify key parameters for studying variations in the system response due to CO_2 degassing. Then, a numerical modeling will be performed to simulate the formation of preferential migration pathways and their evolution over time. The numerical results will be compared with those obtained from seasonal repeated surveys of geoelectric measurements.

The major challenge that the project expects is to attempt an estimation of the time intervals for non-volcanic CO_2 migration as a function of the thickness of the involved soil layers for the definition of future scenarios and possible changes in the amount of non-volcanic CO_2 emissions.