HYDROGEOPHYSICAL BASE APPROACH FOR MONITORING FLUID CIRCULATION IN CARBONATE RESERVOIRS

M. Guerriero, L. Capozzoli, G. De Martino, V. Giampaolo, E. Rizzo
Istituto di Metodologie per l'Analisi Ambientale - Consiglio Nazionale delle Ricerche (CNR-IMAA), Italy
Hydrogeosite Laboratory (CNR-IMAA), Marsico Nuovo (PZ), Italy

Introduction. The purpose of this article is to present a innovative hydrogeophysical research project aimed to understand the circulation of fluids in carbonate reservoirs through innovative hydrogeophysical methodologies. The starting point of the research is the study

(characterization and monitoring) of carbonate environments and the fluids circulation through innovative hydrogeophysical methodologies. The scientific discipline that deals with the study of the circulation of fluids in the subsoil is hydrogeophysics, which consists in the integration of the geophysical methods with hydrogeology. The target of the research is represented by monitoring of carbonate rocks and karst systems able to host two of the most important natural resources for the human life: water and hydrocarbons. Water is the most abundant resource in the subsoil and plays a crucial role for the life of the earth, for this reason rightly called also blue-gold. Indeed, water is a fundamental socio-economic resource constantly subjected to stresses, due to industrial and agricultural activities, which deeply affect the quality. The safeguard of the water is essential for the preservation of the biosphere. (Barlow *et al.,* 2002). In Italy, carbonate rocks represent the second most important hydrogeological complex (Sappa, 2013) for the circulation of groundwater. This type of aquifers are characterized by high hydraulic permeability and high groundwater flow speeds. In order to safe carbonate aquifers, the Italian legislator has promulgated more than ten year ago a law to ensure quality of aquifers aiming to realize a effective management of the resource (DL n.152/2006).

Moreover, the importance of carbonate system for water management and exploitation does not end with the only supply of water for drinking use or for agricultural and industrial activities. Indeed, carbonate rocks can provide useful information to exploit the natural energy connected to the water resource. This is the case of the geothermal energy caused by the heat present in the deeper layers of the Earth's crust.

Further, in the last years, the interest of governments, companies and research institutes for the geothermal exploitation is considerably increased. There are many European countries which are investing in this field for developing new technologies connected to the monitoring and exploiting of the geothermal energy. Italy was the first country (in 1913) where geothermal energy was exploited for industrial power production and is now the sixth-largest geothermal electricity producer in the world. The geothermal potential of Italy, both for power production and direct uses, is really huge due to particular geological conditions. For this reason, many industrial and scientific projects have been carried out in Italy the last years for assessing shallow and deep geothermal resources (Santilano *et al*., 2015).

Finally, it should not be forgotten, that carbonate complexes host the main source of non-renewable energy in the world: hydrocarbons. Porous and permeable rocks that host hydrocarbons are called reservoir rocks. Their nature geometry are the main target of the mining exploration (Macini *et al*. 2009). However, carbonate rocks host not only oil, but also water. The contemporary presence of oil and water represents one of the biggest problems for oil companies that deal with extraction of crude oil. Due to the density difference of the various components, usually carbonatic reservoirs host separately water, oil and gas resources; moreover, during extraction operations, possible intrusion of the various components can occur. From the economic point of view, this aspect is crucial since that water management costs are extremely high, ranging from 5 to 50 cents per oil barrel. Just think of the fact that for one barrel of crude, generally are extracted three barrels of water. For reducing the impact of water during oil-extraction, oil producers are looking for new technologies and techniques of monitoring to improve production efficiency (Bailey *et al*., 2000).

A possible solution for the problem consists in monitoring hydrocarbon reservoir during production through the use of geophysical non-invasive methods. Several approaches are currently adopted for this purpose based on the integration and combination of geophysical methods, including seismic and non-seismic methods. For example, Dell'Aversana *et al*. (2017) highlight the potential of EM measurements performed in multiple boreholes using electrodes installed directly on the well casing as a new methodology to study the phenomenon of water intrusion in oil reservoirs. Their results indicate that borehole EM methods are effective for reservoir monitoring even in presence of metallic casing.

Fig. 1 - Localization of Castel di Lepre's cave (Marsico Nuovo, Italy) where real scale experiment test will be performed to evaluate the proposed hydrogeophysical approach for investigating carbonate reservoirs.

Methodology. With the aim to investigate the hydrogeophysical behavior of carbonate rocks, two distinct phases will be analyzed where s hydrogeophysical based approach will be adopted.

The first phase will be characterized by the realization of a laboratory case study where a small scale carbonate system (<1m^3) will be simulated. EM and acoustic techniques will be applied to create and support hydrogeological mathematical models realized to predict the water flow distribution in fractured zones characterizing the carbonate reservoirs.

The second phase will consist in reproducing the experiment in a natural carbonate complex where a full scale test will be performed to evaluate the effectiveness of a hydrogeophysical approach for monitoring carbonate reservoirs. This phase will be realized in the karst area of Castel di Lepre (Marsico Nuovo, Basilicata, Italy) (see Fig. 1) where an impressive fluid circulation coming from the top of the mountain has been investigated with use of non-conventional geophysical methods in the past (Rizzo *et al.*, 2017).

Expected results. The target of the research is aimed to develop methodologies and new hydrogeophysical approach able to monitor fluid circulation in carbonate rocks. Assessment of indirect and low cost methods is certainly important to protect water resource and promotes its use for renewable energy production. Further, the understating of water circulation flow has important implications also for a smart managing of oil or geothermal reservoirs to effective reduce costs and increase productivity of the exploitation phases.

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