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Geophysical investigations in the Gañuelas-Mazarrón Tertiary basin (SE Spain): A natural analogue of a geological CO_2 storage affected by anthropogenic leakages

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ABSTRACT

In the framework of a Spanish project focused on CCS technologies (PSE-CO_2 Project), the Gañuelas-Mazarrón Tertiary Basin (SE Spain) was globally studied as a natural analogue of a CO_2 reservoir affected by anthropogenic leakages. In this context, geophysical investigations were carried out in order to determine the location, morphology and extent of the CO_2-enriched saline aquifer existing in the bottom of the basin, and evidenced by two core drills performed in the 1980s for geothermal purposes (La Ermita de El Saladillo and El Alto de El Reventón. The geophysical researches were performed by reprocessing the vertical electrical soundings also made in the 1980s, but also by means of new campaigns of electrical resistivity tomography, time-domain electromagnetic surveys and gravimetry. The main results from geoelectric and electromagnetic investigations have allowed identifying three main different geological materials in the basin based on their resistivity: metamorphic materials from the Nevado-Filábride Complex, and Tertiary sedimentary materials mainly consisted of sandy calc-marls and intruded by more or less altered Neogene volcanic rocks. Furthermore, it has been defined the basin as a graben limited by the Nevado-Filábride materials affected by very vertical faults and frequently filled by volcanic rocks, reaching a depth of about 500 m. However, the gravimetric research has allowed to better identifying the strong gradients in the borders of the basin, which is indicative of fairly net and vertical contacts, and also to establish a geological model of the basin. This model includes the SW and NE boundaries very vertical and a deeply sunken central zone with about 9 km wide. This area has been divided in turn into two sections, within which the one located at the SW (~5 km) has a depocenter that reaches a depth of about 900 m. Consequently, the possibility that the CO_2 be in supercritical state in certain areas of the aquifer, which should be hosted at the contact between the Tertiary sediments/volcanic rocks and the Nevado-Filábride materials, has not to be discarded. Therefore the studied basin would represent an excellent natural analogue for a geological CO_2 storage in a deep saline aquifer.

1. Introduction

Carbon Capture and Storage (CCS) technologies are currently one of the most important options to reduce the CO_2 emissions to the atmosphere, among which the CO_2 Deep Geological Storage (CO_2-DGS) represents the last stage of an internationally envisaged technology for CO_2 sequestration. The increasing interest in this option is reflected in the numerous studies focused on the long-term behaviour of a potential CO_2-DGS, considering the safety assessment as well (Anderson et al., 2006; Hansen et al., 2013; Keating et al., 2013; Lafortune et al., 2009; Lewicki et al., 2007; Quattrocchi et al., 2009; Summers et al., 2005). Gas and oil depleted or quasi-depleted reservoirs, unmineable coal seams and deep saline aquifers are the best options for the long-term storage of CO_2, the latter being the most suitable option for Spain, where it was estimated a global capacity of CO_2 storage of about 45,000 Mton (Zapatero et al., 2009).

As a consequence of the abovementioned option for CO_2 storage, many studies focused on the CO_2-rock-water interaction processes have been performed during the last decade, which have greatly contributed to the prediction and assessment of the long-term behaviour and safety of any CO_2-DGS hosted in deep saline aquifers (Annunziatellis et al., 2008; Auqué et al., 2009; Auqué et al., 2013; Chopping and Kaszuba, 2012; Harvey et al., 2013; Li et al., 2013;

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Oldenburg and Lewicki, 2006; Pauwels et al., 2007; Prado-Pérez and Pérez del Villar, 2011; Prado-Pérez et al., 2014; Rodrigo-Naharro et al., 2013a, 2017; Trippetta et al., 2013; Vaselli et al., 2010).

In the framework of a Spanish project focused on CCS technologies (PSE-CO_2 Project), the Gañuelas-Mazarrón Tertiary Basin (GMTB), located in the Murcia Region (SE Spain), was globally studied as a natural analogue of a CO_2 reservoir affected by leakages due to anthropogenic activities (Nisi et al., 2010a, 2010b; Pérez del Villar et al., 2008; Rodrigo-Naharro, 2014; Rodrigo-Naharro et al., 2011, 2012, 2013a, 2013b, 2017). Among the studies performed, a geophysical investigation of the GMTB was carried out in order to determine the location, morphology and extent of the CO_2-enriched saline aquifer existing in depth, which was intersected, at different depths, at the bottom of the basin by two core drills performed for geothermal purposes in the 1980s (La Ermita de El Saladillo and El Alto de El Reventón). Consequently, the aquifer evolution, including its morphology and depth, should be directly related to the evolution of the bottom of the basin. In order to infer this evolution, it has been performed the reprocessing of the vertical electrical soundings (VES) made by IGME-ADARO in the 1980s, but also several geophysical campaigns by means of electrical resistivity tomography (ERT), time-domain electromagnetic (TDEM) surveys and gravimetry.

VES and ERT were used with the aim to identify the characteristics of the different geological materials and to define the structural model of the basin as well. VES can reach an important depth (>500 m in several surveys) and this allowed readjusting the shape of the subsoil up to the bottom of the basin from an electrical point of view. However, ERT profiles, due to the limitation of this method regarding the depth reached (~150 m), were located in the borders of the basin considering their orientation. In relation to TDEM, they were placed in the central points of the basin with square loops of 200 and 300 m to reach the basement of the basin that could reach a depth > 500 m, as suggested from VES data. Finally, a gravimetric research was performed, being the density of measurements of ~2.3 stations/km^2. This density allowed to define the morphology of the basement of the sedimentary basin and to identify the contacts with the outcropping materials as well, being also estimated the thickness of the different geological units and the depth of contact between them.

Though the resolution of the abovementioned geophysical methods is directly related to the resistivity and density contrasts among the explored geological materials and inversely related to the exploration depth, these methods were used because they were considered suitable for the objective pursued in this investigation. Thus, it is convenient, on the one hand, to compare the observations in depth through the resistivities obtained by electrical and electromagnetic methods and, on the other hand, to contrast the previous results with other obtained from a very different technique as gravimetry, in order to obtain more robust conclusions. Accordingly, densities of the outcropping lithologies

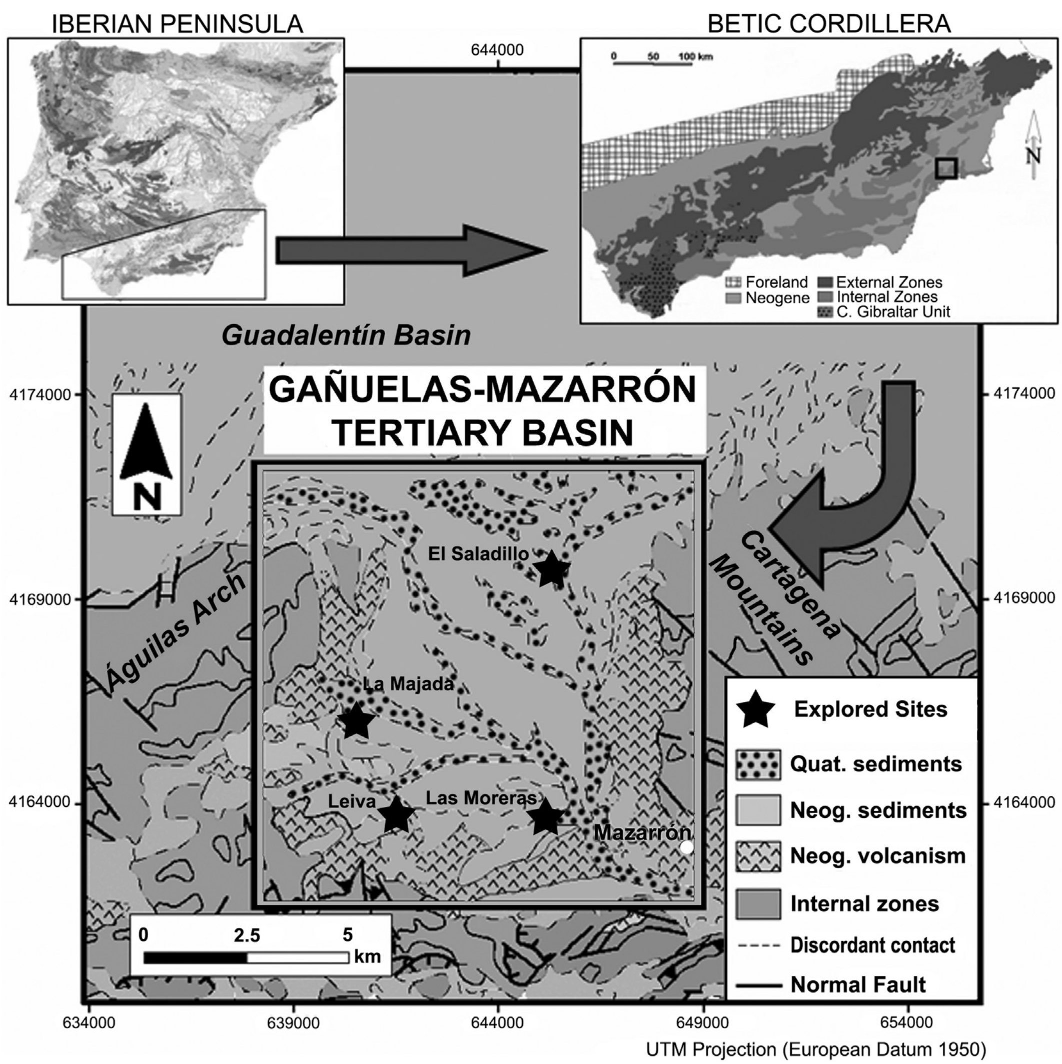

Fig. 1. Schematic geological map of the Gañuelas-Mazarrón Tertiary basin.