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Diffuse soil CO_2 flux to assess the reliability of CO_2 storage in the Mazarrón–Gañuelas Tertiary Basin (Spain)

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ABSTRACT

In the framework of a global investigation of the Spanish natural analogues of CO_2 storage and leakage, four selected sites from the Mazarrón–Gañuelas Tertiary Basin (Murcia, Spain) were studied for computing the diffuse soil CO_2 flux, by using the accumulation chamber method. The Basin is characterized by the presence of a deep, saline, thermal (~47 °C) CO_2-rich aquifer intersected by two deep geothermal exploration wells named "El Saladillo" (535 m) and "El Reventón" (710 m).

The CO_2 flux data were processed by means of a graphical–statistical method, kriging estimation and sequential Gaussian simulation algorithms. The results have allowed concluding that the Tertiary marly cap-rock of this CO_2-rich aquifer acts as a very effective sealing, preventing any CO_2 leak from this natural CO_2 storage site, being therefore an excellent scenario to guarantee, by analogy, the safety of a CO_2 storage.

1. Introduction

Carbon dioxide is a greenhouse gas (GHG) that naturally exists in the atmosphere. Anthropogenic activities, especially those related to the power generation from fossil fuels, are causing the increase of this gas concentration in the atmosphere since the industrialisation era that began in the early XIX century [1], and it is predicted to increase further. This phenomenon likely contributes to the known and worldwide accepted climate change.

One of the most important options to reduce CO_2 emissions to the atmosphere is the development of Carbon Capture and Storage technologies (CCS), which have been mainly deployed into large industrial emission sources, such as power and cement plants, refineries, steelworks and ceramic industries. These technologies firstly involve the separation of the CO_2 from the rest of the gases emitted by such emission sources. Later on, it is compressed to obtain a concentrated stream of CO_2. Finally, it is transported and injected into a suitable geological storage formation in a depth greater than 800 m, where CO_2 reaches the supercritical state. Therefore, the CO_2 deep geological storage represents the last stage of CCS technologies and, what is more important, the most internationally accepted method for CO_2 sequestration, in order to minimize the effects on the global climatology.

Among the possible deep geological storage formations, deep saline aquifers are apparently the most suitable options, particularly in those countries where other options, such as gas and oil depleted or *quasi* depleted reservoirs, as well as non-mining coal seams, are not viable. In Spain, the estimated capacity of geological CO_2 storage in deep saline aquifers is about 45,000 Mton, according to data from the EU GeoCapacity Project [2].

However, in order to provide robust predictions of the performance of CO_2 disposal sites at the required timescale (>1000 a), the study of natural CO_2 accumulation sites is required [3,4], since they are powerful tools to understand the long-term behaviour of the CO_2 once injected into the suitable geological formation.

The scientific community has indeed generally accepted that long-term extrapolation in terms of safety of a deep geological storage of toxic industrial wastes (high activity radioactive wastes, industrial and mining wastes) and even greenhouse gases cannot be satisfactorily realized on the basis of short-term laboratory investigations [5]. Therefore, countries affected by these problems have developed methods of investigation, which include both laboratory tests, where the variables are controlled, and the study of industrial and natural analogues.

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Although investigations on natural CO_2-rich accumulation systems are not yet sufficiently developed, some authors [6,7] have listed the existing CO_2 natural reservoirs worldwide and the experimental reactions between CO_2 and the storage formations [8]. Moreover, in the last decade several studies have focused their attention on the evaluation of the safety of a CO_2 geological storage by investigating CO_2 natural analogues [9–17].

In this respect, one of the most important aspects concerning the performance assessment of a deep CO_2 geological repository in a deep saline aquifer is to increase the knowledge on the interaction among CO_2 and the storage and sealing formations, as well as the physico-mechanical resistance of the sealing formation. As a consequence, the measurements of the surficial CO_2 leakage rates are an important tool to evaluate: (i) the efficiency of the aforementioned interaction processes; (ii) the capacity of the sealing geological formation for the retention of CO_2; and (iii) the possible effects of the CO_2 released on the environment.

For these reasons, this work is focused on the retention capacity of the cap-rock by measuring the diffuse soil CO_2 flux in a selected site, according to: (i) the presence of a deep CO_2-rich saline aquifer; (ii) the structural geological characteristics; and (iii) the nature of the cap-rock. This site is located in the Mazarrón–Gañuelas Tertiary Basin, which it is in the southeast of the Iberian Peninsula, inside the Internal Zones of the Betic Cordillera (Fig. 1).

The deep CO_2-rich saline aquifer is hosted in an important marble formation and discovered through geothermal investigations carried out in the 1980s [18]. The cap-rock is formed by Tertiary marls (>500 m thick), that avoided the CO_2 leakages until irrigation wells were drilled in the 1960s. The over-exploitation of the shallowest fresh aquifers caused their contamination by the deep-seated CO_2. In addition, CO_2 might be released through leakage paths represented by the main faults.

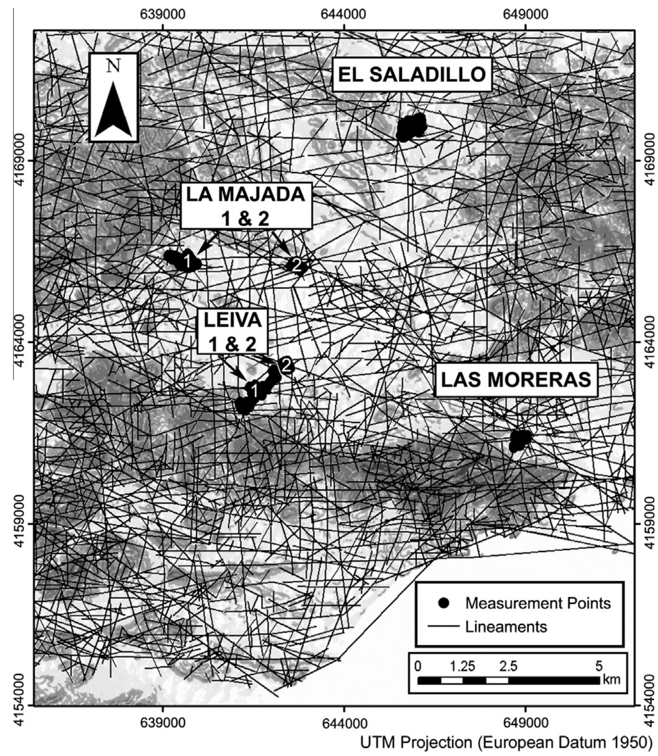

Fig. 2. Location map of the explored sites. Notice the high lineament intersection density existing in these sites.

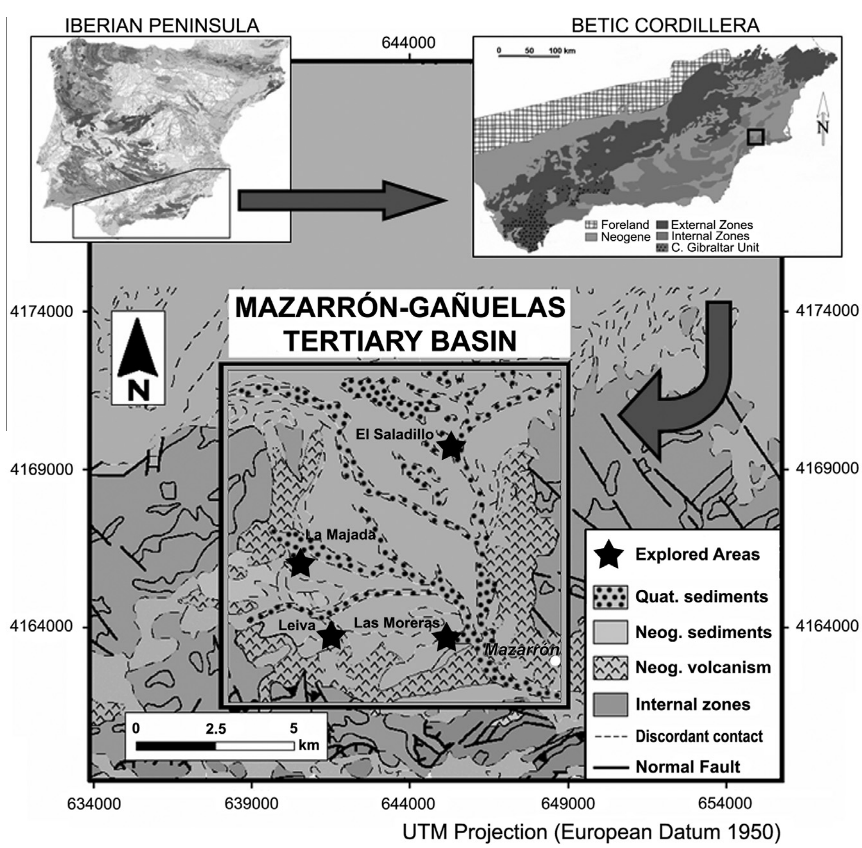

Fig. 1. Schematic geological map of the Mazarrón–Gañuelas Tertiary Basin.