High-Pressure CO_2 Adsorption and Mineralogical Evaluation of Sandstones from the Mesohellenic Trough (Greece) for Geological Carbon Storage

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Introduction

Carbon capture and storage (CCS) is considered one of the most promising strategies for mitigating anthropogenic CO_2 emissions and enabling a transition toward low-carbon energy systems. Well confined saline aquifers within porous geological formations of clastic rocks and lithology such as sandstones are particularly attractive candidates as reservoirs for long-term CO_2 storage. This is mainly due to their favorable porosity, permeability, mineralogical composition, thickness and widespread distribution as exemplified by the Utsira Formation at the Sleipner Project in Norway [1]. The Mesohellenic Trough (MHT) represents a large sedimentary molassic basin located at the northern central Greece. Deposition of various geological formations commenced in Late Eocene and lasted up to the Early Miocene age. Since the sandstones are the dominant facies of the MHT formations and they are potentially suitable for CO_2 sequestration applications, we explore their validity in this geologic regime. Previous studies have shown that sandstones from this region contain mineral phases capable of interacting with injected CO_2, potentially leading to mineral trapping mechanisms and long-term storage stability [2,3]. The present study investigates the CO_2 adsorption behavior and structural evolution of a representative sandstone sample from the Pentalofos clastic formation of the southeastern MHT under high-pressure CO_2 and temperature exposure conditions, simulating subsurface storage environments of a potential injection well.

Materials and methods

The sandstone sample was crushed into small fragments and subjected to high-pressure CO_2 adsorption measurements using a customized manometric gas sorption system consisting of a high-pressure autoclave, gas burette, control unit and relevant data acquisition software. Adsorption experiments were performed at temperatures of 303, 308, 313 and 318 K and pressures ranging from 1 to 5 MPa. To evaluate the effect of CO_2 exposure on the rock matrix, the sandstone sample was characterized before and after the adsorption experiments using X-ray diffraction (XRD) for mineralogical analysis, Fourier transform infrared spectroscopy (FTIR) for identifying chemical and structural changes and N_2 adsorption/desorption at 77 K to determine specific surface area and pore structure.

Results and discussion

The investigated MHT-derived sandstone sample exhibited measurable CO_2 adsorption capacity under high-pressure conditions, with a maximum uptake of approximately 5.93 mg/g (0.59 wt.%) at 303 K and 5 MPa. The obtained CO_2 adsorption isotherms are depicted in Figure 1. The gas adsorption capacity decreased with increasing temperature, indicating that physisorption mechanisms dominate the interaction between CO_2 molecules and the sandstone surface. Preliminary mineralogical characterization revealed that the sandstone is mainly composed of quartz, feldspars, and calcite, typical of sandstones belonging to the Pentalofos

Formation of the MHT basin. The porous structure of the rock provides adsorption sites and pathways for CO_2 migration and retention. Comparative characterization of the samples before and after high-pressure exposure aims to identify potential structural or mineralogical alterations induced by CO_2 interaction, including possible changes in pore structure, mineral phases or surface chemistry. These analyses provide valuable insights into the stability of sandstone reservoirs under repeated CO_2 injection conditions.

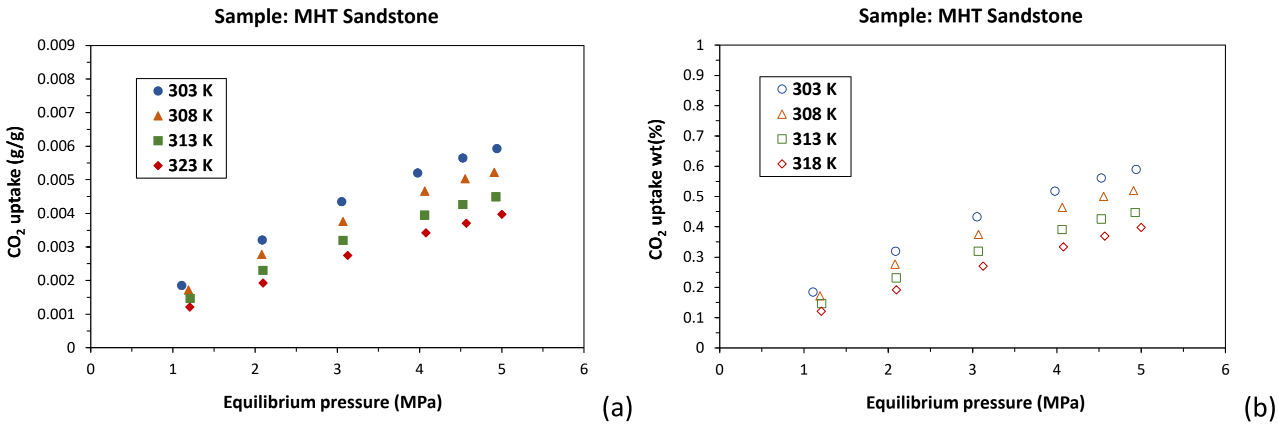

Figure 1. *CO_2 adsorption isotherms at 303, 308, 313 and 318 K for the MHT-derived sandstone sample. The CO_2 adsorption uptake is expressed as (a) g adsorbed CO_2/g dried sample and (b) wt.% CO_2*

Conclusions

This study evaluates the CO_2 adsorption performance and structural stability of MHT sandstone under simulated geological storage conditions. The results indicate that the investigated sandstone exhibits measurable CO_2 adsorption capacity and structural features favorable for CO_2 retention. The combined adsorption and characterization analyses contribute to assessing the suitability of sandstone formations in the Southeast Mesohellenic Trough as potential geological reservoirs for CO_2 sequestration in Greece.

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