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A natural analogue for CO_2 mineral sequestration in Miocene basalt in the Kuanhsi-Chutung area, Northwestern Taiwan

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ABSTRACT

In general, CO_2 sequestration by carbonation is estimated by laboratory experimentation and geochemical simulation. In this study, however, estimation is based on a natural analogue study of the Miocene basalt in the Kuanhsi-Chutung area, Northwestern Taiwan. This region has great potential in terms of geological and geochemical environments for CO_2 sequestration. Outcropping Miocene basalt in the study area shows extensive serpentinization and carbonation. The carbon stable isotopes of carbonates lie on the depleted side of the Lohmann meteoric calcite line, which demonstrates that the carbonates most probably precipitate directly from meteoric fluid, and water–rock interaction is less involved in the carbonation process. Oxygen stable isotope examinations also show much depleted ratios, representative of product formation under low temperatures (~50–90 °C). This translates to a depth of 1–2 km, which is a practical depth for a CO_2 sequestration reservoir. According to petrographic observation and electron microprobe analysis, the diopside grains in the basalt are resistant to serpentinization and carbonation; therefore, the fluid causing alteration is likely enriched with calcium and there must be additional sources of calcium for carbon mineralization. These derived geochemical properties of the fluid support the late Miocene sandstone and enclosed basalts as having high potential for being a CO_2 sequestration reservoir. Moreover, the existing geochemical environments allow for mineralogical assemblages of ultramafic xenoliths, indicating that forsterite, orthopyroxene and feldspar minerals are readily replaced by carbonates. Based on the mineral transformation in xenoliths, the capacity of CO_2 mineral sequestration of the Miocene basalt is semi-quantitatively estimated at 94.15 kg CO_2 chemically trapped per 1 m^3 basalt. With this value, total CO_2 sequestration capacity can be evaluated by a geophysical survey of the amount of viable Miocene basalt at the potential sites. Such a survey is required in the near future.

1. Introduction

Burning of fossil fuels has considerably increased the total load of CO_2 in the atmosphere. Although the long-term consequences of increasing atmospheric CO_2 are still being debated, one possible outcome is global warming as additional CO_2 and other greenhouse gases trap heat from escaping the earth's surface. This has lead to atmospheric CO_2 reduction efforts. The Intergovernmental Panel on Climate Change (IPCC) held a workshop in November 2002 in Regina, Canada to identify geological sequestration as one of several options that have the potential to help lessen the effects and costs of climate change (IPCC, 2002). The CO_2 is captured after combustion and injected back into geological reservoirs where it is immobilized by natural processes. Some potential reservoirs have been evaluated, including deep saline aquifers, depleted oil and gas fields, coal-bearing formations, and the deep ocean (IPCC, 2002). An IPCC Special Report published in 2005 made an extensive technical review on carbon dioxide capture and storage (IPCC, 2005). Underground geological storage is still one of the most effective strategies to sequestrate CO_2. Based on these guidelines, the Taiwan Government initiated the national wide Taiwan CO_2 Reduction Project (TCRP) in 2007 to develop technologies for CO_2 capture, reuse, and storage in Taiwan. This study is part of TCRP's research efforts to investigate potential geological storage sites in Taiwan.

In the IPCC Special Report on carbon dioxide capture and storage, the storage mechanisms for geological formations are categorized into structural/stratigraphic, hydrodynamic, and geochemical trappings (IPCC, 2005). Structural and stratigraphic traps are reservoir-trap-seal systems such as those that trap hydrocarbons. In the case of hydrodynamic trapping, the residence time of CO_2 in deep saline aquifers of low permeability is potentially thousands to millions of years. The CO_2 migrates through a deep saline

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