Introduction

As decarbonisation becomes a hot topic in the industry, PETRONAS is very committed to accomplishing net zero carbon emissions by 2050, as part of the company's commitment to the Paris Agreement (Hassan et al., 2018). To achieve this aspiration, PETRONAS has identified carbon capture and storage (CCS) as a vital method to manage excess carbon dioxide (CO_2) gas, either from high CO_2 fields or anthropogenically from power plants and hydrocarbon platforms. CCS requires an underground formation called CO_2 storage site where the captured CO_2 can be safely injected and stored without potential leakage in the near future. A good CO_2 storage site usually comprises high permeability reservoir rock that can store the CO_2 and a low permeability caprock formation to contain the gas.

In PETRONAS, there is a plan to repurpose depleted hydrocarbon fields to become a potential CO_2 storage. One of the identified depleted fields is N Field, a carbonate field located in offshore East Malaysia, which was previously developed mostly for gas production, with minimal oil production (Khalid et al., 2014). Because it is already depleted, there is a challenge in getting fresh core samples, as the appraisal well (N-3 Well) was drilled in 1992. Despite having around 111 m of reservoir core samples, many core plugs from the N-3 well were extracted for routine core analysis (RCA), leaving only limited samples in the reservoir sections. On the other hand, the N-3 well's caprock samples were only around 3.5 m and were not properly preserved, making them dehydrated, disintegrated, and fractured, and therefore not suitable for analysis, as shown in Figure 1 below. Nevertheless, N Field has full coverage of drill cuttings in the overburden section, which can be used as an alternative for mineralogical analysis in the caprock section.

Figure 1 *Picture of dehydrated and fractured caprock samples of N Field after being exposed air and humidity without proper preservation.*

Before N Field can be deemed suitable to be a CO_2 storage site, a thorough feasibility study must be conducted, which covers many different disciplines including geology, geomechanics, petrophysics, reservoir engineering, injectivity, and monitoring, measurement, and verification (MMV). The comprehensive study will involve both experimental and simulation works. However, this paper will focus on one part of the overall study, which is the experimental mineralogical study of the field's reservoir and caprock formations.

Method and/or Theory

The objectives and methodology of mineralogical analyses in the reservoir section of the N Field are different from the ones in the caprock section. In the carbonate reservoir section, we are interested to know the changes in mineralogy after the rock samples were in contact with supercritical CO_2 and formation water. The reservoir integrity of CO_2 storage may be in jeopardy if the carbonic acid is formed from the reaction between the CO_2 and water, as the acid could be the cause of the weathering of carbonate rocks (Mohd Amin, 2014). On the other hand, N Field's caprock section is classified as clastic sedimentary rocks, with minimal geochemical reaction when in contact with carbonic acid (Md Shah, 2022). The mineralogical analyses on caprock are usually done as preliminary studies of caprock integrity, with a focus on identifying dominant minerals and particle size distribution.

Experimental mineralogical analysis of N Field's carbonate reservoir rock includes X-ray diffraction (XRD) and inductive coupled plasma (ICP). In addition, we also conducted digital core analysis (DCA) by scanning the selected samples under micro-CT scan and QEMSCAN. To mimic the geochemical reaction during CO_2 storage, the selected samples underwent a static ageing experiment using supercritical CO_2 at reservoir temperature and pressure for 45 days (Md Shah et al., 2018; Sterpenich et al., 2009). After ageing, the same analyses were performed on the aged samples, to observe any changes related to the geochemical reactions (Sazali et al., 2020). The analysis on caprock samples is a bit simpler, as it does not involve a static ageing experiment.

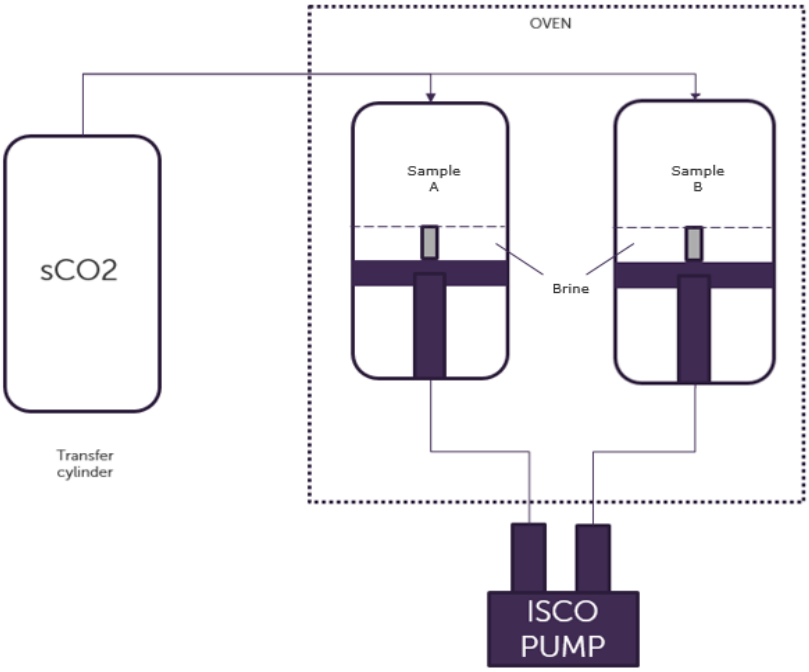

Figure 2 *Schematic diagram of static ageing experiment. The assembly are made from hestaloy to withstand supercritical CO_2 from transfer cylinder. The pressure and temperature of static ageing experiments is controlled by the ISCO pump and oven respectively.*

Observation

Based on RCA and well log data, N Field's reservoir section can be separated into three zones of different permeability values (high, medium, and low). As the low permeability zone is not suitable for CO_2 injection, we only selected core plugs from high and medium permeability zones for experimental analyses. Interestingly, samples from the high permeability zone have higher calcite percentages, while samples from the medium permeability zone have higher dolomite percentages. After ageing, only minimal changes are observed in both samples. The changes are associated with the dissolution of minerals, as proven from the loss of dry weight and from ICP. Micro-CT scan and QEMSCAN images are also consistent, with the detection of minimal changes in pore volume and mineral mapping. On a separate note, quartz and clays are the dominant minerals in the caprock section of N Field. However, the presence of calcite and dolomite in the caprock section is quite significant, at around 10 % of the overall bulk mineralogy.

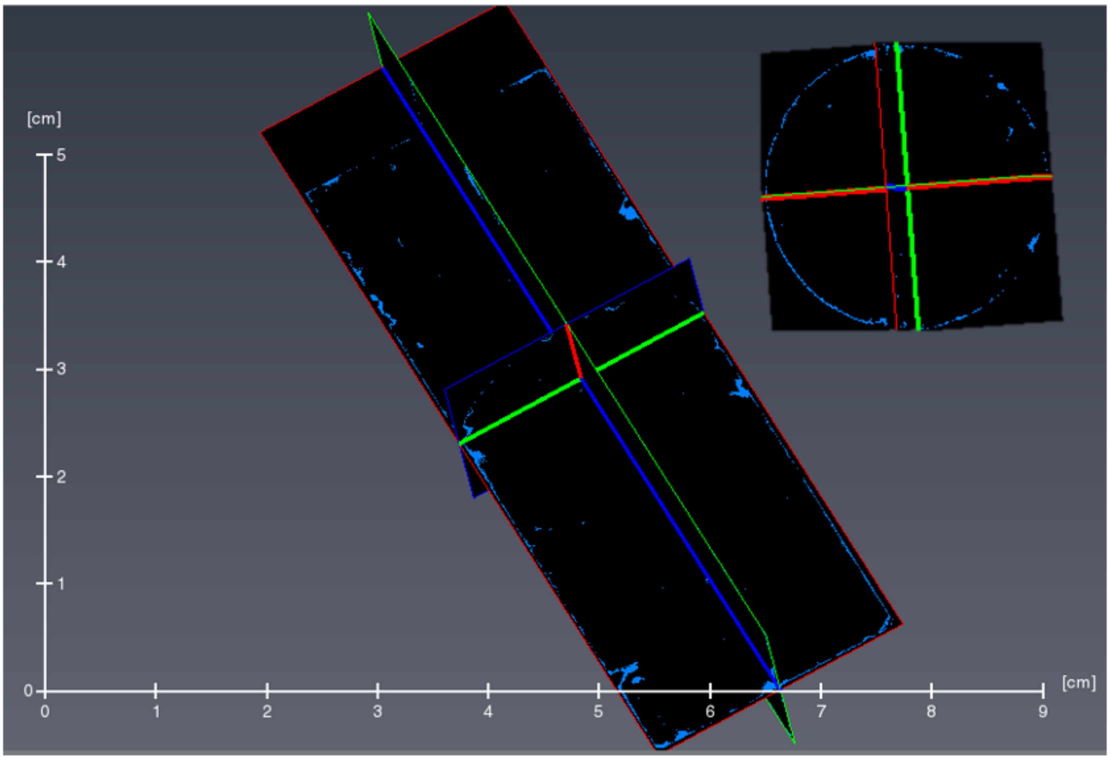

Figure 3 *The minimal changes due to the dissolution of mineral after ageing with CO_2, visualised via digital core analysis (DCA) by overlapping pre- and post-micro-CT images using registration algorithm.*

Conclusions

Based on the preliminary mineralogical study, the minimal changes due to geochemical reactions suggested that the reservoir section of N Field has the potential to be a CO_2 storage site, coupled with low permeability caprock. However, the findings from this research must be integrated with other findings from multiple disciplines before any decision can be made.

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