A QUICK CAPROCK INTEGRITY ANALYSIS FOR CARBON DIOXIDE STORAGE SITES IN MALAYSIAN FIELDS

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ABSTRACT

The purpose of this research work is to establish a quick method for caprock integrity assessment for carbon dioxide (CO_2) storage site selection. There are three main components to evaluate a seal potential which are through seal capacity, seal geometry, and seal integrity. This research work focuses on evaluation of seal characteristics through its pressure behavior and evidence of potential leakage. Various logs data such as gamma ray, sonic logs, density logs, and resistivity are utilized to establish 1D pore pressure analysis. At the same time mud logs data are used to investigate the similarity of hydrocarbon from reservoir and seal (if any). In this study, two fields namely Camos and Zhann have been identified and evaluated for their seal characteristics, thickness, environment of deposition and pressure regimes differences in order to determine their seal effectiveness through integration of pore pressure analysis, background gas or gas while drilling evidence and seal capacity from Mercury Injection Capillary Pressure (MICP) data. Camos field, a depleted carbonate field in Sarawak Basin with continuous seal shows an overpressure regime with gas chimney in immediate seal above it. Meanwhile Zhann field, a depleted clastic field in Malay Basin shows slight overpressure in deeper reservoirs and hydrostatic in most of the multistack sand reservoirs. Both fields show the evidence of effective seal through their own geological characteristics, pore pressure and gas component analysis. Nevertheless, both fields have their own challenges to be converted to potential storage sites. A detailed understanding and analysis is required for seal integrity evaluation which can lead to better plan establishment that may further reduce risks during selection of CO_2 injection site and help to execute future well or field monitoring design.

ABSTRAK

Tujuan penyelidikan ini adalah untuk menghasilkan kaedah pantas bagi penilaian terhadap integriti batuan induk untuk memilih tapak penyimpanan karbon dioksida (CO_2). Tiga komponen utama diguna pakai untuk menilai potensi kedapan batuan induk, iaitu kapasiti batuan, geometri batuan, dan integriti batuan. Penyelidikan ini memberikan tumpuan terhadap penilaian ciri-ciri batuan induk menerusi tingkah laku tekanannya dan pengesanan kebocoran. Pelbagai data log termasuk sinar gamma, sonik, ketumpatan, dan keberintangan diguna untuk melaksanakan analisis tekanan liang 1D. Pada masa yang sama, data log lumpur digunakan untuk menilai kesamaan hidrokarbon dari reservoir dan batuan induk (jika ada). Dalam kajian ini, dua medan iaitu Camos dan Zhann telah dikenal pasti dan dikaji tentang ciri-ciri kedapan batuan, ketebalan, persekitaran pengendapan, dan perbezaan rejim tekanan bagi menilai keberkesanan batuan induk masing-masing menerusi integrasi analisis tekanan liang, bukti aliran semula jadi gas atau gas ketika menggerudi, dan kapasiti batuan kedapan daripada data Tekanan Rerambut Suntikan Merkuri (MICP). Camos yang merupakan medan tersusut karbonat di Lembangan Sarawak dengan batuan induk secara berterusan menunjukkan rejim tekanan yang berlebihan dengan cerobong gas di dalam kedapan perantaraan di atasnya. Sementara itu, Zhann yang merupakan medan tersusut klastik di Lembangan Semenanjung Malaysia telah menunjukkan sedikit tekanan lebih pada reservoir yang lebih dalam dan hidrostatik pada sebahagian besar reservoir pasir bertingkat. Kedua-dua medan menunjukkan bukti tentang kewujudan batuan kedapan induk yang berkesan menerusi ciri geologi masing-masing, tekanan liang, dan analisis komponen gas. Walau bagaimanapun, kedua-dua medan itu mempunyai cabaran tersendiri untuk ditukarkan menjadi tapak penyimpanan yang berpotensi. Kefahaman dan analisis secara terperinci diperlukan untuk penilaian integriti kedapan batuan induk bagi menghasilkan perancangan yang lebih baik supaya boleh mengurangi risiko dalam pemilihan tapak simpanan CO_2 dan membantu dalam merancang pemantauan telaga atau medan pada masa depan.

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CHAPTER 1

INTRODUCTION

1.1 Background

One of the contributors of carbon dioxide (CO_2) emission into the atmosphere is oil and gas industry. The oil and gas sector emitted 250 million metric tons of CO_2 equivalent, making it the second largest producing greenhouse gas pollution sector after power plants industry (U.S. Environmental Protection Agency, 2011). Hence, to support the greenhouse campaign few policies have been established such as Kyoto protocol, established since 2005 and Paris Agreement back in 2016. These had eventually affected major oil and gas companies in ways these companies operated and run the businesses. These companies aim not only producing profitable hydrocarbon resources but also committed to reduce CO_2 emissions.

Following to CO_2 commitment, major oil and gas studies focus on CO_2 sequestration as one of the options if the operated field is a high CO_2 field. One of the important parts in CO_2 sequestration is CO_2 storage in which to ensure the CO_2 remains in subsurface containment such as depleted reservoirs for a long time. The safe storage of CO_2 in deep reservoir units requires an efficient sealing of the overlaying caprock (Valentina et al., 2018). Therefore, assessment of caprock or seal is one of the compulsory studies for offshore CO_2 storage prior to the selection of CO_2 storage fields or sites.

A seal is any rock with extremely low permeability to prevent the upward flow of buoyant fluid (Engelder, 2011) from the reservoir (Figure 1.1). One of the criteria to determine a good seal for $CO2$ storage is the thickness of the seal itself. Lateral extension of the seal is also important as lateral migration or leakage may occur if there is any potential leakage pathway such as sand layers or sand streak in between the shales. Other criteria of good sealing are the caprock must resist the short-term excess injection pressure and the long-term buoyancy pressure (Espinoza et al., 2017). In order for a seal to retain and impede the excess of injection pressure, the seal needs to have higher pressure hence, an overpressure caprock is more favorable for storage or injection sites.

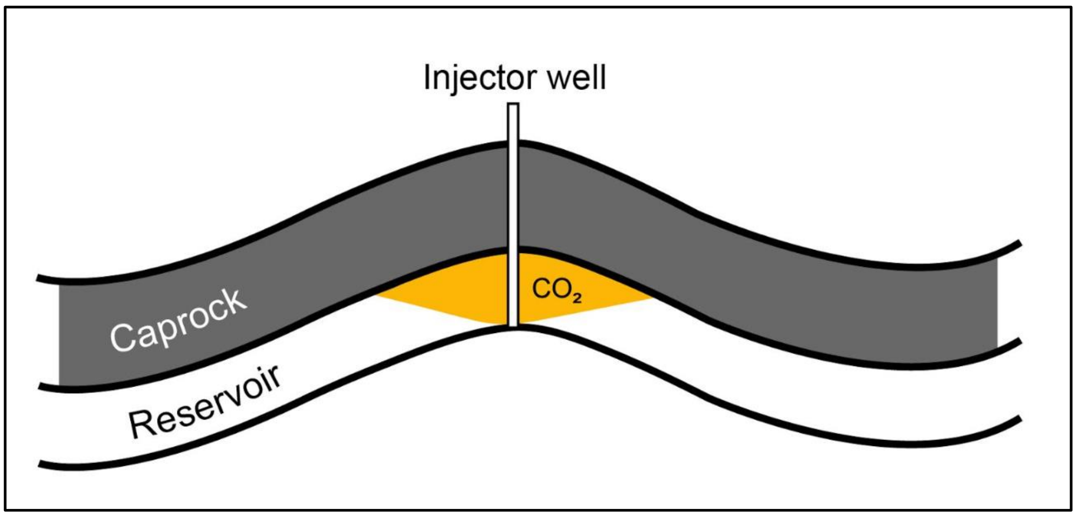

Figure 1.1: Illustration of reservoir, caprock and $CO2$ injector. (Source: Andrew et. Al., 2016)

The long term-term buoyancy pressure is the ability of the caprock to retain pressure from moving further into the caprock through pore throat over time. This reflects sealing potential or sealing capacity of the caprock. The sealing capacity of a caprock is indicated by the magnitude of the breakthrough pressure (or sealing pressure), defined as the differential pressure across the caprock that just exceeds the capillary pressure (Li et al., 2005).

The capillary entry pressure depends on the porous structure of the seal lithologies (Pourtoy et al., 2013). Hence, apart from pore pressure analysis and potential leakage pathway, the seal's geological characteristics are also important in determining the seal potential for CO_2 injection sites.

In this study, one of the focused areas is located in Sarawak basin whereas the seals are mainly deep marine shale with thickness from 300 m to 500 m. Seals in Sarawak basin is mainly from Cycles V and VI which equivalent to Late Miocene age. This seal has a good lateral extension and was deposited during rapid deposition in basinal area. This rapid deposition of sediments has caused seals to be overpressured since the fluids in between the pores in shales are not able to escape. Another focused area is Zhann oil field located in Peninsular Malay Basin Further details will be discussed in Chapter 2.

1.2 Problem Statement

One of focus area of this study is to evaluate caprock effectiveness through pore pressure analysis. Even though the pore pressure method is widely used in the industry for drilling wells however very little application has been realised for caprock evaluation. Pore pressure analysis can be performed once well logs data are made available. However, during drilling, the quickest method to analyze pore pressure is through drilling exponent which consider the drilling parameters in calculations. Overpressure seals can also be determined through type of cavings occurrences during drilling. Another important data that qualitatively shows the seal effectiveness is the background gas data that were recorded during drilling. Gas while drilling analysis can be used to evaluate the overburden sealing potential qualitatively by recording the gas peak in shale during drilling. This data is usually recorded in mudlog report together with gas components (C1 to C6) from reservoir and overburden caprock is also recorded. Therefore, it helps to locate gas evidences at wells, correlate results between wells and distinguish between gas leaking from carbonate structure and biogenic gas.

Overall, the motivation of the study is to utilize the available data mentioned above for caprock evaluation. To date, there are still lack of quick method to analyze caprock integrity by utilizing available data gathered during drilling. Moreover, understanding in differentiating the gas from reservoir and caprock is not fully established. The integration of laboratory analysis, geology understanding and engineering solutions in caprock integrity assessment also is not fully established. In the meantime, full field geomechanics model may take longer time and more data is needed to evaluate the caprock hence a quick method is needed in order to get an overview on the sealing potential especially in selecting fields for CO2 storage sites. Hence, in this study, the is to determine the caprock effectiveness by conducting the objectives which are further explained in the next section.

1.3 Hypothesis

Hypotheses of this study are as follow:

1. Overpressure seal usually caused by rapid deposition where fluid would not be able to escape. Hence, it can be said that overpressure seal may form an effective seal as it impedes any fluid migration and pressure further into the seal.
2. If the gas composition ratio from reservoir and seal are lying on the same ascending trend of the gas composition, this may reflect there is a communication between reservoir and seal. Hence, the seal effectiveness can be determined qualitatively.

1.4 Objectives

In this study, both pore pressure analysis and gas while drilling analysis are the main analyses that have been conducted. The fields selection is based on available data to conduct both studies as well as availability of capillary entry pressure data in the caprock. Overall, the integration of these analyses will be conducted to achieve the following overall study objectives:

1. To evaluate the sealing potential from overpressures seal perspectives by characterizing pore pressure magnitudes and trends in the overburden interval.
2. To qualitatively determine overburden seal effectiveness.
3. To develop a quick methodology or workflow to assess caprock integrity and quality using common data gathered during exploration and drilling.

1.5 Research Scope

The following research scope are covered thoroughly: -

1. Conduct pore pressure analysis for sealing potential evaluation.
2. Plotting gas composition ratio, identify potential sealing and leakage pathway from reservoir to overburden.
3. Develop fit for purpose methodology and workflow in assessing caprock integrity.
4. Conducting propose solution for caprock integrity limit during injection using seal capacity data.

1.6 Significance of Study

The study of pore pressure analysis combining with gas while drilling for caprock assessment can identify lateral extension of seal and top of overpressure seal for nearby reservoirs or containments for CO_2 storage. It also promotes cost avoidance in performing unnecessary studies or acquiring more data that may take longer time for identification of CO_2 injection sites/fields. The ultimate application is not limited to immediate evaluation for CO2 storage but also important for fields with injection activities such steam-assisted gravity drainage (SAGD) and water injection which can be properly planned without jeopardizing the caprock integrity and creating potential leakage pathway. At the same time, for a new exploration area, where wells data are limited and the potential sealing of caprock still needs to be evaluated, this method can be applied to get the overview on the sealing effectiveness for respective new field discovery.

1.7 Chapter Summary

When considering potential storage sites, it is important to have caprock integrity assessment to ensure CO_2 can be stored safely underground for long-term. The quick assessment may ease basin screening and fields selection for potential storage sites. It includes pore pressure analysis, gas while drilling analysis and integration with seal capacity analysis for a full overview of sealing potential. At the end of this study, it is aimed to achieve evaluation of sealing potential from overpressures seal perspectives by developing methodology and workflow to assess caprock integrity and quality using common data gathered during drilling. At the same time, the factors that influence the caprock sealing effectiveness and any potential of leakage pathway throughout the field structures can be identified. This can be done through identification of overpressured seal and distinctive gas component ratio trend comparisons in reservoir and overburden. Meanwhile, the limit of a seal capacity is determined through capillary entry pressure data. Overall, this assessment can save time and cost by utilizing available data and may be suitable for potential storage sites screening as well as quick evaluation of seal in new exploration areas.

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