J. SE Asian Appl. Geol., Jan–Jun 2009, Vol. 1(1), pp. 19-24

GEOLOGICAL CONSIDERATION FOR CO_2 STORAGE IN INDONESIA: A BASINAL SCALE OUTLOOK

Hendra Amijaya*

Department of Geological Engineering, Gadjah Mada University, Yogyakarta, Indonesia

Abstract

Carbon dioxide capture and storage (CSS) is alternative of reducing atmospheric emissions of CO_2. The concepts of CO_2 storage refer to the injection of carbon dioxide in dense form into aquifers, which basically must meet several conditions. Three types of geological formations that can be used for the geological storage of CO_2 are oil and gas reservoirs, deep saline formations and unmineable coal beds. Indonesia has 60 Tertiary basins, however that great precautions must be taken for selecting particular sedimentary basin in Indonesia for carbon dioxide storage because of high possibility of leakage and the need to find deep formations as CO_2 host since the geothermal gradient is high. One possibility to find proper basins is by selected "mature" basin as the detailed geological conditions are well known. Candidates are are North East Java or South Sumatra Basins.

Keywords: *Carbon dioxide capture, storage, emission, basin.*

1 Introduction

The increasing amount of greenhouse gas in the atmosphere recently has become one of the discussed topics in relation with the world's concern on climate change. Strategies to respond the increasing emissions of carbon dioxide (CO_2) have been proposed. Carbon dioxide capture and storage (CSS) is considered as one of the options of reducing atmospheric emissions of CO_2. Storaging CO_2 by sequestresing it into geological formations is one alternative which has been implented in some countries since a decade ago, varying from pilot scale to large scale commercial application (see IPCC, 2005).

Indonesia has a chance to participate in this global action, since geologically Indonesia is promosing to provide sites which are suitable for CO_2 storage. This paper is an outlook of the geological condition of sedimentary basins, especially of Tertiary age, in Indonesia and short preliminary review on their feasibility for carbon dioxide storage.

2 Selection of geological formations for CO_2 storage

The concepts of CO_2 storage refer to the injection of carbon dioxide in dense form into aquifers, into situations that either (1) trap the carbon dioxide into flow systems for geological periods of time (hydrodynamic trapping) or (2) convert the carbon dioxide to carbonate minerals and,thus, render it immobile (mineral trapping) (Hitchon *et al.*, 1999).

Hitchon *et al.* (1999) explain that aquifers suitable for injection of carbon dioxide must satisfy the following general conditions: (1) From the physical and geochemical points of view, the top of the aquifer must be (usually) more than 800 m deep (at this depth the carbon dioxide will be in a supercritical state); (2)

*Corresponding author: H. AMIJAYA, Department of Geological Engineering, Faculty of Engineering, Gadjah Mada University, Jl. Grafika 2 Yogyakarta, 55281, Indonesia. E-mail: amijaya@gmail.com

The aquifer should be capped by a regional aquitard (sealing unit); (3) The aquifer should have enough porosity and adequate permeability. The near-well permeability should be high to allow good injectivity, but the regional permeability should be low so that the residence time of the carbon dioxide is high; (4) The injection site should be close to the carbon dioxide emitting source.

Three types of geological formations have received extensive consideration for the geological storage of CO_2: oil and gas reservoirs, deep saline formations and unmineable coal beds. Those can be onshore or offshore formations (IPCC, 2005). One of the most suitable sinking of CO_2 are oil and gas reservoirs since the geological processes that allowed the accumulation of hydrocarbons also permit the secure sequestring of injected carbon dioxide. The attraction of disposing of carbon dioxide in coalbeds is that it can be coupled directly with the production of coal bed methane. Storage of CO_2 in deep saline formations is relatively more complicated since it should consider the multiple mechanisms for storage, including physical trapping beneath low permeability caprock, dissolution and mineralization (see Hitchon *et al.*, 1999; IPCC, 2005).

In basinal scale, the parameter that should be highly considered is the potential of storage leakage. Based on Kingston's sedimentary basin classification, Hitchon *et al.* (1999) proposed the risk of leakage in each type of basin, which is affected by the degree of sediment compaction and fluid flow (see Figure 11). It will be recalled that all basins have a point of lowest hydraulic head, ranging from the lowest topographic elevation in the case of a consolidated basin to the sea bed in the case of a basin still undergoing compaction. A short flow path, for example to the sea bed, means that the carbon dioxide may not be confined for geological periods of time. Hence, the higher the risk of leakage, the greater is the need for a hydrogeological evaluation of the basin around the injection site.

The capacity of CO_2 storage is also supported by the geothermal characteristics of the basin. 'Cold' sedimentary basin (low surface temperature and/or low geothermal gadients) are more favourable for the storage than 'hot' sedimentary basin (high surface temperature and/or high geothermal gadients) because CO_2 attains higher density at shallower depths (see Bachu 2005).

3 Indonesian Tertiary sedimentary basins

Darman and Sidi (2000) stated that about 60 Tertiary sedimentary basins are identified in Indonesia (see Figure 2), but only around 38 basins have been explored, especially for petroleum and coal. Indonesia is located on the southeastern tip of Eurasia Plate. It is bounded to the south and west by Indo-Australian Plates and to the east by Philippine and Pacific Plates which form collision zone dominated in particularly by subduction zone.

Physiographically, Indonesian Archipelago can be divided into Sunda Shelf (Sundaland) to the west and Sahul Shelf to east. The shelfal area consists of intensively deformed Pre-Tertiary and crystaline igneous and metamorphic rocks. The marginal parts have been subjected to Tertiary mountain buildings (volcanic arcs and non-volcanic outer arc) and accompanying subsidence movements.

Katili (1980) published the configuration of sedimentary basins in western Indonesia in plate tectonic setting. Along transverse section of Sumatra and Java, he identified active subduction zone, magmatic/volcanic arc and foreland (back arc) basin. In detail, Darman and Sidi (2000) noted following structural elements: (1) trench, (2) nonvolcanic outer island arc, (3) fore arc basins, (4) volcanic/magmatic arc, (5) back arc basin and (6) Sunda continental craton.

Sibolga and Bengkulu Basin are fore arc type basin in Sumatra whereas North, Central, and South Sumatra Basins are back arc basin, well known for their hydrocarbon prospects. Northwest Java basinal area is considered as pull-apart basins although currently positioned in back arc setting. However, the Northeast Java Basin is a classical back arc basin. Kendeng through, the eastern extension of Bogor through

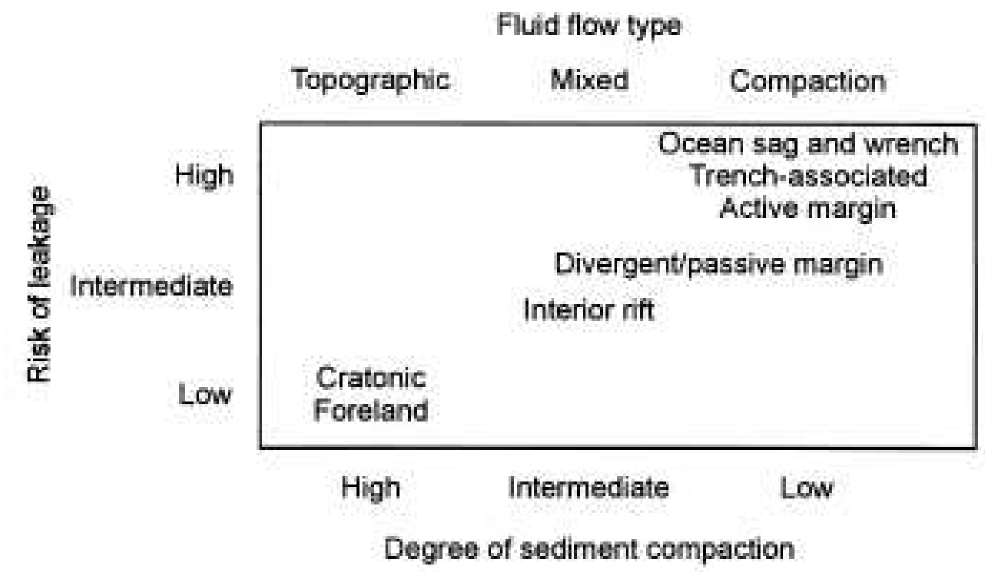

Figure 1: Sedimentary basins classified by degree of sediment compaction, type of fluid flow, and risk of leakage (Hitchon et al., 1999)

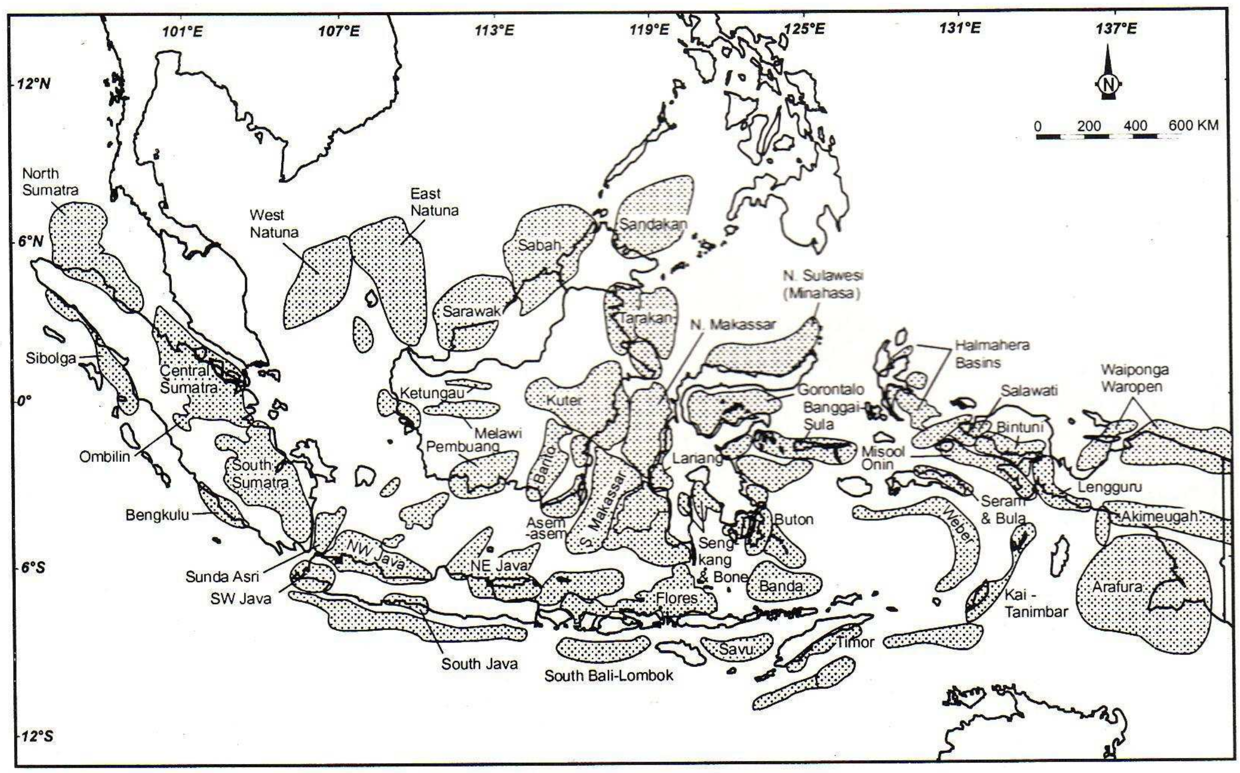

Figure 2: Tertiary basin of Indonesia and surrounding (Darman & Sidi, 2000)

is a deep sea basin. The South Java basin is also typical fore arc basin.

Between Sumatra and Kalimantan there are West and East Natuna Basins. West Natuna was formed as an inra-continental rift basin within the Sunda Platform, whereas East Natuna was part of a large fore arc basin extending from offshore Vietnam. The Kutai Basin developed along an arm of Makassar rift system (which form North and South Makassar Basin) while Melawi-Ketungau Basins occupy more of a fore arc to intra arc position to Tertiary volcanism. The Barito Basin formed as back arc or continental rift basin.

The Sulawesi-Banda region in eastern Indonesia is the focal point of convergence between three plates, resulting in complicated geologic setting. However in Banda arc region following features are recognized: (1) inner ridge, comprising volcanic islands of Bali, Sumbawa, Flores, and further east located islands, (2) outer ridge, such as islands Sawu, Roti, Timor, (3) outer arc basin, include Lombok Basin, Sawu Basin and (5) trench.

In Arafura shelf region, most basins are outer arc and shelf type basins. These types are also found in Papua region, such as the well known Salawati, Bintuni, Akimeugah, Merauke and Waropen Basins, and also Seram basin, as well as offshore basins in the Sulawesi region, like Sulawesi Sea.

4 Outlook on suitability for CO_2 storage

As summarised by Bachu (2005), divergent basins are the most suitable for CO_2 storage as a result of their stability, reduced tectonic activity and favorable structure. Foreland basins are also favorable for CO_2 storage. Convergent basins are located in tectonically active areas and usually subject to volcanism, earthquakes and active faulting. This makes them generally unsuitable for CO_2 storage unless great precaution is taken. Convergent intramontane basins are largely unsuited to CO_2 storage. Cratonic platforms lack the porosity and permeability required for CO_2 storage. Orogenic belts lack continuous seals. Both are unsuited to CO_2 storage.

Looking at the condition of Indonesian sedimentary basins that mostly located in active tectonic condition, it is likely that almost all Tertiary sedimentary basins in Indonesia have relatively high risk of leakage for CO_2 storage (see Figure 4). In term of geothermal condition, Indonesian basins are located in the tectonic setting positions which pose high heat flow density, especially for back arc type basins. Heat flow densities appear to decrease regularly from high (to very high) values in the back-arc basins to low in the fore-arc basins (Thamrin, 1985, see Figure **??**).

Those geological conditions indicate that great precautions must be taken for selecting particular sedimentary basin in Indonesia for carbon dioxide storage because of high possibility of leakage and the need to find deep formations as CO_2 host since the geothermal gradient is high.

One alternative that can be used to screen the proper basins for CO_2 storage in Indonesia is by selected "mature" basin (see Bachu, 2005), where the detailed geological conditions are well known. Basins in this case are selected by its "maturity" in hydrocarbon exploration and production. It is well known that basins with good petroleum play also give advantages for CO_2 storage locations. This is especially because the seal-reservoir conditions are well proven. Alternative that can be taken is by selecting mature-depleted petroleum basin. Therefore, CO_2 storage can be coupled with enhanced oil/gas recovery, what so called" value-added CO_2 storage". Example for this case is some oil/gas field in North East Java or South Sumatra Basins.

5 Concluding remarks

To find suitable basins in Indonesia for CO_2 storage in Indonesia is a great challenge because of the geological conditions of Indonesia which is relatively complex. Detailed studies should be conducted to explore the characteristics of each basin in Indonesia. One aspect that can be advantageous for screening process is by considering the "maturity" of basins by utilizing well known data from hydrocarbon ex-

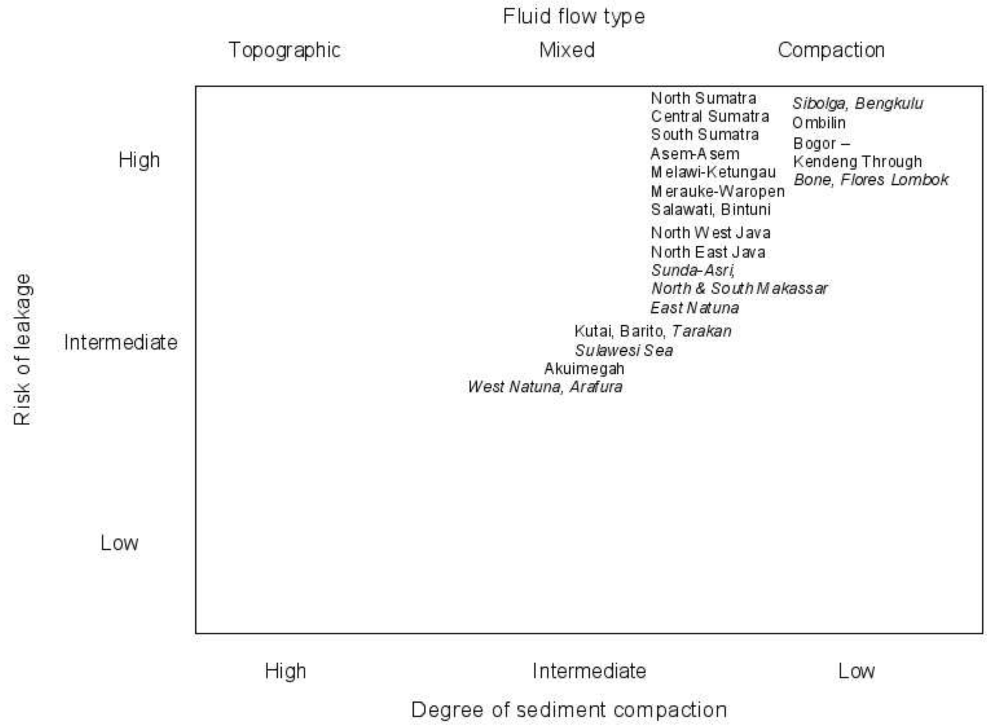

Figure 3: Diagram showing risk of leakage of Indonesian sedimentary basins

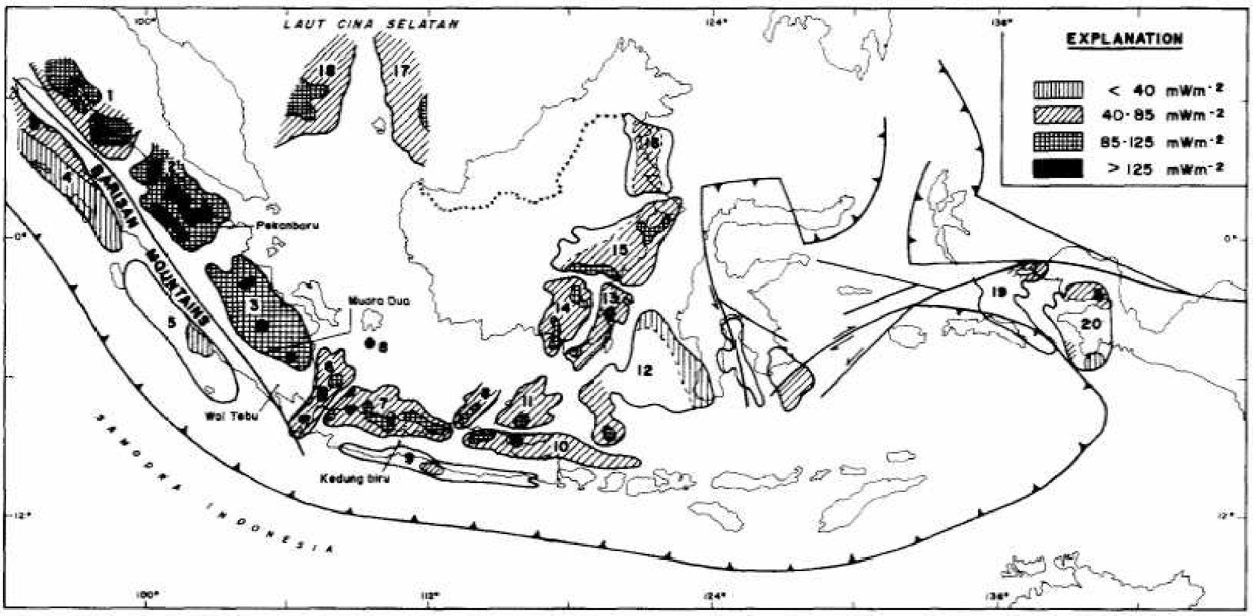

Figure 4: Heat flow density map of Tertiary Basins in Indonesia (Thamrin, 1985)

ploration and production. Possible basins that might be suitable for CO_2 storage in Indonesia are North East Java or South Sumatra Basins.

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