Evaluation of Suitability for CO_2 Geological Storage in Offshore Basins in China

Introduction

Carbon Capture, Utilization, and Storage (CCUS) is indispensable for achieving Paris Agreement climate targets, particularly where fossil fuel phase-out is unfeasible (IPCC, 2018; Zhang et al., 2023； Wang et al., 2024). Globally, CCUS is transitioning from pilots to commercial application, with projections showing it must contribute billions of tons of CO_2 reductions annually by mid-century (IEA, 2020; IRENA, 2020a, 2020b; GCCSI, 2022; Cai et al., 2021). Offshore geological storage is a key CCUS strategy, offering advantages over onshore sites, including reduced risk to populations and the natural containment provided by seawater (Shen, 2009; Mi et al., 2023; Chen et al., 2024).

While site-specific evaluation systems exist, a critical research gap remains: a basin-level suitability framework for offshore regions that integrates geological conditions, engineering feasibility, and storage potential (Bachu, 2003; Guo et al., 2014). This study addresses that gap by focusing on China's offshore basins, which recent studies highlight for their vast storage potential and favorable geology (Li et al., 2021; Yuan et al., 2023; Wang et al., 2023; Chen et al., 2024; Luo et al., 2024). Our primary aim is to establish a tailored suitability evaluation framework to support large-scale storage planning and site selection for demonstration projects in China's offshore regions.

Geological Background

China's offshore region comprises ten major sedimentary basins (e.g., Bohai, Pearl River Mouth, Yinggehai). These basins are located at the complex tectonic junction of the Circum-Pacific and Tethys-Himalayan domains (Figure 1). Their formation results from multi-phase interactions, including Pacific plate subduction and the expansion of the South China Sea, creating an active continental margin setting distinct from Atlantic-type passive margins (Zhu, 2015; Liu, 2021).

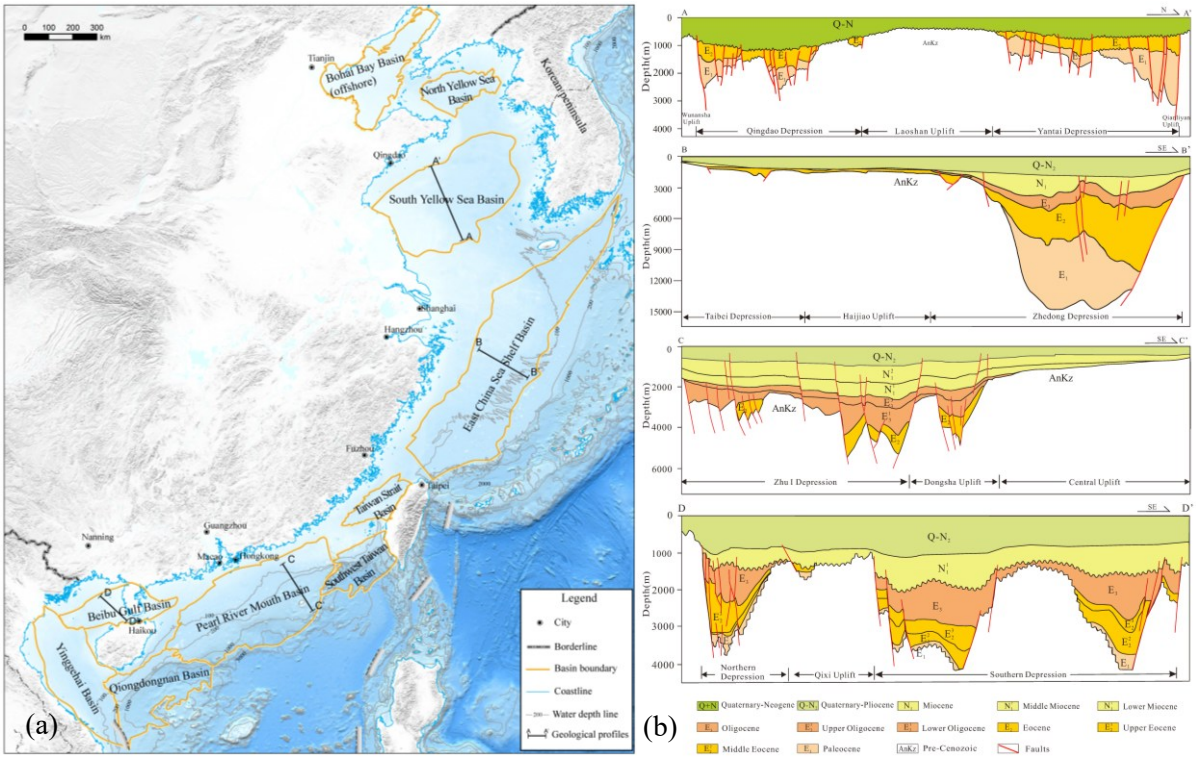

Figure 1 *(a)Topography, water depth, and distribution of major basins in China's offshore regions (adapted from Chen et al., 2024) and (b) Typical features of offshore dual-layer overlap in China's Cenozoic basins (adapted from Zhu et al., 2010 and He et al., 2022).*

The basins generally record a two-stage Cenozoic evolution: an initial rifting phase forming Paleogene faulted depressions, followed by Neogene thermal subsidence. This produced diverse basin types with dual-layer structures, including intracontinental rift, back-arc extensional, and strike-slip pull-apart basins (Li et al., 2012; Zhang et al., 2012). Most of the region lies within a broad, shallow continental shelf (water depths <200 m), which is highly favorable for CO_2 storage projects. The few basins extending into deeper waters (>200 m) still offer substantial shelf areas for initial development.

Methods

To assess suitability for CO_2 geological storage in China's offshore basins, we developed an indicator system based on established frameworks (Bachu, 2003; Huo, 2014; Guo et al., 2014; Yan et al., 2024). The system integrates necessary indicators for basin-scale feasibility and critical indicators for safety and viability.

Necessary Indicators are grouped into three primary categories comprising 11 secondary indices:

- **Storage Potential:** Quantifies theoretical capacity using basin area, stratigraphic thickness, total storage potential, and capacity per unit area, following CSLF guidelines (Bachu et al., 2007).
- **Geological Conditions:** Includes exploration level, seismic activity magnitude, pressure coefficient, and geothermal gradient—factors influencing storage safety, reliability, and capacity.
- **Engineering Conditions:** Encompasses development level (existing infrastructure), offshore distance, and seawater depth, which directly impact project costs and technical feasibility.

Critical Indicators function as decisive factors. These include whether the basin is located on an active seismic belt (affecting long-term stability) and the presence of pre-existing oil and gas wells (influencing seal integrity and drillability). Given the complex maritime context, these indicators also implicitly address legal and safety constraints.

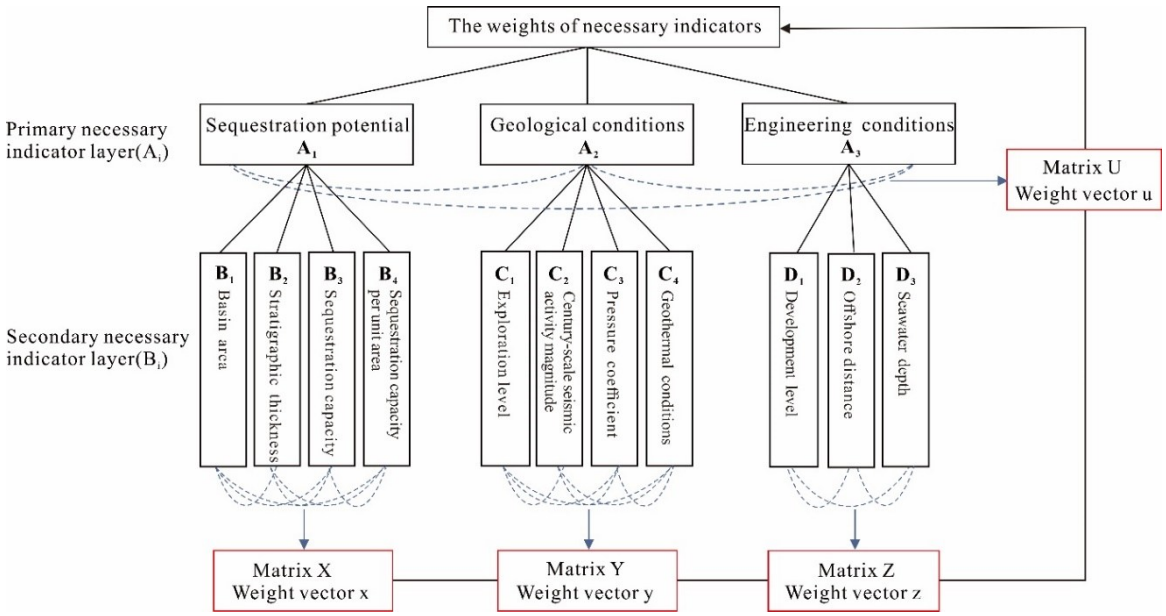

Figure 2 *Weight calculation model for the necessary indicator system.*

Geological storage conditions

China's offshore basins feature thick Cenozoic strata (up to 18,000 m in the Yinggehai Basin) with multiple reservoir–caprock assemblages, providing substantial storage space. Reservoirs at 800–3,200 m depth have 10%–45% porosity, with regional mudstone seals ensuring containment. Crustal stability varies: the northern South Yellow Sea and East China Sea Shelf are tectonically stable with

weak seismicity, while the Bohai Basin and southwestern Taiwan have active faults and higher seismic risk. Most basins have low-to-moderate geothermal gradients (<30–46°C/km), favoring CO_2 density, though the Yinggehai and Qiongdongnan Basins feature overpressure zones below 1,600–2,200 m that complicate storage. Overall, the northern shelves offer the most favorable storage conditions.

Suitability Evaluation

China's offshore basins have medium-to-high suitability for CO_2 storage, with a combined theoretical potential of 1.39×10^{12} t. The Pearl River Mouth, East China Sea Shelf, and Bohai Basins are most suitable due to their vast capacity, stable geology, and proximity to industrial zones. The Beibu Gulf and South Yellow Sea Basins (especially the Yantai Depression) also show strong potential, while the Qiongdongnan and Yinggehai Basins face challenges like distance from emission sources. The North Yellow Sea, Southwest Taiwan, and Taiwan Strait Basins are least suitable due to poor reservoirs and seismic risks. These findings refine previous assessments with updated data.

Conclusions

(1) A suitability evaluation system for the feasibility of CO_2 geological storage in offshore areas in China is established by incorporating necessary and critical indicators.

(2) China's offshore sedimentary basins exhibit favorable geological conditions for CO_2 storage. The offshore crust is generally stable with limited regional deep faults.

(3) The Pearl River Mouth, East China Sea Shelf, and Bohai Basin are identified as primary candidates for CO_2 storage. The Beibu Gulf and South Yellow Sea Basins are secondary candidates, and the Qiongdongnan and Yinggehai Basins are potential alternatives.

(4) The current evaluation outcomes have inherent uncertainties attributed to the uneven exploration maturity across China's offshore basins, where well data and seismic coverage constrain geological interpretations are limited.

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