RESEARCH ARTICLE

Carbon Storage Dynamics in Lower Shimentan Formation of the Qiantang Sag, East China Sea Shelf Basin: Stratigraphy, Reservoir−Cap Analysis, and Source−Sink Compatibility

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Abstract

Excessive carbon emissions have resulted in the greenhouse effect, causing considerable global climate change. Marine carbon storage has emerged as a crucial approach to addressing climate change. The Qiantang Sag (QTS) in the East China Sea Shelf Basin, characterized by its extensive area, thick sedimentary strata, and optimal depth, presents distinct geological advantages for carbon dioxide (CO_2) storage. Focusing on the lower section of the Shimentan Formation in the Upper Cretaceous of the QTS, this study integrates seismic interpretation and drilling data with core and thin-section analysis. We reveal the vertical variation characteristics of the strata by providing a detailed stratigraphic description. We use petrophysical data to reveal the development characteristics of high-quality carbon-storage layers and favorable reservoir−caprock combinations, thereby evaluating the geological conditions for CO_2 storage in various stratigraphic sections. We identify Layer B of the lower Shimentan Formation as the most advantageous stratum for marine CO_2 storage. Furthermore, we analyze the carbon emission trends in the adjacent Yangtze River Delta region. Considering the characteristics of the source and sink areas, we suggest a strong correlation between the carbon emission sources of the Yangtze River Delta and the CO_2 storage area of the QTS, making the latter a priority area for conducting experiments on marine CO_2 storage.

Keywords Carbon storage; Qiantang Sag; Reservoir-cap; Source−sink dynamics; East China Sea Shelf Basin

Article Highlights

- The study investigates the carbon storage potential in the Lower Shimentan Formation within the Qiantang Sag, East China Sea Shelf Basin.
- Stratigraphic and reservoir−cap rock assessments evaluate the geological suitability for CO_2 storage.
- The compatibility between carbon sources and sinks is analyzed to determine effective storage strategies.
- Results highlight the critical role of stratigraphy and reservoir characteristics in influencing carbon storage capacity and efficiency.

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1 Introduction

Global warming and consequent greenhouse effect pose a notable climatic challenge, with carbon emissions identified as a primary cause (Plass, 1956; Manabe and Wetherald, 1967, 1975; Fleming, 1998; Gao et al., 2001; Feng and Fu, 2007; Shepardson et al., 2011; Freudenburg and Muselli, 2013; Wang et al., 2014; Chai and Xu, 2014; Cook et al., 2016; Mandal et al., 2021). In response, global efforts to reduce carbon dioxide (CO_2) emissions have intensified, culminating in notable international treaties such as the United Nations Framework Convention on Climate Change (UNFCCC) (Bian et al., 2011). The "Sunnylands Statement on Enhancing Cooperation to Address the Climate Crisis," issued by China and the United States in 2023, emphasizes a shared commitment toward addressing the climate crisis through effective implementation of UNFCCC and the Paris Agreement, aiming to limit the global temperature increase and promote cooperative carbon capture, usage, and storage (CCUS) projects (Xie and Kerry, 2023).

CCUS has been recognized as a pivotal strategy for

achieving carbon neutrality and mitigating global climate change, highlighted by the Intergovernmental Panel on Climate Change (IPCC)'s "Special Report on Carbon Capture and Storage" and subsequent studies (Metz, 2005; Haszeldine et al., 2018; IPCC, 2018, 2022; Li et al., 2023a). Moreover, the opinions of the CPC central committee and the state council on accelerating carbon peak and carbon neutralization endorse CCUS as a crucial technological approach toward China's dual carbon target, promoting its development across various sectors.

In CCUS, "storage" refers to the process of transporting CO_2, which has been separated from industrial emissions using carbon capture technology, to locations such as underground or subseabed for deposition. The principal methods of storage encompass geological storage, oceanic storage, and chemical storage (Van Der Burgt, 1992; Holloway, 1997; Oldenburg et al., 2000; Bachu, 2000; Mamora and Seo, 2002; Orr, 2004; Sim et al., 2008; Jang et al., 2010; Li, 2011; Peckham, 2014; Group, 2015; Cai et al., 2021; Hu et al., 2023).

From a geological perspective, CO_2 storage is categorized into terrestrial and marine carbon storage on the basis of the location of storage sites. In China, several terrestrial sites, including the Ordos Basin, Songliao Basin, and Subei Basin, are considered appropriate for storage (Sun et al., 2021). However, in provinces such as Jiangsu, Zhejiang, and Guangdong along China's eastern coast, where CO_2 emissions are high, it is challenging to find appropriate terrestrial storage sites nearby that meet all necessary conditions. While basins such as the Subei Basin on land could provide storage solutions for these coastal areas, their feasibility is constrained by factors such as high population density, scarcity of land resources, and concentration of notable infrastructure projects, increasing the safety risks associated with carbon storage in these regions (Chen et al., 2023). However, marine basins near China, such as the Bohai Basin, Southern Yellow Sea Basin, East China Sea (ECS) Shelf Basin, and Pearl River Mouth Basin, are in close proximity to the mainland. These basins have been the topic of extensive foundational research related to marine carbon storage. In recent years, many scholars have highlighted the advantages of marine carbon storage, such as large storage potential, high safety, minimal environmental impact, and long storage duration, all of which are difficult to match by terrestrial storage (Huo et al., 2014; Zhang et al., 2012) Among the major sedimentary basins in China's offshore areas, the ECS Shelf Basin, located near the Yangtze River Delta, ranks high in terms of suitability for submarine carbon storage. Furthermore, the Taibei Depression is recognized as the unit with the highest comprehensive suitability for CO_2 storage within the ESC Basin (Ke et al., 2023). Noteworthily, the Qiantang Sag (QTS) is a constituent of the Taibei Depression.

The QTS, as one of the marine sedimentary basins with high suitability for carbon storage, is located in close proximity to China's primary carbon emission zone, the Yangtze River Delta region. This geographical advantage is unparalleled by other marine basins. However, foundational geological research on the QTS, as well as studies on its potential for geological carbon storage, are notably scarce. In fact, research on the QTS is often discussed within the broader context of the ESC Shelf Basin (Chen et al., 2003; Zhao, 2005; Xia, 2012; Liang et al., 2016; Zhong et al., 2018, 2019; Zhang et al., 2015; Zhao, 2019; Yang et al., 2022). In addition, while some studies have briefly examined the structural environment surrounding the QTS (Jiang et al., 2016, 2020; Tang et al., 2018), research focused on the QTS remains relatively limited, particularly in terms of investigations targeting its Mesozoic sedimentary layers. Thus, we must conduct high-precision stratigraphic studies and investigate the reservoir−caprock combinations to promote research on marine CO_2 storage in this strategically important area.

2 Regional geological conditions

The ESC Shelf Basin is the largest Mesozoic−Cenozoic superimposed basin in China's offshore areas. Some scholars suggest that this basin is situated within the thinning lithosphere of the West Pacific Triangle Zone, forming a notable convergent zone at which the Indo−Australian Plate and Pacific Plate meet the Eurasian Plate. The basin's eastern and western sides are, respectively, linked to the evolution of the Tethys tectonic domain and West Pacific tectonic domain (Li et al., 2013; Faccenna et al., 1996), constituting an important part of the Western Pacific continental margin system. In the recent years, numerous domestic and international scholars have extensively researched various aspects such as the tectonic evolution and sedimentary characteristics of this basin, gaining many new insights. This has established the basin as one of the most extensively studied regions in China's offshore areas (Hall, 2002; Lin et al., 2003; Chen et al., 2003; Zhao, 2005; Lee et al., 2006; Zhu and Mi, 2010; Zhu et al., 2019, 2022b; Ding et al., 2017; Wang et al., 2012; Xia, 2012; Yang et al., 2013, 2022; Suo et al., 2015; Liang et al., 2016; Jiang et al., 2016, 2020; Xu et al., 2017; Zhong et al., 2018, 2019; Zhang et al., 2015; Tang et al., 2018; Zhao, 2019; Fu et al., 2022; Xu et al., 2023).

The ESC Shelf Basin covers an area of 267 000 km^2 and extends ~1 100 km from north to south and 325−500 km from east to west. Overall, it is oriented in the NNE direction, geographically bounded by the Ryukyu Uplift and the Zhe-Min Uplift structural units to the east and west, respectively. From west to east, the basin is divided into three primary structural units, namely the Western Depression Belt, Central Uplift Belt, and Eastern Depression Belt, and seven

secondary structural units. The Western Depression Belt includes the following tertiary units: the Yangtze Depression, the Taibei Depression, and the Pengjia Island Depression (Zhong et al., 2019).

The QTS is located within the Taibei Depression of the Western Depression Belt, specifically to the southwest of the Haijiao Uplift. To the south, it adjoins the boundary of the Yushandong Uplift, transitions to the Haijiao Uplift in the north, lies adjacent to the Zhe-Min Uplift zone in the west, gradually transitions to the Xihu Sag in the east, and connects with the Jiaojiang Sag in the southwest (Figure 1) (Zhao, 2005).
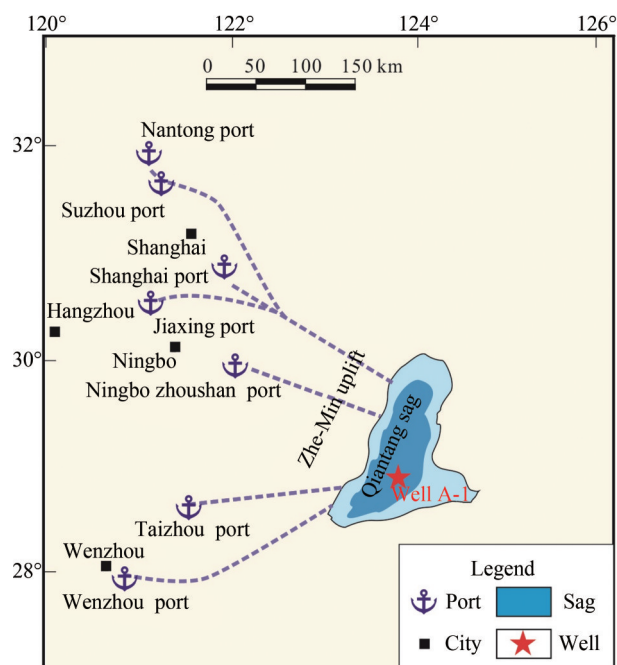

Figure 1　Regional location map of the Qiantang Sag (QTS) (location references from Lin et al. (2003); Zhu et al. (2010, 2019); Feng et al. (2024))

Regarding sedimentary strata and basin types, the QTS is filled with Mesozoic−Cenozoic sedimentary strata and might also contain Paleozoic strata. The sag exhibits a distinct double-fault structure, classifying it as a rift basin that has experienced a prolonged subsidence process (Zhao, 2005; Xia, 2012).

3 Method and data

3.1 Basin scale and stratigraphic suitability

We reviewed previous studies and regional maps to evaluate whether the size of the sedimentary basin meets the criteria required for carbon storage potential. Further, we employed seismic profile interpretation to assess if the thickness of the basin's sedimentary strata meets the conditions necessary for carbon storage. The seismic data were analyzed at the Center for Marine Resources, Tongji University. Key stratigraphic reflection interfaces on seismic lines passing through Well A-1 were identified and marked on the basis of a stratigraphic division scheme. These markers facilitated the tracking of the extension of strata. The distribution of strata from different periods within the QTS was revealed via the integration of the well and seismic data (Al-Masgari et al., 2021).

3.2 Key stratigraphic geological characteristics

The study primarily focused on the lithologic sequence derived from drilling at the only well, i.e., Well A-1, in the QTS, supplemented by some microscopic thin section and core observations. This approach was to clarify the petrological characteristics and lithological variations of this stratigraphic segment, inferring the characteristics of its depositional facies.

The thin-section samples were pretreated at the Key Laboratory of Marine Geology, Tongji University. Prior to preparing the thin sections, the samples were thoroughly washed with pure water to eliminate any mud interference and then dried using a dryer. After drying, the samples were left unstained and prepared into 50-μm microscopic thin sections according to the rock thin-section identification standard SY/T 5368−2016. Observations were made using an Mshot MP41 professional polarizing microscope, with a particular focus on unique lithological thin sections.

3.3 Carbon storage layers and caprocks

In the context of geophysical well logging, interpretation of specific parameters is fundamental to assessing the quality of a reservoir and determining its carbon storage capacity (Dashtian et al., 2011; Ning et al., 2013; Grana et al., 2017). Gamma Ray (GR) logging, which is used to measure rock radioactivity, is crucial for identifying rock types and depositional environments. These elements indicate heterogeneity and potential storage zones of a reservoir, laying the groundwork for detailed analysis. Spontaneous potential logging offers critical insights into pore fluid characteristics and rock permeability, essential for evaluating a reservoir's capacity to secure and maintain carbon deposits. Furthermore, the borehole diameter was assessed via caliper (CAL) logging, providing vital evaluations of wellbore stability, a key factor in preserving the integrity of carbon storage sites. Density (DEN) logging is crucial in deducing mineral composition and porosity, which are directly linked to the reservoir's storage capability and the integrity of the seal. Collectively, these logging parameters create a comprehensive framework, allowing for a thorough assessment of the quality of the reservoir and suitability thereof for effective carbon storage, integrating geological characteristics with geophysical data to identify high-quality carbon-storage layers and caprocks with optimal continuity.

3.4 Carbon source−sink compatibility

The study systematically compiled and analyzed carbon emission data from the Yangtze River Delta region to examine growth trends and spatial distribution. This analysis included a detailed evaluation of the alignment between carbon emissions from industrial and urban activities in the Yangtze River Delta and the geological carbon storage potential identified in the QTS. The compatibility between the carbon sources and sinks in the region, as reported by studies on carbon storage source−sink matching and economic impacts (Sun and Chen, 2022; Sun et al., 2024), along with foundational assessments of carbon capture and storage potential (Carneiro et al., 2011), emphasizes the importance of integrating economic and geological considerations. By correlating these findings with the geographical position of the QTS and its geological potential for carbon storage, this assessment aimed to identify synergies that could optimize the utilization of the QTS as a carbon sink, thereby contributing to regional carbon management strategies.

4 Results and discussion

4.1 Geological conditions for carbon storage

4.1.1 Basin and stratigraphic characteristics

The size of a sedimentary basin is a critical indicator in evaluating its suitability for marine geological CO_2 storage (Chen et al., 2023; Ke et al., 2023). Depressions with an area exceeding 250 km^2 are considered viable candidates for CO_2 storage. The QTS, with a total area exceeding 10 000 km^2, considerably surpasses this criterion, making it an ideal large-scale sedimentary depression for marine geological carbon storage.

The thickness of sedimentary strata is also a key determinant in evaluating suitability for marine geological CO_2 storage. For similar fundamental geological conditions, thicker sedimentary layers represent the higher potential for geological CO_2 storage (Figure 2) (Chen et al., 2023; Ke et al., 2023).

The QTS is characterized by its substantially thick sedi-

Figure 2   Seismic geological Interpretation profile through the Yushan Dong uplift-Qiantang Sag-Haireef Uplift

mentary strata, predominantly composed of Mesozoic deposits, followed by Paleocene and Eocene formations from the Cenozoic era (Zhao, 2005; Xia, 2012; Zhong et al., 2019; Feng et al., 2024). Well A-1, a hydrocarbon exploratory well in the central part of the QTS, reaches a total depth of 4 501 m. This well has specifically revealed that the Mesozoic and Cenozoic sedimentary layers alone are up to 3 600 m thick. Seismic profile interpretations suggest unencountered Jurassic strata in the QTS. We can infer that the total sedimentary thickness in the central part of the QTS may exceed 4 000 m, indicating exceptionally favorable stratigraphic conditions.

In addition, the depth of the sedimentary strata plays an important role in the effectiveness of geological CO_2 storage. Strata located at depths less than 800 m are unlikely to achieve the temperature and pressure conditions necessary for supercritical CO_2 storage. Conversely, the porosity and permeability of sedimentary layers tend to diminish at depths exceeding 3 200 m, resulting in increased challenges and costs associated with CO_2 injectability (Chen et al., 2023; Ke et al., 2023).

In this study, the lower section of the Shimentan Formation of the Upper Cretaceous, with a depth range of 1 987– 2 210 m, falls within the optimal depth range for marine CO_2 storage. Therefore, this study has selected this stratum as the target layer for carbon storage.

The lower section of the Shimentan Formation in the Upper Cretaceous has a total thickness of 223 m and lies above the Minjiang Formation of the Upper Cretaceous. This sedimentary sequence is characterized by terrestrial deposits, predominantly consisting of fluvial−lacustrine sediments. We speculate that it represents a cyclical vertical stacking of deltaic-arid lake environments composed of mudstone, silty mudstone, siltstone, and sandstone in a fining upward sequence. However, the sedimentary cycles may have been considerably altered because of the proximity of the sediment source and the abundance of coarse detrital supply (Figure 3).

In light of the characteristics of the Mesozoic strata in the QTS, as revealed by analysis of Well A-1, and considering the features of the lithological combinations, the lower section of the Shimentan Formation can be further subdivided into four layers, A, B, C, and D (Figure 3) according to variations in lithology.

The first layer, "Layer A," spans a depth of 1 987.00– 2 041.00 m with a thickness of 54.0 m. The primary lithological assemblage comprises brownish mudstone, silty mudstone, gray silty mudstone interbedded with off-white siltstone, and light gray argillaceous siltstone (Figure 4). The siltstone within this layer is characterized by high mud content and is cemented by kaolinite, resulting in relatively loose texture. The mudstone predominantly exhibits a brownish hue, with intermittent silty components, indicating these are not pure mudstones and possess a softer nature.
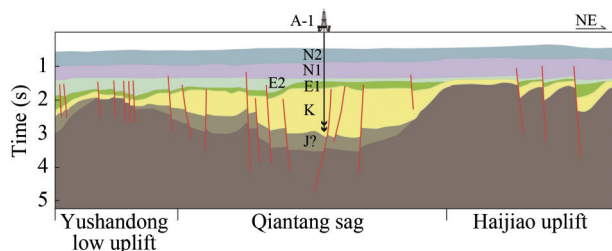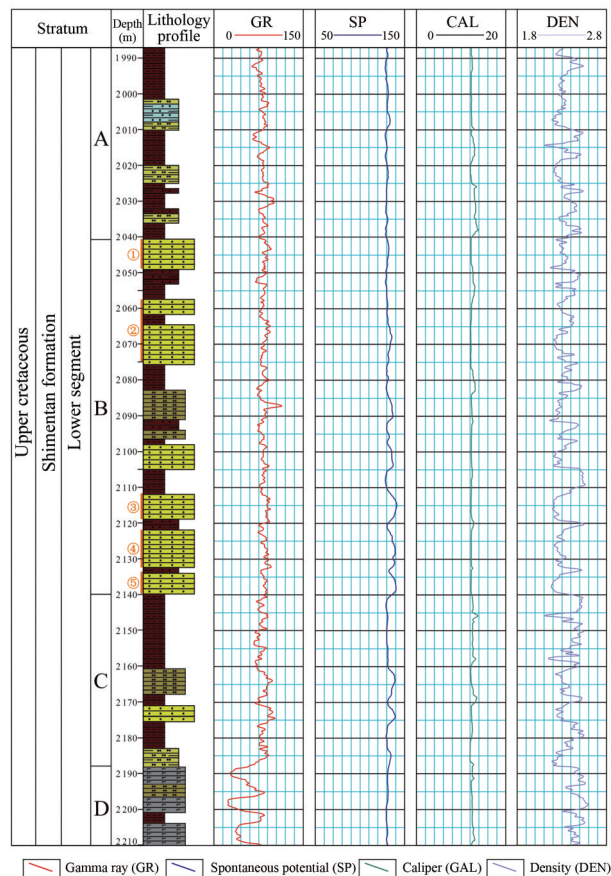
Figure 3   Comprehensive geological columnar diagram of the lower Shiementan Formation in the upper cretaceous system, QTS

Figure 4   Well A-1: Brownish Mudstone, Muddy Siltstone, 2 027 m

Layer B, with a depth ranging from 2 041.00 to 2 140.00 m with a thickness of 99.0 m, is primarily composed of light gray fine sandstone, grayish-white siltstone, and brown muddy siltstone in an even-thickness interlayering. The fine sandstone developed in this layer is primarily quartz, followed by feldspar and dark minerals, exhibiting satisfactory sorting, subrounded abrasion, and clay cementation, affording it a loose texture. The mudstone, predominantly brown, is purer in mud content and softer.

Layer C extends from 2 140.00 to 2 188.00 m deep, with a thickness of 48.0 m. The upper part is brownish mudstone, while the lower part develops interlayers of grayish-white siltstone, light gray fine sandstone, muddy siltstone, and brownish mudstone. The fine sandstone in this layer is similar to that in Layer B. The siltstone in this layer is rich

in mud, has kaolinite cementation, and is loose in texture. The mudstone is mainly brown, purer in mud content and softer.

Layer D, at a depth of 2 188.00–2 210.00 m and with a thickness of 22.0 m, predominantly comprises green–gray altered basalt interbedded with light gray siltstone and brownish mudstone (Figure 5). The altered basalt developed in this layer exhibits a porphyritic structure with irregularly distributed, automorphic, elongated microcrystalline plagioclase (clayized), and the interstices are filled with pyroxene (dolomitized) grains and magnetite. It is in pseudoconformable contact with the underlying strata.
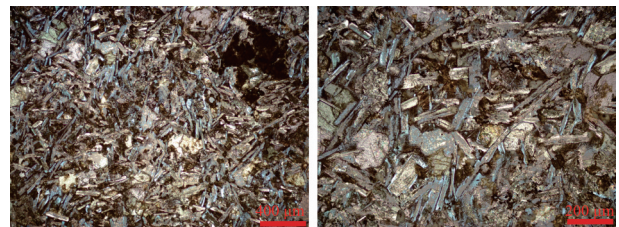

Figure 5   A-1well, microscopic photograph of Altered Basalt

4.1.2 Carbon storage layers and caprocks

Evaluating the suitability of a basin for marine geological CO_2 storage critically depends on reservoir–caprock combination, encompassing caprock lithology, thickness, distribution continuity, and porosity and permeability of the reservoir. Caprock integrity is vital for storage, as the geological properties and mechanical stability of cap rocks are crucial in preventing CO_2 leakage (Shukla et al., 2011). Moreover, the selection of optimal reservoir–caprock combinations for CO_2 storage requires comparative analysis based on safety, storage capacity, and efficiency (Rasool et al., 2023). However, the identification of suitable combinations poses considerable challenges, provided the complexities of ensuring long-term storage integrity and mitigating environmental impacts (Aminu et al., 2017). These considerations are key to determining if a sedimentary stratum can serve as a viable site for storing geological CO_2. While unsuitable combinations are characterized by poor conditions, discontinuity, and breaches in either the reservoir or cap layer, suitable ones are characterized by moderate-to-good conditions and a continuous link between the reservoir and caprock.
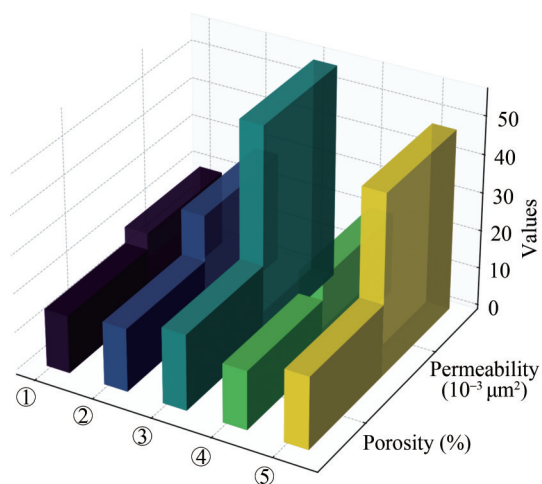
As per the well log data, the lower section of the Shimentan Formation is characterized by the development of multiple sets of sandstone reservoirs (Figure 3). We selected five representative sandstone strata from within this target formation, aiming to elucidate several key parameters, including porosity, permeability, and sand content (Table 1).

The data analysis results revealed that the sandstone reservoirs within the lower section of the Shimentan Formation possess favorable petrophysical characteristics, with porosity levels in the range of 15×10^{-3}–20×10^{-3} μm^2 and

Table 1 Physical properties of sandstone layers ①−⑤, data derived from well A-1 logging data (Zhao, 2005)

Number	Depth	Thickness (m)	Permeability (%)	Oil saturation (%)	Porosity (10^{-3} μm²)	Mud content	Sand content
①	2 040.4−2 048.8	8.4	19.392	2.321	15.087	21.188	63.726
②	2 056.5−2 075.3	18.8	28.520	1.562	16.446	15.382	68.172
③	2 112.2−2 119.0	6.8	55.900	4.835	19.776	12.887	67.337
④	2 122.4−2 132.4	10.0	21.145	0.361	15.367	25.910	58.723
⑤	2 134.6−2 140.0	5.4	47.427	6.837	18.884	15.989	65.127

permeability between 19% and 56%. Notably, two sandstone layers developed in Layer B have permeabilities of 55.9% and 47.427%, respectively (Figure 6, Table 1). Core sample analysis results indicated that the sandstones in the lower section of the formation are relatively loose and well sorted. Consequently, with the development of multiple thick sandstone layers suitable for carbon storage, this stratigraphic section exhibits remarkable sandstone reservoir conditions, classified as Class I and II.

Figure 6 Three-dimensional Bar Graph of Porosity and Permeability in Sandstone Layers ①−⑤

As per the drilling data from Well A-1 in the QTS, mudstone primarily develops in the Shimentan and Minjiang formations within this region, accounting for 40%−60% of the stratigraphic sections. However, the development of mudstone in other stratigraphic layers is comparatively less prominent. Notably, the mudstones in Layer A are impure, containing partial silty elements (Figure 4), whereas those in Layers B and C are of higher purity, with the mudstones in Layer B being particularly ideal in terms of cap rock conditions, exhibiting continuous cycles and thicker layers. This suggests that cap rock conditions in the lower section of the Shimentan Formation are relatively favorable.

From the perspective of reservoir−caprock combinations, this stratigraphic section is characterized by the continuous development of multiple sets of mudstone−sandstone associations (Figure 3). In particular, Layer B, which enjoys the most advantageous storage conditions, features six sets of these combinations. Furthermore, the CAL curve of Layer B does not considerably fluctuate, indicating that this segment of the stratum possesses relatively superior continuity and stability. In contrast, Layer D is primarily composed of basalt strata, lacking favorable reservoir−cap conditions (Figure 5). However, it presents potential as a study topic for basalt mineralization carbon storage, warranting further research.

4.2 Carbon source−sink compatibility

An important factor affecting the feasibility of CO_2 storage is the potential for a strong source−sink relationship between the carbon emission sources and carbon storage area. The QTS is adjacent to China's Yangtze River Delta region, forming a favorable source−sink relationship with its carbon emission sources (Figure 1). The Yangtze River Delta, China's largest urban agglomeration, primarily includes 41 cities across Shanghai, Jiangsu Province, Zhejiang Province, and Anhui Province. It is also the world's sixth-largest urban area and most economically developed region in China, making it the region with the highest carbon emissions in the country (Fan et al., 2020; Zhu et al., 2022a; Li et al., 2023b). The carbon emissions in this region extremely increased from 161.97 million tons in 2 000 to 596.99 million tons in 2020, at a growth rate of 6.74%. However, the carbon sink in the region only increased from 12.67 million tons in 2 000 to 14.58 million tons in 2020, at an annual growth rate of merely 0.70%, considerably lower than the rate of increase in carbon emissions (Li et al., 2023b) This discrepancy highlights that the carbon sink capacity in the Yangtze River Delta is considerably lower than its carbon emissions. Achieving the carbon neutrality target by 2 060 will be challenging without timely and effective CO_2 storage measures.

Delta from 2000 to 2020 (Data Derived from Li et al. (2023a)) From the spatial distribution of carbon emissions in the Yangtze River Delta region (Li et al., 2023b), one can clearly see that the coastal and riverside areas, represented by cities such as Shanghai, Suzhou, Nantong, and Ningbo, exhibit considerably higher levels of carbon emissions compared with other areas. This pattern highlights a pronounced need for marine CO_2 storage in these regions.

The Yangtze River Delta region enjoys comprehensive infrastructure, which includes dense networks of high-
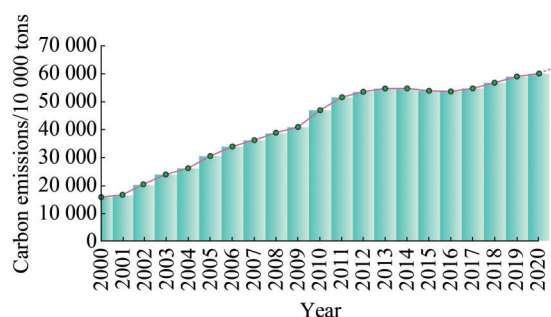
Figure 7   Changes in carbon emissions in the Yangtze River

ways, railways, and electrical grids. In terms of port and shipping facilities, which are highly relevant for the storage of marine CO_2, the region houses two of the world's leading ports: Shanghai Port and Ningbo-Zhoushan Port. In addition, the region features several large seaports, such as Jiaxing Port, Wenzhou Port, Taizhou Port, and Lianyungang Port, along with notable inland river ports such as Suzhou Port, Nantong Port, and Nanjing Port (Mou et al., 2020; Zhou, 2023). These ports are large in scale and have extensive shipping networks, providing an exceptional foundation for implementing initiatives for marine CO_2 storage (Figure 1).

As an example, let us discuss the CO_2 transport ship ordered by Norway's Northern Lights project. This vessel is ~130 m in length, with a breadth of 21.2 m and a draft of 8 m, enabling it to easily dock at the major ports in the Yangtze River Delta region.

The QTS is a depression nearest to the main carbon emission area and crucial hub ports of the Yangtze River Delta within the ESC Shelf Basin, located within a distance of 80−200 km. The most proximate is the Ningbo-Zhoushan Port, the world's largest port. Furthermore, the average water depth in the QTS area is less than 100 m. Provided that the preferred operational depth for China's offshore oil engineering activities is within 200 m, this geographical positioning offers considerable advantages for undertaking marine CO_2 storage projects.

5 Conclusions

1) The QTS in the ECS Shelf Basin enjoys several advantages for marine CO_2 storage, including a large depression area, thick sedimentary layers, relatively shallow water depth, short CO_2 transportation distance, superior carbon storage conditions, and mature engineering capabilities, making it a prime target area for marine carbon storage projects.

2) The lower section of the Shimentan Formation of the Upper Cretaceous in the QTS offers suitable stratigraphic depth and favorable reservoir−caprock combinations. In particular, Layer B exhibits the optimal continuity of the

reservoir−cap combination, making it an ideal carbon storage space.

3) The carbon emissions from the Yangtze River Delta region and the carbon storage area of the QTS form an excellent source−sink relationship. Implementation of marine carbon storage in the QTS is expected to considerably contribute to achieving Carbon Peaking and Carbon Neutrality Goals in the Yangtze River Delta region.

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