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Application of Geological Measurement Technology in Carbon Sink Research

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Abstract

Climate change stands as one of the foremost challenges confronting the world today, with carbon sequestration technology emerging as a pivotal method for mitigating greenhouse gas emissions. This technology aims to permanently store carbon dioxide from the atmosphere underground, thereby reducing greenhouse gas concentrations. In this context, geological research technology plays a crucial role in carbon sequestration applications. Geological testing techniques encompass a range of methods such as geophysical surveys, drilling, core analysis, and groundwater monitoring. These techniques are not only instrumental in selecting suitable underground storage sites but also in assessing the characteristics of subsurface rocks, including permeability, porosity, and storage capacity. Several successful carbon sequestration projects have underscored the indispensable role of geological testing technology in site selection and management. Nonetheless, the field of carbon sequestration confronts ongoing challenges, including the identification of suitable underground storage sites, evaluation of subsurface rock properties, securing community and public acceptance, and establishing effective monitoring and maintenance procedures. Therefore, continual innovation and development of geological research technology remain imperative for advancing the implementation and enhancement of carbon sequestration technology.

Keywords

Traditional Geology; Carbon Sink; Interdiscipline.

1. Introduction

Climate change has emerged as a paramount global challenge, marked by soaring temperatures, rising sea levels, and a surge in extreme weather events, all significantly impacting our planet[1-3]. To confront this formidable challenge, not only is it crucial to reduce greenhouse gas emissions, but it is equally imperative to enhance carbon sequestration, effectively storing atmospheric carbon dioxide permanently (Figure 1)[4]. Geological testing technology occupies a pivotal role in carbon sequestration research and management, offering invaluable insights into the potential of underground carbon storage[5].

2. Overview of Geological Testing Technology

Geological testing technology encompasses a comprehensive toolkit of methods and tools designed to investigate and assess subterranean geological features. These techniques encompass a wide range of applications, spanning from the petroleum and natural gas sectors to environmental research, underground water resource management, and carbon sequestration studies.

2.1 Geological Exploration and Subsurface Analysis

Conventional geological exploration methods, including seismic exploration, resistivity surveys, and gravity surveys, serve as indispensable tools for identifying potential underground storage sites.

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These methods facilitate a profound understanding of subsurface rock formations, encompassing their structure, permeability, and storage potential. This insight guides scientists in selecting the most suitable locations for carbon sequestration[7].

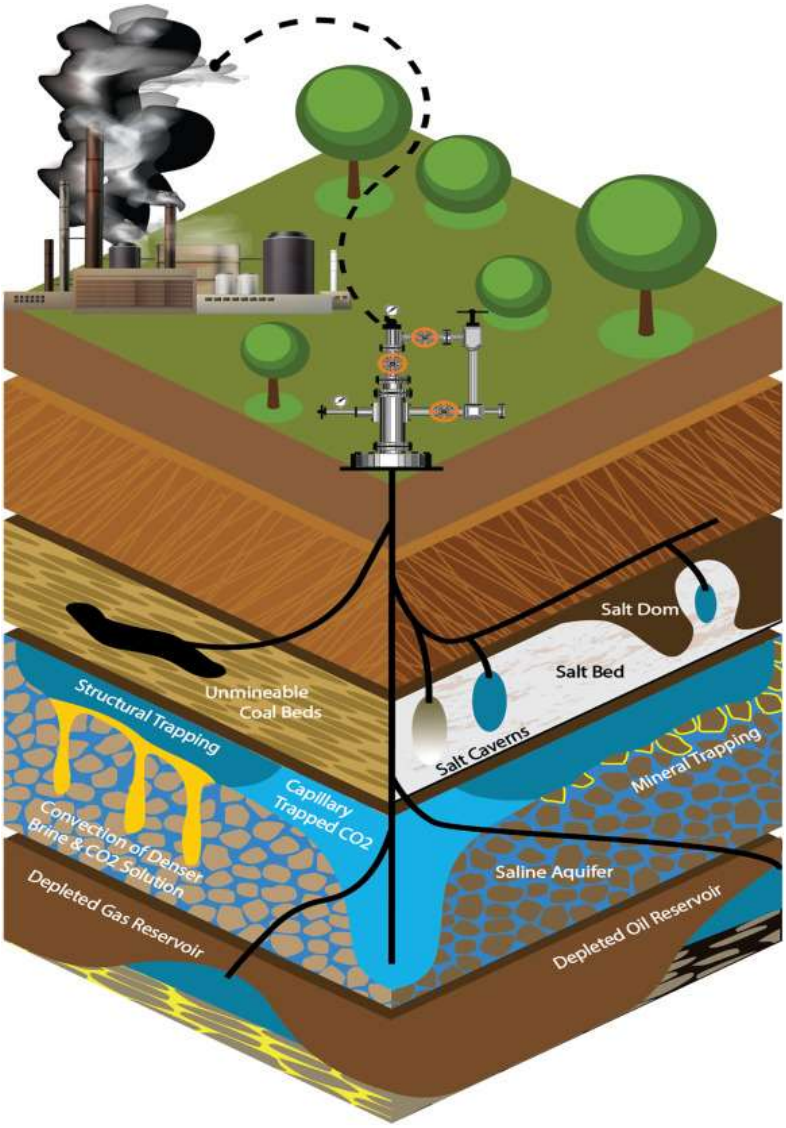

Figure 1. Carbon capture and storage mechanisms[6]

2.2 Core Sampling and Analysis

The collection of core samples and subsequent laboratory analyses represent pivotal steps in comprehending subsurface rock characteristics. This encompasses the study of permeability, porosity, rock types, and the feasibility of carbon storage within these formations. These data are instrumental in evaluating the suitability of subsurface rocks for carbon sequestration and determining their storage capacity.

2.3 Analysis of Subsurface Water Flow

A comprehensive assessment of subsurface water flow is imperative for evaluating the safety of carbon sequestration projects[8]. Groundwater dynamics can significantly impact the stability and permeability of carbon storage, necessitating an in-depth analysis of factors such as speed, direction, and potential impacts on underground storage (Figure 2).

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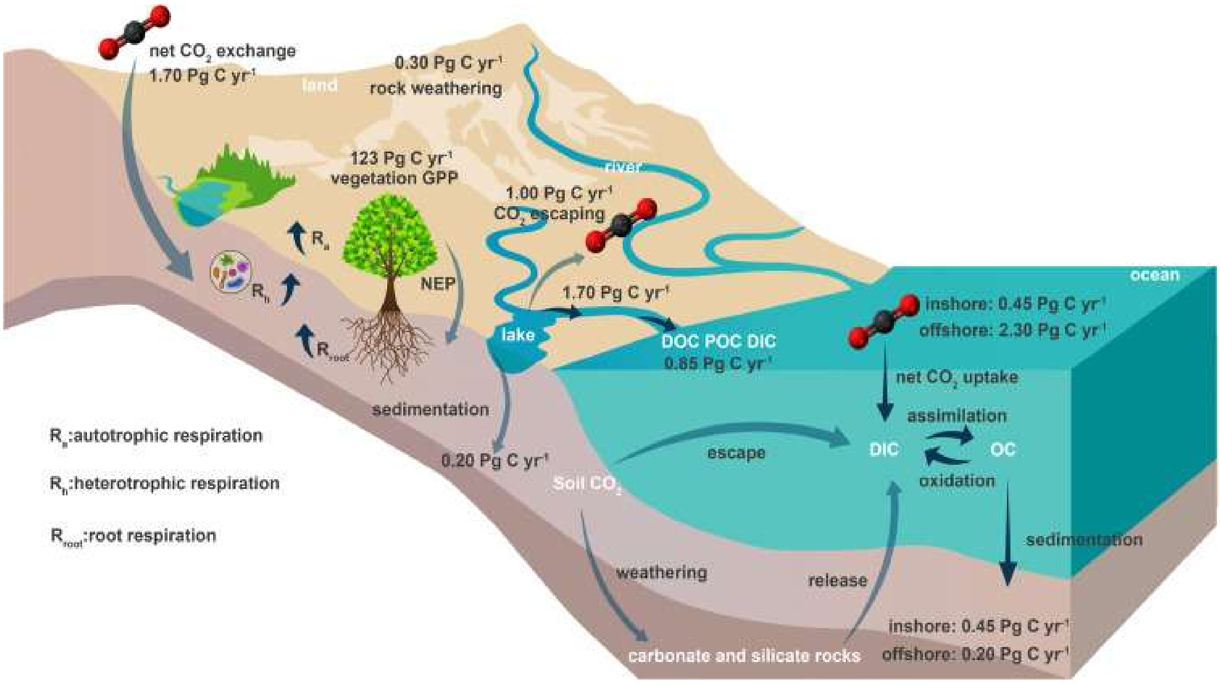

Figure 2. Carbon transported by terrestrial ecosystem control C escaping from inland water[9]

2.4 Geological Modeling and Simulation

Leveraging geological data, researchers can construct three-dimensional models of underground storage. These models are invaluable for simulating carbon storage outcomes in various scenarios and assessing potential leakage risks. Furthermore, they aid in the planning and optimization of carbon sequestration projects.

2.5 Monitoring and Tracking Technologies

Once carbon sequestration projects are in operation, conventional geological research techniques continue to play a vital role in monitoring project effectiveness[10]. Techniques such as seismic exploration and underground water monitoring enable the tracking of carbon gas distribution and movement post-injection, ensuring the long-term success of carbon storage efforts.

3. Geological Storage of Carbon Sequestration

Geological storage is a method for permanently sequestering carbon dioxide (CO_2) underground within rock formations. Typically, this involves injecting CO_2 gas into suitable underground storage reservoirs, such as deep salt formations or depleted oil and gas fields. In the subsurface environment, CO_2 gas interacts with rock formations, gradually forming stable carbonate minerals. This technology holds immense potential for significantly reducing greenhouse gas concentrations in the atmosphere, making it a pivotal tool in combating climate change.

3.1 Salt Formation Storage

Salt formations are commonly employed for carbon sequestration storage. In salt formation storage, CO_2 is injected into deep underground salt formations[11]. These formations exhibit high permeability and sealing properties, rendering them suitable for long-term carbon storage. Typically located deep underground, salt formations ensure storage stability.

3.2 Coal Seam Storage

Coal seam storage entails sequestering CO_2 in unmined coal mines. CO_2 is injected into coal seams, where it adsorbs onto coal surfaces, resulting in the permanent storage of the gas. This method proves particularly advantageous for abandoned coal mines, as it can extend the life of the mine while concurrently reducing greenhouse gas emissions.

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3.3 Oil and Gas Field Storage

Depleted oil and gas fields that have already been exploited can also serve as geological storage sites for carbon sequestration. CO_2 is injected into abandoned oil and gas wells to enhance oil recovery. Simultaneously, the CO_2 is permanently sequestered underground. This method is known as Carbon Gas Enhanced Oil Recovery (EOR) or Carbon Gas Enhanced Gas Recovery (EGR)[12].

4. Successful Cases of Geological Research in Carbon Sequestration

Geological research has yielded several noteworthy successes in the field of carbon sequestration, underscoring the critical role of geology in ensuring the feasibility and safety of carbon capture and storage (CCS) technologies.

4.1 Sleipner Project (Norway)

The Sleipner project stands as a landmark in CCS, located in the Norwegian North Sea. Geological research played a pivotal role in selecting an underground storage site characterized by excellent rock sealing properties and permeability. CO_2 captured from offshore natural gas production is injected into an underground storage layer. Operational since 1996, the project has successfully stored millions of tons of CO_2, validating the feasibility and safety of geological storage[13].

4.2 In Salah Project (Algeria)

Another success story in carbon sequestration is the In Salah project situated in Algeria. Geological research led to the selection of an appropriate underground storage site adjacent to a natural gas field. The underground storage layer consists of salt formations renowned for their robust sealing properties. Since 2004, the project has effectively stored millions of tons of CO_2[14].

4.3 Petra Nova Project (USA)

In Texas, the Petra Nova project represents the United States' inaugural commercial carbon capture and storage endeavor. Geologists conducted comprehensive geological assessments when choosing the storage site, ensuring the safety of underground storage. The project captures CO_2 from a coal-fired power plant and injects it into underground salt formations, highlighting the indispensable role of geology in carbon sequestration technology.

4.4 Otway Project (Australia)

The Otway project in Australia serves as an underground storage trial project, aimed at assessing the feasibility of geological storage. Geologists selected an underground salt formation in Victoria for storage and conducted a series of injection tests. This project provides valuable insights for future carbon sequestration projects in Australia[15].

These cases vividly illustrate that geological research and assessments are pivotal in the selection, design, and operation of carbon storage projects. The judicious choice of underground storage sites and meticulous evaluation of geological conditions are paramount in ensuring the success and safety of carbon sequestration technologies. These successful cases offer invaluable experience and references for addressing the global challenge of climate change.

5. Challenges and Issues

While geological research plays a pivotal role in carbon sequestration, there are also notable challenges and issues that demand attention.

5.1 Selection of Underground Storage Sites

The selection of suitable underground storage sites remains a critical challenge. Geologists must consider a myriad of factors, including sealing properties, permeability, the stability of rock formations, and proximity to CO_2 emission sources. In certain regions, identifying appropriate underground storage sites can prove challenging, necessitating extensive geological exploration and assessment.

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5.2 Utilization of Salt Formations and Salt Domes

Many carbon sequestration projects opt to inject CO_2 into underground salt formations or salt domes. While these formations generally exhibit commendable sealing properties, geologists must carefully study potential challenges, such as formation shifts and salt dissolution, to effectively mitigate associated risks.

5.3 Monitoring and Leak Prevention

Ensuring the secure and leak-free storage of injected CO_2 underground presents a significant challenge. Geologists must develop robust monitoring methods capable of tracking CO_2 movements within storage sites, detecting potential leaks, and enabling timely corrective measures. This necessitates the utilization of advanced technology and monitoring systems.

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