Energy Proceedings
Vol 34, 2023
ISSN 2004-2965

Application prospects of geophysical exploration techniques in the field of CCUS

[1*]Chen Juan, [1]Song Xilin, [1]Liu Xuejun, [1]Shi Yanling, [1]Zhao Wenju, [1,2]Yu Gang
[1]BGP, CNPC, Zhuozhou, Hebei, China
[2]Optical Science and Technology (Chengdu) Ltd., Chengdu, Sichuan, China
(*Corresponding Author: chenjuan01@cnpc.com.cn)

Abstract

In the field of carbon capture, utilization and storage (CCUS), geophysical exploration technology can make great contributions and has wide applications. Injecting high-pressure liquid or gaseous CO_2 into the existing underground oil and gas field can drive oil and gas moving in the reservoir to improve the output of oil and gas production wells and increase the recovery rate of oil and gas fields. At the same time, most of the CO_2 can also be sequestrated inside the reservoir formation. Sequestration of CO_2 underground is one of the important means and measures to achieve the goal of "Carbon Reduction". Integrated geophysical exploration technologies have a wide application prospect in the CO_2 storage site selection, onsite monitoring of CO_2 injection process, and long-term real-time dynamic monitoring of the CO_2 storage site safety.

The high-density and high-resolution 3-D seismic, gravity and electromagnetic surveys can accurately evaluate the stability and sealing conditions of the underground geological structure for CO_2 sequestration, and identify all faults and fracture zones within the CO_2 sequestration site. Borehole seismic and borehole electromagnetic surveys can monitor and evaluate the CO_2 injection process in real time to avoid any safety risks such as CO_2 leakage from the injection well. In the underground area where a large number of CO_2 is stored, the time-lapse borehole seismic and electromagnetic surveys can be used to map the migration and storage status of CO_2 plume underground. Using the downhole armored optical cables outside the casing can conduct long-term real-time dynamic monitoring of the safety state of underground CO_2 to prevent and avoid catastrophic events where underground sealed CO_2 migration leaks to the surface.

Over the past 60 years, gravity, magnetic, electromagnetic and geochemical survey methods have been widely used in the field of geophysical exploration. Therefore, they are becoming more and more popular in the oilfield technical service market. Nowadays, the state has put forward the requirements of "carbon reduction" for companies specializing in oil and gas exploration and development. BGP has focused on expanding its applications in CCUS during last three years. It has not only made contributions in the stability, reliability and tightness of CCUS storage site selection, but also made use of the advantages of optical fiber sensing technology for the real-time engineering monitoring of the CO_2 injection operation. At the same time, it has carried out research on the long-term safety monitoring of CO_2 sequestration sites aimed at preventing surface leakage. When applied to the field, it can provide real-time evaluation of CO_2 driving the oil and gas moving, which is of great reference significance for reservoir evaluation and enhanced oil recovery.

This paper analyzes the applications of the above-mentioned geophysical technologies on CCUS and makes a prospect from four aspects. It hopes to provide help to many oil companies make scientific

This is a paper for International CCUS Conference 2023 (ICCUSC2023), April 14-15, 2023, Beijing, China.

decisions and accurately find oil and gas under the background of improving quality and efficiency and achieving the requirements of the national green energy strategy.

Key words： CCUS, CO_2 sequestration, borehole seismic, optical fiber sensing, non-seismic

1. Introduction

Since “the implementation of the 14th Five-Year Plan”, China has attached great importance to the green and low-carbon development of energy, stressing the need to "accelerate the green transformation of development" and "pay close attention to green and low-carbon technology research and development.". Carbon dioxide capture, utilization and storage (CCUS) is the core essence and focus of China's efforts to reduce carbon dioxide emissions. Accelerating the application of CCUS and the development of industrial chain is the rigid demand and the only way for the energy industry to achieve the goal of "dual carbon". In recent years, PetroChina has attached great importance to the development of the CCUS industry. It has been vigorously promoting the research and development of CO_2 enhanced crude oil recovery, actively innovating and forming the technology system of the whole CCUS industry chain, and maintaining the leading level of CO_2 injection and storage in China. At the same time, it devotes itself to jointly promote China's CCUS project in the field of oil driving utilization into the industrial application stage, which is always playing a pivotal role in ensuring national energy security and promoting green and low-carbon energy development.

Firstly, from the perspective of carbon sources, the oil and gas field enterprises served by PetroChina are mostly located around refining and chemical enterprises, power plants, cement plants, etc. As a result, it can provide an external source of carbon for the development of CCUS through the establishment of carbon capture units. Meanwhile, PetroChina itself is both a giant energy producer and a major energy consumer. Carbon dioxide from internal energy production is a "pain point" for the company to achieve its “dual carbon” goal, and is also one of the "landing points" for the development of the CCUS industry. This measure can provide sufficient carbon sources for CCUS projects. Secondly, in terms of geological resources, it is roughly estimated that there are over 6.7 billion tonnes of geological reserves within the China National Petroleum Corporation's mineral rights area that are suitable for the use of carbon dioxide as an oil drive, and the geological potential for carbon dioxide drive or burial is considerable.

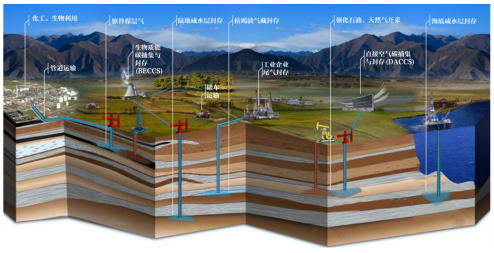

Figure 1 Illustration of the subsurface CO_2 injection and sequestration.

As a subsidiary of BGP, who is only taking the non-seismic exploration task, the Non-Seismic Division has not only tried its hand in the BGP Oman 44.01 project in 2022, but also set about cooperating with Optical Science and Technology (Chengdu) Ltd., who is good at using the fibre optic sensing technology. In addition to enriching and improving the knowledge system of integration on gravity, magnetic, electric and seismic, we have also gained and summarized the practical experience of CO_2 oil drive from field applications. In the past three years, Non-Seismic Division of BGP has not only clarified the overall deployment of "clean substitution, strategic replacement and green transformation" for the new energy business, but also made the CCUS demonstration project a key layout for the green industry. The establishment of a dedicated CCUS technical team, the establishment of an internal coordination mechanism to promote the comprehensive development of CCUS projects, the continuous improvement of CCUS planning schemes, the timely launch of key CCUS projects, the well-timed creation of CCUS demonstration projects, and the organization of the preparation of CCUS for the medium and long-term development plans. What we have done not only boosted the development strength of the Group's entire CCUS industry chain, but also to achieve a quantitative breakthrough in the annual CO_2 injection volume and scale up of CCUS industry.

2. Current challenges

Geologic carbon sequestration (or geologic carbon sequestration for short) is to inject captured carbon dioxide into underground space for permanent storage, thereby reducing carbon dioxide emissions into the atmosphere. The geologic sequestration of carbon dioxide works in the same way that oil, natural gas and other hydrocarbons have been trapped in the Earth's underground medium for tens of millions of years.

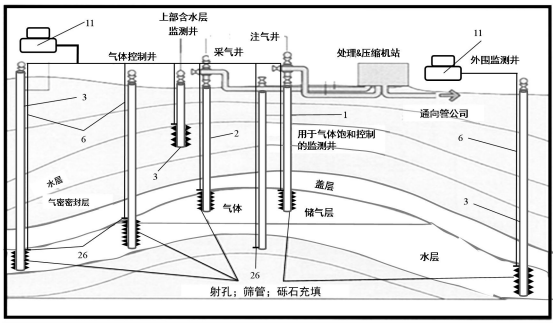

Figure 2 the distribution of CO_2 injection, monitoring wells and downhole monitoring system.

There are also some security problems in terms of geological storage of carbon dioxide. The safety issues here mainly include two aspects: first, whether the carbon dioxide stored underground will leak, it pollutes and damages the shallow strata and groundwater environment, or leak into the atmosphere; Second, whether the high pressure caused by underground carbon dioxide storage will damage the cap rock and underground geological structure, forming faults or causing geological disasters such as earthquakes. Therefore, carbon dioxide geological sequestration requires long-term monitoring of its effectiveness and safety. In a word, carbon dioxide geological storage has the advantages of large storage capacity, long storage time. The mature technology can be transferred and can be combined with carbon dioxide utilization. But leakage monitoring is a tricky problem, facing the risk of storage leakage under the condition of long-term storage. Therefore, we should use targeted, accurate, reliable, and low-cost permanent monitoring technology to improve the ability of anomaly detection, anomaly tracing and leakage quantification, so as to effectively realize the risk management of carbon dioxide geological storage (Yu et al., 2022, White et al., 2021, Zhao, 2023).

3. Coping strategies

First, Microgravity and surface/ground-well or well-surface time-frequency EM can monitor the transport of CO_2 plumes within subsurface reservoirs from the following pictures.

Second, Time-lapse surface seismic and borehole seismic monitoring results before and after CO_2 injection is showing as following figures.

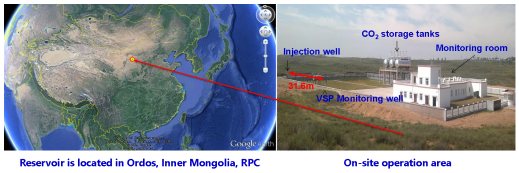

Figure 3 The CO_2 injection site location (left) and injection and morning boreholes (right).

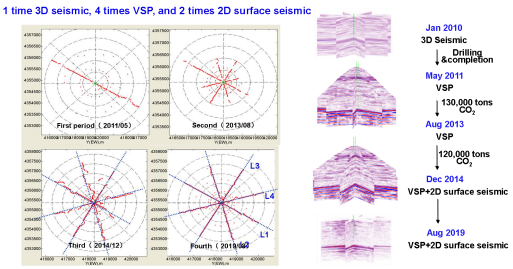

Figure4 the 4D borehole seismic survey (4-times) configuration (left) and the surface seismic and borehole seismic data processing results (right).

Figure 3 shows the first CO_2 injection project location in China (left) and the picture of CO_2 injection facility as well as the injection and morning boreholes (right).

The 4D borehole seismic survey (4-times) configuration (left) and the surface seismic and borehole seismic data processing results (right) are shown in Figure 4.

In Figure 5, the CO_2 migration status in Shiqianfeng formation (above) and Shihezi formation (below) from 2014 to 2019 can be observed.

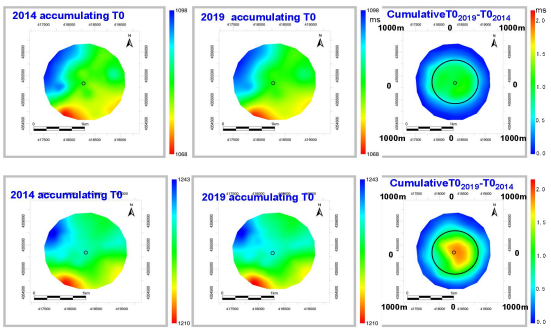

Figure 5 the CO_2 migration in Shiqianfeng formation (above) and Shihezi formation (below) from 2014 to 2019 can be shown.

4. Conclusions

This paper analyzes the applications of non-seismic exploration and Optical fiber sensing technology on CCUS from all aspects above. Integrated geophysical exploration technologies have a wide application in the prospects, including CO_2 storage site selection, onsite monitoring of CO_2 injection process and long-term real-time dynamic monitoring of the CO_2 storage site safety. We sincerely hope non-seismic geophysical technologies mentioned above can be a priority to much more oil companies than before, combining the advantage of optical fiber sensing technology. Therefore, handling their respective complexities more easily for Clients, who need to make decisions and discovery oil and gas precisely.

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Acknowledgements

The authors wish to thank BGP and Optical Science and Technology (Chengdu) Ltd. for the permission to publish the paper, and the support of BGP's research project 'Research of comprehensive non-seismic technology in the dual complex region of eastern Sichuan Province' (08-03-2022).

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