Introduction

The purpose of Carbon Capture and Storage (CCS) is to store CO2 deep into the geological formations permanently to mitigate greenhouse emissions. On the contrast, the purpose of Underground Gas Storage (UGS) is to store natural gas into the formations temporarily to meet seasonal peak-shaving and emergence needs.

There are many similarities between CCS and UGS for depleted oil&gas type reservoir gas storage in terms of site selection criteria, reservoir characterization, containment evaluation and monitoring, measures, and verification (MMV) of storage site.

In this paper, we will show an UGS case which has implemented Trinity Integrity Risk Management (TIRM) for the whole life cycle, whose concept and practice may be a good demonstration for CCS MMV of depleted oil&gas reservoir. The case UGS has run 12 injection and production cycles since 2013. It was converted from a depleted gas reservoir with 35 years of production history, which is located at the tectonically complex reverse fault region in Sichuan Basin of Southwest China, Jiang, H. et al, 2024 and Li, L. et al, 2022.

The Idea and Concept of Trinity Integrity Management of UGS

UGS has the characteristics of multi-cycle heavy injection and withdrawal in that the operational risk will increase with continued operation. The integrity management of UGS requires functional and physical integrity of geological body, wellbore, and surface facilities during the UGS whole life cycle. Based on operational practice of the studied UGS case, the "geological body-wellbore-surface facility" trinity integrity management model is established. It has ensured a safe, stable, and efficient operation of the mentioned UGS so far.

Management of Geological (Geobody) Integrity

This is focusing on the effectiveness of traps, integrity of caprock, and stability of faults and reservoir. The management of geobody integrity is to investigate monitoring technologies of dynamic sealing of traps.

Management of Wellbore Integrity

This is focusing on the management of wellbore integrity for UGS wells under 'high rate of injection and withdrawal, and alternative loading'. This includes the evaluation and diagnosis of wellhead, casing string and annulus pressure and forms the monitoring technology of well engineering integrity, thus ensuring safe operation of injection and withdraw wells.

Management of Surface (Facility) Integrity

This is focusing on the integrity management of pipeline and station, which sets up a management process including data collection, risk assessment, inspection, maintenance, efficiency evaluation, online diagnosis and monitoring.

Figure-1 showed the practice of 'geological body-wellbore-surface' trinity integrity management for the studied UGS case.

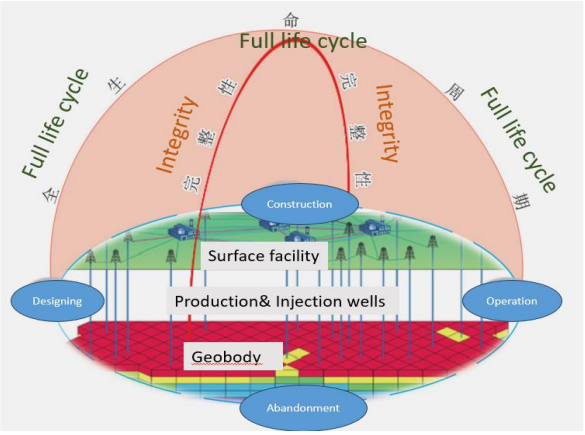

Figure-1a, Schematic for UGS whole life cycle integrity management concept and idea

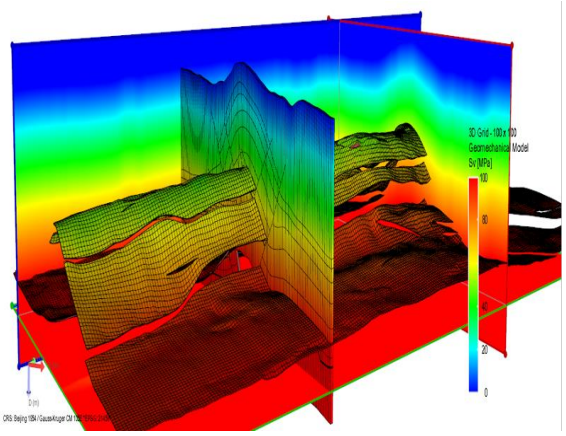

Figure-1b, Subsurface Integrity- Three-dimensional stress distribution diagram of the case UGS

Geological Reservoir Management

To achieve full lifecycle management of geological reservoirs during the “appraisal phase, construction phase, and operation phase”, a comprehensive monitoring system integrating "conventional monitoring + fibre optic monitoring + micro seismic monitoring + 4D geomechanical dynamic monitoring" was established to dynamically evaluate the sealing integrity of the geological formation, ensuring the gas storage formation remains safe and controllable. Shown in Figure-2.

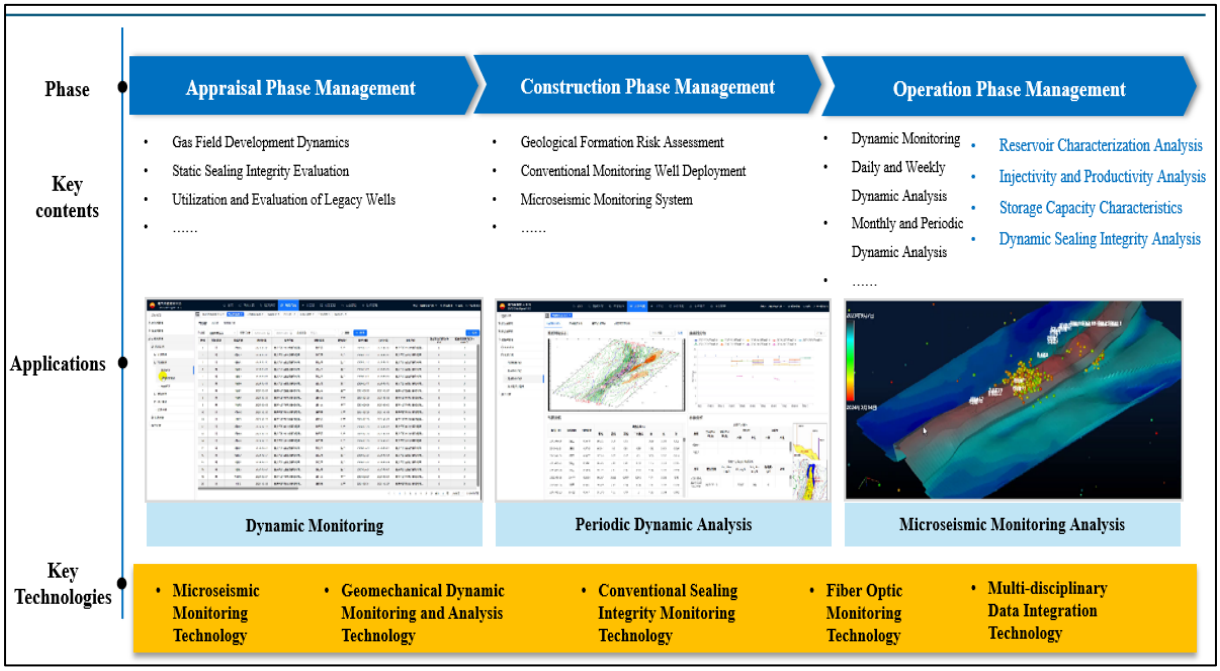

Figure-2, Phased Geological Reservoir Management with corresponding monitoring technologies integration to dynamically evaluate the sealing integrity of the Geobody, ensuring the gas storage formation remains safe and controllable

Monitoring Measures

The studied UGS case has deployed monitoring wells, micro-seismic network, surface equipment or pipeline monitoring system, satellites, remote control system, and pre-warning system to perform all around and multi-dimensional dynamic monitoring to ensure operation in a safe and controlled manner. Figure-3 showed the micro seismic deployment, inSAR geo-disaster monitoring system and virtual real-time monitoring system.

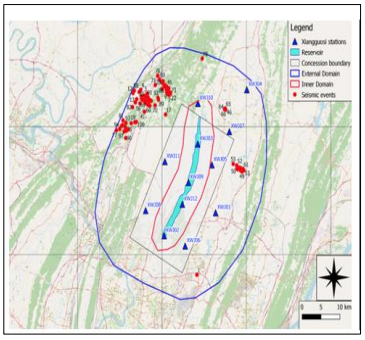

Figure-3a, micro-seismic monitoring network deployment

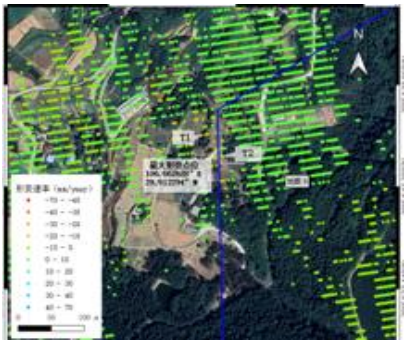

Figure-3b, inSAR geo-disaster monitoring system

Figure-3c, Virtual real-time monitoring system

Conclusions

This paper shows an UGS case which has implemented innovative Trinity Integrity Risk Management (TIRM) and dynamic 4D monitoring system for the whole life cycle of UGS operation. These ensure a safe, stable, under control and efficient operation, whose concept and practice may be a good referral for CCS MMV utilizing depleted reservoir to storage CO2.

Acknowledgements

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References

1) Jiang, H., Yu, H., Mao, Ch., Tang, Zh., Li, L., Ofi, A., Burns, C., Wang, Y., Wen, T., Gui, F., Zhou, Y. and Wang, Sh. [2024] The Practice and Effect of Underground Gas Storage Expanding the Range of Operation Pressure Beyond the Original Reservoir Pressure to Increase Gas Storage Capacity. Society of Petroleum Engineers DOI 10.2118/220019-MS. This paper was prepared for presentation at the SPE Europe Energy Conference and Exhibition held in Turin, Italy, 26 - 28 June 2024.

2) Li, L., Yu, H., Kshirsagar, A., Samy, A., Mao, C., Qu, L., Kuswiranto, A. and Gui, F. [2022] A Practical Approach to Maximize UGS Storage Efficiency in Order to Secure Energy Supply. Society of Petroleum Engineers DOI 10.2118/209658-MS.This paper was prepared for presentation at the SPE EuropEC - Europe Energy Conference featured at the 83rd EAGE Annual Conference & Exhibition held in Madrid, Spain, 6 - 9 June 2022.