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Advancing Passive/Microseismic Technology to Monitor Subsurface Reservoir During CO_2 Injection.

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Introduction

In the pursuit of enhanced environmental stewardship and sustainable energy practices in the carbon capture and storage business, there exists an inherent necessity, which is mutually recognised by both commercial and public stakeholders, for the continuous monitoring of CO_2 storage sites. Reservoir monitoring is crucial to verify that the stored CO_2 is exhibiting anticipated behaviour and remains confined within defined containment boundaries, without any leakage occurring. Continuous passive seismic monitoring has the potential to function as an early warning system, facilitating timely investigation and potential implementation of mitigation measures. Additionally, it can also function as an indicator for assessing the integrity of the storage reservoir and the stability of CO_2 that has been injected into the reservoir, while providing valuable information that can be used to determine optimal CO_2 injection schedules.

TenzorGEO aim to advance passive seismic CO_2 monitoring technology to enhance environmental stewardship in carbon capture and storage monitoring, and together with operator partners ADNOC have deployed the technology in the Middle East. The results showcase the ability of passive seismic data to visually verify the containment of CO_2 and serve as a warning system and reservoir stability indicator for injected CO_2. The solution known as Cuttlefish Carbon Guard (CCG) integrates both passive seismic and microseismic methods with a wider frequency spectrum from 0 – >100Hz to locate microseismic events, analyse the integrity of the caprock and the storage reservoir, and analyse spectral responses due to CO_2 saturation velocity changes to visualise the reservoir fluid and injected CO_2.

Method:

The technology solution was deployed onshore in the field in UAE with ADNOC to monitor a live CO_2-EOR (Enhanced Oil Reservoir) injection project. To develop and standardise acquisition, processing and interpretation of microseismic and passive seismic data acquired we focused on: Data acquisition, method workflow, and software and algorithm testing, upgrade and development.

Data Acquisition: Here we designed an effective combination of sensor types 1C and 3C deployed as patches in a grid array to create an integrated data acquisition and interpretation workflow with reduced volume of acquired data and improved SNR (Signal to Noise Ratio) with calibration shut performed in the field. Data acquired is in the frequency range of 0.1 - >100Hz with tests performed onsite prior to acquisition to determine and suppress surface waves.

Method Workflow: Integrate and adapt two standalone microseismic and passive seismic methods into one – Cuttlefish Carbon Guard with an enhanced method workflow and

capability.
Full Wave Location (FWL) aims to locate the microseismic events and determine the moment tensor in the reservoir rock – i.e. in response to changes in pressure, fluid displacement, pore fluid saturation, reactivation of fractures and filtration channels. We employ a proprietary noise stable technique “location by maximum likelihood” to improve the SNR.
While Low Frequency Seismic (LFS) analyses the spectral response of vertically directed P-waves from ambient background microseismic noise (0.1 – 10 Hz) to delineate CO_2 saturated rock due to velocity changes.

Data Interpretation: Finally, test the capability of our interpretation methods and the software on the acquired data in the field. The data acquired was processed and integrated into the developed subsurface model, analysed and interpreted following numerical modelling and simulation. The results are visualised and used to have better understanding of the impact of CO_2 on the reservoir.

Results

The solution successfully achieved multiple objectives which includes delineation of oil-water contact boundaries, visualisation of injection-driven reservoir changes, detection of microseismic events, identification of elevated microseismic activity zones during CO_2 injection, assessment of caprock integrity, and comprehensive mapping of horizontal stress distribution. These results validate CCG as a robust surface monitoring solution for CO_2 storage projects, providing crucial insights into reservoir dynamics and ensuring safe carbon storage operations.

Conclusion

The field project highlights the capability of an integrated passive/microseismic solution, paving the way for a standardised continuous surface monitoring solution in CO_2 injection projects. The project underscores the technology's potential to add cost, security and innovative value while monitoring subsurface reservoir integrity and track CO_2 velocity changes. The continuous monitoring nature of the technology can help to increase public and stakeholder confidence.

Novel/Additive Information:

a. First-of-its-kind integration of microseismic (FWL) and passive seismic (LFS) methods to monitor CO_2 injection.
b. Proprietary maximum-likelihood event location enhances accuracy in detecting microseismic activity.
c. Successful field deployment in ADNOC’s CO_2 injection project, proving scalability for industrial applications.
d. Future potential to integrate AI-driven seismic interpretation for automated real-time monitoring.

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