16th International Conference on Greenhouse Gas Control Technologies **GHGT-16**

23-27th October 2022, Lyon, France

Effective microseismic monitoring of the Quest CCS site, Alberta, Canada

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Abstract

Microseismic monitoring represents a key surveillance technology to verify the integrity of any large-scale CO_2 storage, since the interpretation of microseismic events provides direct insight into CO_2 migration within the storage reservoir as well as potential caprock failure in the overburden. Verification of seal integrity requires the recognition of tiny precursor movements as indicators of injection-related reservoir and caprock dynamics before potential seal failure. Such minuscule events are often observed in CO_2 injection operations. Figure 1 shows an example from the Quest site. However, optimally designing cost-efficient monitoring systems for this particular purpose has been identified as a critical knowledge gap for the maturation and scale-up of CCS technology.

In this study, we focus on the comparative analysis of different microseismic monitoring solutions available at the Quest Carbon Capture and Storage (CCS) site in Canada, Alberta. The Quest CCS Facility is a fully integrated commercial-scale CCS site located at the Scotford Industrial Complex near Fort Saskatchewan, Alberta, Canada. The storage reservoir in a saline aquifer consists of a 350 m thick sedimentary sequence, which includes the Basal Cambrian Sandstone (BCS) reservoir, capped by the Middle Cambrian shale and the Lotsberg salts. At the Quest site, approximately one million metric tonnes of CO_2 are stored each year, with the intent to operate at these injection rates for 25 years. As of 2020, the Quest facility has safely injected over five million tonnes of CO_2.

Microseismic monitoring is in operation at Quest since November 2014 with the aim of addressing risks associated with containment and induced earthquake hazard. Low level, small magnitude microseismic activity occurs deep beneath the storage complex in the Precambrian basement. The site is monitored with a variety of sensor types and networks, including a downhole geophone array, surface geophone arrays, as well as a borehole distributed acoustic sensing (DAS) system. Parts of the data acquisition (DAS and surface geophones) are ongoing. This rich dataset offers a unique possibility for robust determination and comparison of microseismic detection thresholds and the application of novel processing tools for long-term seal stability assessment. We present methods to assess and optimize the quality and efficiency of microseismic monitoring arrays for CCS seal integrity verification.

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While event locations and magnitudes are often routinely estimated, more advanced earthquake source parameters, such as stress-drops, b-values, and focal mechanisms are only estimated selectively and may require certain network configurations. However, it has been shown that earthquake source parameter variations can be linked to geomechanical properties and can be used as a proxy to monitor the pore pressure distribution. We evaluate the different network setups for their ability to estimate these advanced parameters. Data analysis also includes the quantification of network acquisition footprints with state-of-the-art modelling and processing tools. We assess differences in seismicity levels and seismo-statistics between the different sensor networks. A rich dataset like this may not only demonstrate the suitability of different microseismic monitoring technologies for CCS measurement, monitoring and verification (MMV), but also determine the relative value of different acquisition types and geometries for this purpose.

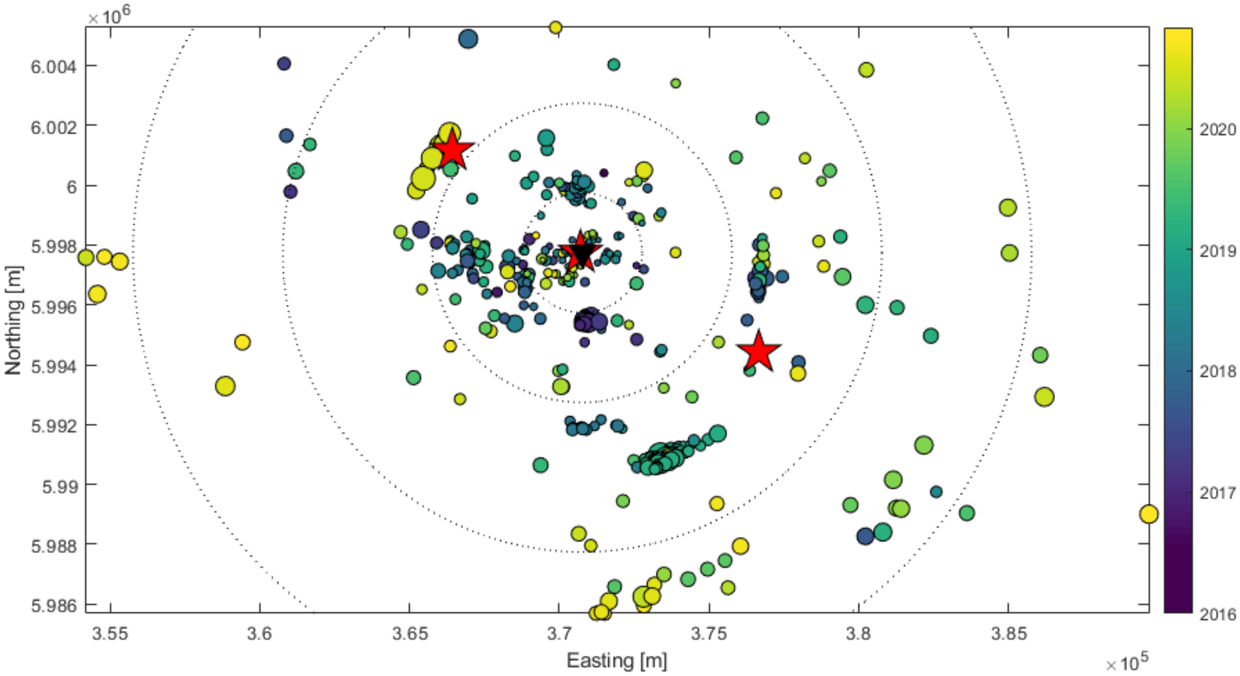

Figure 1: Map view of microseismic event locations (circles) at the Quest CCS site as of October 2020. Events are coloured by origin time. Circle size scales with event magnitude. The red stars show the three CCS injection wells. The black inverted triangle marks the location of the downhole geophone array. The black dashed circles indicate equal distances from the monitoring well ranging from 2 km to 15 km.

Keywords: microseismicity; induced seismicity; fiberoptic; array seismology, source parameters; DAS; sruface array; monitoring; CCS