AMPLIFIED GEOCHEMICAL IMAGING LLC

Technical Note

Ultrasensitive Sensitive CO_2 Monitoring and Reservoir Integrity Assessment

A primary mode of Carbon Capture and Sequestration (CCS) is geologic sequestration in which carbon dioxide (CO_2) is injected into underground geologic sinks. Critical to the success of geologic sequestration is the need to ensure that underground storage sinks have adequate seal and do not leak.

However, the ability to determine if these subsurface structures have an adequate seal prior to CO_2 injection and that those seals do not leak is difficult since there are not many CO_2 monitoring technologies available to provide adequate sensitivity and coverage for underground sequestration. But, passive geochemical sorbers placed near-surface **provide the ability to monitor leakage over reservoirs, faults, natural fractures, and around injection wells and P&A'd wells**.

Amplified Geochemical Imaging's (AGI's) proprietary passive surface detection and mapping technology provides a unique ability to detect hydrocarbons at parts per billion (ppb) levels **which is 1,000 times more sensitive than surface seismic methods**.

The passive sampler (**Figure 1**) contains a specially engineered polymeric adsorbent encased in a microporous membrane. These membrane pores are small enough to prevent soil particles and water from entering, but large enough to allow CO_2 and hydrocarbon molecules to pass through.

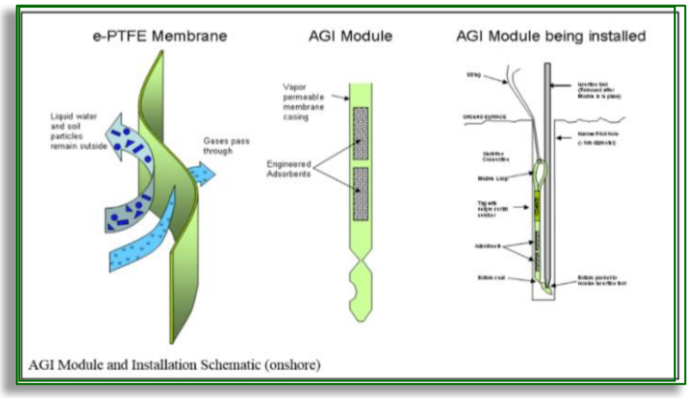

Figure 1.

The first case study took place in the Yibal field located in the Fahud Salt Basin in northwestern Oman, ~310 km SW of Muscat. The Yibal field is **a depleted gas field** in the Cretaceous Natih A Formation, with significant faulting throughout.

The purpose of the survey was to assess reservoir seal integrity for CO_2 sequestration. AGI's passive geochemical imaging was selected to map potential hydrocarbon seepage along faults and to identify potential CO_2 spill point.

Approximately 152 samplers were deployed for 20 days over structural closures at depth (i.e. depleted petroleum reservoirs) along specified fault projections to monitor indications of natural leakage pathways. Samples were deployed along single transects and double transects with 200 m spacing (**Figure 2**).

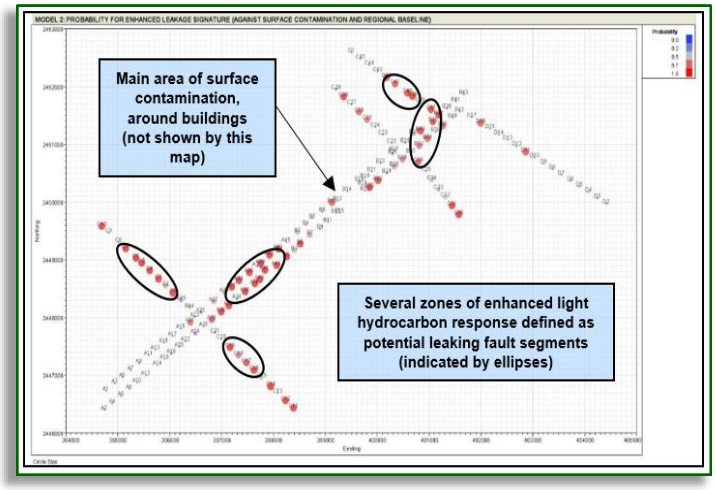

Figure 2.

Hierarchical Cluster Analysis identified two primary signatures: a baseline gas signature and an elevated (4X) gas signature. The regional baseline signature, represented by gray dots in **Figure 3**, exhibited the lowest mass response, primarily consisting of C_4 and C_5 light hydrocarbon compounds migrating to the surface from the reservoir.

In contrast, the enhanced light hydrocarbon signature (**Figure 3**), comprised of C_2–C_7 compounds, shown as red dots, was mapped along coherent segments of projected fault lines, inferring reservoir leakage along specific fault traces.

The leakage indicated the reservoir was unsuitable for sequestration purposes given the depleted reservoir had minimal pressure but already leaked.

The detection of CO_2 leakage would occur in the same manner , but would use a separate CO_2 calibration curve for accurate CO_2 quantification. It is also important to note the data also indicates the method can detect gradual increases in CO_2 levels. This allows for early detection of CO_2 leakage which allows for mitigation of the situation before the leakage becomes catastrophic.

Passive Geochemical Imaging is 1,000 times more sensitive than Seismic.

Seismic data tells you where you MIGHT have a leak, not where you do have a leak.

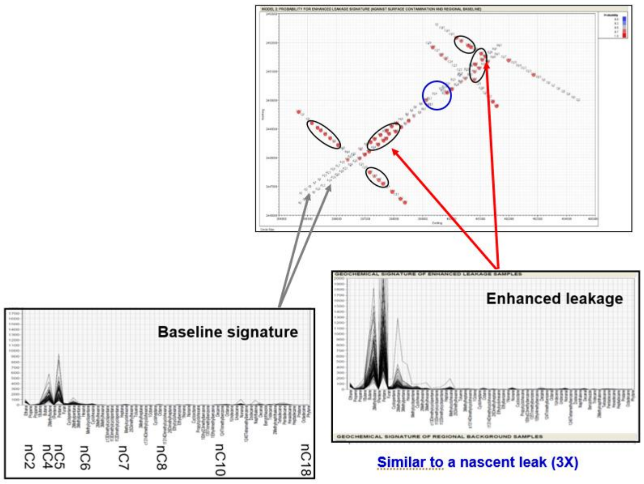

Figure 3.

The second case study involves the In Salah CCS program in the Algerian Krechba Field. Gas with high amounts of CO_2 was being produced from a ~20 m thick reservoir at ~1850–1900 m, see **Figure 4**. The reservoir is overlain by ~950 m carboniferous mudstones, siltstones, and limestones which is overlain by ~900 m of Cretaceous sandstone deposits (Ringrose, 2009).

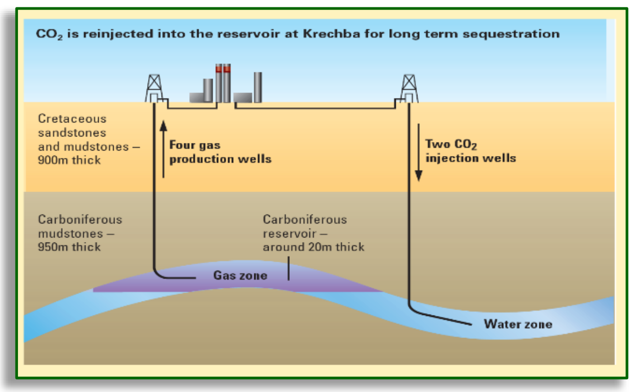

Figure 4.

The CO_2 was injected into the ~20m thick down-dip water leg of the gas reservoir at ~1.9 km depth. There were five gas producing wells, colored red, inside the yellow shaded area (**Figure 5**) and three injection wells, colored blue, (the KB-1, KB-2, & KB-3).

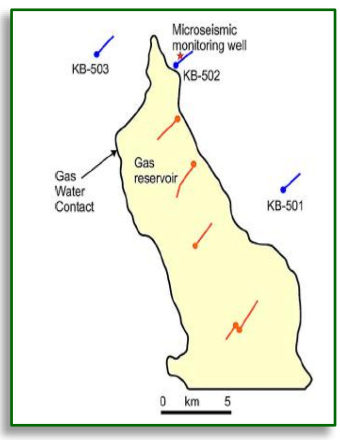

Figure 5.

Response to the CO_2 injection was observed from InSAR (Interferometric Synthetic Aperture Radar) imaging. Surface deformation, or up-welling, of several centimeters was observed around each one of the injection wells (**Figure 6**). The 3D seismic survey indicated that the CO_2 injection had activated a deep natural fracture extending several hundred meters horizontally and approximately 150 m above the reservoir.

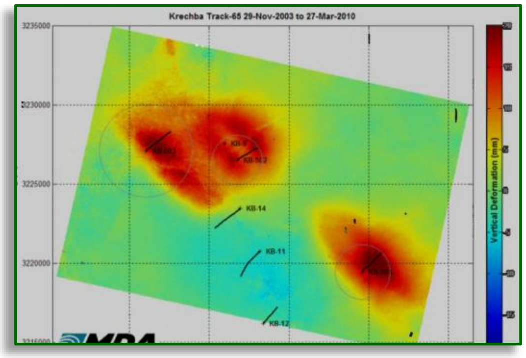

Figure 6.

Thus, an AGI survey, using fluorinated CO_2 tracers and 143 samples, was employed to evaluate subsurface leakage. A different fluorinated tracer was used for each injection well to determine if detected CO_2 leakage could be linked to the appropriate injection well.

Background hydrocarbon levels were detected above the reservoir and along fractures. None of the samples recorded detectable levels of perfluorocarbons, indicating no evidence of leakage from the gas storage reservoir.

A question was raised regarding the functionality of the AGI modules. Since this was an active gas field, even if the AGI method had failed to detect CO_2 leakage, it would have still detected extremely elevated concentrations of natural gas hydrocarbons. The absence of such anomalies confirmed that the AGI system was operating correctly, and that no leakage had occurred.

So, the study demonstrated the ability of passive geochemical imaging to monitor CO_2. AGI monitored the field from 2015 to 2020.

Since this project, AGI's research has advanced such that tracers are no longer needed. A paper presented by Eduardo Luna-Ortiz, et. al, at the Offshore Technology Conference in 2022 documented that industrial CO_2 sources have impurities (e.g. amines). These impurities can be detected by AGI's method. The detection of these impurities provides AGI's method with the ability to unequivocally determine if the CO_2 detected at the surface is subsurface or ambient in source.

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