CO_2 Monitoring: Geophysical Techniques vs Passive Geochemical Sensing

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 an effective seal and do not leak to pose a potential threat to human health and the environment. So, the question becomes, what is the best method for monitoring potential CO_2 leakage?

The majority of the current CO_2 monitoring methods rely on a variety of geophysical techniques: 2D seismic, 3D seismic, passive seismic, Vertical Seismic Profiling (VSP), and Cross Well Seismic (CWS). These techniques fall into two basic groups: 1) surface seismic imaging (e.g., 2D, 3D, passive seismic); and 2) technologies anchored to observation or monitoring wells (e.g., VSP, CWS).

Active seismic (2D, 3D) surveys use induced energy sources at the surface to create seismic waves that move through the stratigraphic section to be detected at surface sensors deployed in specific patterns. Seismic wave energy is refracted and reflected as it passes through the earth according to differences in rock properties, and by analyzing the intensity and timing of seismic energy returns recorded by surface sensors it is possible to infer the configuration of subsurface rock layers.

Certain physical attributes such as layer depth and thickness, rock type, and bulk porosity may be determined as well. The ability of seismic techniques to resolve subsurface features is limited by seismic wave frequency, estimated wave velocity profiles as a function of depth, orientation of rock layers and discontinuities (faults), and other factors that cause seismic wave dispersion. It may be possible to determine the type of fluid fill in porous rock sections although this usually requires well log data and more extensive seismic data processing and can be prone to inaccuracies.

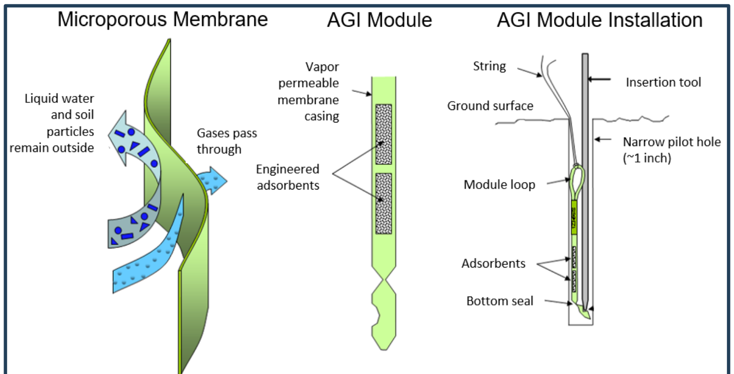
Similar challenges are involved when using seismic techniques (active or passive) to detect CO_2 plumes and leakage during or after injection. Seismic techniques **infer fluid composition** in porous sections indirectly by changes in bulk rock property and wave dispersion conditions which may not be reliably detectable in the seismic data. For example, acoustic impedance in carbonate reservoirs can be very high, thus masking or interfering with fluid signatures. Aslo, these techniques **require large volumes of CO_2 to be reflected in seismic imaging conditions** which may not be reliably detectable in the seismic data.

VSP and CWS suffer from the same sensitivity problems as surface seismic surveys. These techniques have an additional drawback in that an observation well must be proximal to the CO_2 injection well. **Not only are observation wells extremely expensive to drill, but they are a single monitoring point in an entire field**.

Consequently, observation wells provide only one data point for plume location and do not have the sensitivity required to detect CO_2 leakage.

An alternative method, used for real-world CCS projects for over 20 years, is passive geochemical imaging. Amplified Geochemical Imaging's (AGI) proprietary passive surface detection and compound mapping technology provides the unique ability to detect volatile organic compounds directly at parts per billion (ppb) levels, **which geophysical methods cannot do**.

The AGI passive sampler, **Figure 1**, contains specially engineered polymeric adsorbents encased in a microporous membrane. The membrane pores are small enough to prevent soil particles and water from entering but large enough to allow CO_2 gas molecules to pass through and concentrate on the adsorbents.



AGI onshore module and installation scheme

Figure 1.

CO_2 Detection Sensitivity is the Key

Figure 2 illustrates the sensitivity difference between ultrasensitive passive geochemical imaging and surface seismic approaches. Passive geochemical imaging can detect CO_2 leakage at low parts per billion (*ppb*) levels, whereas seismic imaging requires large CO_2 plumes for detection. As such, geophysical approaches are better suited for plume tracking and mapping, as opposed to CO_2 leak detection.

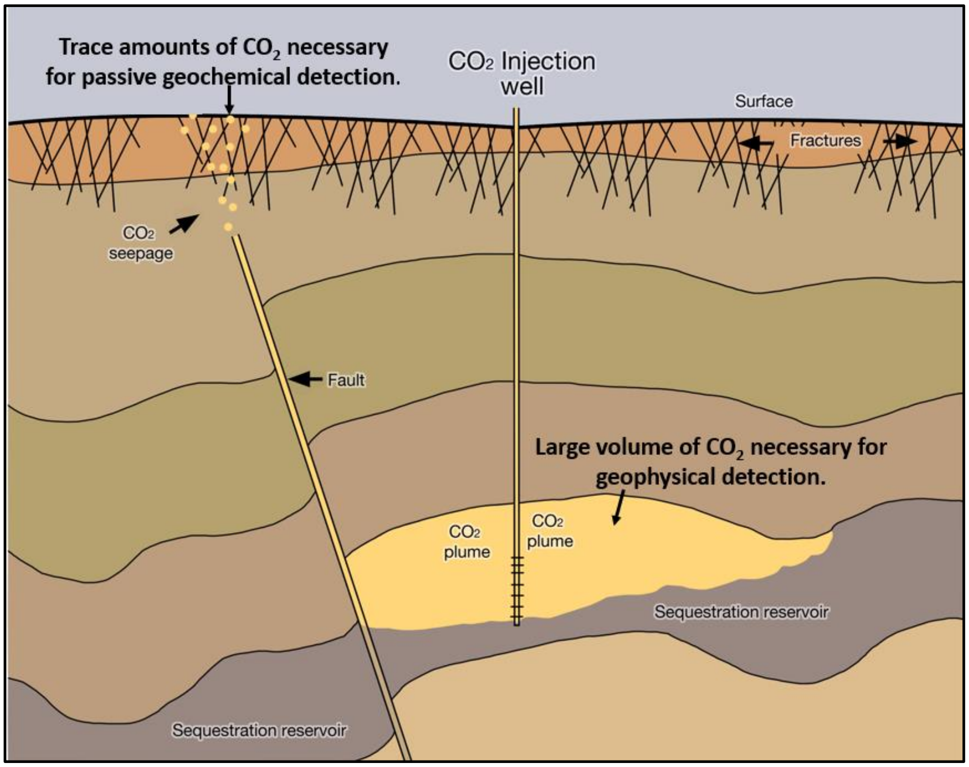


Figure 2.

Conclusion: Geophysical and passive geochemical imaging are critical tools in the sequestration arsenal. Yet, it is critical to chose the right tool for the right job.

Geophysical techniques:

- Are excellent for detecting and mapping plumes.
- Can identify potential spill points and structural changes such as the opening of natural fractures.
- VSP and CWS lack the mobility to be deployed field-wide.
- **Cannot detect CO_2 leakage across the field or around plugged & abandoned wells**.

Passive geochemical imaging:

- **Directly measures CO_2**, not proxies for CO_2 like geophysical methods.
- Can be deployed in grid patterns across an entire field to **detect leakage at any potential spill point**.
- Can be **deployed around plugged & abandoned wells**.
- **Can detect trace or nascent CO_2 leaks**, allowing companies to take corrective action before leaks become catastrophic.
- Importantly, passive geochemical surveys cost roughly 10-times less than geophysical methods.

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