# Cutting-edge Advances in Offshore $CO_2$ Monitoring

Current offshore $CO_2$ detection and monitoring falls into two primary categories: geophysical methods and $CO_2$ testing methods associated with existing wells.

Geophysical methods:
1. are critical for the evaluation and identification of potential spill points;
2. can image the opening of natural fractures as pressure increases during $CO_2$ injection;
3. can map the $CO_2$ plume as it moves across the field.

However, geophysical methods do not answer the critical question: Is $CO_2$ actually leaking? These methods highlight where $CO_2$ may be leaking.

The majority of $CO_2$ monitoring methods, like vertical seismic profiling, distributed acoustic sensing, cross-well seismic, pulsed neutron capture, borehole gravity logging, distributed temperature sensing, and geochemistry ($C^{13}$ analysis of well head brine) are performed at or in existing wells.

So, the ability to monitor offshore $CO_2$ is constrained by the well location. This is particularly problematic where the well density is sparse. The closest $CO_2$ monitoring well may be miles away from potential spill points.

Additionally, as $CO_2$ injection begins, subsurface conditions can change and new spill points or areas of concern may emerge, where data from existing wells are not effective.

Amplified Geochemical Imaging (AGI) has been working with Ocean Bottom Seismic (OBS) companies for 8 years to develop a new cutting-edge technology for the industry. AGI passive samplers are attached to the bottom of OBS nodes or Automated Underwater Vehicles (AUVs) **(Figure 1)**.

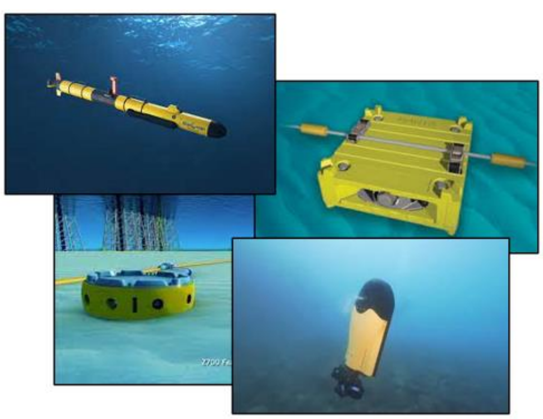

**Figure 1.**

The weight of the OBS node or AUV presses the AGI passive ultrasensitive module into the seafloor to establish connection with microseepage. The outer portion of the module is a microporous expanded polytetrafluoroethylene (ePTFE) material with small pore spaces to allow vapors to pass through but prohibit the passage of liquids and soil particles.

As such, $CO_2$, $CO_2$ tracers, and hydrocarbon molecules migrate upwards, pass through the membrane and concentrate during the 3 – 4 week deployment, yielding parts per billion (*ppb*) level compound signatures.

The product is high resolution seismic data with ultrasensitive $CO_2$, $CO_2$ tracer, and hydrocarbon data acquired simultaneously over co-located sites. The ability to overlay co-located data sets allows for the alignment of faults, natural fractures and $CO_2$ leakage data with a high degree of accuracy.

As mentioned previously, the majority of offshore $CO_2$ monitoring methods are performed at existing well locations. **Figure 2** illustrates the problem with these existing methods.

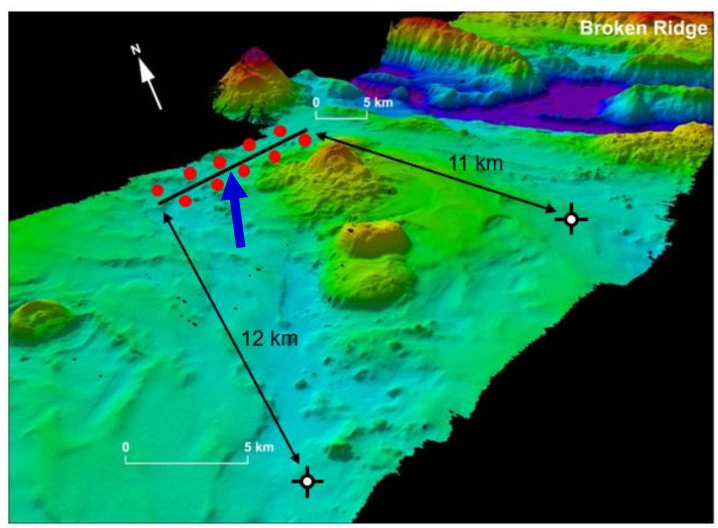


**Figure 2.**

This diagram illustrates a spill point of concern, as designated by the blue arrow. The solid black line indicates a fault of interest for potential leakage. The red dots represent AGI samplers deployed on the seafloor in combination with OBS nodes. Note the closest well for $CO_2$ monitoring is 11 km away. The mobility of AGI / OBS tandem technology gives the ability to align high resolution seismic imaging and $CO_2$ monitoring at such spill points.

# Small mobile OBS/AGI deployments dramatically reduce monitoring costs

A frontier onshore geochemical survey in Tanzania illustrates the benefit of co-located seismic and geochemical data **(Figure 3)**. The geochemical survey identified two potential petroleum systems: gas-condensate in the eastern portion of the block, and oil in the western part of the block. A subsequent 2D seismic survey laid a transect over six geochemical anomalies. The seismic data indicated structures beneath each one of the geochemical anomalies.

The reverse can be accomplished with the joint OBS imaging and geochemical modules. If one of the structures, faults, or natural fractures leak, geochemical modules would be directly above the point of concern to detect $CO_2$ and $CO_2$ tracer leakage.

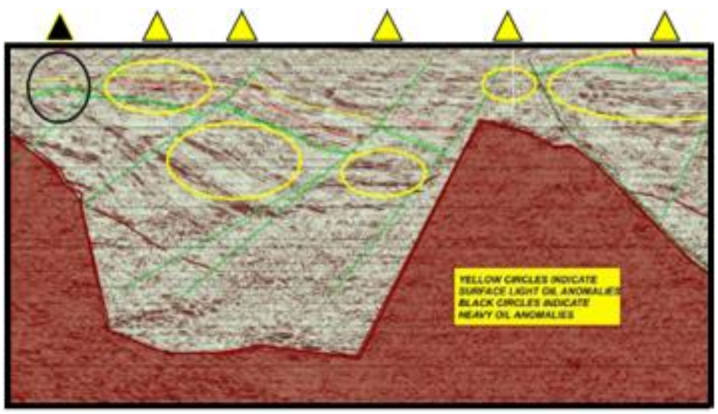


**Figure 3.**

As noted in AGI's Algeria Krechba CCUS case study, after $CO_2$ injection the INSAR data indicated surface deformation had occurred. 3D seismic imaging indicated a deep fracture had activated resulting in an opening several hundred meters wide and extending ~150 meters above the reservoir (Rutqvist, 2012).

Seismic imaging could not determine if $CO_2$ was leaking to the surface. A subsequent AGI geochemical survey for $CO_2$ established that $CO_2$ was not leaking to the surface. Reduction in the $CO_2$ injection rate appeared to have annealed the natural fracture. The Krechba $CO_2$ monitoring program is still active today.

During site characterization, deployment of OBS nodes / AUVs, as well as passive geochemical sensors can be extensive depending on the size of the project and the amount of legacy seismic data available.

However, the expense of subsequent monitoring efforts can be significantly reduced by the use of the tandem OBS / AGI capability. In the onshore AGI Yibal sequestration case study, located within the Fahud Salt Basin of northwestern Oman, the client evaluated the reliability of a depleted reservoir for $CO_2$ sequestration. AGI sensors were placed along seismic transects. The results indicated leakage along various points of the fault trace, indicating the reservoir was not suitable for sequestration.

This same approach can be applied offshore, as seen in **Figure 4**. The pink polygons represent structures and the black dots indicate OBS / geochemical sample points deployed just over potential spill points, not in a large swath. Thus, the flexibility and mobility of the tandem technology allows for dramatically smaller sampling patterns, which significantly reduces the cost of on-going monitoring efforts.

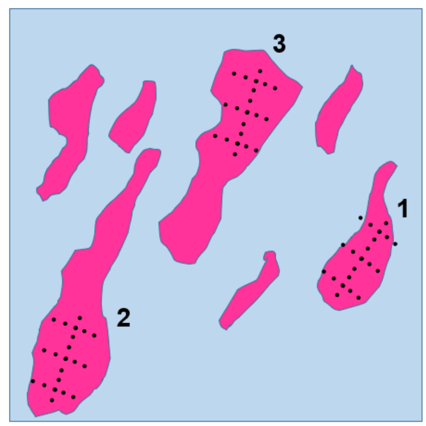


**Figure 4.**

**Summary:** AGI's 18 years of CCUS experience has provided the impetus over the last 8 years for the development of this game changing advancement in offshore $CO_2$ monitoring.

The tandem technologies provide a unique capability to measure $CO_2$ directly over potential spill points, not miles away. Additionally once $CO_2$ injection has begun and changes occur in the subsurface, this flexibility allows movement and deployment of seismic and geochemical sensors directly over potential spill points.

The ability to mobilize small sets of OBS nodes and $CO_2$ sensors significantly reduces the number of seismic nodes necessary over the life of the project, and can thereby reduce program costs dramatically.

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