CCS reservoirs and CO_2 pathways

Injecting captured CO_2 into deep geological formations below the seabed is seen as one mitigation strategy to reduce anthropogenic CO_2 entering the atmosphere and ocean. The principle is simple: suitable reservoirs are identified, the CO_2 is captured at source, transported and then pumped into 'spaces' within and between geological strata, where it will remain for thousands of years at least.

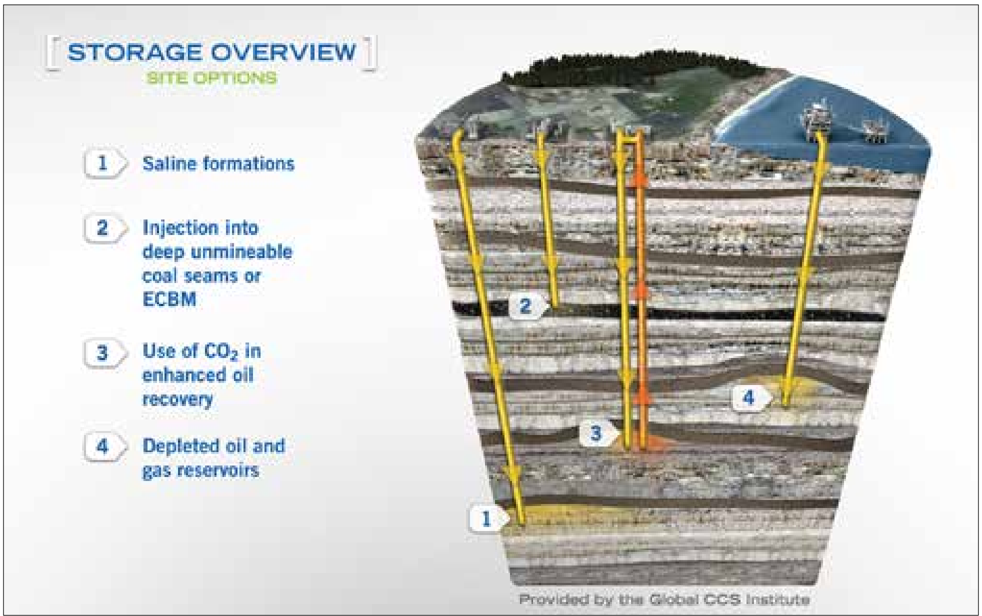
The execution is far more difficult and relies on detailed analysis and identification of suitable storage reservoirs that can safely contain large quantities of CO_2 well into the future. Currently, three potential storage media have been identified: uneconomic coal deposits, depleted or near depleted oil and gas reservoirs, and deep saline aquifers.

Coal beds are seen as the least preferred option, as they generally have limited capacity and the associated CCS technologies are less developed. Gas reservoirs are more favourable than oil reservoirs: they tend to offer greater capacity due to their higher recovery factor during extraction, which can be as much as 90%, thus leaving plenty of space for CO_2 to be stored. However, if CCS is used as a means of extracting further oil from a 'depleted' reservoir (Enhanced Oil Recovery) then the cost of CO_2 injection and storage may be reduced, which could make this scenario an attractive option. Deep saline aquifers, which have the greatest CO_2 storage capacity and often occur in areas devoid of hydrocarbon reservoirs, hold the most potential.

Site selection and characterisation

Any potential CO_2 storage site must satisfy some basic criteria: it should be able to store the proposed mount of CO_2; it should be able to do so at the rate the CO_2 is supplied to the site, and it should not pose any unacceptable risks. There is an explicit expectation that there will be either no leakage from the site (or minimal leakage at a rate below accepted levels of CO_2 emissions), and that the site meets all health, safety and environmental criteria. Not all selected sites will be perfect; if they fall below acceptable criteria then other measures could be employed to bring them closer to standards.

Other essential criteria in evaluating site suitability include: suitable geology that can accept and contain injected gas; location of the reservoir at a suitable depth of 1000m or more below the seabed, and the reservoir is effectively sealed to prevent CO_2 migration and potential escape. To characterise a potential reservoir, detailed geological investigations are necessary including seismic surveys to determine structural integrity. Any potential leakage routes, including existing or redundant wells and drillholes should be identified, and the proposed reservoir should have a suitable pressure regime that will allow gas to be injected and contained safely.



Left: The different types of geological storage units suitable for CCS. Image courtesy Global CCS Instutute, www.globalccsinstitute.com

At a more local level, site screening should also include any legal or regulatory issues, access restrictions to the site, the economics of using the site and attitudes of interested parties who may be for or against use for CO_2 storage. Each potential site will be different and the numerous eliminatory and suitability criteria will fluctuate in importance with location.

Identifying potential pathways

Large-scale reservoirs for CO_2 storage present the most cost-effective strategy for containing the gas, but scale presents other challenges - such as determining, over a large area, whether there are any potential escape routes to the seafloor and then into the marine environment. Where depleted oil or gas reservoirs are being considered there may be a level of confidence that having once held fluids securely, they can do so again. However, these reservoirs may be extensively penetrated by formerly active wells or drillholes; any of these, and their associated infrastructure, might provide a route to the seabed for escaping CO_2 and other fluids. Detailed mapping will be required to ensure all possible artificial CO_2 escape pathways are identified for a potential storage site.

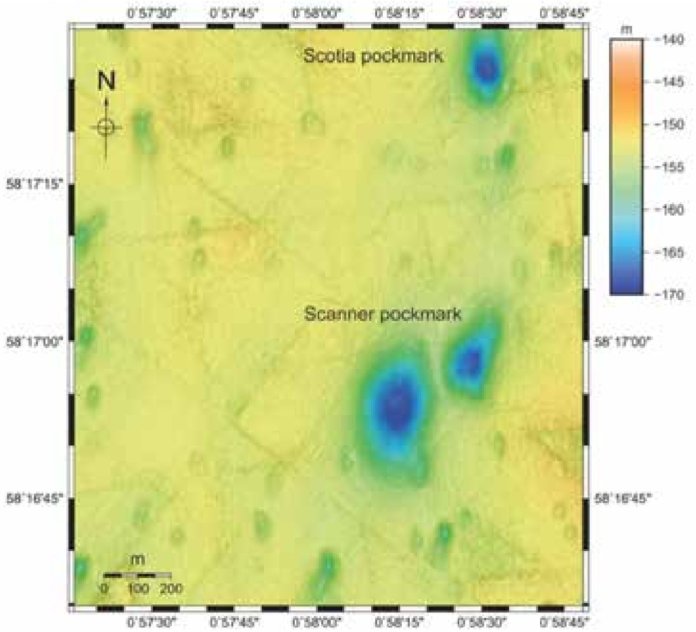
Natural pathways

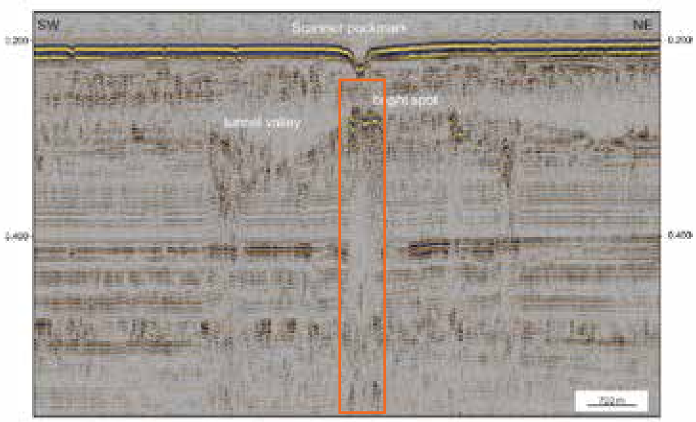
In addition to potential leakage routes resulting from previous hydrocarbon prospecting and extraction activities, there are a number of other naturally-occurring pathways that could link reservoirs to the seabed. Sonar survey techniques can identify seabed features such as chasms, pockmarks, scars and craters, whilst broader-scale geophysical surveys, often used in hydrocarbon prospecting, can reveal subsurface chimney structures and faults. These have potential to be reactivated as a result of tremors or earthquakes, thus a thorough assessment of seismic activity and its potential to open up fluid/gas pathways should be carried out.

Pockmarks and chimneys

Pockmarks often occur in clusters on the seabed. They range in size from 1 to 200m in diameter and may reach 20m in depth below the seafloor. One theory on their formation suggests that they are created by fluid discharging from beneath seafloor sediments as a hydrocarbon reservoir seal fails due to a rise in gas pressure below. The rising gas creates a chimney structure and migrates up to the seabed surface; this structure may take as little as ten years or more than a century to form. Pockmarks and their associated chimneys are often linked to a deeper source of seeping hydrocarbons, which migrate through thick layers of rock. These structures could provide pathways for CO_2 stored in reservoirs below them, so careful investigation should be carried out to determine if this is a risk at a potential storage site.

Pockmarks are known to provide unique habitat for a range of organisms, and because of this and their morphology some are subject to conservation orders. Indeed the presence of particular microorganisms might indicate an active seep or leak at a pockmark. However, further study is needed to establish whether it is possible to distinguish between active pockmarks and quiescent pockmarks that may be reactivated.





Top: Bathymetric image showing the surface expression of the Scanner pockmark and adjacent pockmarks. Bottom: Seismic section illustrating the Scanner pockmark and underlying chimney structure (outlined in orange) in the North Sea. Images courtesy GEOMAR / Permo cruise 2017.

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