Research Mission of the German Marine Research Alliance (DAM)
»Marine carbon sinks in decarboniation pathways«

KNOWLEDGE SUMMARY

Geological methods

A deep-sea experiment on carbon dioxide storage in oceanic crust

On Iceland, water enriched with carbon dioxide has been injected into the upper ocean crust since 2014 – and successfully. The carbon dioxide mineralises within a short time and is firmly bound for millions of years. However, since ocean crust only rises above sea level in a few places on Earth, researchers are currently investigating the option of injecting carbon dioxide into ocean regions where huge areas of suitable basalt crust lie at medium to great water depths. One possible advantage: In the deep sea subsurface, the carbon dioxide would either be stable as a liquid or dissolve in the seawater circulating in the rock.
Due to the high pressure, both the liquid carbon dioxide and the carbon dioxide-water mixture would be heavier than seawater, making leakage from the underground unlikely. But would carbon dioxide storage in the deep sea subsurface be technically feasible and ultimately also economically viable? The research mission CDRmare provides answers – with the help of the world's first deep-sea research experiment on carbon dioxide storage on cooled flanks of the Mid-Atlantic Ridge.

The big climate goal: a net zero of carbon dioxide emissions

> There is a consensus in climate research: Even with ambitious climate policies, Germany is still expected to release **10 to 20 percent** of current greenhouse gas emissions by the middle of the 21st century, further accelerating climate change. However, there is still no social consensus on how high possible **residual emissions** may be and which sectors may cause them. Currently, residual emissions are unavoidable, for example, in cement production, air and heavy goods transport, but also in agriculture and waste incineration.

> To compensate for these residual emissions, humankind will have to either capture carbon dioxide directly at its sources or remove it from the atmosphere to the same extent. The gas must then be safely stored underground. **Carbon capture and storage** processes are also known as CCS. The abbreviation stands for carbon capture and storage.

Carbon dioxide storage in oceanic crust

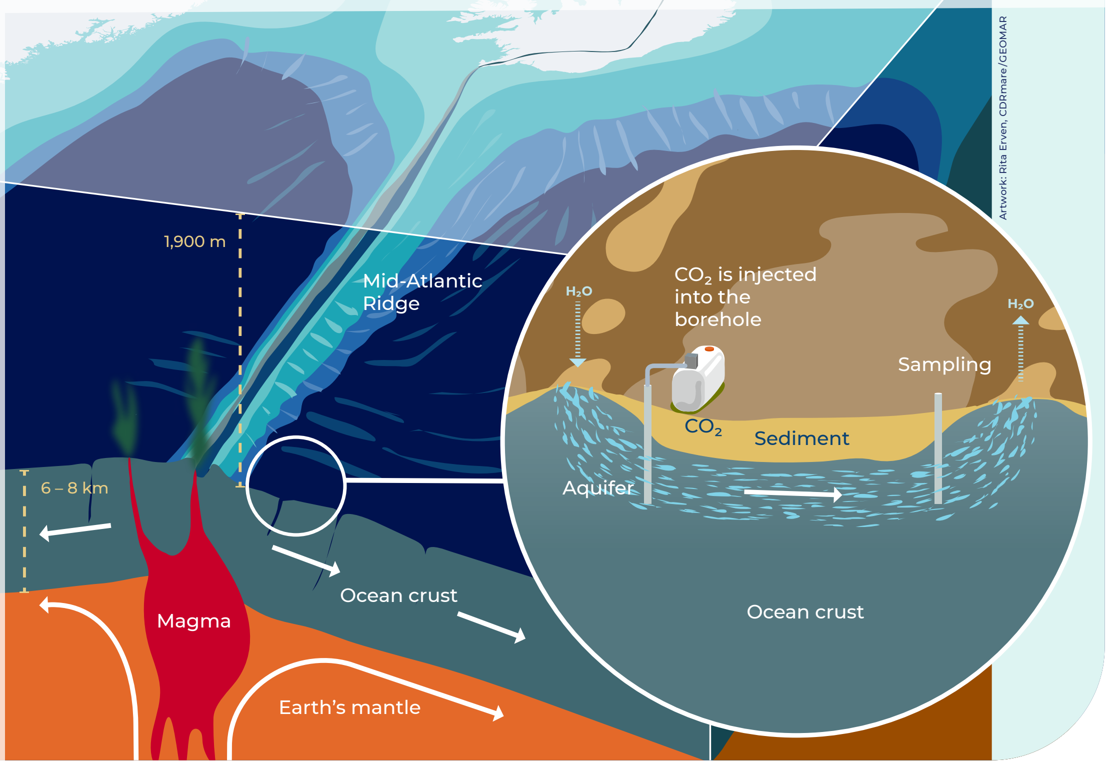
Cost: on Iceland ca. 25 to 45 US-Dollar per metric ton CO_2, but for **deep water settings so far unknown**.

Scalability: A **carbon dioxide storage at industrial scale is in principle possible** (but may be an expensive option.

Duration of storage: After mineralisation the CO_2 is fixated for **many millions of years** as carbonate.

Technical level of development: On Iceland, seawater enriched with carbon dioxide has been successfully injected into the upper ocean crust since 2014. **This process has not yet been sufficiently tested in greater water depths.**

The highly porous and reactive basalt rock of the Earth's upper crust is an ideal storage site for captured carbon dioxide. In a first carbon dioxide injection experiment in the deep sea, researchers are now investigating whether this is also the case under deep-sea conditions and how the injected carbon dioxide is distributed in the basalt rock and mineralised there.



> Carbon dioxide is a long-lived gas. Its extraction and storage must therefore be **effective and permanent**. Some key carbon capture methods, such as direct air capture and bioenergy generation with carbon capture and storage (BECCS), rely on **deep underground storage**.

Porous and reactive: the upper ocean crust as a carbon dioxide reservoir

> The **upper, 400-metre-thick basalt layer of the oceanic crust** lends itself to storing captured carbon dioxide. This basalt rock is **hot, highly porous and very reactive**. This means that, on the one hand, it offers a lot of space. On the other hand, it contains many minerals that react with the carbon dioxide dissolved in the seawater and **bind it firmly by forming new minerals (= rock) – for millions of years**.

Successful project on Iceland: 98 percent of carbon dioxide mineralises

> On Iceland, carbon dioxide that has been separated and dissolved in fresh water has been injected into the upper ocean crust for eight years. The volcanic island lies exactly on the axis of the Mid-Atlantic Ridge, so that the ocean crust here reaches above the sea surface and young, still warm and thus very reactive basaltic rock can be reached even by comparatively short drill holes. The mineralisation rates are correspondingly high: **within two years, 98 per cent of the injected carbon dioxide mineralises**.

In search of the optimal solution: A carbon dioxide discharge experiment in the deep sea

> Places where the ocean crust rises above sea level, as in Iceland, are scarce and usually far from industrial centres where many carbon dioxide emissions occur. Researchers therefore investigate the option of injecting carbon dioxide into ocean regions where **huge areas of suitable basalt crust lie at medium to great water depths**. One possible advantage is that the carbon dioxide would either be stored as a liquid in the underground in the deep sea, or dissolve in the seawater circulating in the rock before it mineralises. Due to the high pressure, however, both the liquid carbon dioxide and the carbon dioxide-water mixture would be **heavier than seawater, making leakage from the subsurface unlikely**.

> In the research mission CDRmare, geologists and engineers conduct **a scientific carbon dioxide injection experiment in the North Atlantic deep sea** for the first time. On the one hand, they want to use it to define the spectrum of conceivable carbon dioxide storage options along mid-ocean ridges. On the other hand, the aim is to close existing knowledge gaps on carbon dioxide storage in oceanic crust and to find out whether carbon dioxide storage in the deep sea would be a more sustainable, effective and, in the long term, more cost-effective option compared to geological storage on land.

> In addition, the scientists develop and test **new sensor technology suitable for deep-sea** use as well as modularly deployable **underwater robots**. They are the prerequisite for the large-scale investigation of the deep-sea floor around the injection site for possible leaks and could also be used in the long term to **monitor other approaches for carbon dioxide storage in the ocean floor**.

> The deep-sea research experiment is scheduled to take place in summer 2025 in international waters of the North Atlantic, 300 to 800 kilometres south of Iceland, in the area of the **eastern flank of the Reykjanes Ridge**.

> The scientific drilling and associated experiment planned as part of the CDRmare mission are carried out for research purposes only.

CDRmare provides answers

> Based on the results of the deep-sea experiment and subsequent numerical modelling, the researchers will conduct cost-benefit analyses and for the first time **derive options for action for the entire spectrum of possibilities along mid-ocean ridges** – starting with a possible carbon dioxide injection in basalt rock on land to storage projects in medium and deep water.

> This action knowledge should enable decision-makers from politics, business and civil society to discuss the various options for carbon dioxide storage in the ocean floor in a **fact-based manner**.

All research activities described here are carried out within the CDRmare consortium »AIMS³ – Alternative Scenarios, Innovative Technologies and Monitoring Approaches for Carbon Dioxide Storage in Oceanic Crust«.

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