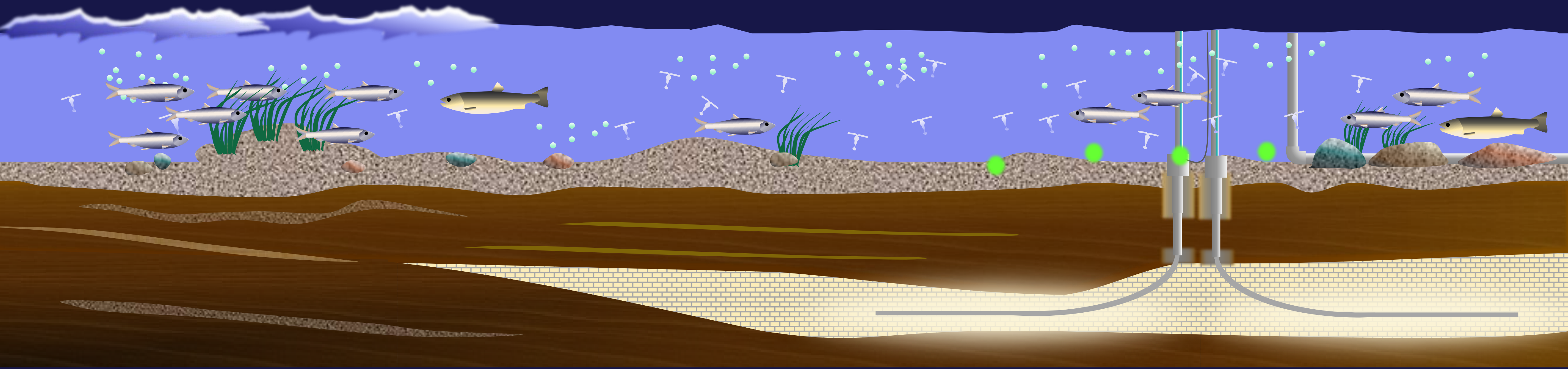
Enabling compliance with EU Regulation on the Reduction of Methane Emissions

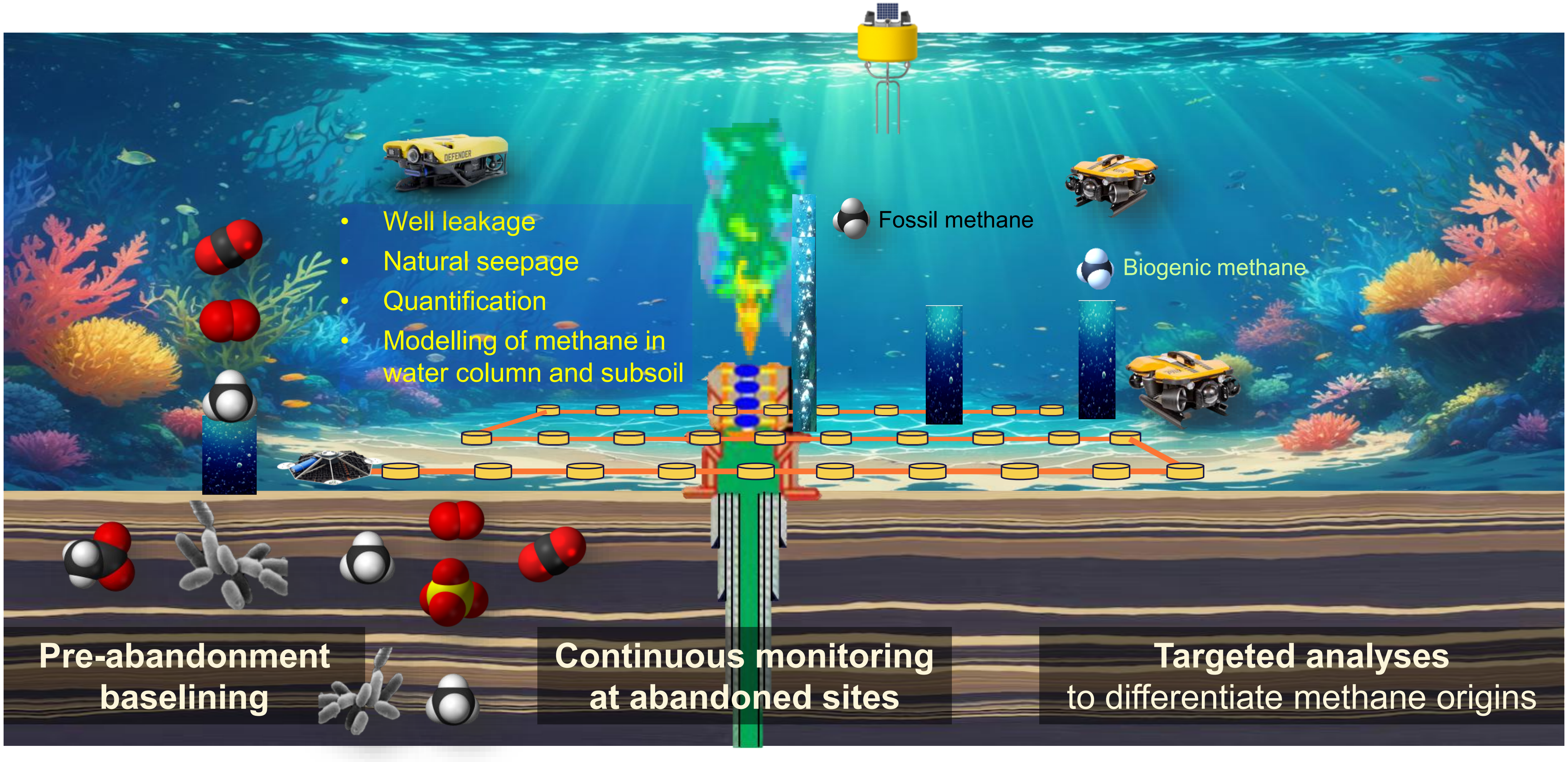
Innovative development of subsea methane sensors for leak detection and methane source determination

Hans Horikx, Charlotte Nørgaard Larsen, Hamid Nick, Paul Feng

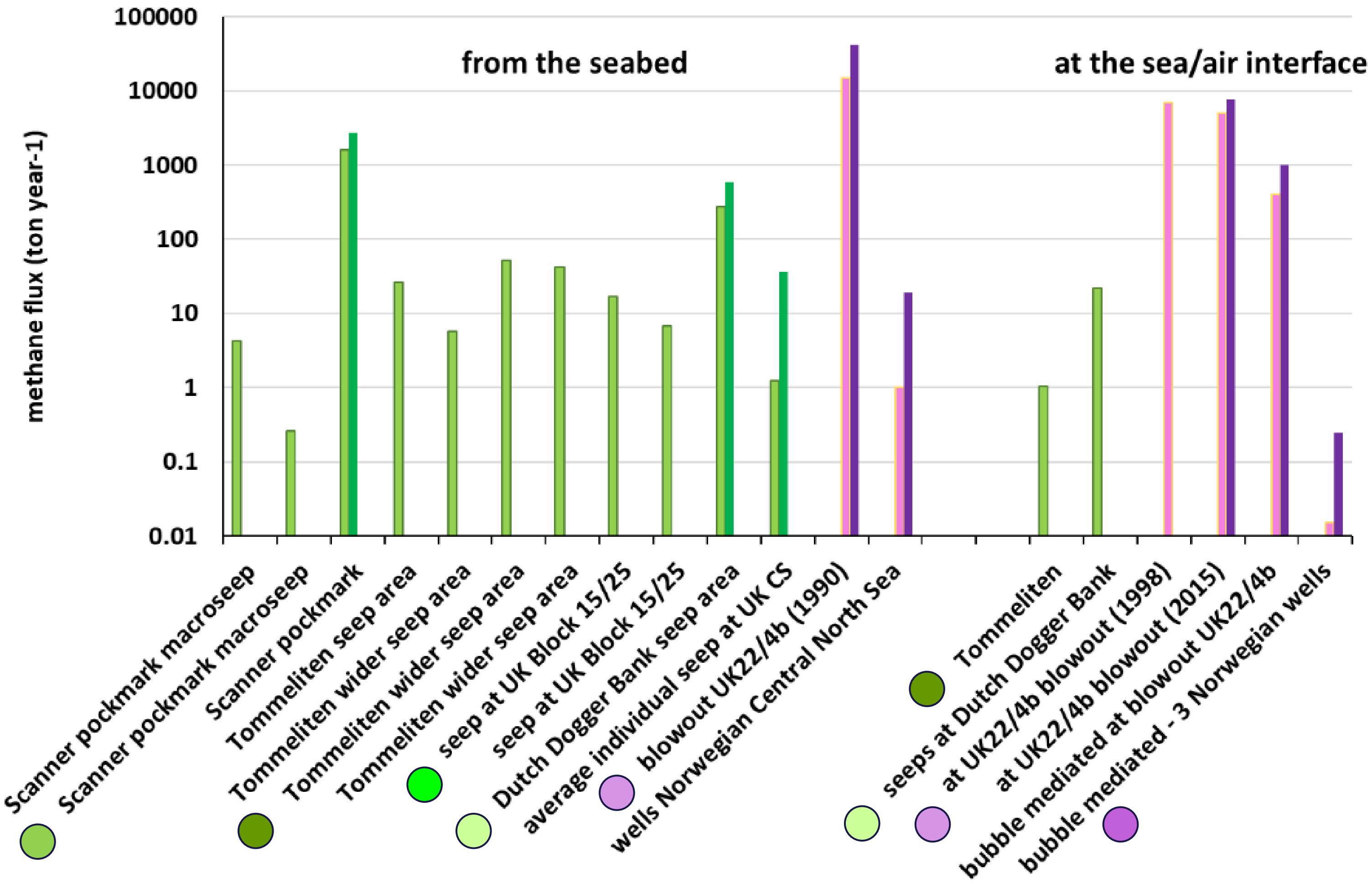


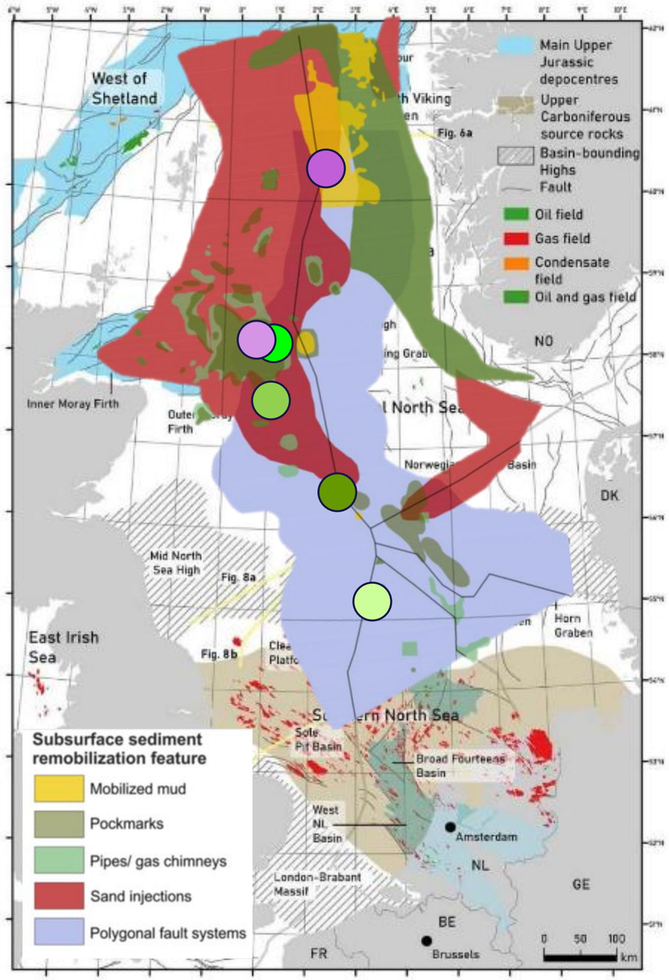
Reduction of Methane emissions

Effective mitigation of offshore methane emissions from abandoned oil and gas wells requires a stepwise monitoring framework



Natural seeps and well seeps of methane in the North Sea

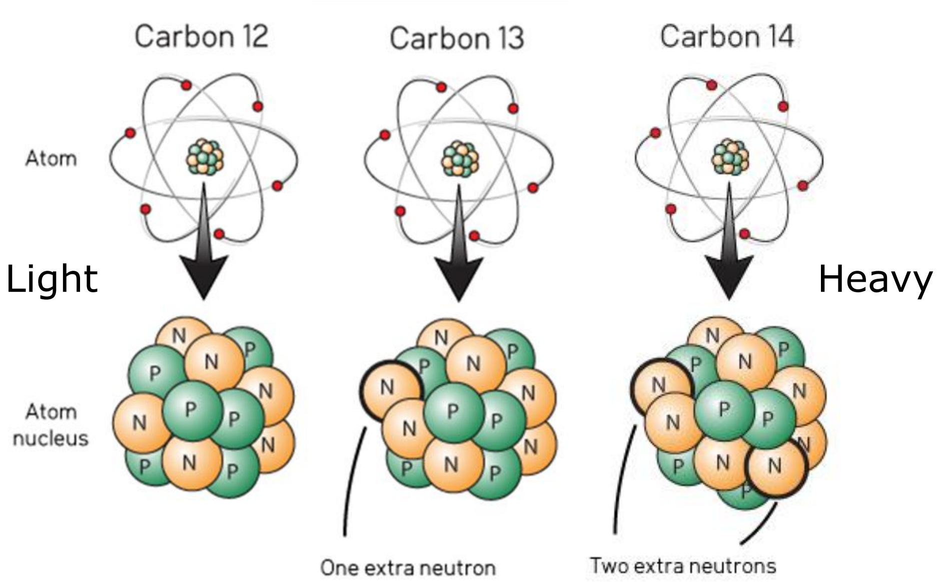




Methane fluxes from natural seeps (green) and associated with gas wells (pink/purple) both from the seabed and directly induced at the sea/air interface as measured in the **North Sea**.

Literature review on natural seepage and human-induced leakage of methane at the North Sea and Gulf of Mexico - Griffioen TNO 2023

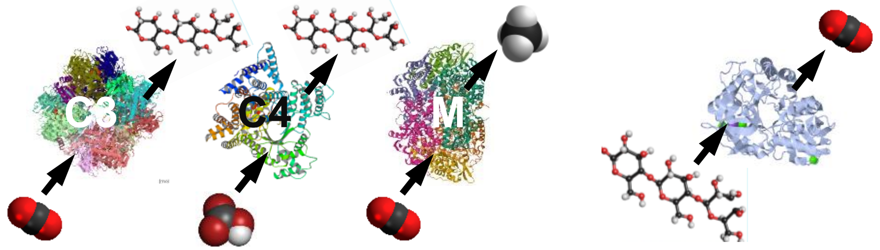
Carbon isotopes can be used to determine source origin



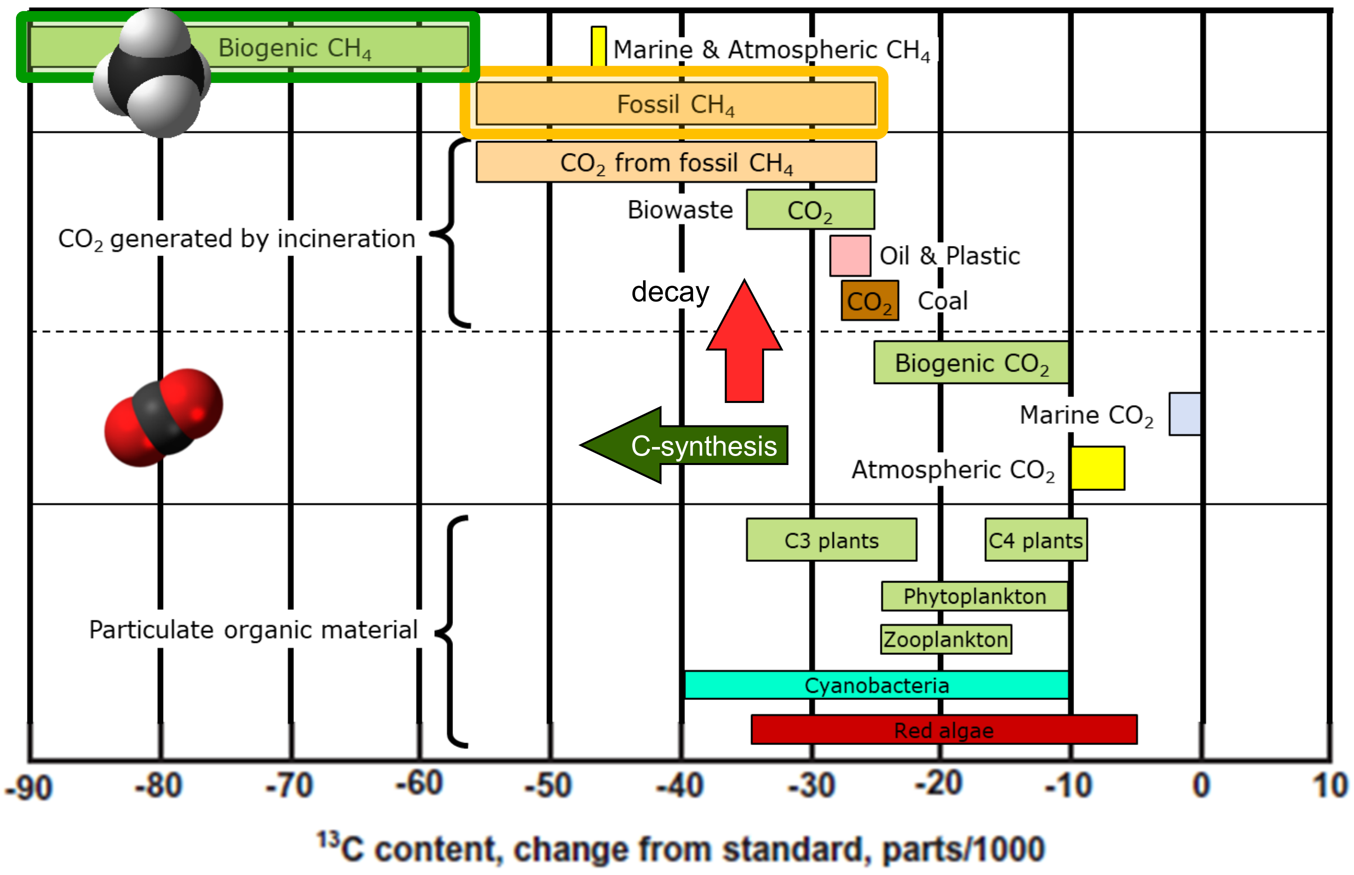
^{12}C 98.9% ^{13}C 1.1% ^{14}C 1 ppt

Kinetic isotope fractionation

- Strong preference for light isotope during synthesis
- No isotope effect during decay

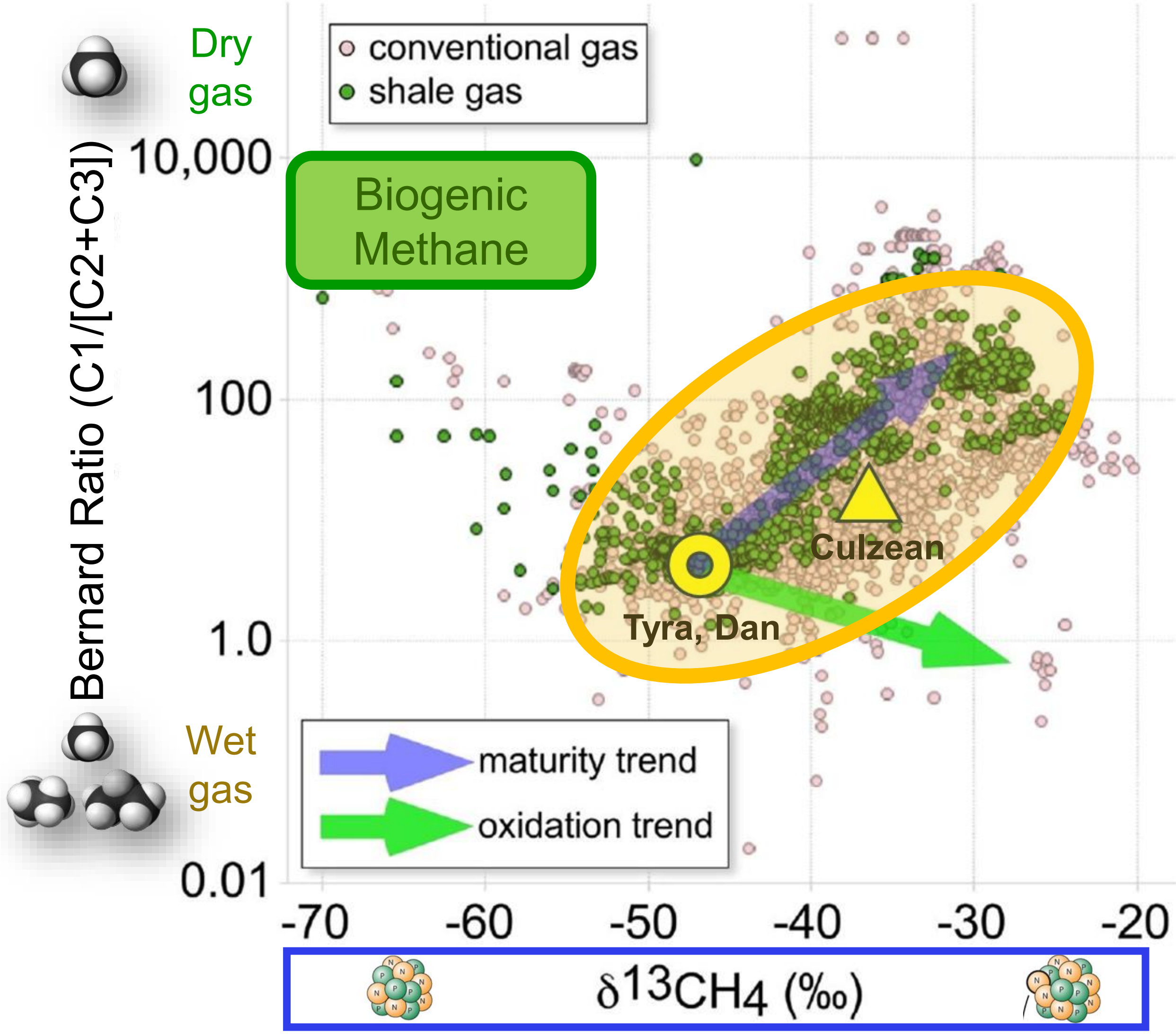


$\delta^{13}C$ isotope ratios of CH_4 and CO_2 in seawater

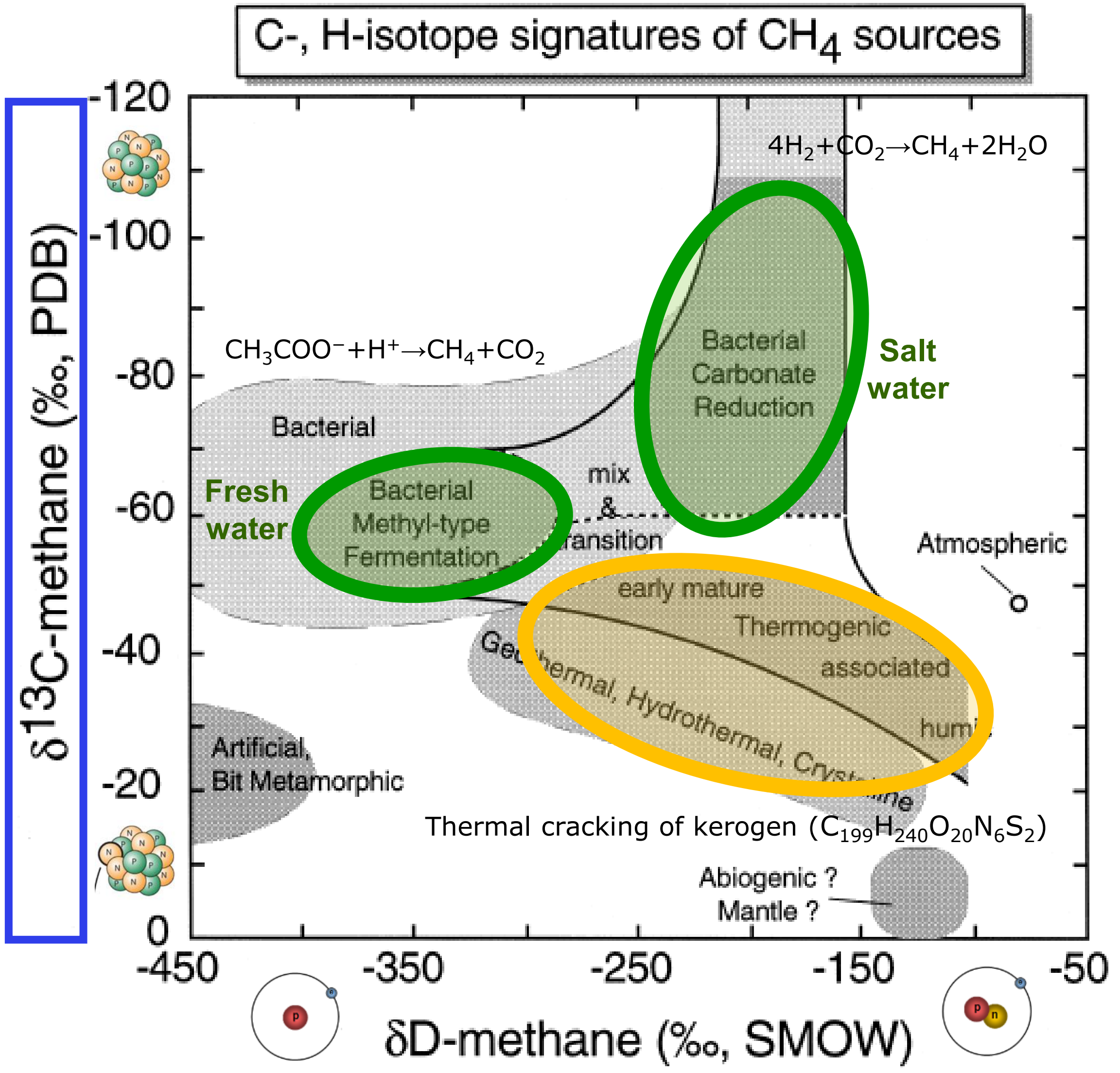


Sources:
- Stable Carbon Isotopes of Phytoplankton as a Tool to Monitor Anthropogenic CO_2 Submarine leakages - Relitti 2020
- The Carbon-Isotope Record of the Sub-Seafloor Biosphere - Meister 2019
- The DIC carbon isotope evolutions during CO_2 bubbling: Implications for ocean acidification laboratory culture - Zhang 2022

Isotope differences of biogenic and fossil-based methane



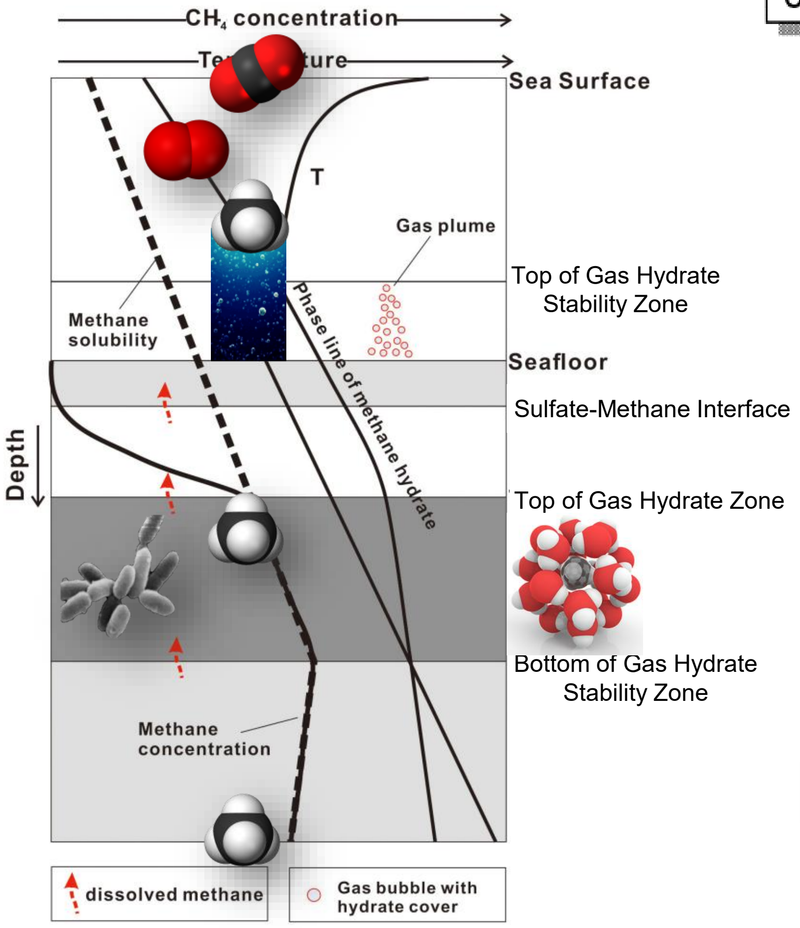
Response by Michael Lewan to Howarth 2019 paper (from Milkow 2020)



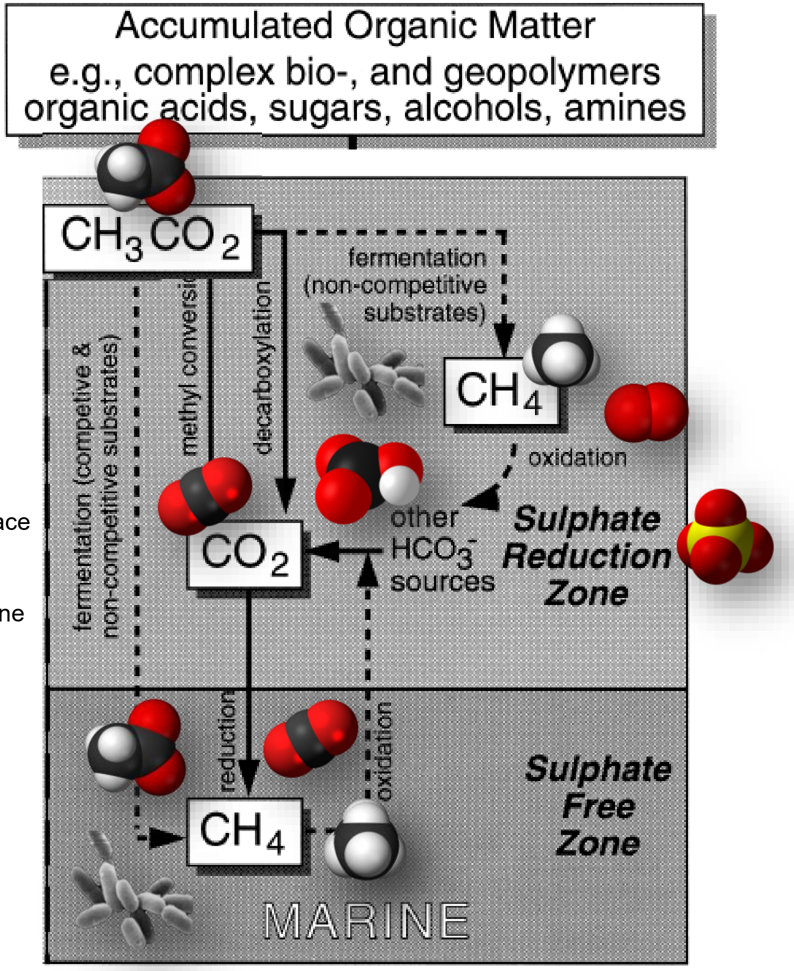
Carbon and hydrogen isotope systematics of bacterial formation and oxidation of methane - Whitcar 1999

Modelling biogenic methane chemistry & isotopes

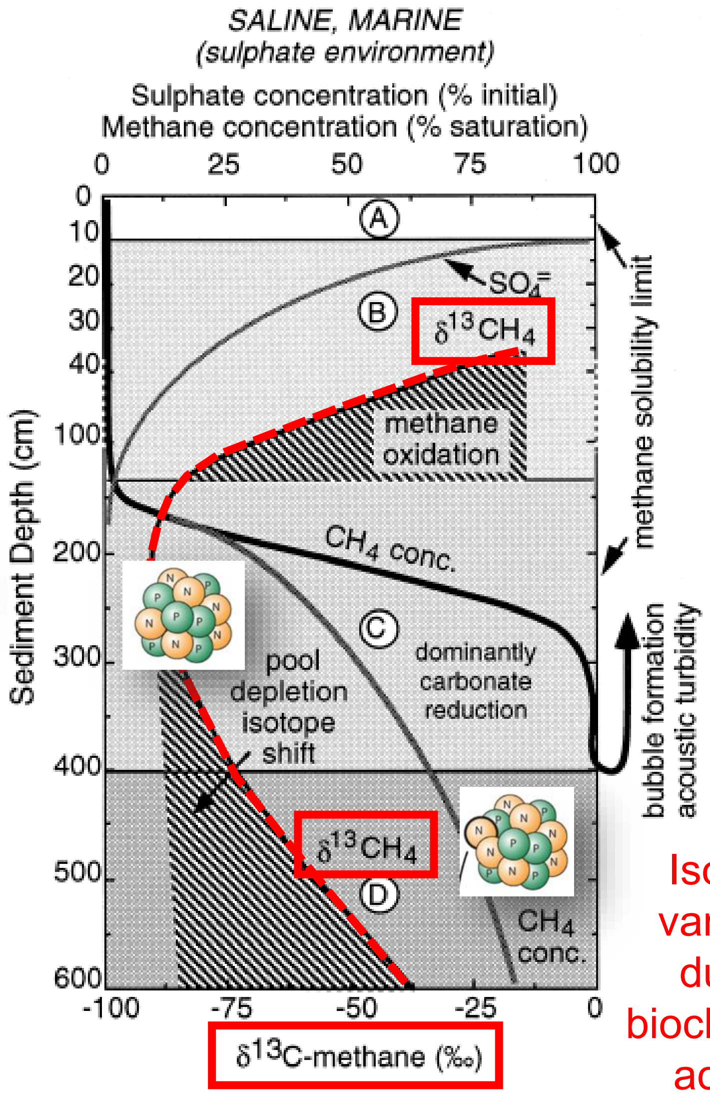
Methane migration pathways



Mechanisms for upward migration of methane in marine sediments - Liu 2022



Methane generation biochemistry pathways (saline environment)

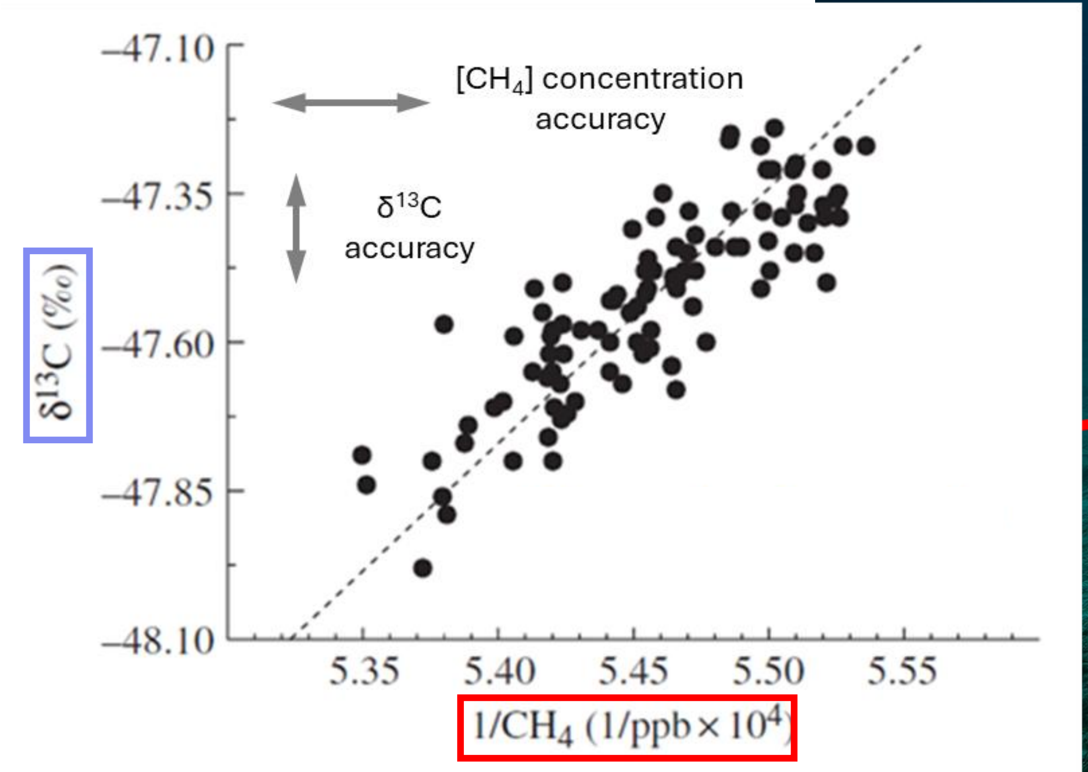


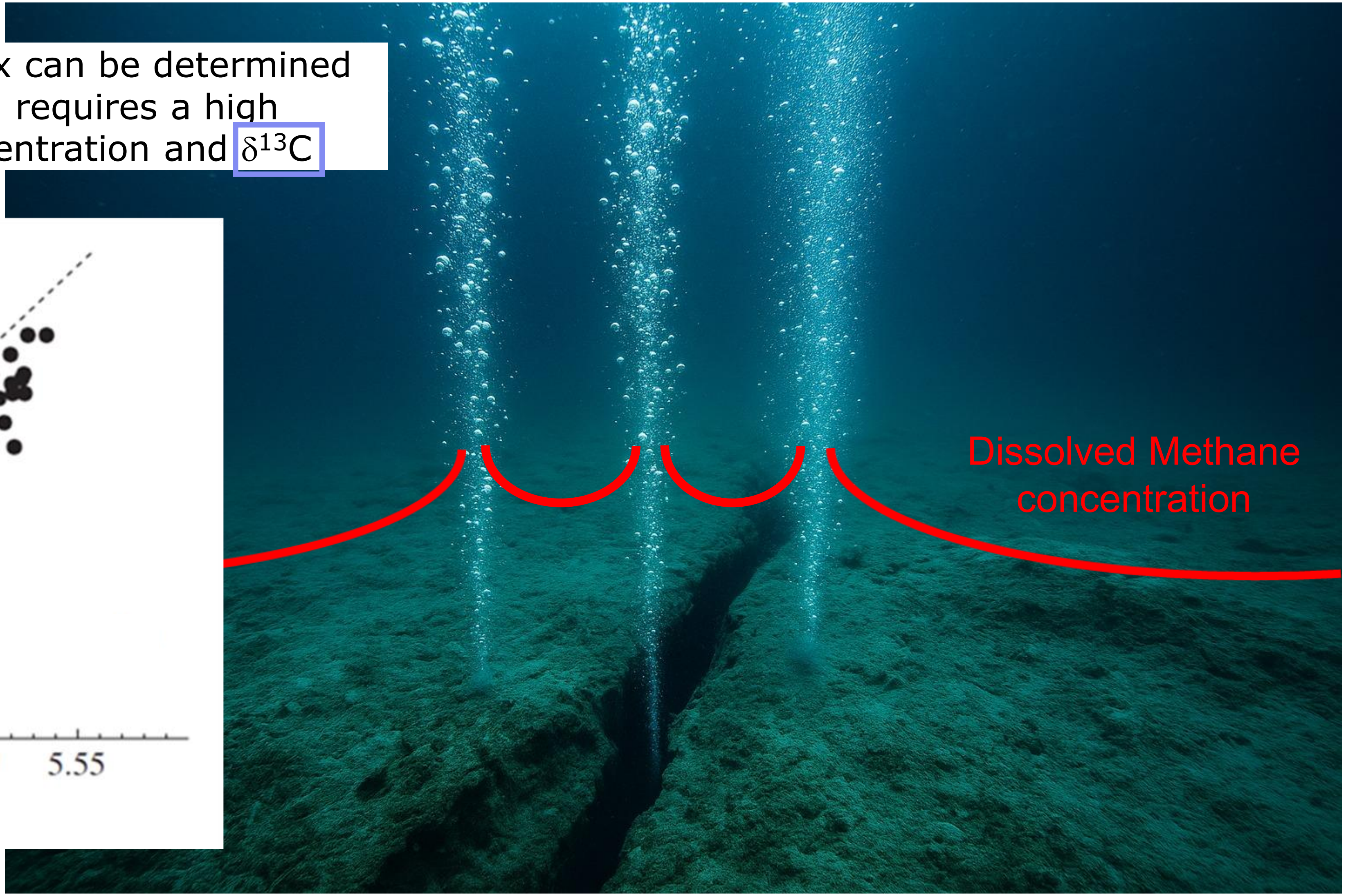
Isotope variation due to biochemical activity

Carbon and hydrogen isotope systematics of bacterial formation and oxidation of methane - Whiticar 1999

Determining $^{13}C/^{12}C$ Carbon isotope ratio of methane seep

The $\delta^{13}C$ isotope ratio of the CH_4 influx can be determined via a Keeling crossplot (below), which requires a high measurement accuracy of $[CH_4]$ concentration and $\delta^{13}C$

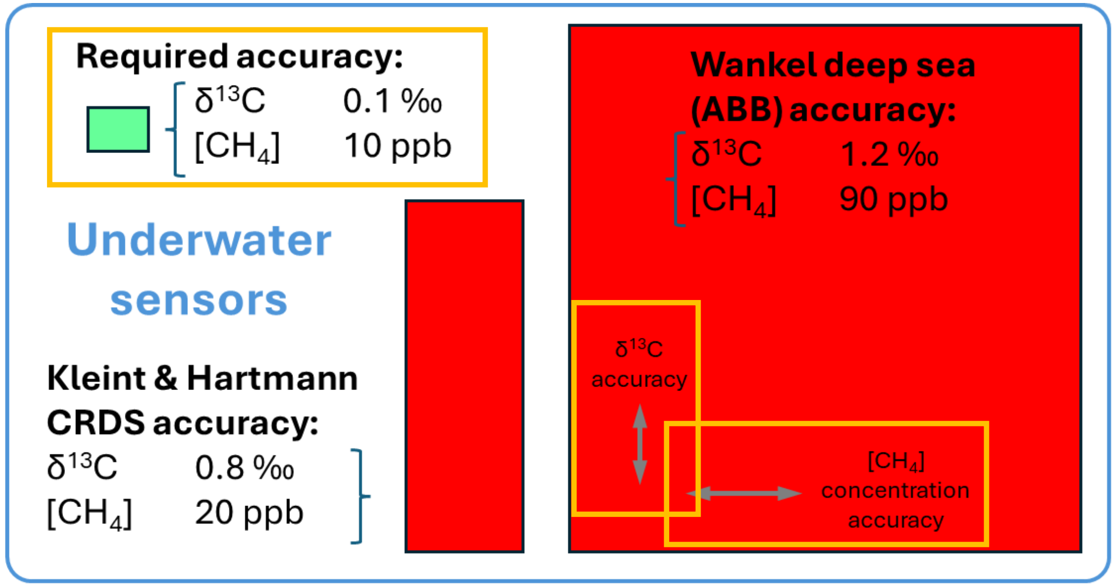


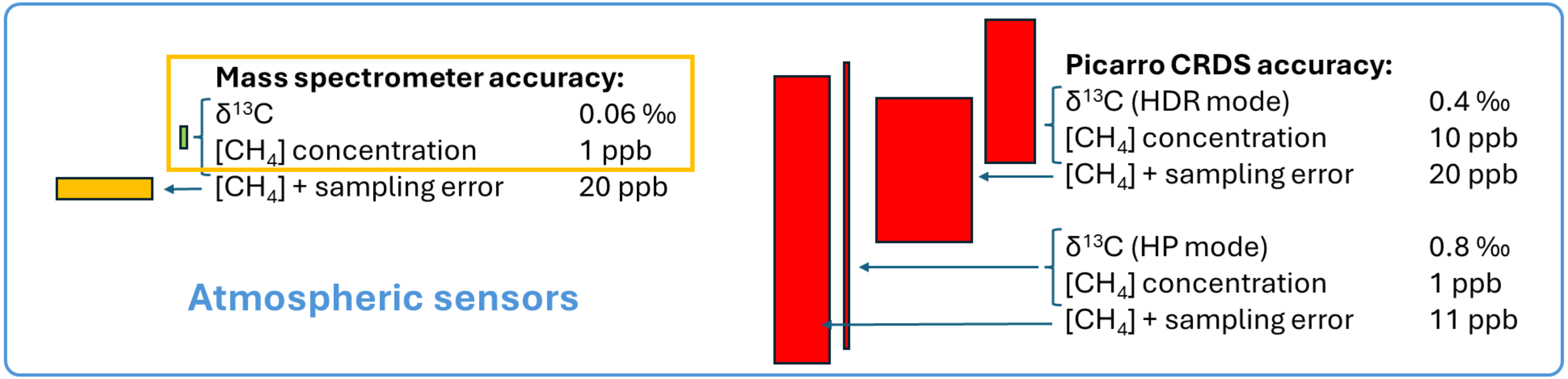


Accuracy comparison of various sensor techniques

New technology aims at real-time underwater

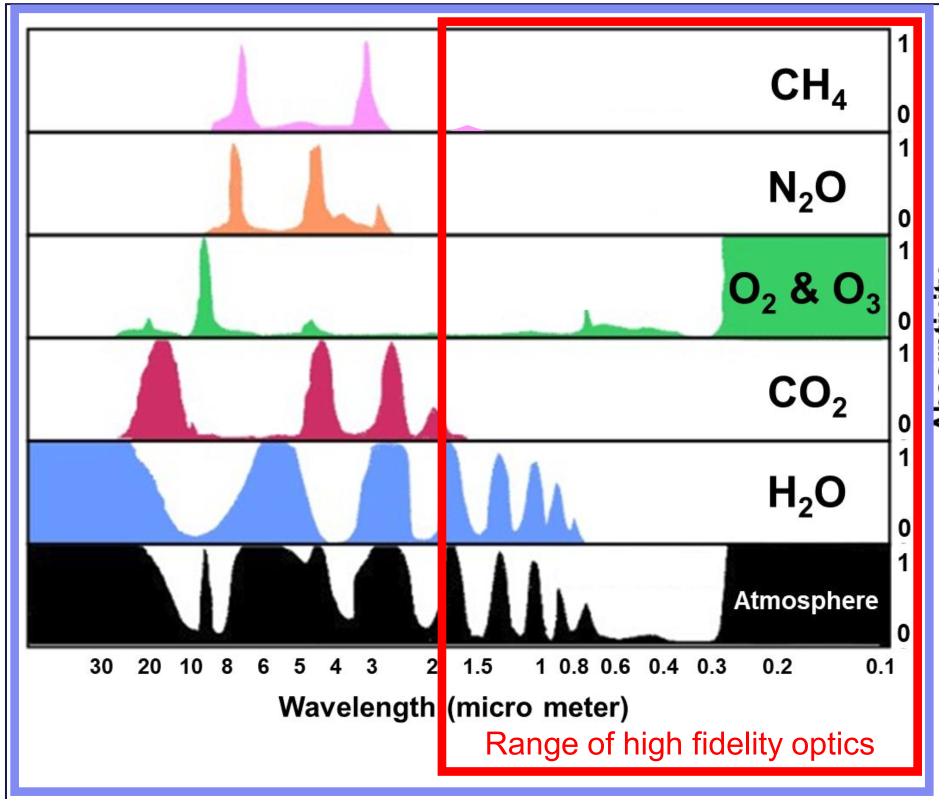
- $[CH_4]$ measurement accuracy of 10 ppb
- $\delta^{13}C$ measurement accuracy of 0.1%





Note that for comparison reasons all methane concentrations and concentration errors are quoted in ppb, which is a standard unit for methane concentration in air. The most widely used unit for methane concentration in water is nmol/l, and the Keeling crossplot method for methane dissolved in water can also be made using concentrations in nmol/l. For comparison: the average atmospheric CH_4 concentration of ca. 1850 ppb corresponds with a seawater CH_4 concentration of ca. 3 nmol/l at equilibrium conditions.

Greenhouse Gas detection using Infra Red absorption



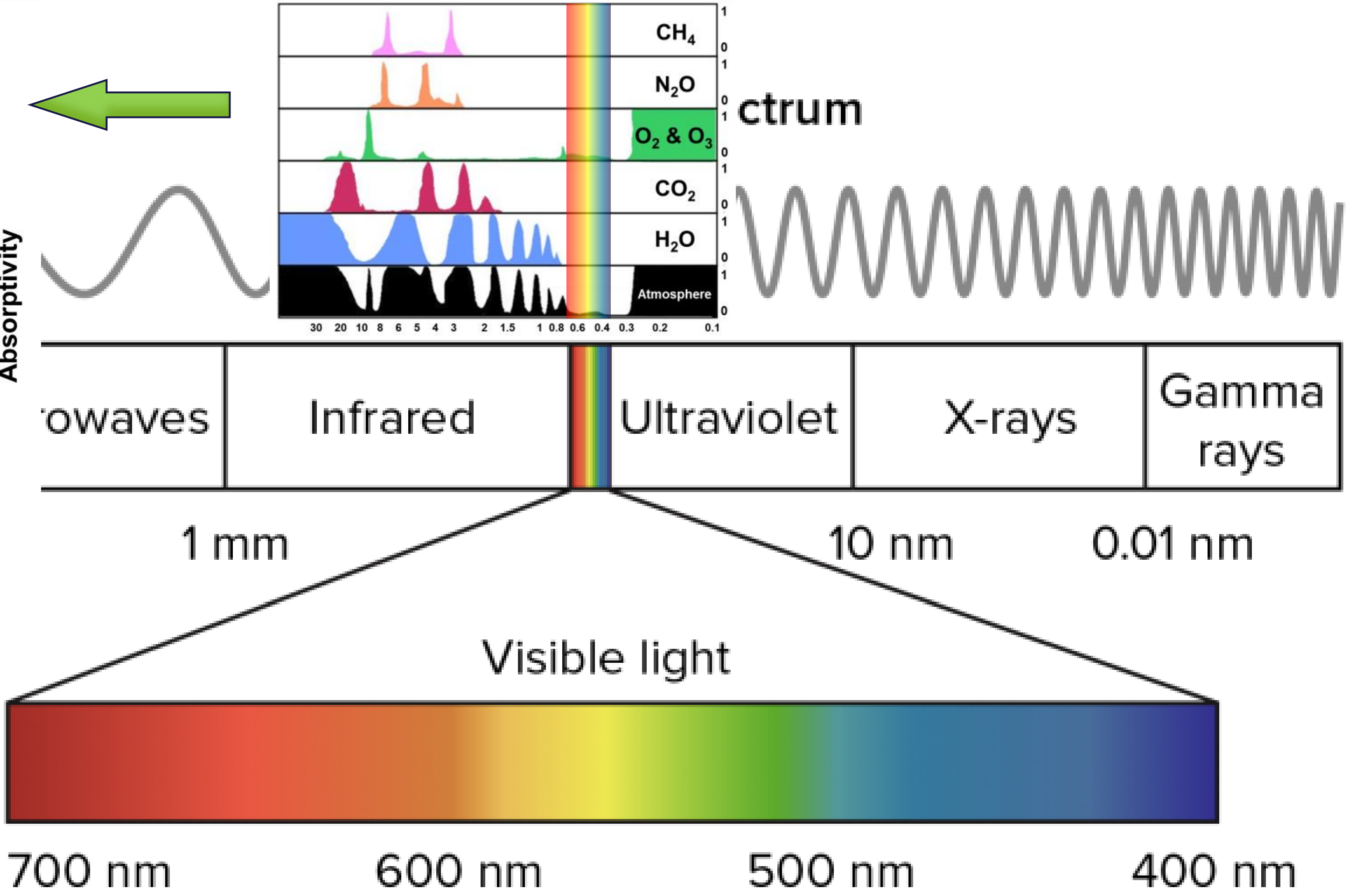


Photo Acoustic Spectroscopy

Optical Spectroscopy

Harmonic oscillator model for molecular vibrations

Frequency $\nu = \frac{1}{2\pi}\sqrt{\frac{k}{\mu}}$

k = bond strength
μ = reduced mass

Mass of $^{13}CH_4$ > Mass of $^{12}CH_4$ → Frequency of $^{13}CH_4$ < Frequency of $^{12}CH_4$

Monitoring opportunity and Project objective

Based on these observations DTU-Offshore and NxPAS ApS have secured EUDP funding of a project to exploit the opportunity that these natural isotope differences provide to distinguish biogenic methane from fossil methane, and build an analyzer that works under water.

CH_4IsotopMonitor - CIM

EUDP description:

- The North Sea region's closed oil and gas fields pose a potential leakage risk that requires monitoring.
- The CIM project develops a technology that can distinguish between methane from natural sources and leaks from oil and gas fields.
- The project also includes a simulator for the correct interpretation of data from the seabed.

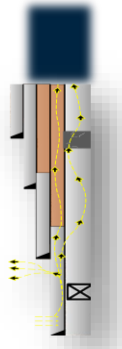
Timeline: 2026-2028

Partners:

Suggested Framework for Compliance with EU regulations

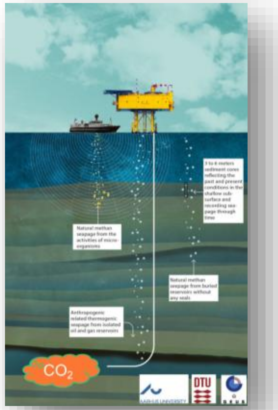
Planning phase

Model Leak path scenarios



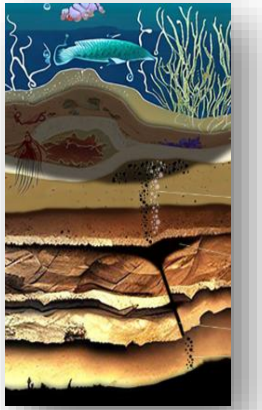
- Wells
- Sediment breach
- Faults & fractures
- Pockmarks
- Aquifers

Develop Environmental Baseline



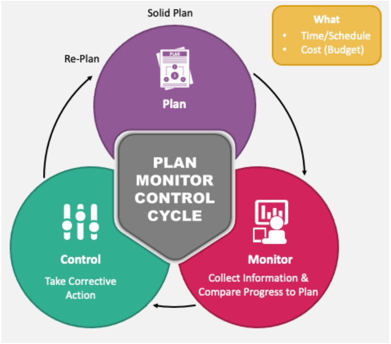
- Modelling
- Data acquisition

Understand leakage composition (chemical and isotopes)



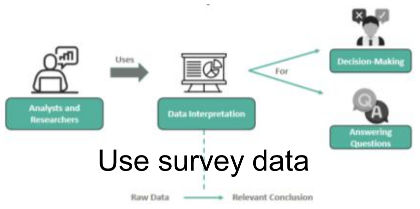
- Modelling
- Data acquisition

Design Monitoring plan



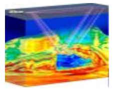
Operational phase

Monitoring and Interpretation of data



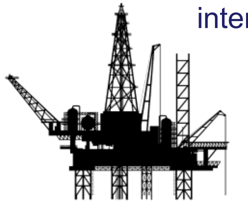
Use survey data

Understand origins of detected methane



- Seismic
- Isotopic sensors (fossil vs biogenic)
- Environmental baseline
- Decision making

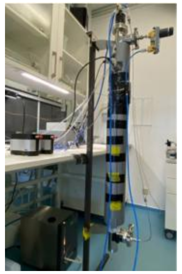
Remediating actions – when/how



Well intervention

Or: e.g. CH_4 scrubbing in water column using UV

AALBORG UNIVERSITY



DTU