Deep Sea in a Can:
Microbial Degradation Under High Pressure

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(1) High-Pressure Low Temperature Studies of sub-surface plumes

(2) Advanced “omics” approaches to oil spill impacts on biota

(3) Massive-scale Barcoding of Ichthyoplankton
Deep Sea in a Can

Biodegradation

- Oil droplet
  - Biodegradation under pressure
- Marine Snow/Oil degrading bacteria
- Oil droplet acceleration by degassing of oil with expansion and dissolution
- Gas vesicle
- Gas bubbles
- Gas hydrate formation
- Gas hydrate

Shift by pressure drop and sudden CH₄ expansion

Initial droplet size distribution
Deep Sea in a Can

experimental biodegradation simulation under controlled lab conditions to validate models with **original oils and sediments**
High Pressure Reactor Setup

• **pressure reactors** for bacterial growth and O$_2$-analysis up to 40 MPa

• **methane reactor** for bacterial growth and analysis up to 15 MPa

• **spindle press system** for mechanical pressurization up to 100 MPa
High Pressure Reactor Setup

innoculated with
- GoM sediment samples (7 sites; top 1cm)
- GoM hydrocarbon degrading model strains
- added crude oil / CH₄ / dispersant

determination of
- growth (CFU)
- bacterial communities
- O₂ / CH₄ consumption
- crude oil analysis (FTIR / GC-MS)

research focus
- effect of pressure & dispersant
- changes in bacterial community
- crude oil / CH₄ biodegradation rates

pressure
- CH₄ max 20 MPa
- N₂ max 20 MPa
- air max 20 MPa

reactor volume 160 ml
pressure max 40 MPa
T 4°C - 20°C
High Pressure Single Strain Experiments

Rhodococcus PC20 isolated from nGoM sediment with crude oil

Dispersant effects the growth and metabolic activity

20 ml MM2 medium, 1% crude oil (LLS, 200 µl), 200 rpm, 20°C.
Dispersant (Corexit EC9500A) addition: 2 µl. N = 3.
CH$_4$ and O$_2$ can be simultaneously measured @ high pressure up to 15 MPa
Methane Biodegradation  

(0.1 MPa methane)

Oxygen consumption rates of *Methylocaldum* P9 under pressure

Oxygen consumption rate (% air saturation/h) vs. total pressure (MPa)

Decreased oxygen consumption with increased total pressure

0.1 MPa methane @ each experiment
High Pressure Reactor Setup (40 MPa)

Mechanical pressurization with $N_2$ up to 40 MPa (1 MPa max CH$_4$ pressure)

Spindle Press System

High Pressure reactor volume 160 ml; pressure max 40 MPa $N_2$ (max 10 bar CH$_4$).
Crude Oil Biodegradation (sediment)

Biodegradation extent effected by pressure & Corexit EC9500A

Influence of Corexit EC9500A (1:25 DOR), LLS crude oil (1% v/v), 1 g of top layer sediment mix (DWH01, DSH08, DSH10, SW01, PCB06), 0.1, 10 and 40 MPa; 4°C; 14 and 28 days. GC-MS
Research Uncertainties / Technical Challenges

Are the research results relevant?
Areas Ripe for Technological Advancements

• Efficiency of biodegradation
  ... depends on microbial activity / community
• Industry is pushing to deeper dwells
  ... pressure effect becomes more important

• Sampling
  @ deep sea @ high pressure
  ... without decompression
  @ small volumes from high pressure reactors
  of sediment and water column prior to drilling to generate better models

• Biodegradation studies @ deep sea
  improved in situ sensors for tracking chemicals & concentrations