

Permanent Carbon Dioxide Storage in Deep Ocean Sediments along the U.S. NE Coast



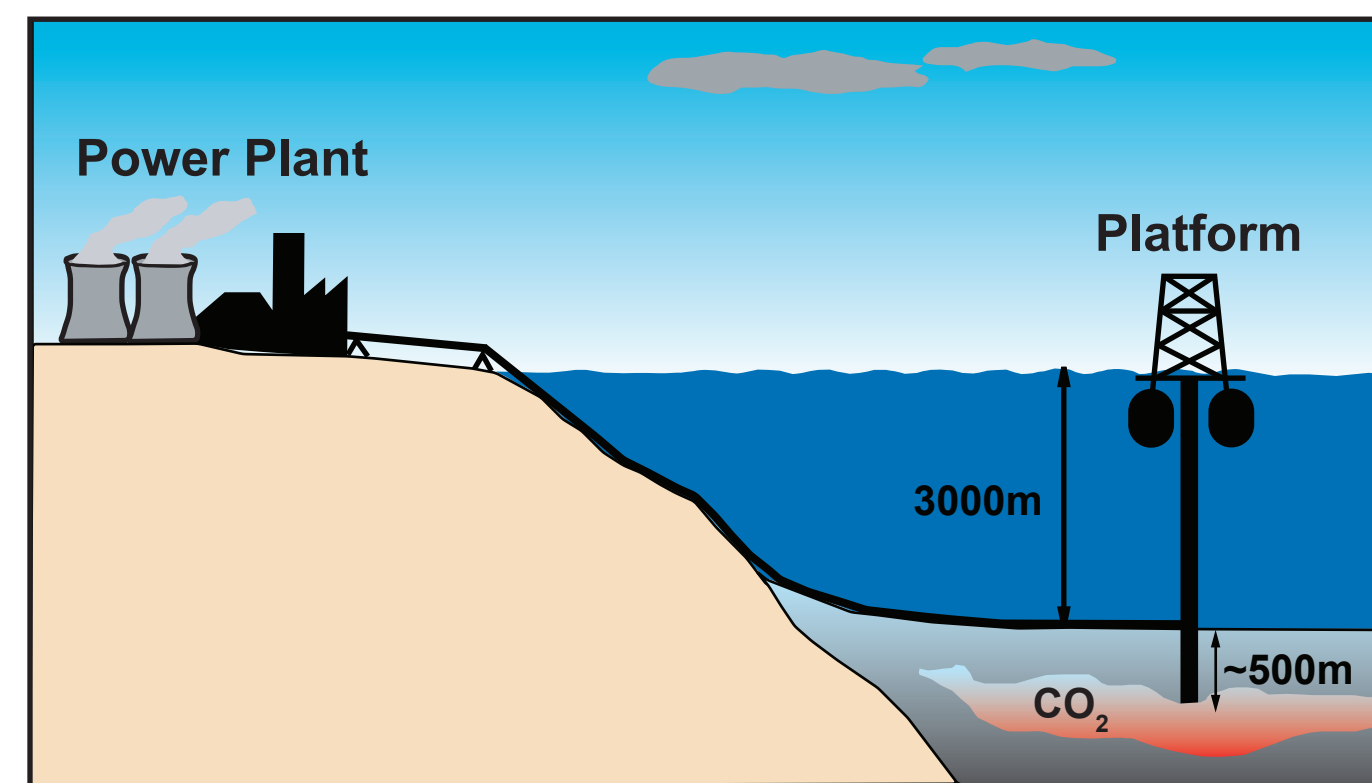
David Goldberg & Juerg M. Matter
Lamont-Doherty Earth Observatory of Columbia University



INTRODUCTION

Onshore deep saline aquifers, which could be used as potential large volume carbon dioxide storage sites, are not widespread along the NY coastline. This results in a mismatch between emission sources and sinks. Deep ocean sediments along the U.S. NE coast could provide the necessary storage capacity for permanent and safe carbon dioxide sequestration. At high pressures and low temperatures common in deep ocean sediments a few hundred meters below seafloor, carbon dioxide will be in its liquid phase and denser than the overlying pore fluid and seawater. The lower density of the pore fluid provides a cap to the denser liquid carbon dioxide and ensures gravitational stability. The majority of tectonically stable ocean floor at necessary depths is composed of calcareous sediments and clays. This study evaluates the feasibility of carbon dioxide injection in deep ocean sediments and estimates the potential storage capacity. Storage capacity varies with permeability and porosity of sediments, seafloor depth, geothermal gradient and pore water salinity. Using field data from deep ocean sediments we show how in-situ conditions may affect permanent storage of carbon dioxide.

GRAVITATIONAL TRAPPING IN DEEP OCEAN SEDIMENTS



Liquid CO₂ could be gravitationally trapped in deep ocean sediments at water depths of 3000 m and several hundred meters below seafloor. The storage capacity is a function of sediment permeability and porosity, and depth of the neutral buoyancy level. The neutral buoyancy level is defined as the depth at which CO₂(l) and pore water have equal densities. The depth of the neutral buoyancy level depends on the geothermal gradient and the pore water salinity. High salinities in the Gulf of Mexico and increased geothermal gradients along the Pacific Coast raise the buoyancy level close to the seafloor, resulting in a strongly reduced storage capacity.

PERMEABILITY AND POROSITY OF DEEP OCEAN SEDIMENTS

Leg	Site	Core	Locality	Lithology	Brine Salinity (ppm)	Bulk Saturated Density (post-test) (g/cm ³)	Porosity	Permeability mD	Comments
11	0105	025	lower continental rise	nannoplankton-rich limestone	35,000	1.881	0.47	27.2	Fractured
11	0105	027	lower continental rise	nannoplankton-rich limestone	35,000	2.148	0.30	9.7	
11	0105	030	lower continental rise	nannoplankton-rich limestone	35,000	2.098	0.37	3.57	
11	0105	033	lower continental rise	limestone with red clay	35,000	2.000	0.39	0.024	
11	0105	038	lower continental rise	very clay-rich limestone	35,000	1.990	0.37	0.045	
150	0906	062	continental slope	clayey chalk	50,000	1.949	0.42	0.005	Visibly deformed
150	0906	065	continental slope	clayey chalk	50,000	1.989	0.38	0.007	Visibly deformed
166	1003	054	platform slope	bioclastic wackestone	50,000	2.242	0.25	4.83	
166	1003	063	platform slope	foraminifer wackestone	50,000	2.374	0.18	10.3	
166	1003	067	platform slope	foraminifer wackestone	50,000	2.266	0.25	6.9	

The majority of deep ocean sediments is composed of calcareous sediments and clays. Clays have permeabilities in the nanodarcy range. Our preliminary measurements on calcareous sediments from the Atlantic reveal permeabilities between 0.005 and 27.2 millidarcy. While calcareous sediments in the deep ocean have high porosities, permeabilities are usually insufficient to achieve reasonable injection rates. Permeability upgrading, such as hydraulic fracturing therefore may be required to achieve sufficient injection rates.

OUR PROPOSED RESEARCH

Task 1: Liquid CO₂ Experiments

Experiments are needed to study the flow behavior of liquid CO₂ within brine saturated ocean sediments. In this task, we will address first the multiphase transport of liquid CO₂ and brine in porous ocean sediments with core flooding experiments. We will define relative permeabilities, wettability conditions, saturation, and capillary pressures for different sediment types.

Task 2: Dissolution Experiments

As the liquid CO₂ expands out into the formation, dissolved CO₂ will form at the front of liquid CO₂ and pore water, resulting in increasing permeabilities due to dissolution of sediment. To probe this effect, a high pressure core flooding device will be used. Rather than flowing liquid CO₂ through in one pass the liquid CO₂ will be used to push pore water partially out. A reversal of pressure will be used to switch flow direction so that CO₂/pore water front is pushed back toward the CO₂ inlet side of the core flooding device. This experimental setup should produce the desired “fingering effect” with attendant dissolution.

Task 3: CO₂ Clathrate Formation

At temperature and pressure conditions encountered 200 to 500 m below seafloor, the formation of CO₂ hydrates is possible, which may add an additional obstacle to CO₂ migration. Quantifying this effect and the time scales it operates on is necessary to understand the depth requirements for CO₂ injection as well as the long term sealing role of hydrates in the sub-seabed CO₂ storage. We propose to conduct experiments with liquid CO₂ under low temperature conditions (1-10 degC) to study the potential formation of CO₂ clathrate as a function of pressure and temperature (thermodynamic effect), different mineralogical composition of sediment, permeability/porosity (matrix effect), and water saturation.