Scaleup of a Continuous-Jet Hydrate Reactor for CO_2 Ocean Sequestration

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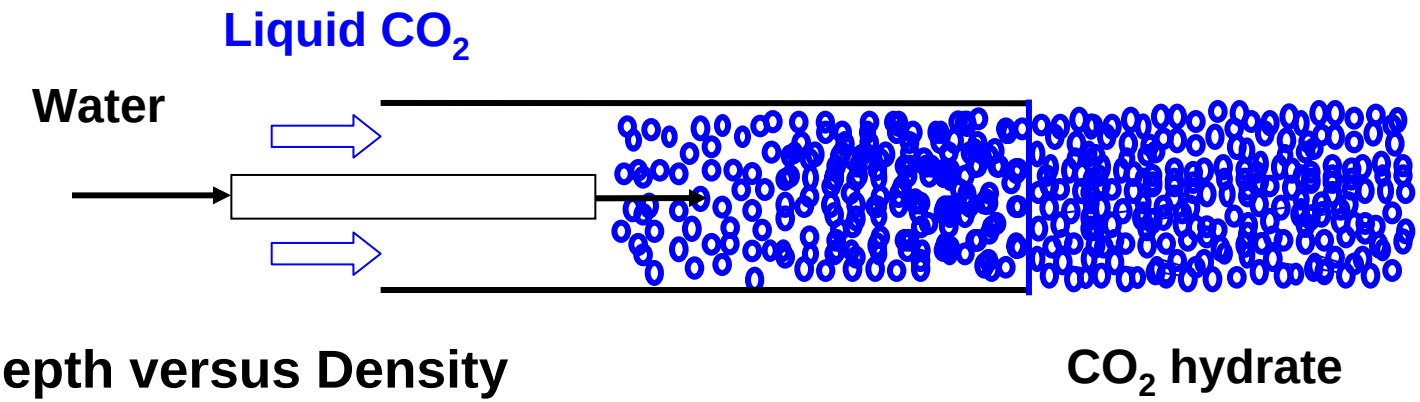
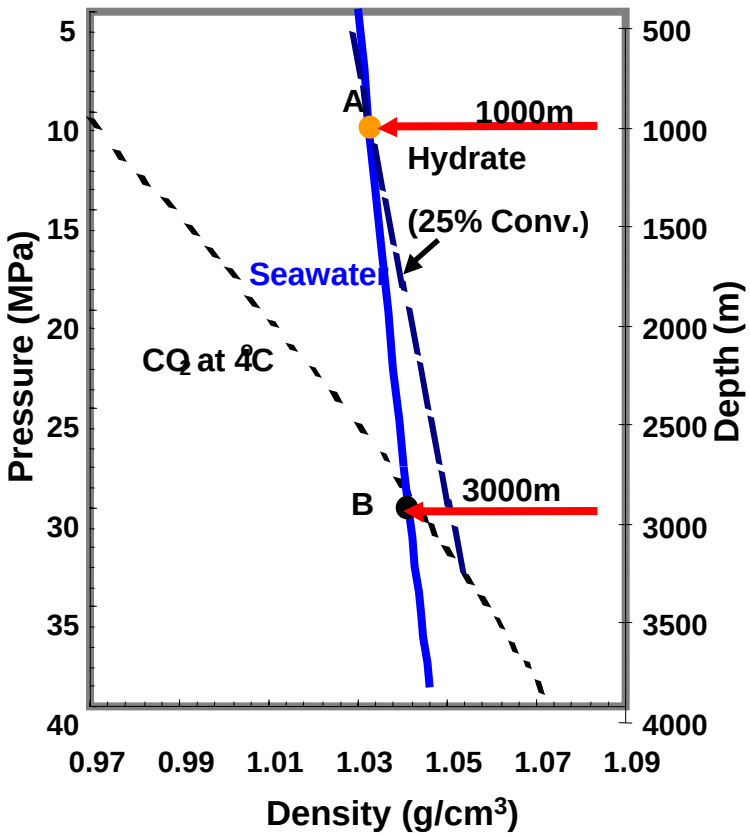
Abstract

Formation and dissociation of CO_2 hydrate is investigated using a coflow CO_2/water reactor at mid-ocean-depth thermodynamic conditions. The objective of converting CO_2 into hydrate is to be able to inject CO_2 in seawater in the form of a dense material that will drive CO_2 to depths in the ocean well below the injection point. In this way, the residence time of CO_2 in the ocean will increase while peak concentrations will occur in the deep ocean rather than at the surface. The thermodynamic conditions allowing the formation of negatively buoyant composite particles have been established for a laboratory-scale, coflow continuous-jet hydrate reactor (CJHR). An investigation has been performed in this work to explore the issues related to the scaleup of the CJHR. Scaleup of two orders of magnitude in the flowrates of the two fluids has been achieved.

Concept for CO_2 Hydrate Formation



Pressure/Depth versus Density

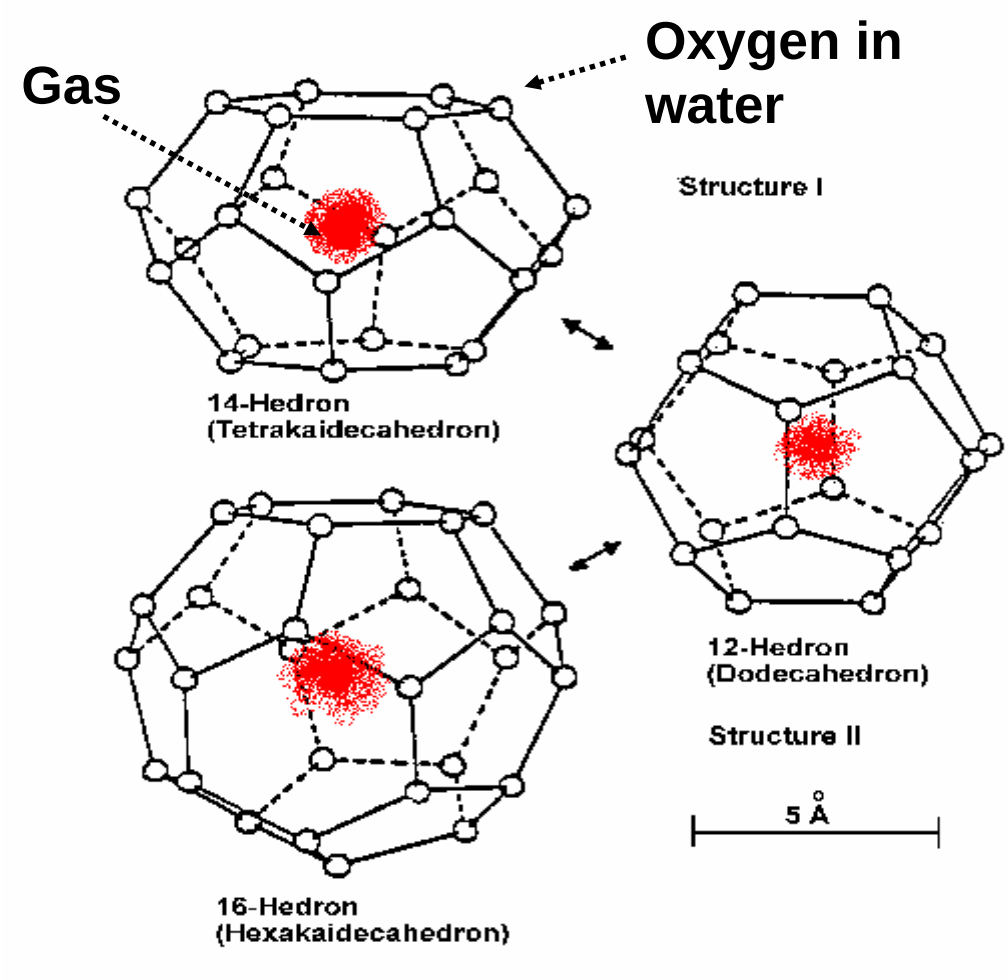


Hydrate formation on the surface of droplets reduces drop coalescence significantly.

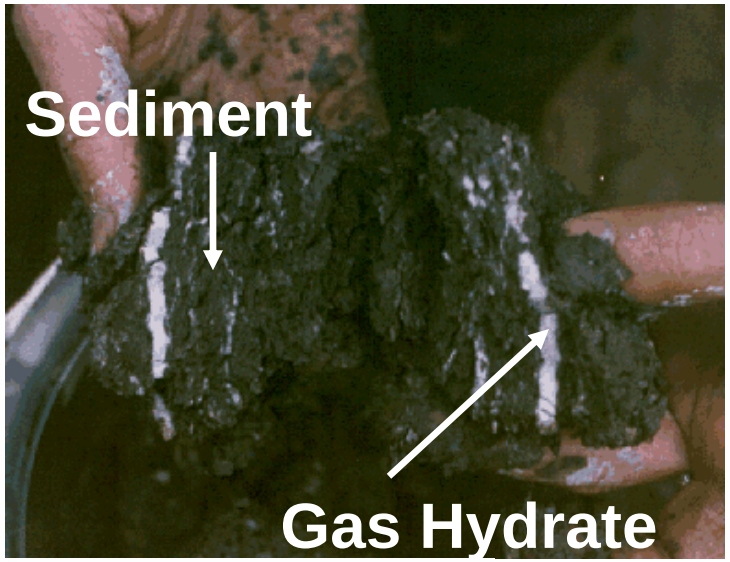
The density of the solid produced depends highly on the conversion of liquid CO_2 to hydrate.

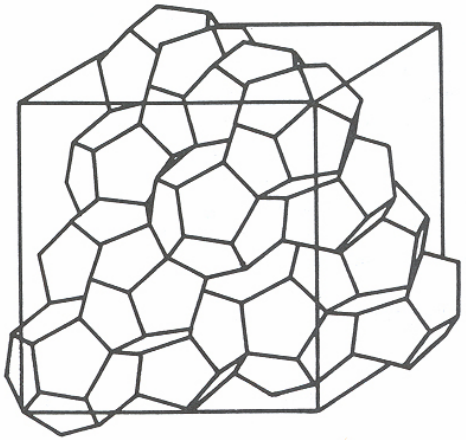
West et al., AIChE J., 2003

Gas Hydrate Structure



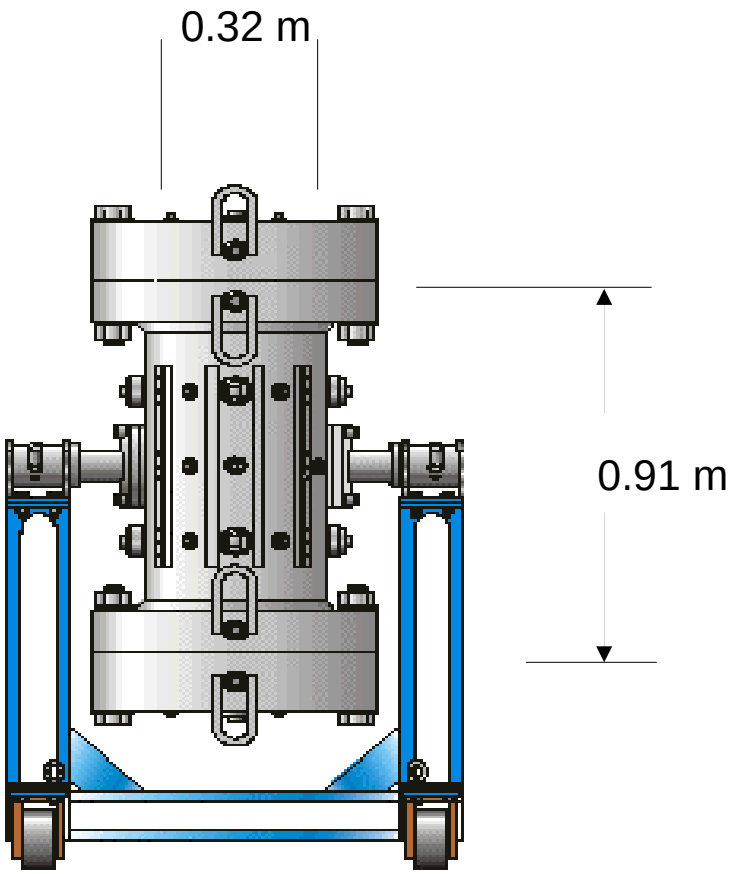
Individual Cages

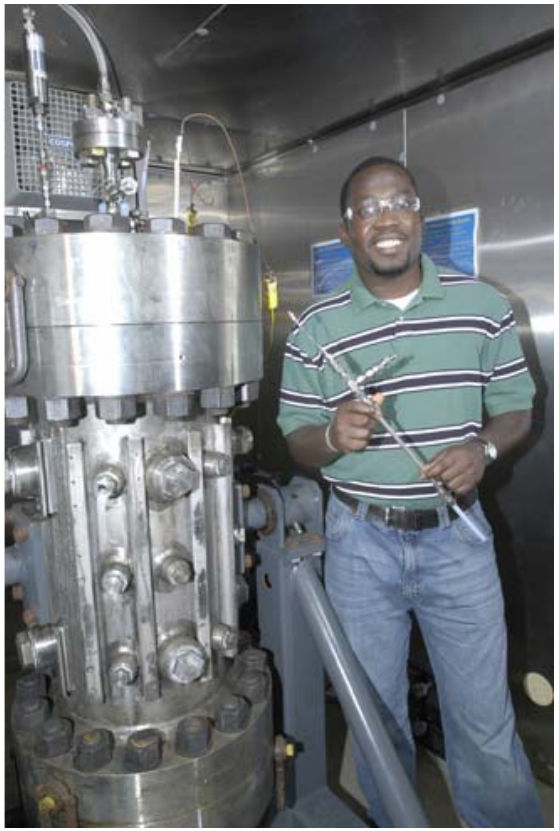




Unit Cell (Structure II)

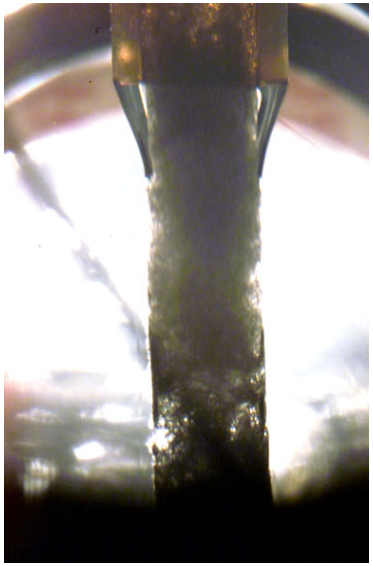
The Seafloor Process Simulator Used in the Experiments



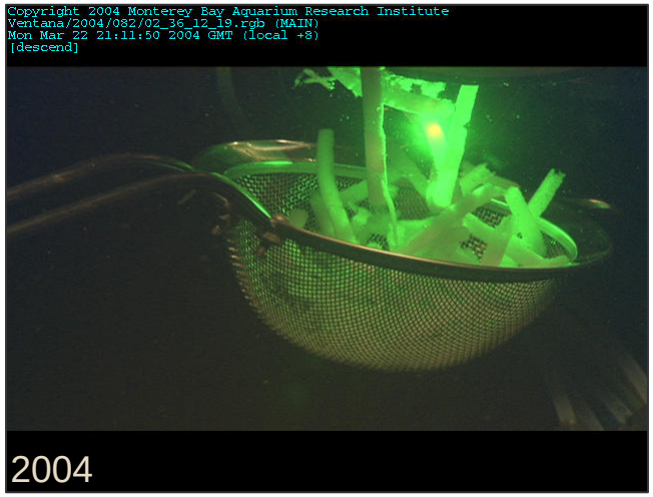


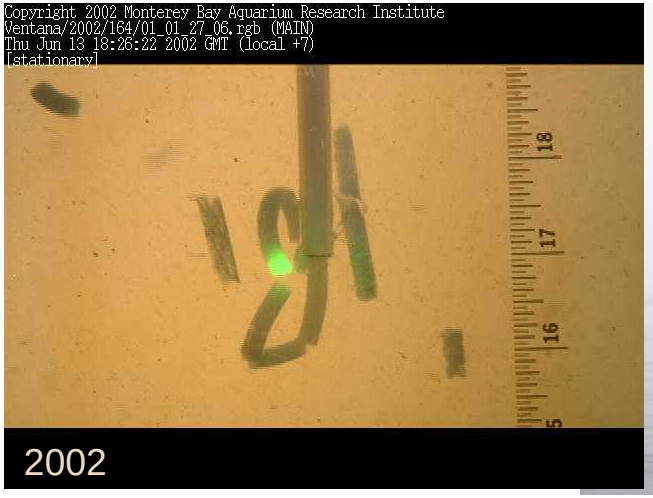
The ORNL Seafloor Process Simulator (SPS) used in this work is a 72 L pressure vessel with observation windows.

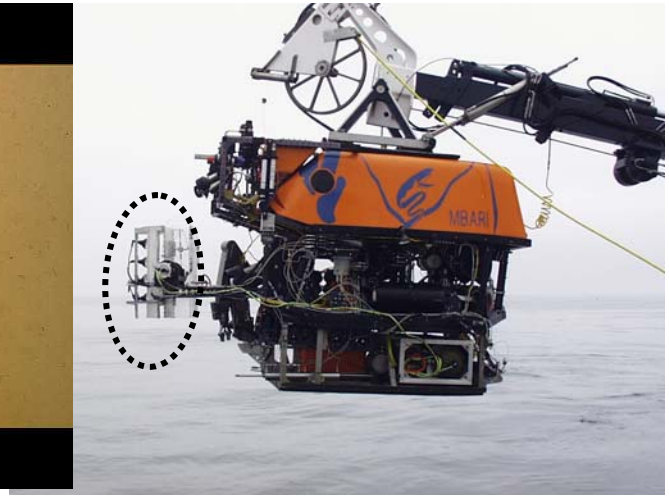
Previous Laboratory and Field Experiments



(Installation of ORNL injector with Raman spectrometer)

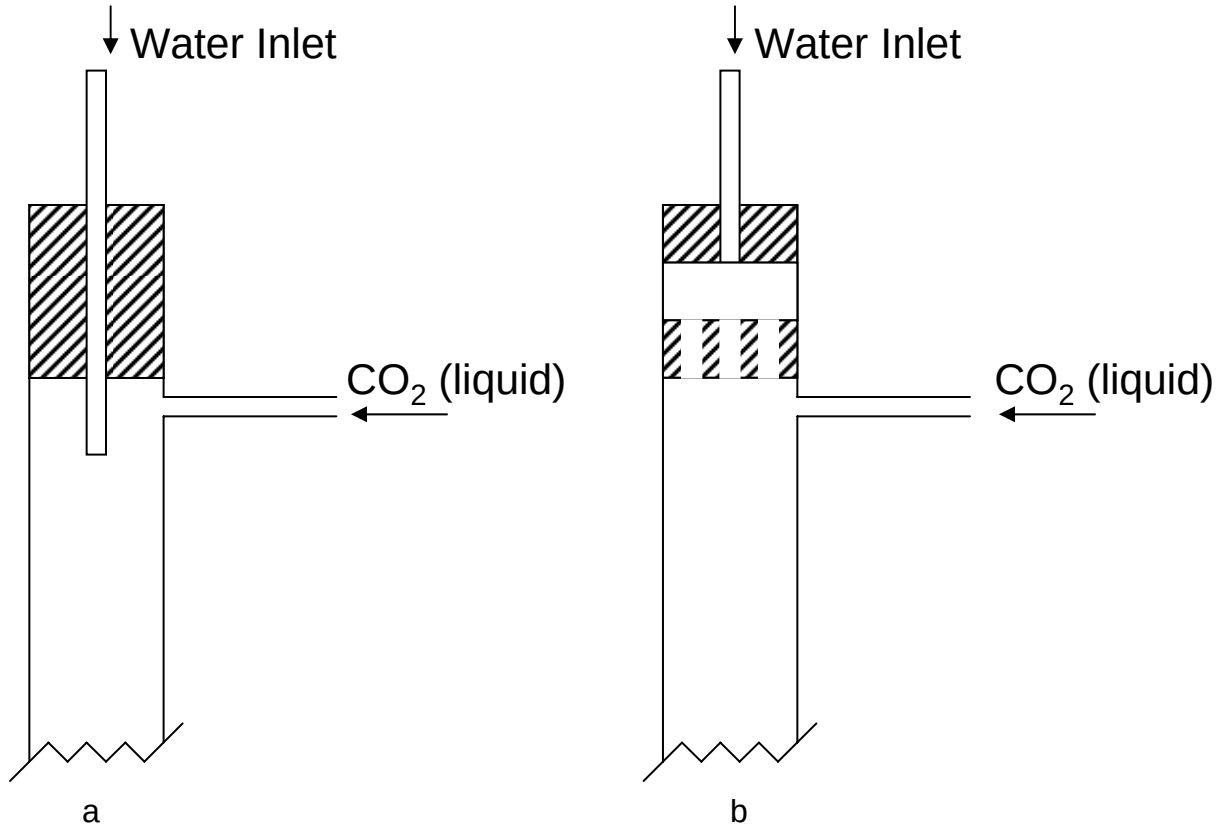






Tsouris et al., ES&T, 2004

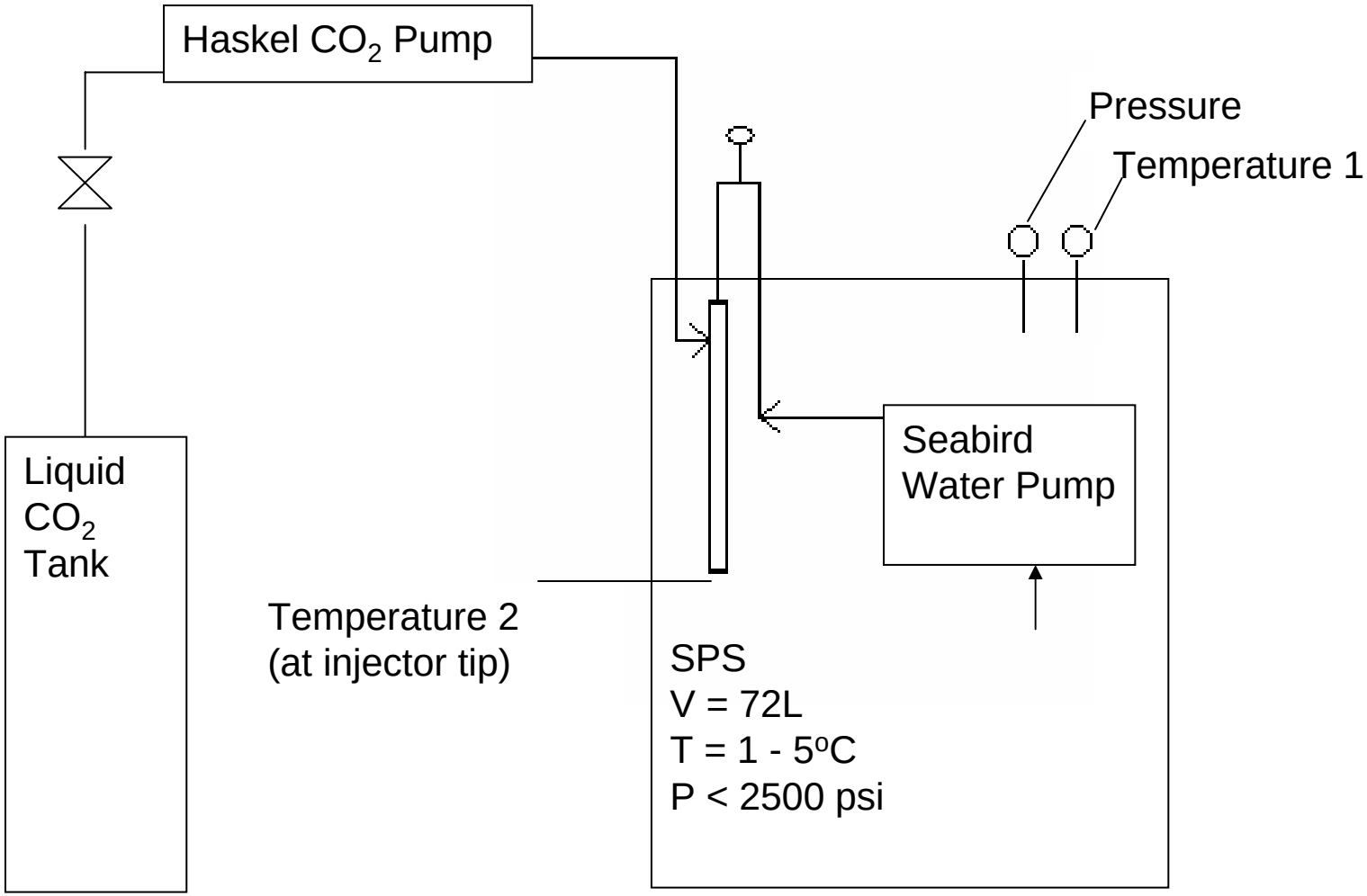
Scale-up CJHR Reactors



(a) Single-capillary, concentric injector

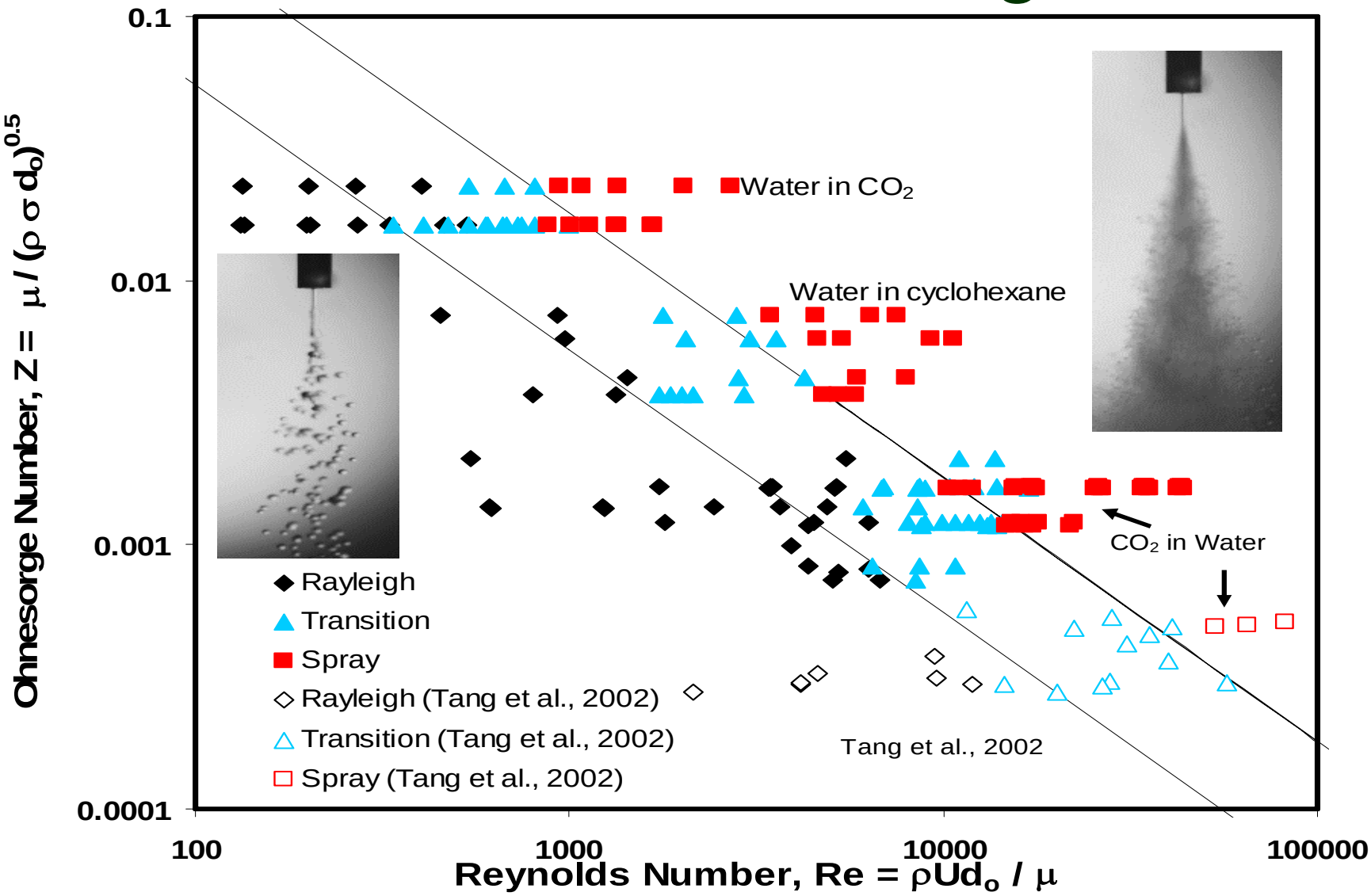
(b) Capillary-array injector

Experimental Setup for Scaleup Studies



The experimental setup for the scale-up experiments included a submersible water pump operating at a high pressure and an externally mounted pulsed CO_2 pump.

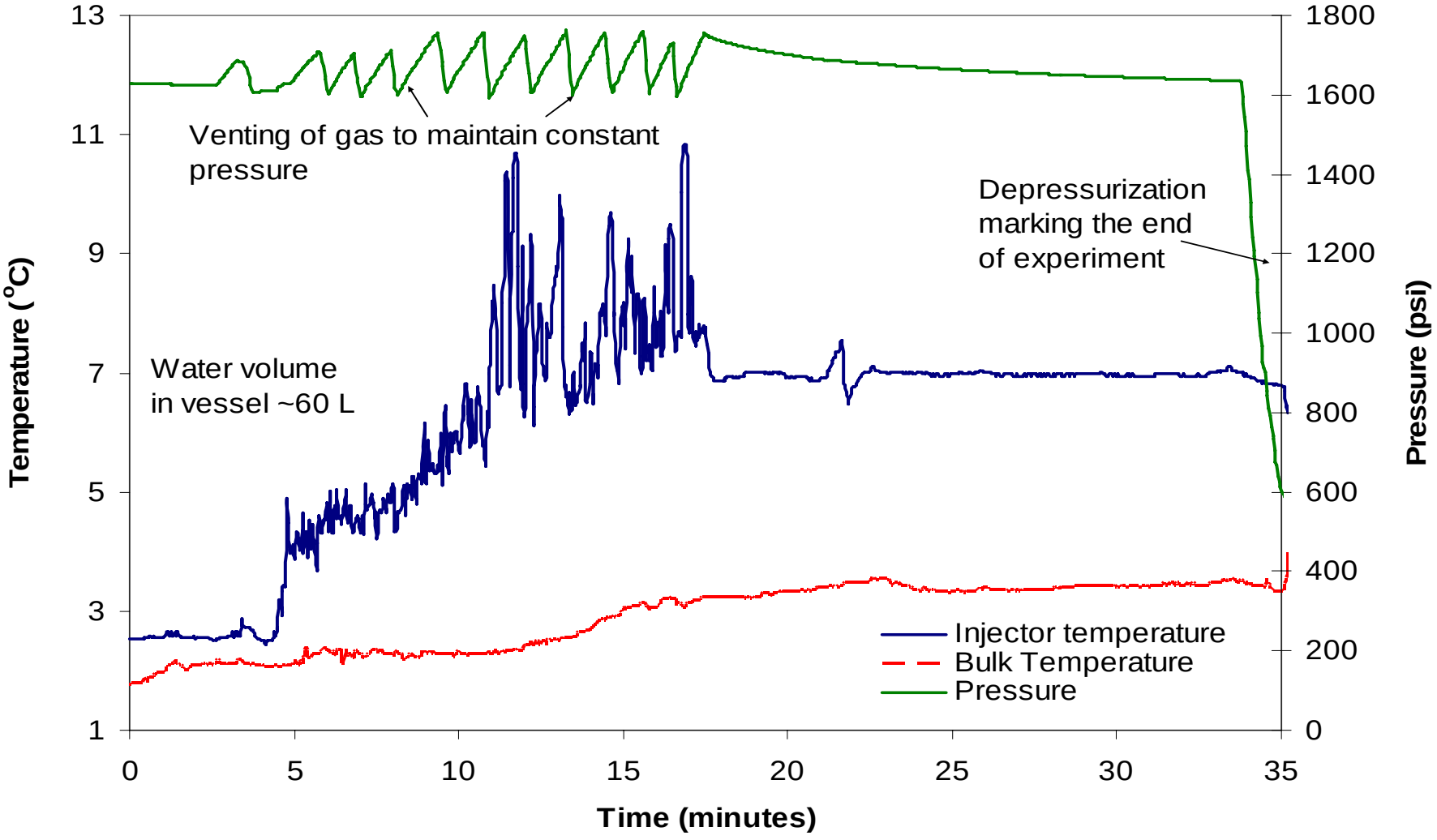
Jet Destabilization Regimes



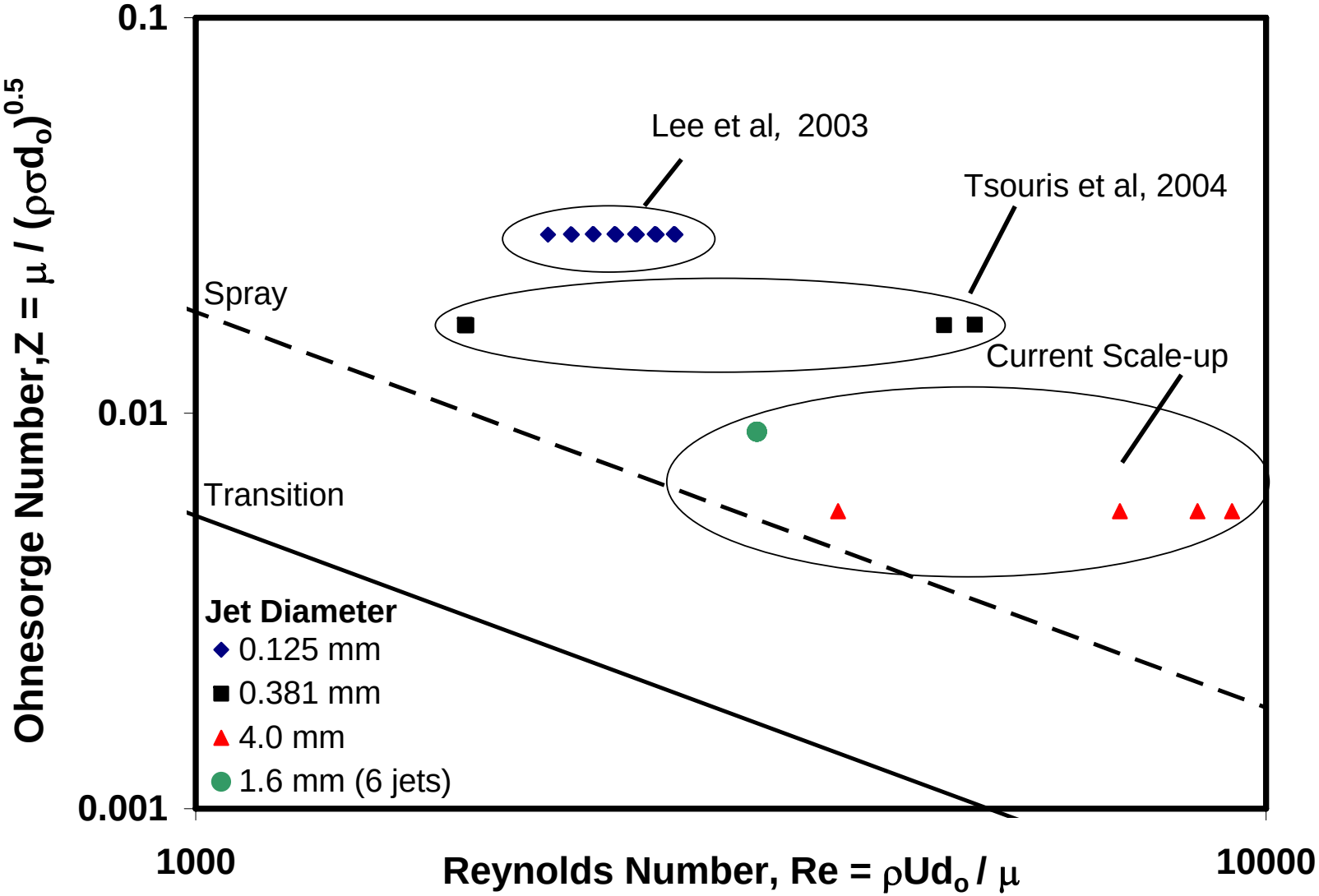
Jet breakup regimes identified in the Ohnesorge vs. Reynolds number diagram.

Riestenberg et al., Amer. Mineralogist, 2004

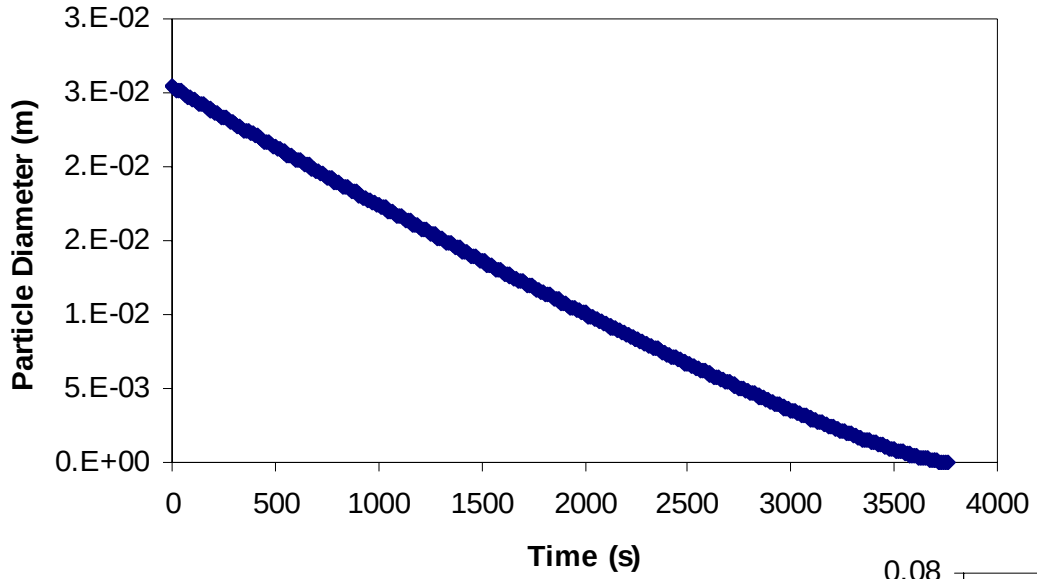
Temperature-Pressure Histories for a Typical Experiment with the CJHR



Ohnesorge-Reynolds Diagram is Used to Select Geometry and Flowrates



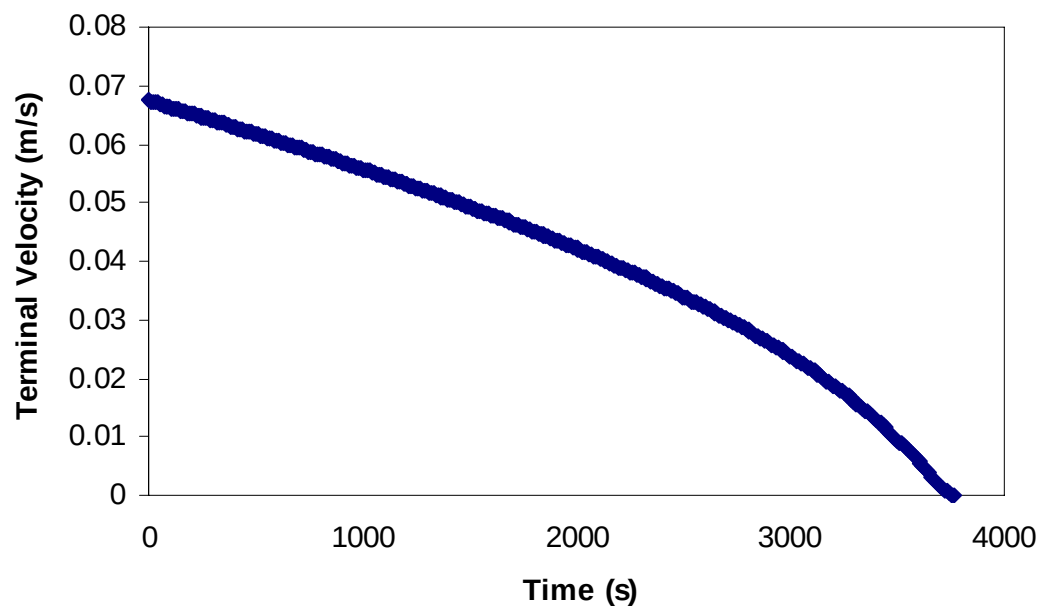
CO_2 Hydrate Dissolves as it Descends in Seawater



Mass-transfer modeling is based on single particle.

Additional effects occur in a plume, allowing the particles to descend for as much as 1000 m before dissolution.

Riestenberg et al., ES&T, 2005



Acknowledgments

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<u>Collaborators</u>

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Eric Adams, Aaron Chow (MIT)