Chemical Sequestration of CO_2 by $CaCO_3$ Dissolution

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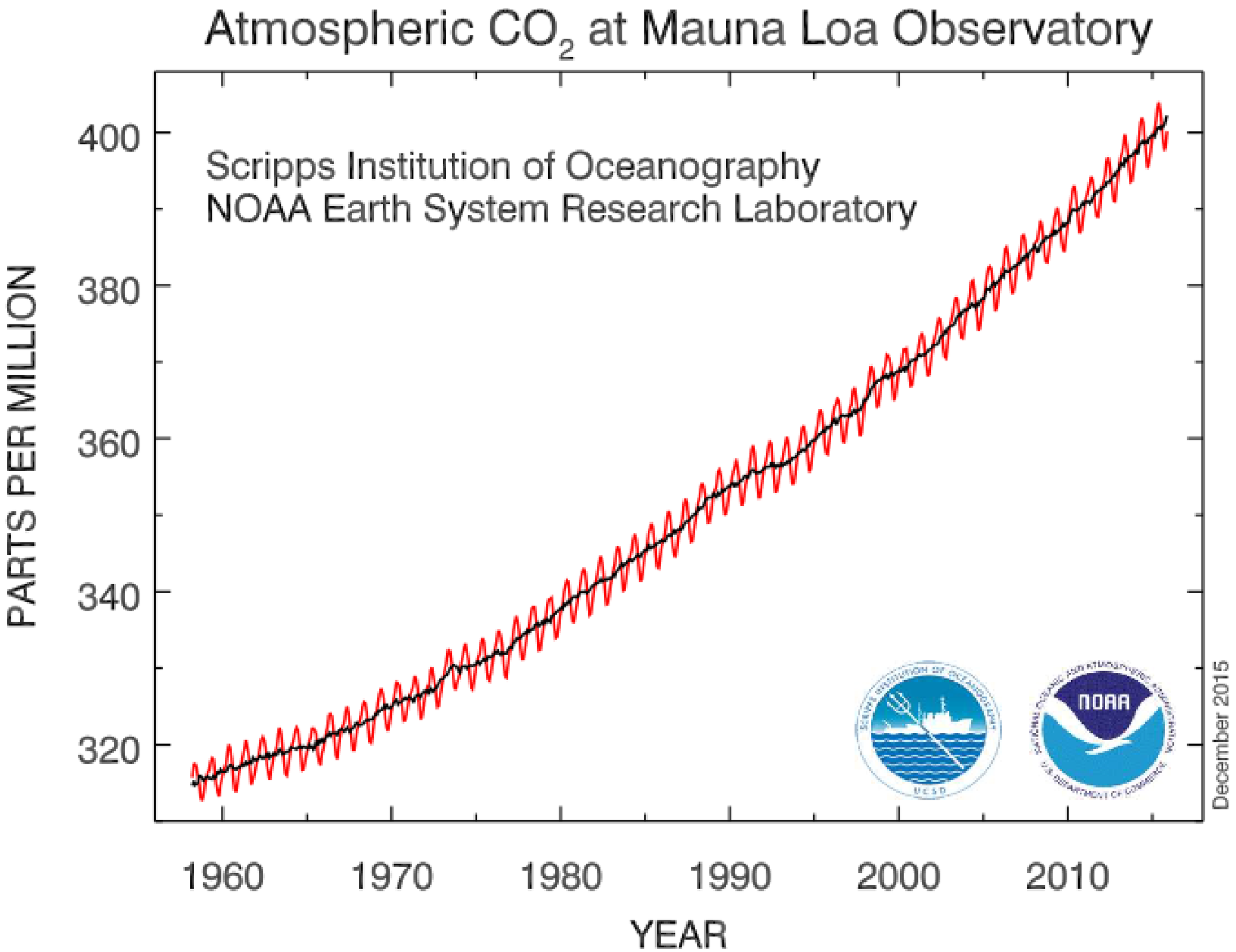
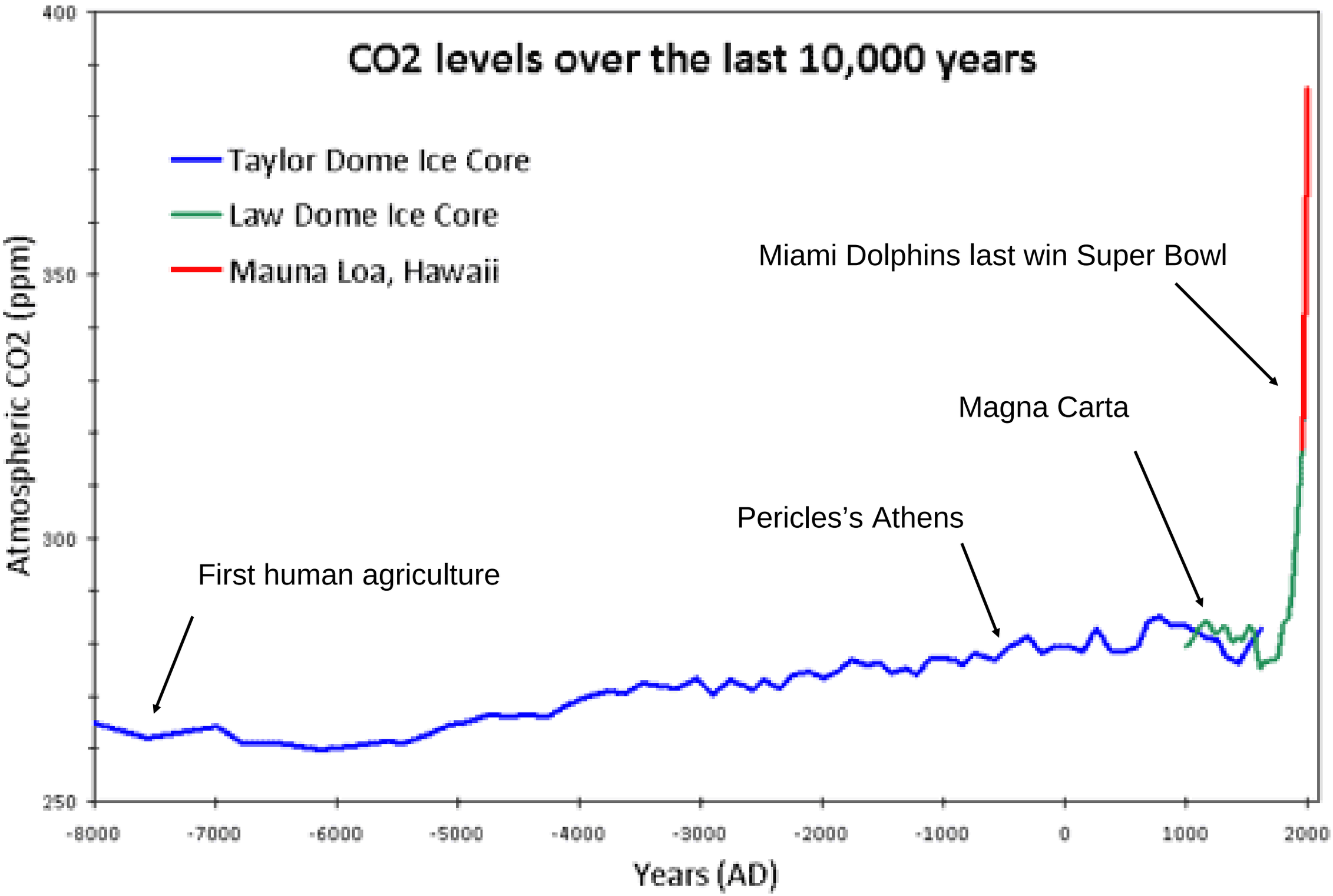
RESNICKINSTITUTE
science + energy + sustainability
CALIFORNIA INSTITUTE OF TECHNOLOGY

NSF

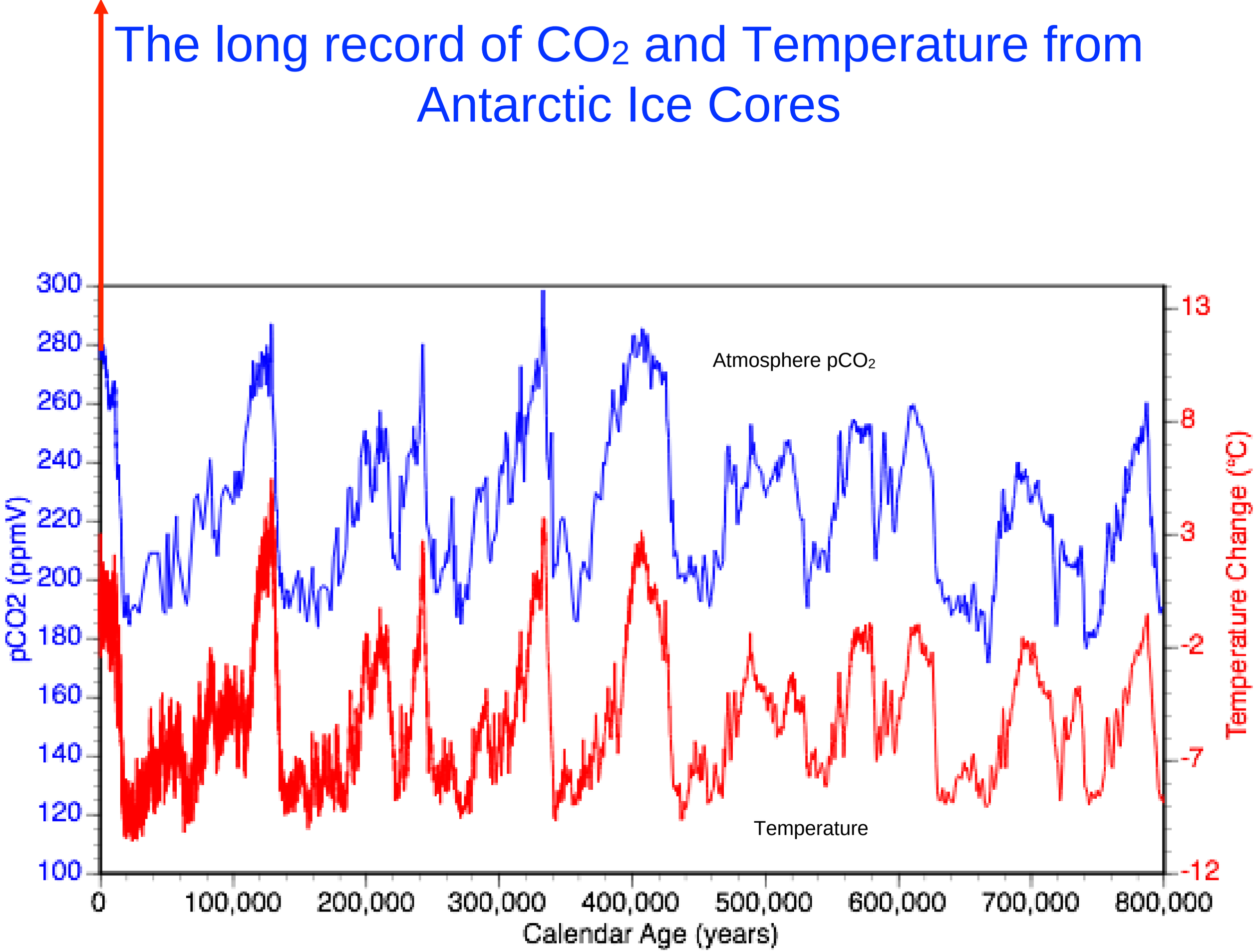
The famous ‘Keeling Curve’



We are conducting an experiment that is global in scale…



The long record of CO_2 and Temperature from Antarctic Ice Cores



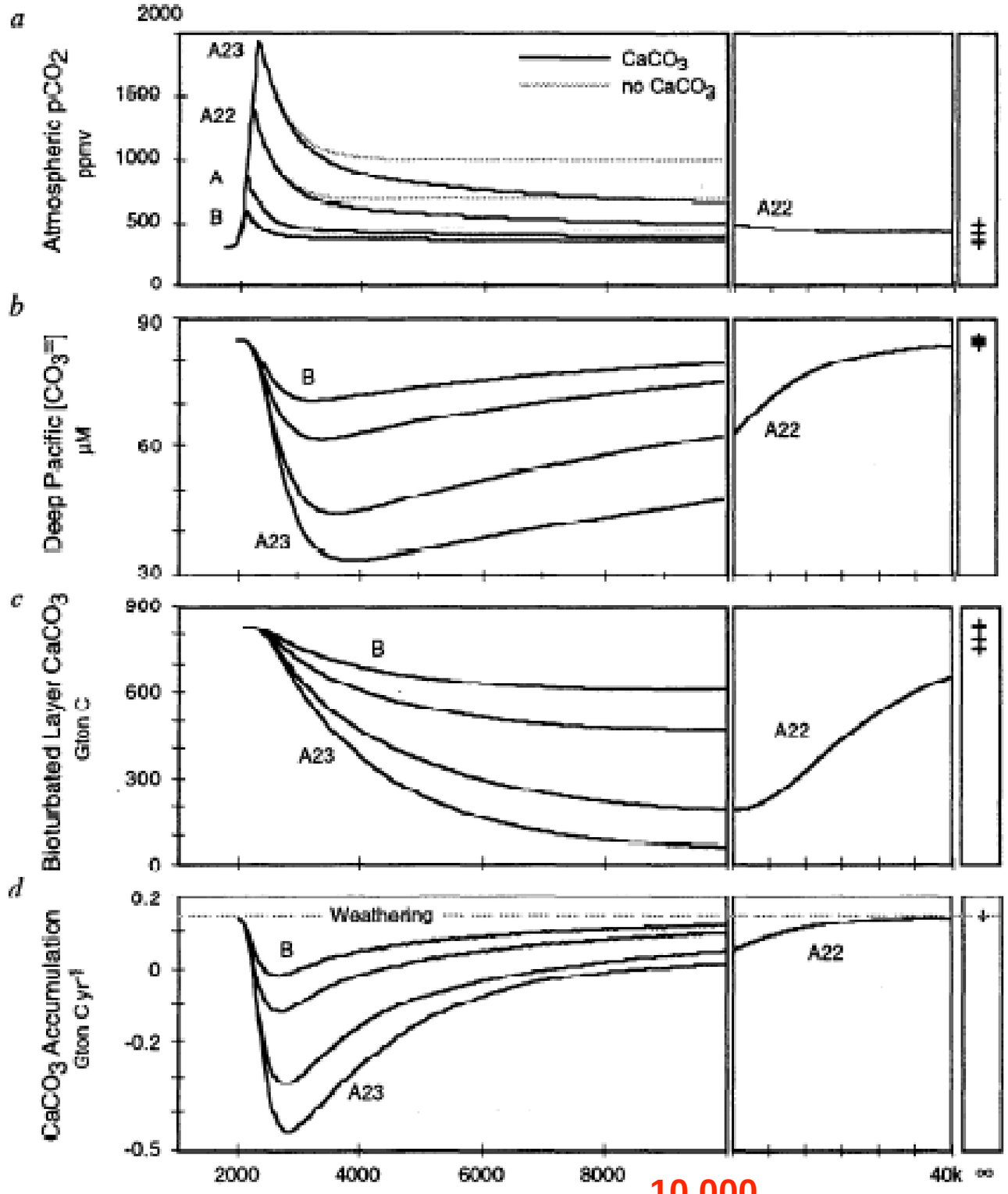
We know how the planet will do CO_2 Sequestration

The ocean and atmosphere will react to excess CO_2 emissions by reacting it with $CaCO_3$ sediments in the deep ocean. That is, the shells of dead plankton will buffer the CO_2 addition.

Ocean Sediment

$+ CO_2 =$

$2HCO_3^- + Ca^{2+}$



pCO_2

Pacific $[CO_3]$

Upper Sed $CaCO_3$

10,000

Time Scale

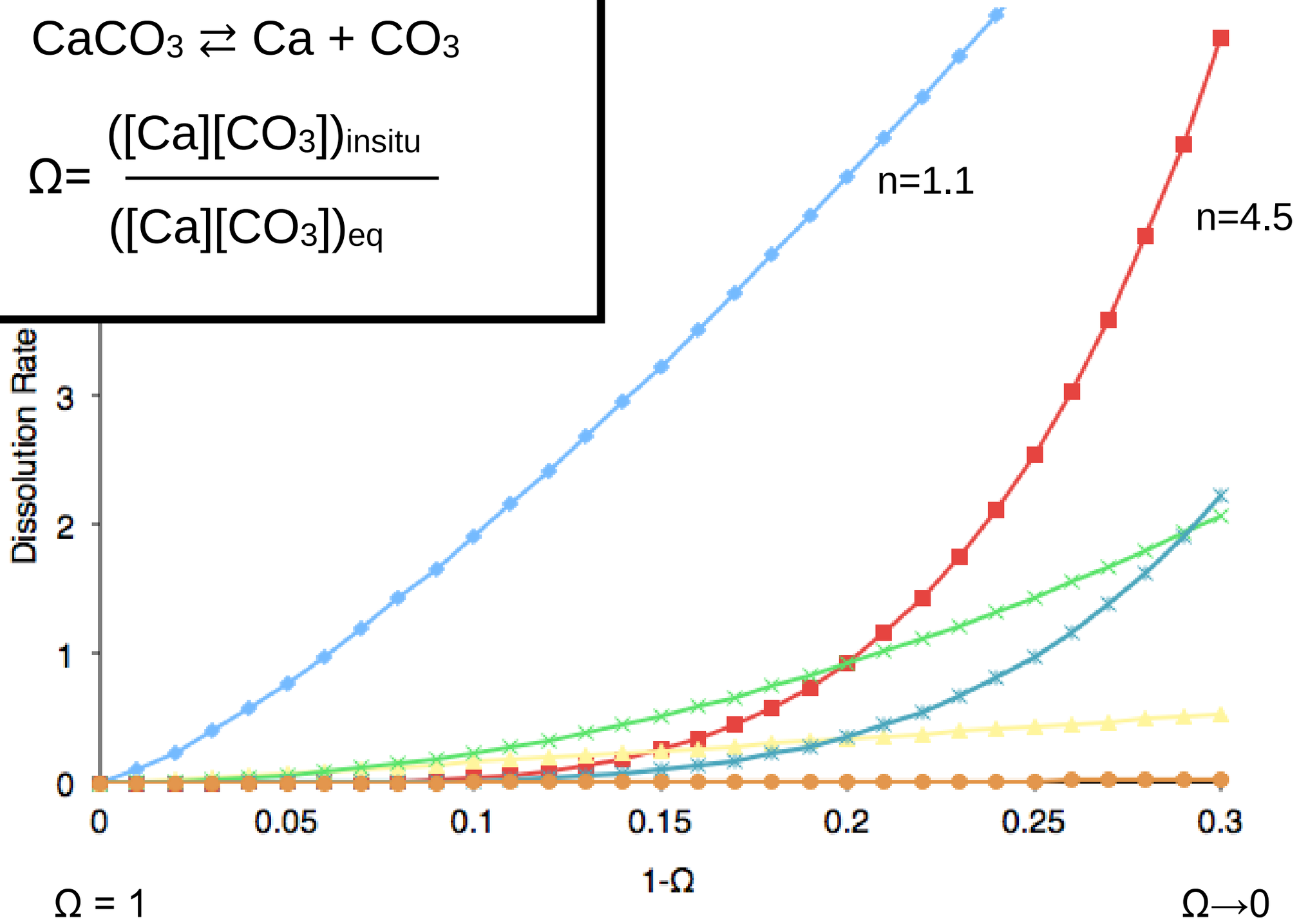
Archer et al., 1997

Close to Equilibrium the ‘Rate Law’ is Poorly Constrained

$$\text{Rate} = k(1-\Omega)^n$$

$$CaCO_3 \rightleftarrows Ca + CO_3$$

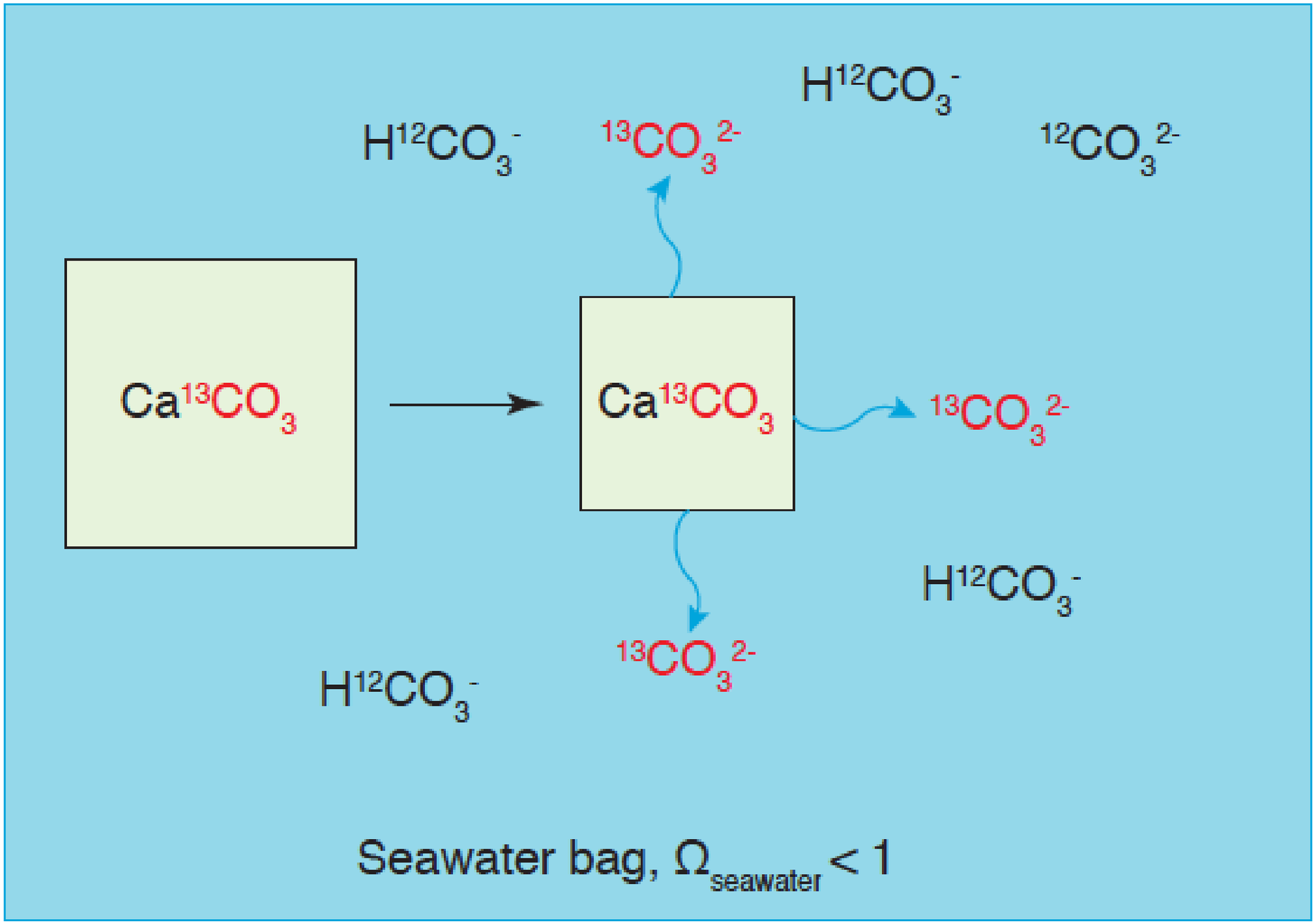
$$\Omega = \frac{([Ca][CO_3])_{insitu}}{([Ca][CO_3])_{eq}}$$



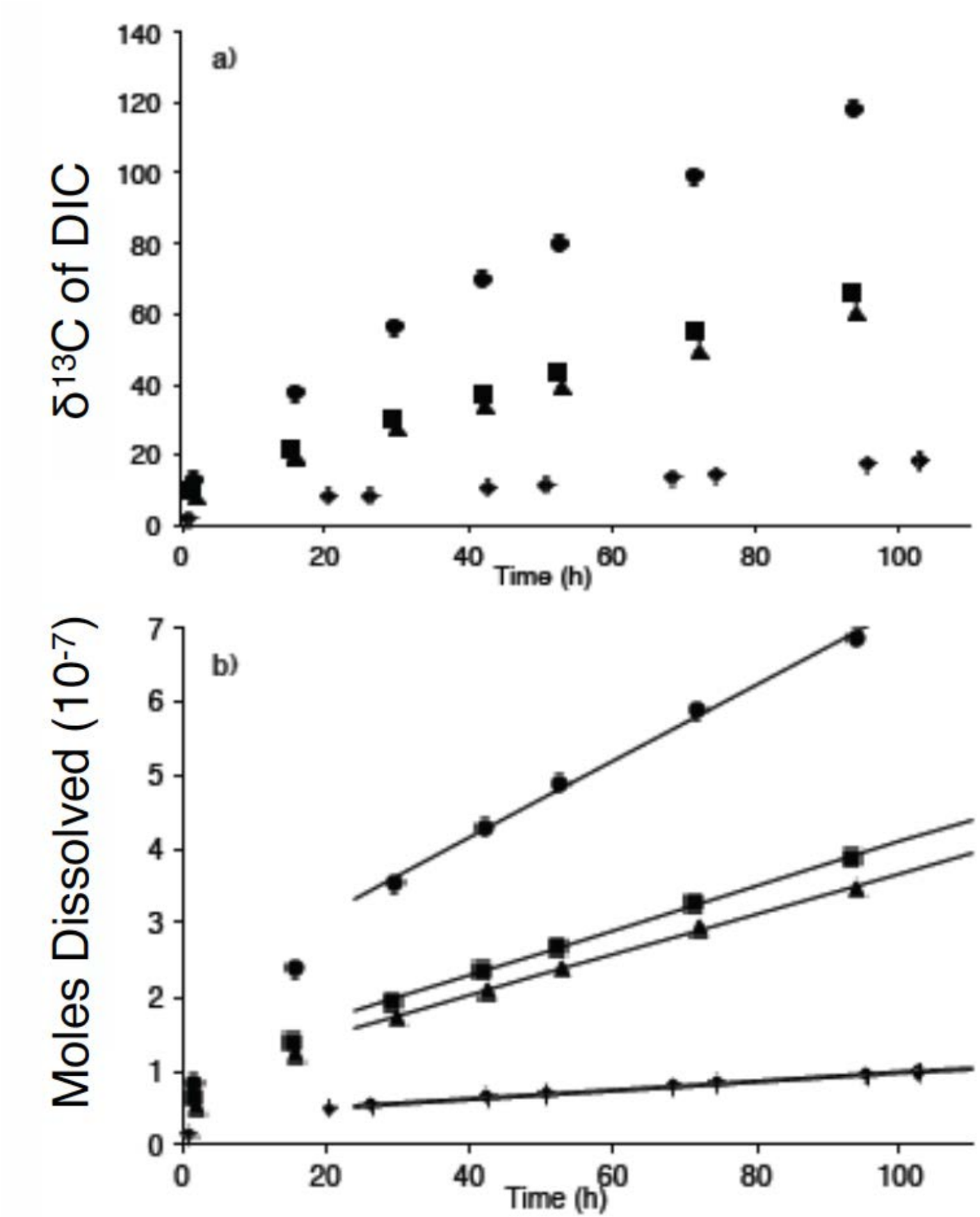
Ω = 1

Ω→0

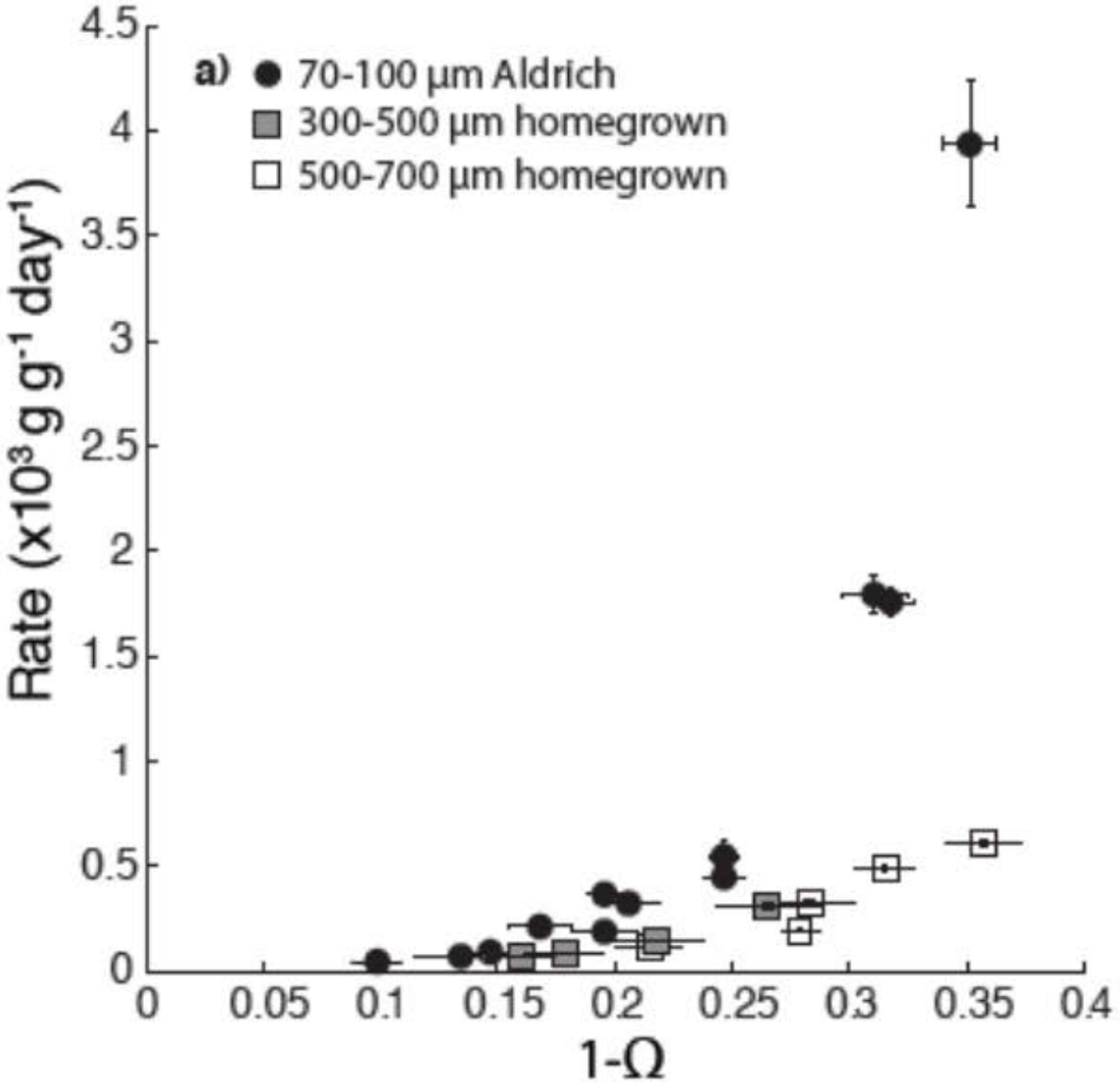
A New Approach to Measuring the Dissolution Rate



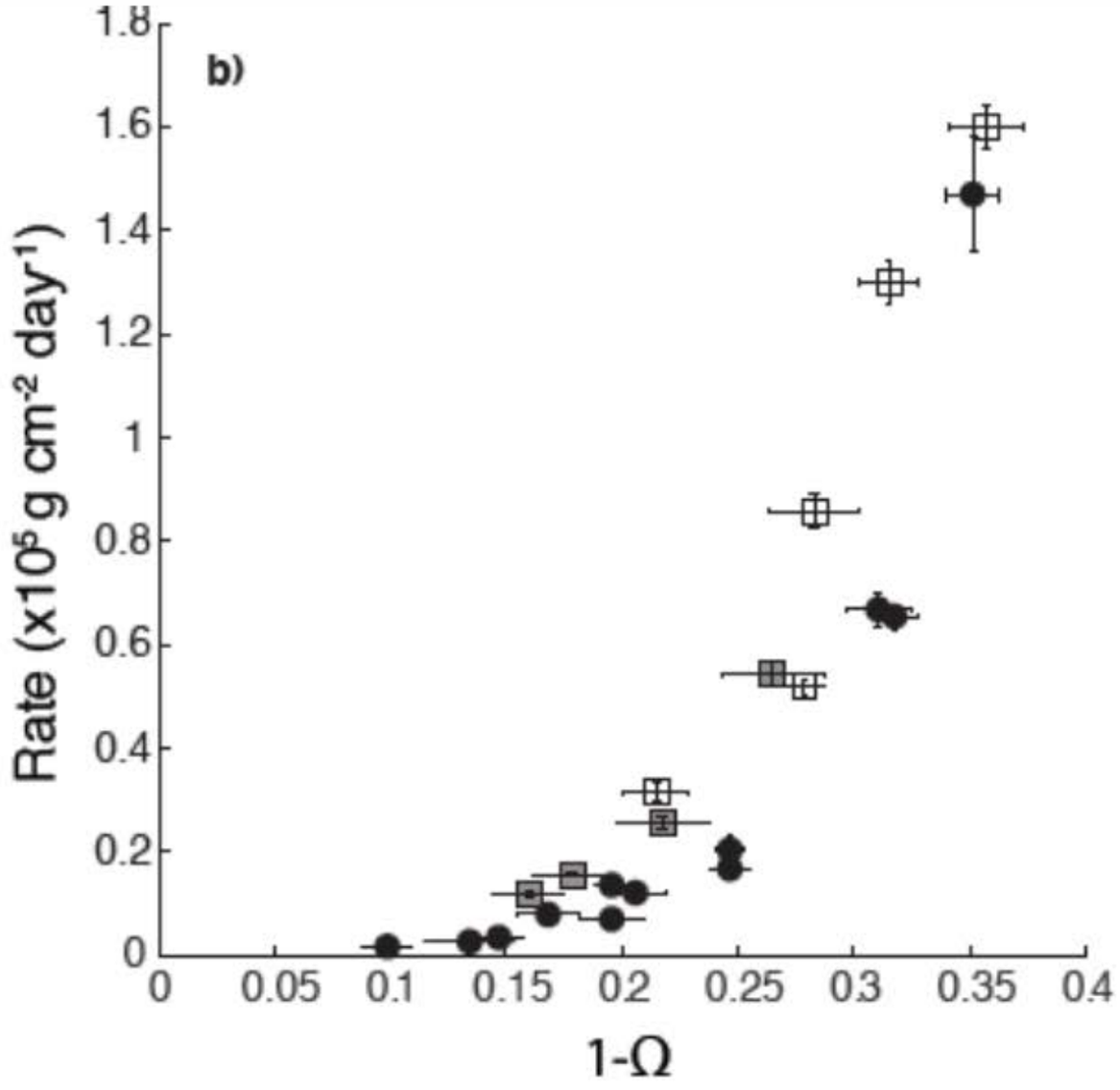
The basic data output from an experiment



The calcite rate law is strongly curved



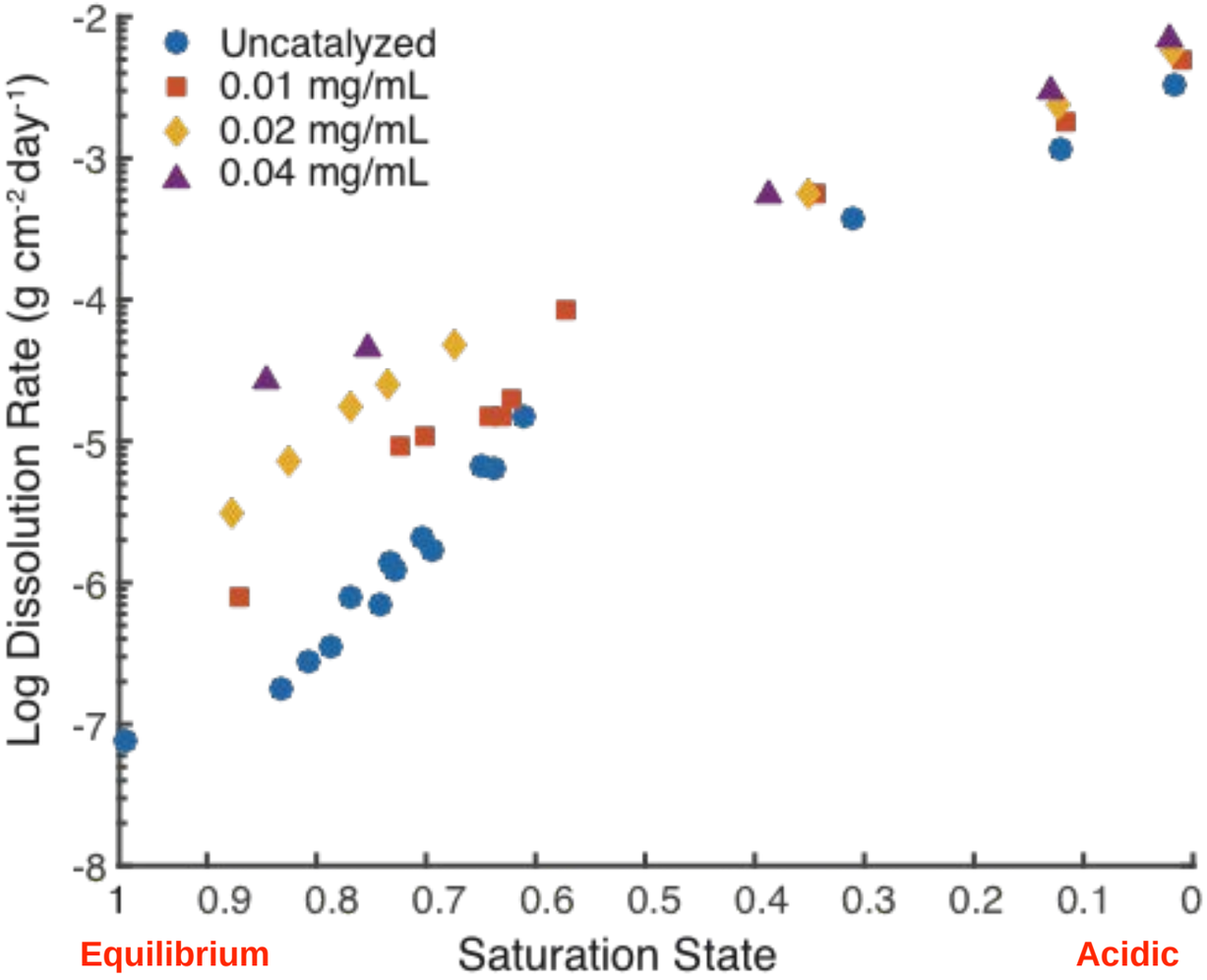
weight normalized only

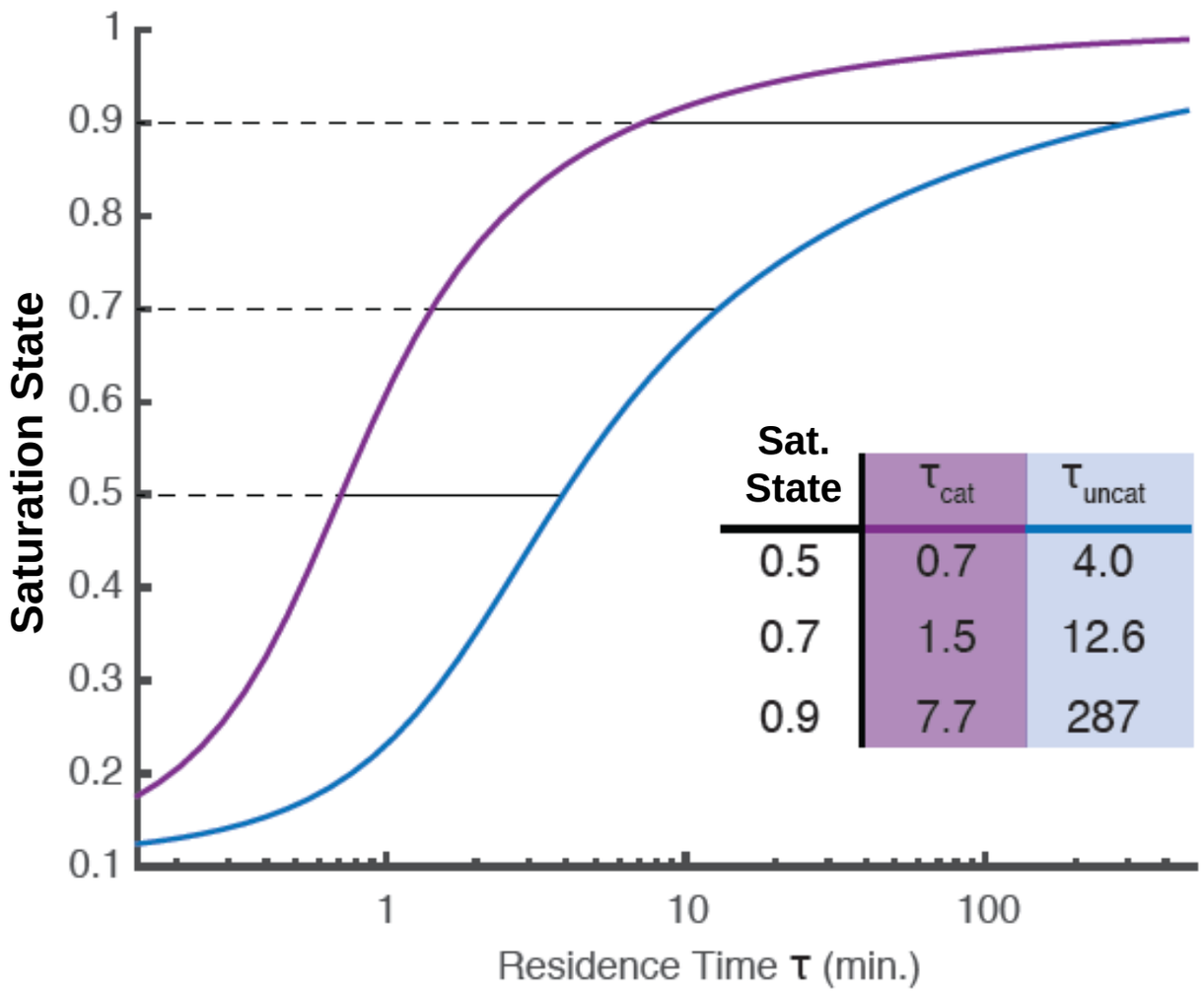


area normalized data

Subhas et al. 2015

We Discovered a Catalyst that make the natural reaction go much faster





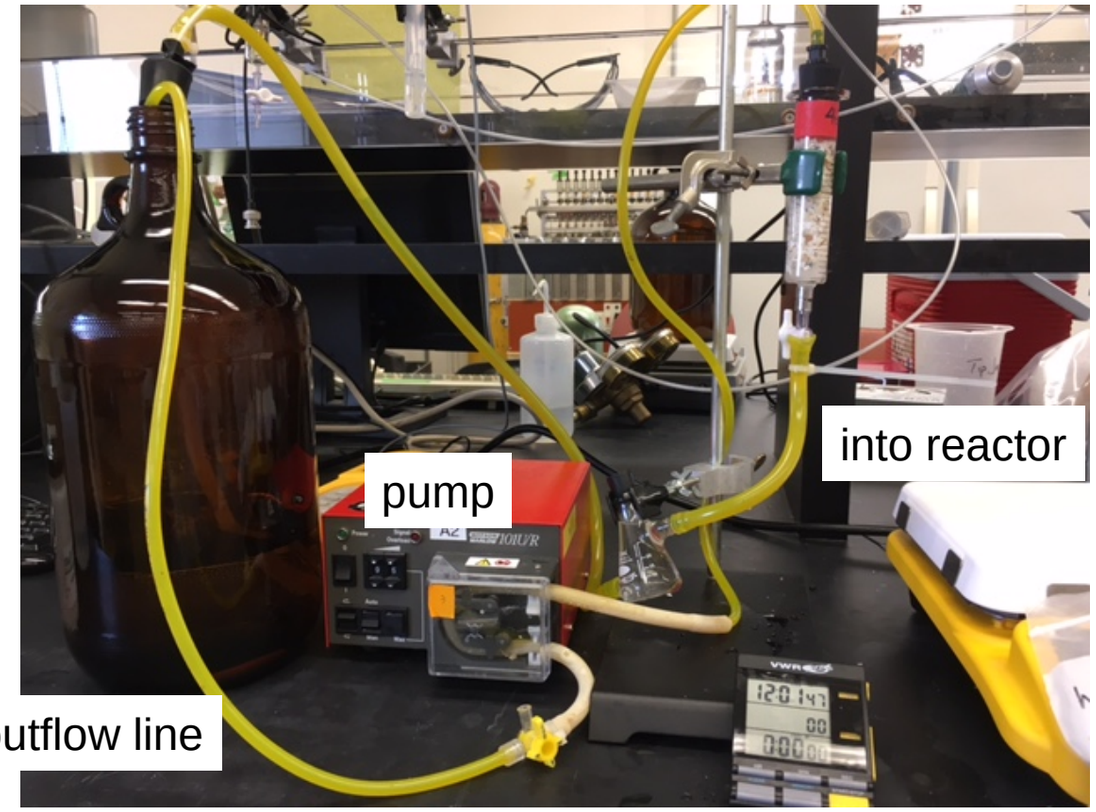
Sat. State	τ_{cat}	τ_{uncat}
0.5	0.7	4.0
0.7	1.5	12.6
0.9	7.7	287

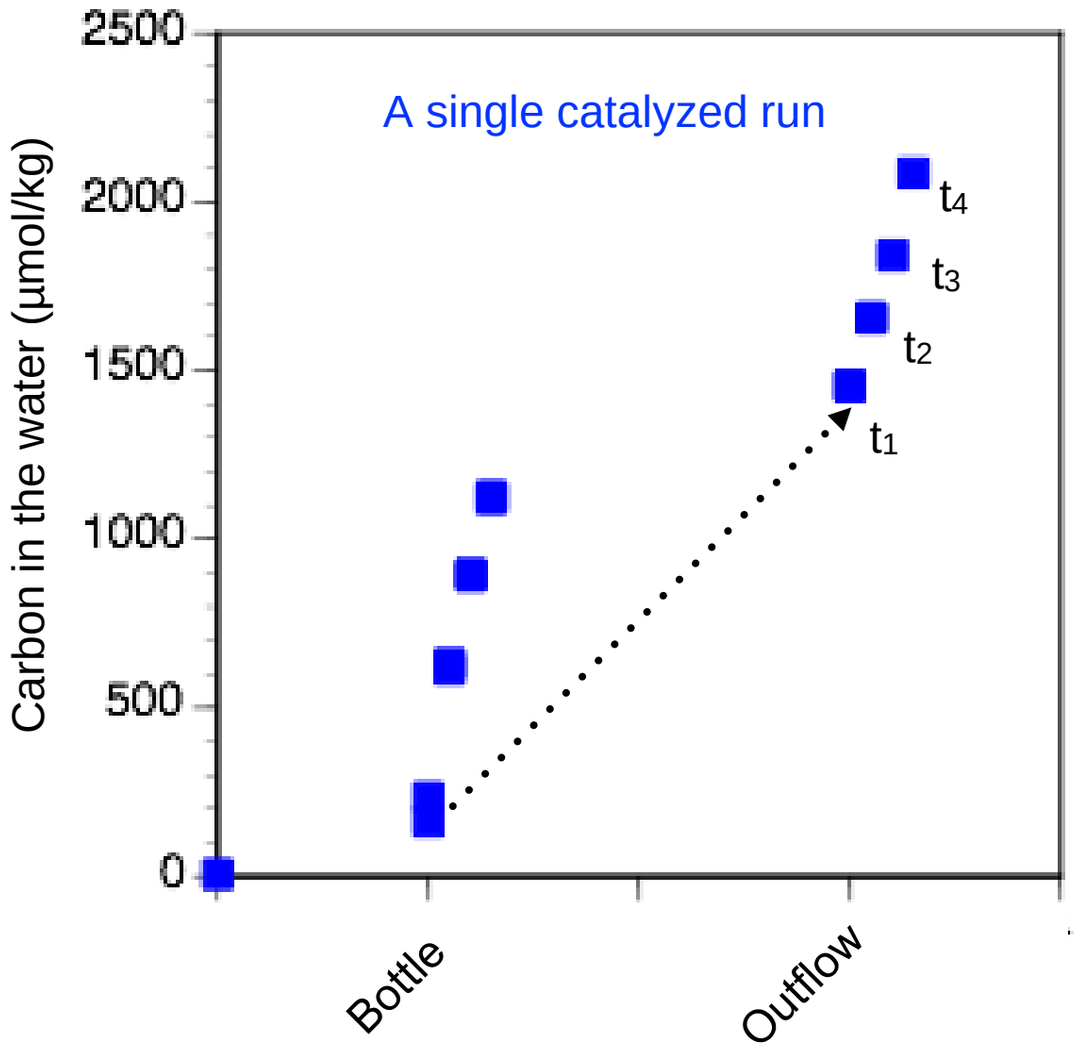
In the lab the enzyme carbonic anhydrase makes the reaction of CO_2 and $CaCO_3$ go almost 1,000 times faster

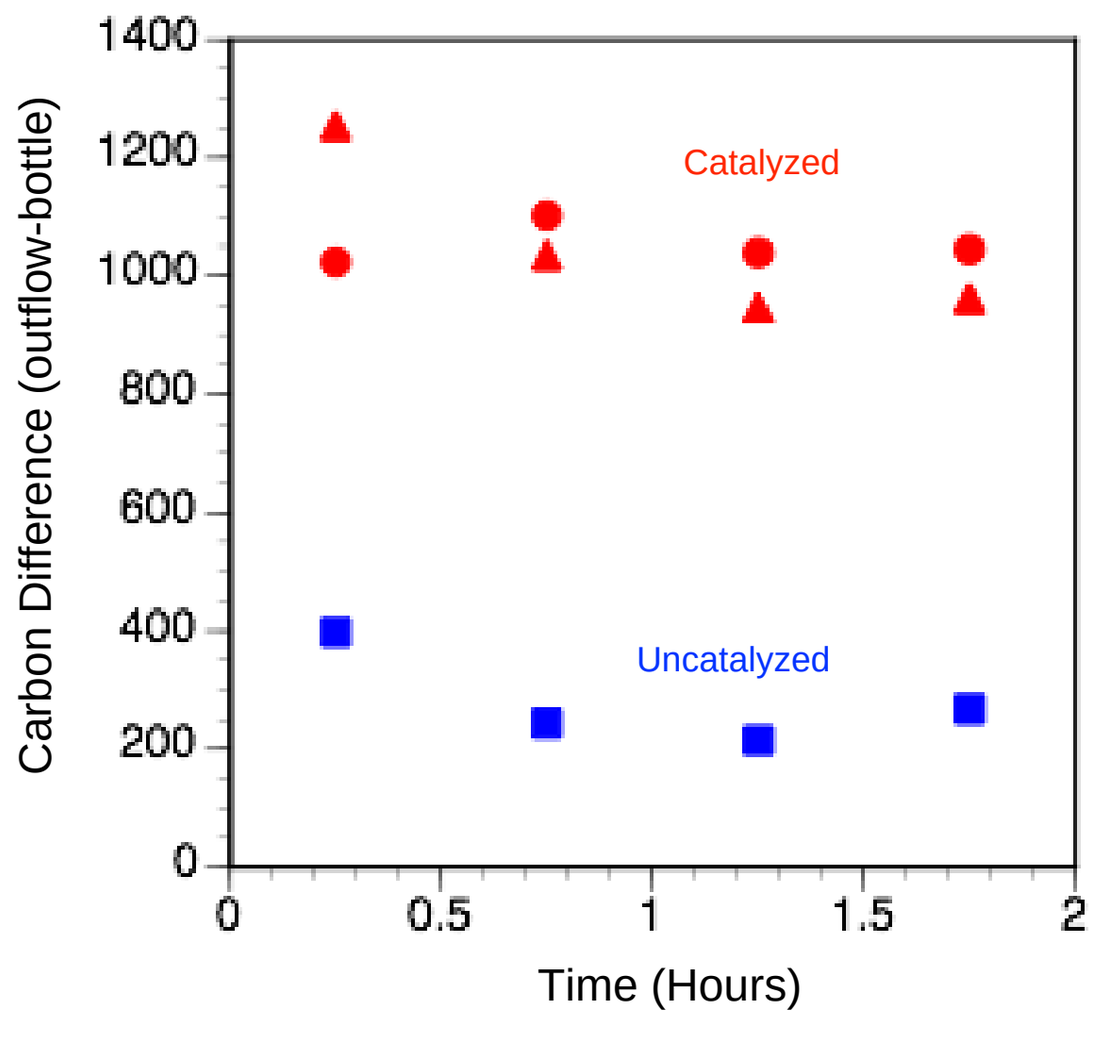
In a business, a reactor located at a power plant would greatly increase the speed of CO_2 sequestration, thus making if feasible to convert the gas into harmless dissolved inorganic carbon

A simple reactor using freshwater and a limestone bed

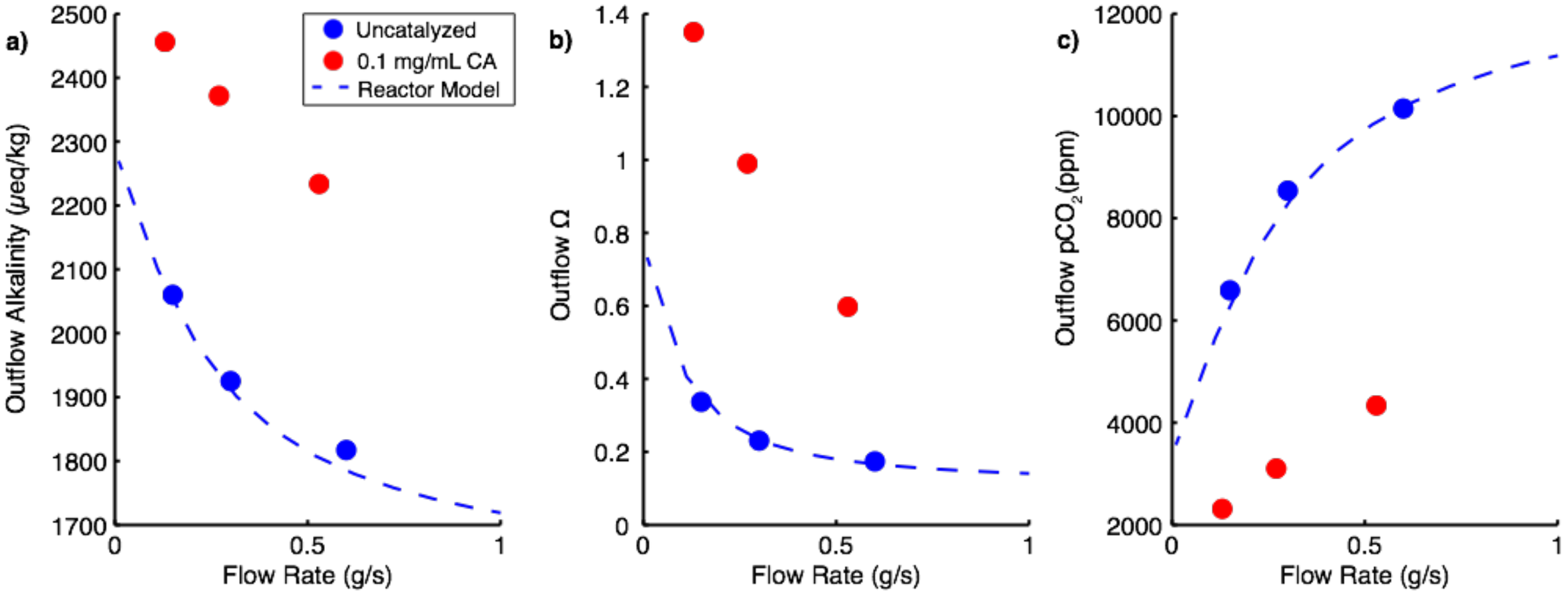
bottle with CO_2 bubbling

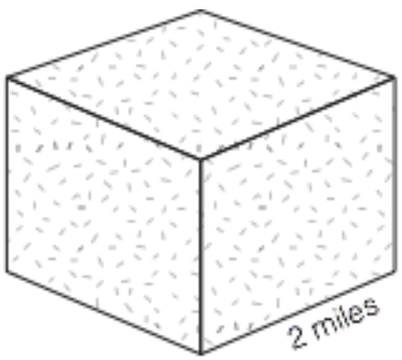




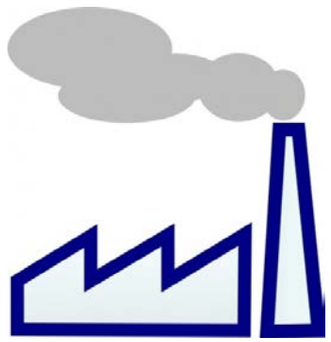


eawater flowing through a packed bed of Limestone in the la





40 GT CO_2
Limestone Equivalent



Walmart-Sized
Dissolution Factory

Catalyzed: 600 Factories

Uncatalyzed: 24,000 Factories

Operationally, What might a factory look like?

A single pass cooling power plant on a water source

We hired Antonio Corradini,PE of Alternative Energy Systems Consulting Inc. to do a cost analysis for CO_2 sequestration at a power plant that already brings in large amounts of water for system cooling.

aesc
energy solutions for a changing world

Basic Costs of Material Processing

Water Pump

$18.20/ton CO_2, assuming 500 µmol/kg carbon in water

Total
$58.30 /ton CO_2

CO_2 Blower

$3.29/ton CO_2, with 7 psi pressure

Does NOT include catalyst cost

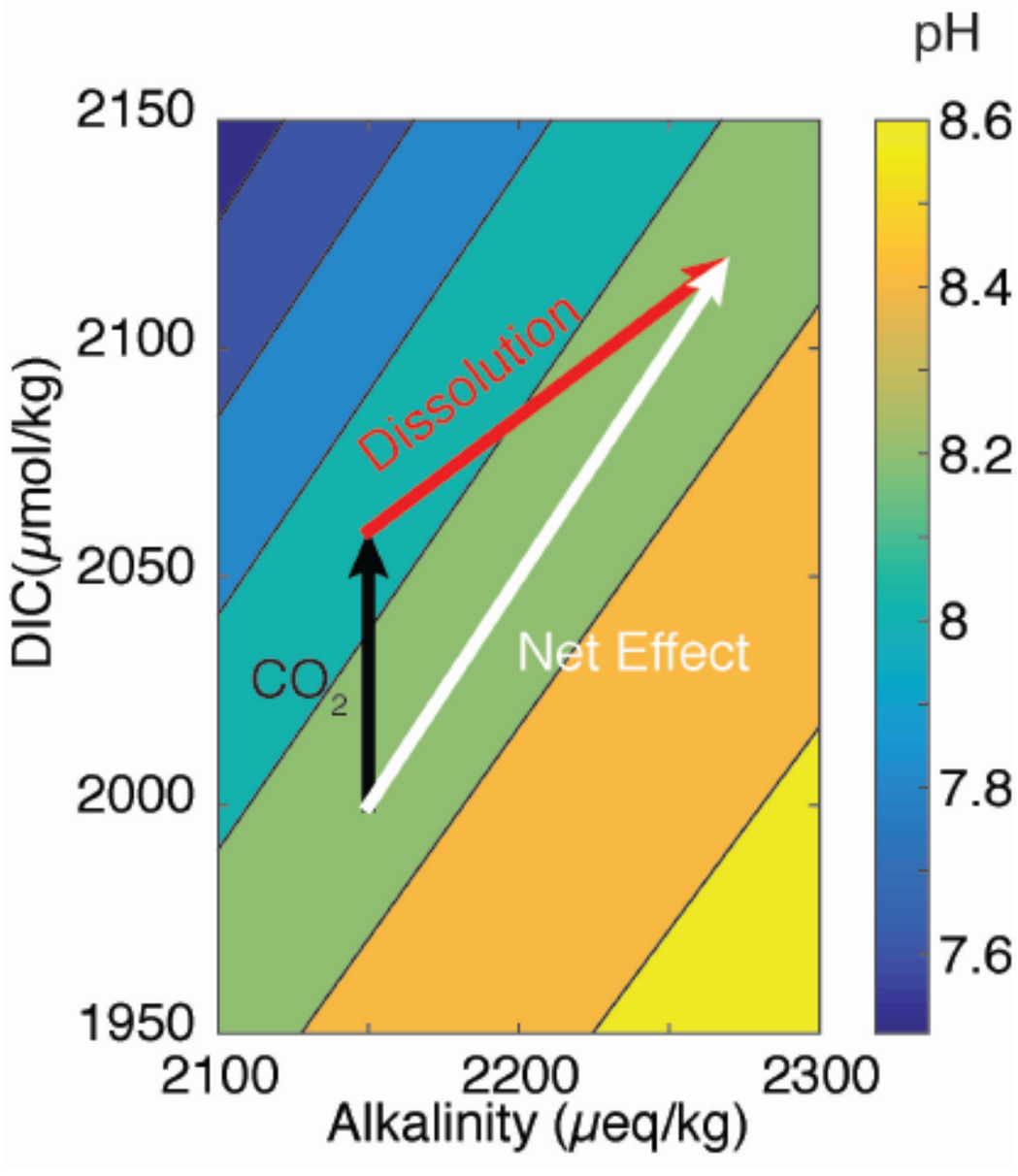
$CaCO_3$ Conveyor

$36.81/ton CO_2, limestone cost of $24.93/ton CO_2 and $11.88/ton rock rail transport 150km away

all assume $0.05/kwh for power

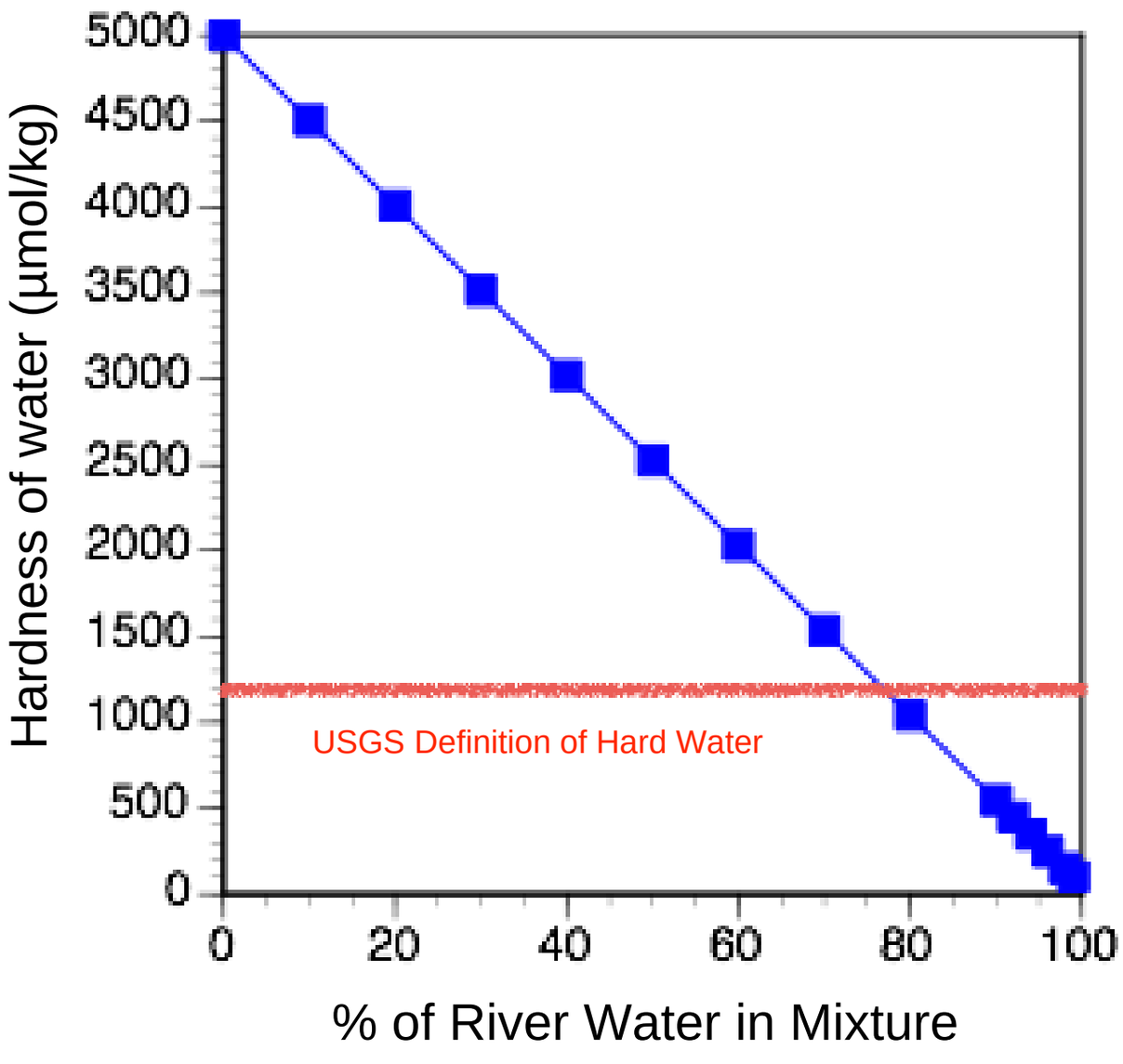
How will our effluent interact with the ocean/river?

Seawater Version of No Harm



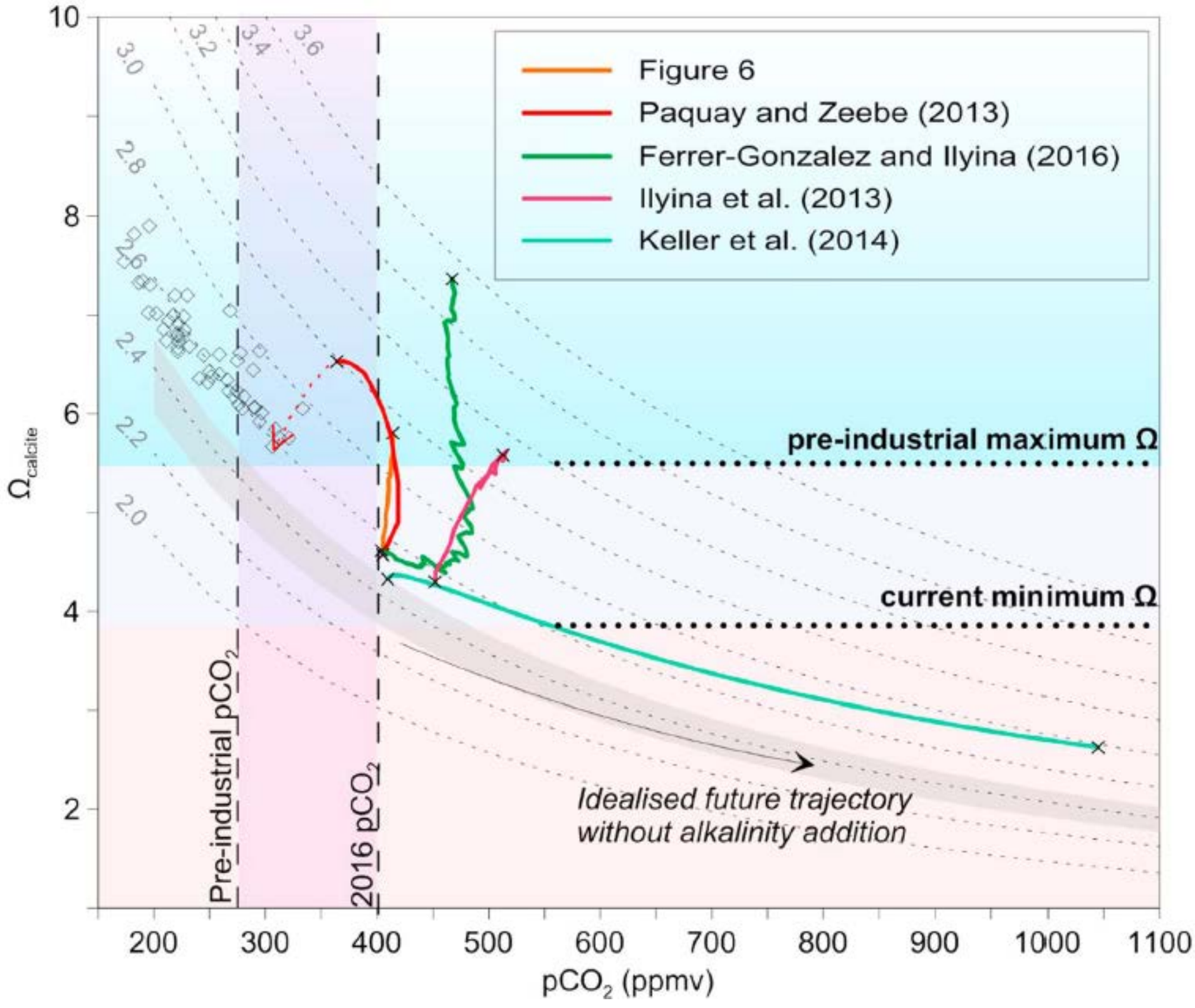
Freshwater Version of No Harm

‘Hard Water’ is our product.



USGS classifies anything below 60mg $CaCO_3$/L as soft. This is 1200µeq/kg alkalinity. We are going to make water of ~5000µeq/kg so a 5:1 dilution factor will put us into the ‘soft’ water category.

The ocean has a vast capacity to take up the effluent



Renforth and Henderson, 2017