

Carbon Sequestration in Oceanic Crust: Preliminary Experimental Simulations

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Today's Talk

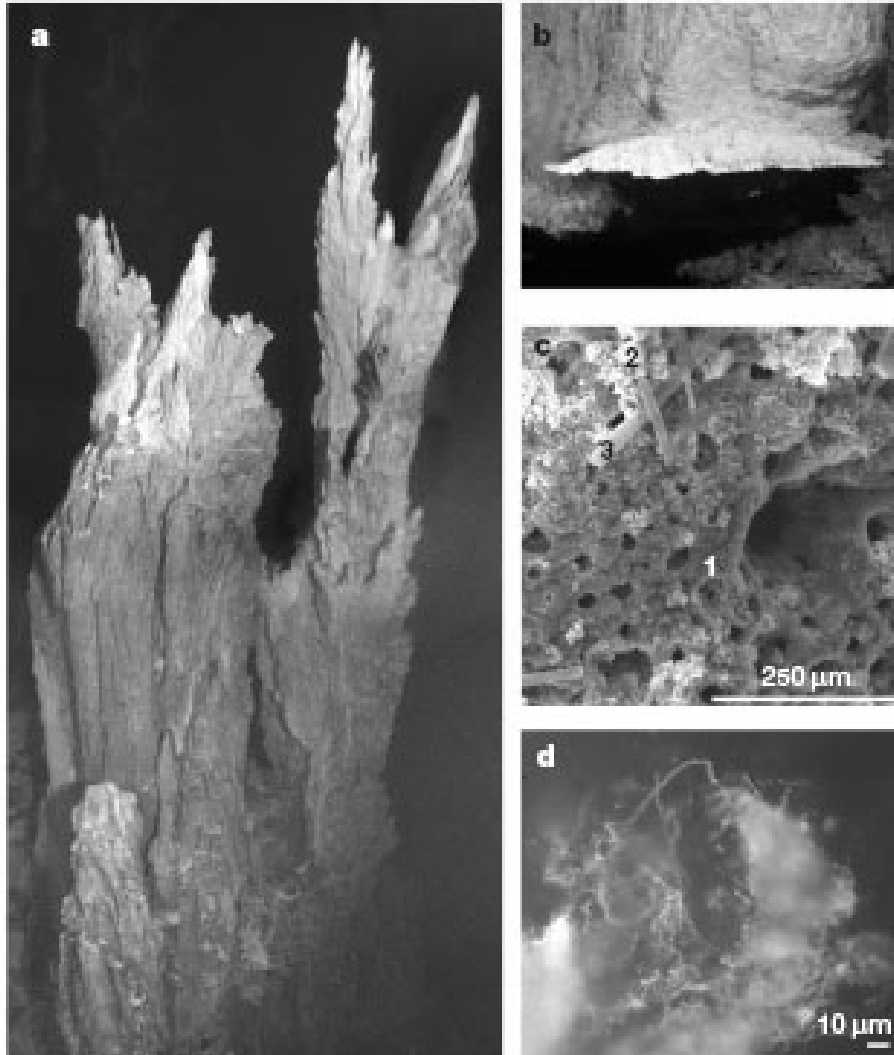
First commercial geologic CO₂ sequestration was Sleipner project in the North Sea, targeting sub-sea clastic sediments

Would injection into oceanic crust be feasible for CO₂ sequestration? Out-of-the-box thinking for future options!

Experimental perspective of CO₂-peridotite-seawater reactions

- **Published experimental studies as baseline**
- **Aqueous and mineralogic effects**
- **Implications for sequestration**

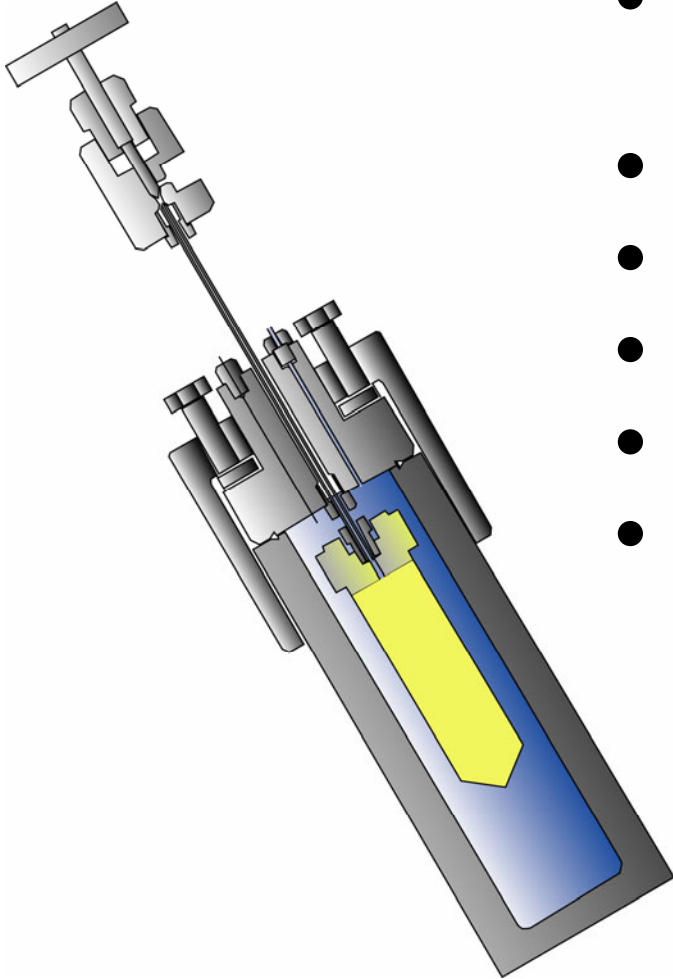
Alkaline Seafloor Hydrothermal Systems



- Carbonate vent chimneys
- Fluids vented at 40°-75°C, pH 9.0 to 9.8
- < 1000 meters water depth

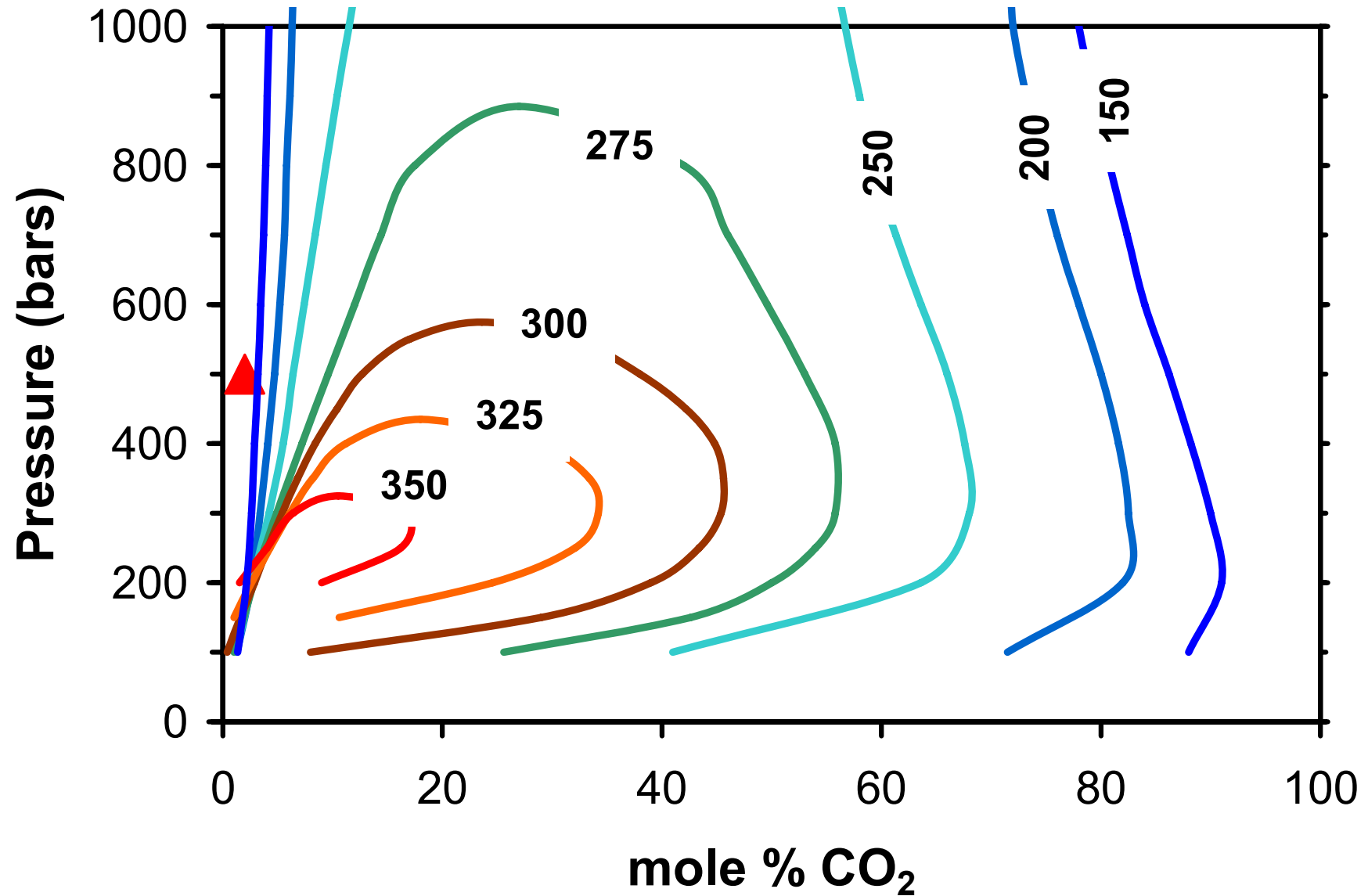
(Lost City Field,
Kelley et al., 2001)

Experimental Approach

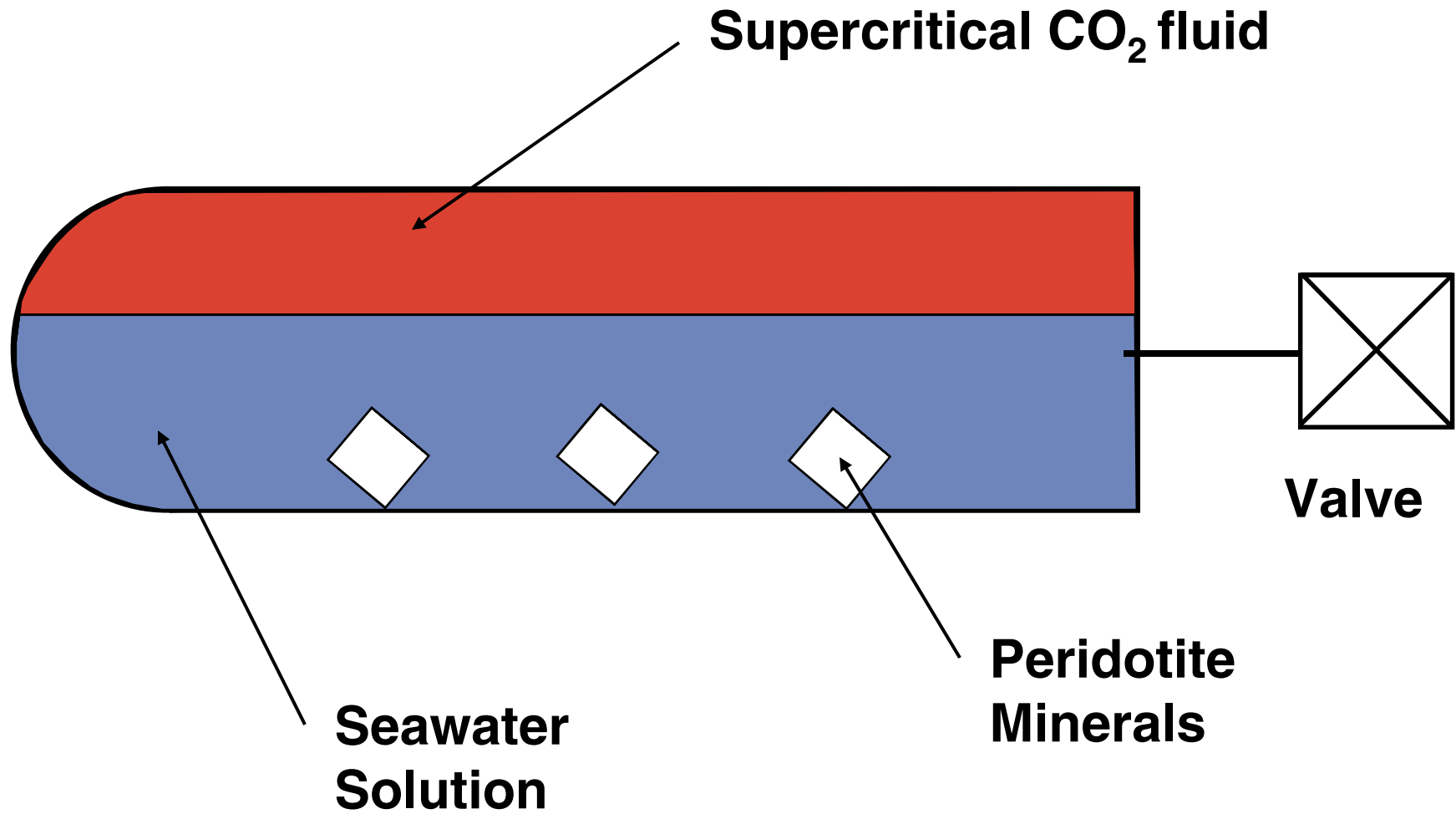


- **Rocking autoclave with flexible cell hydrothermal apparatus**
- **300°C and 500 bars**
- **Rock = Lherzolite**
- **Fluid = Synthetic Seawater**
- **Brine:Rock \cong 10:1**
- **Experiment procedure**
 - **Brine + rock for 38 hours**
 - **Inject 2 mol% CO₂ into ongoing reaction, react additional 530 hours**

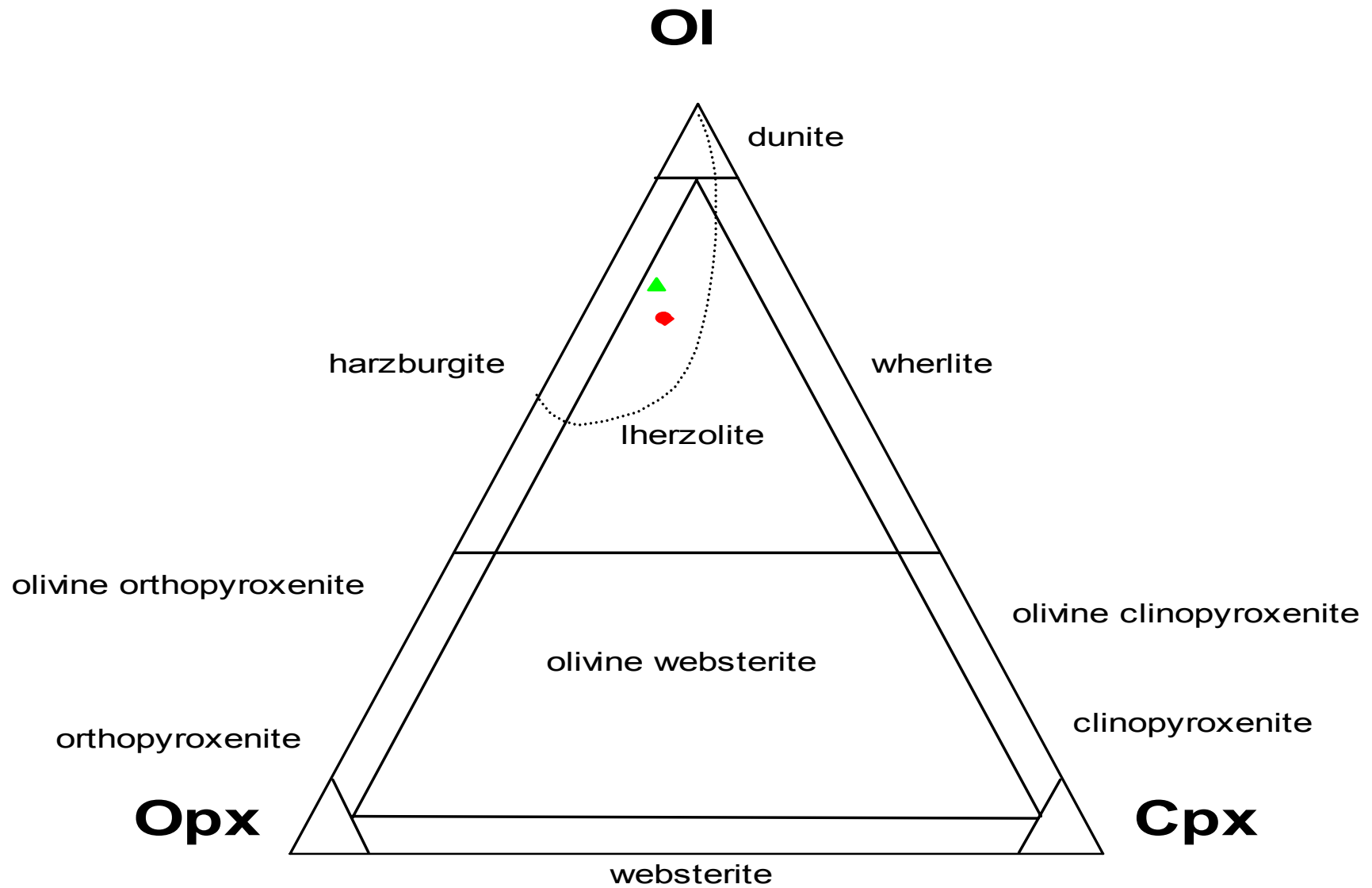
Phase Compositions, System H₂O-CO₂



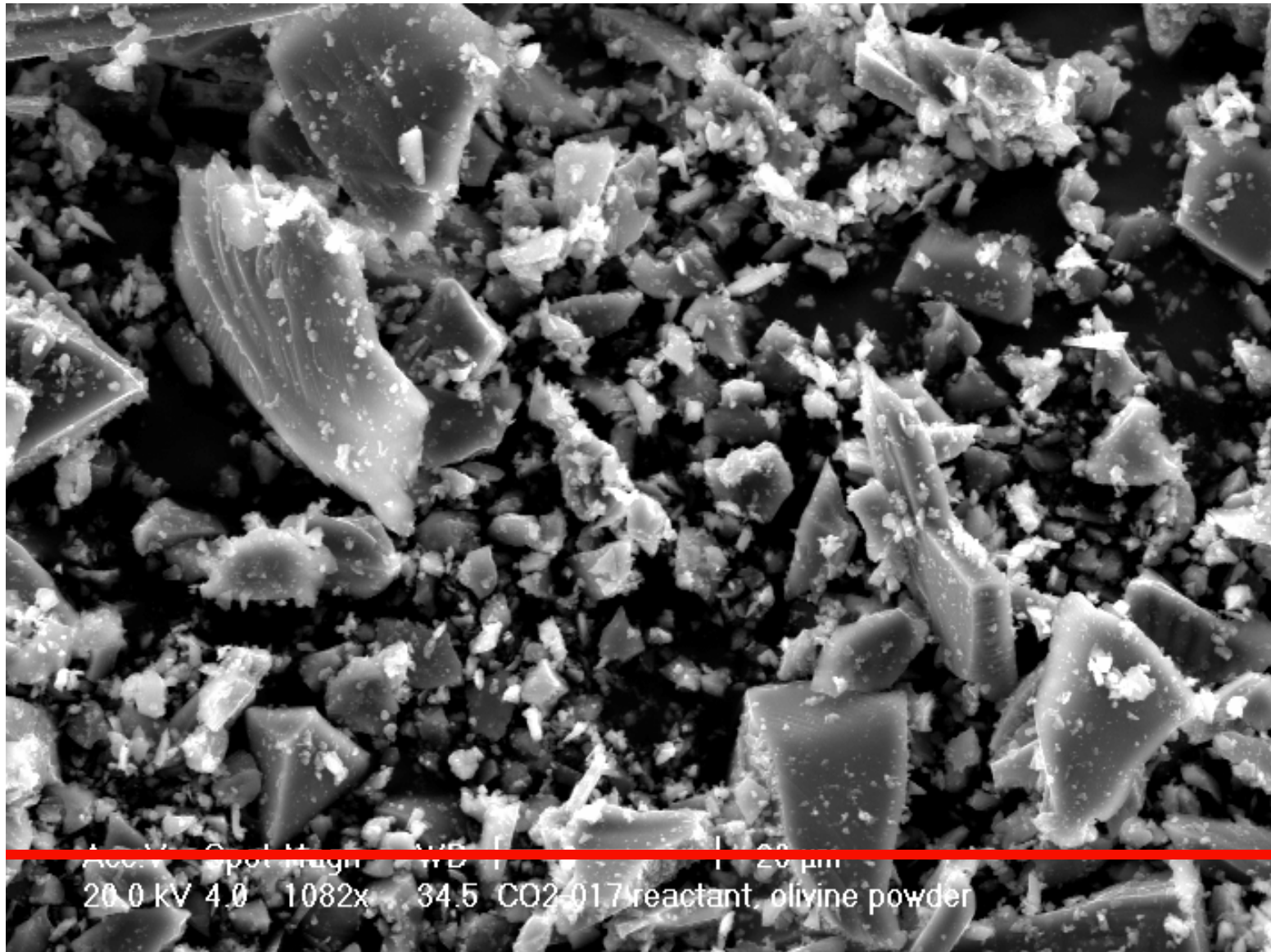
Experimental Approach



Peridotite

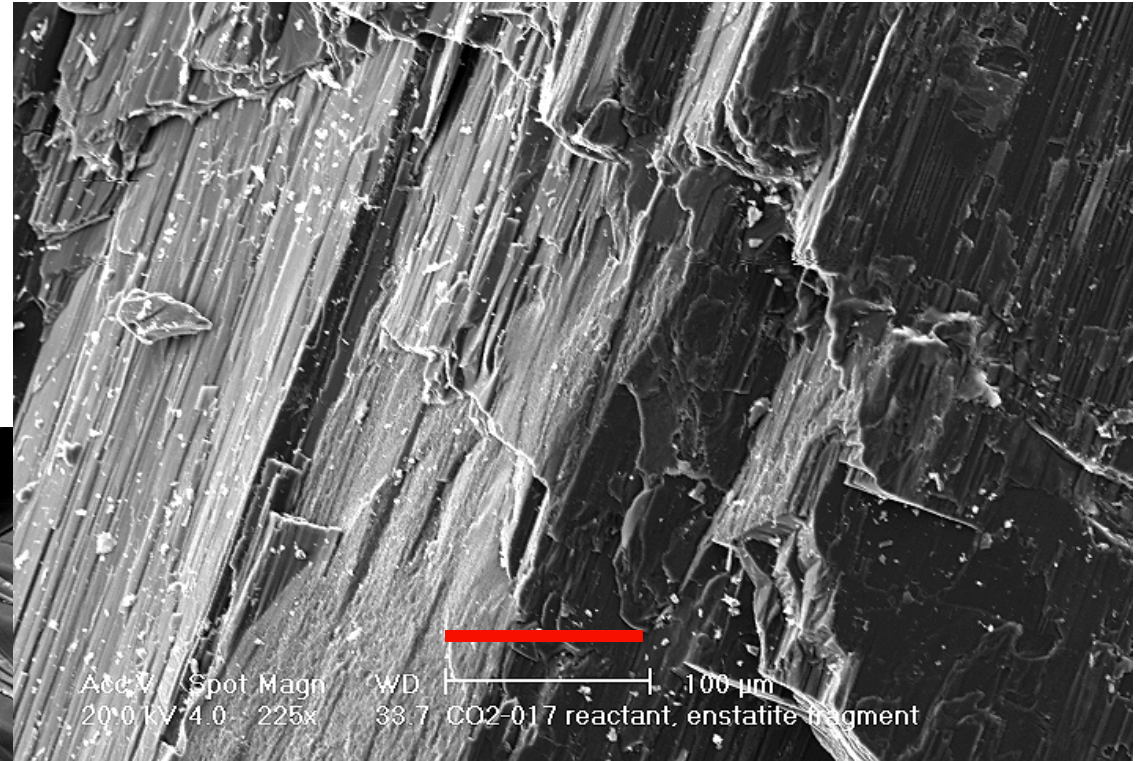
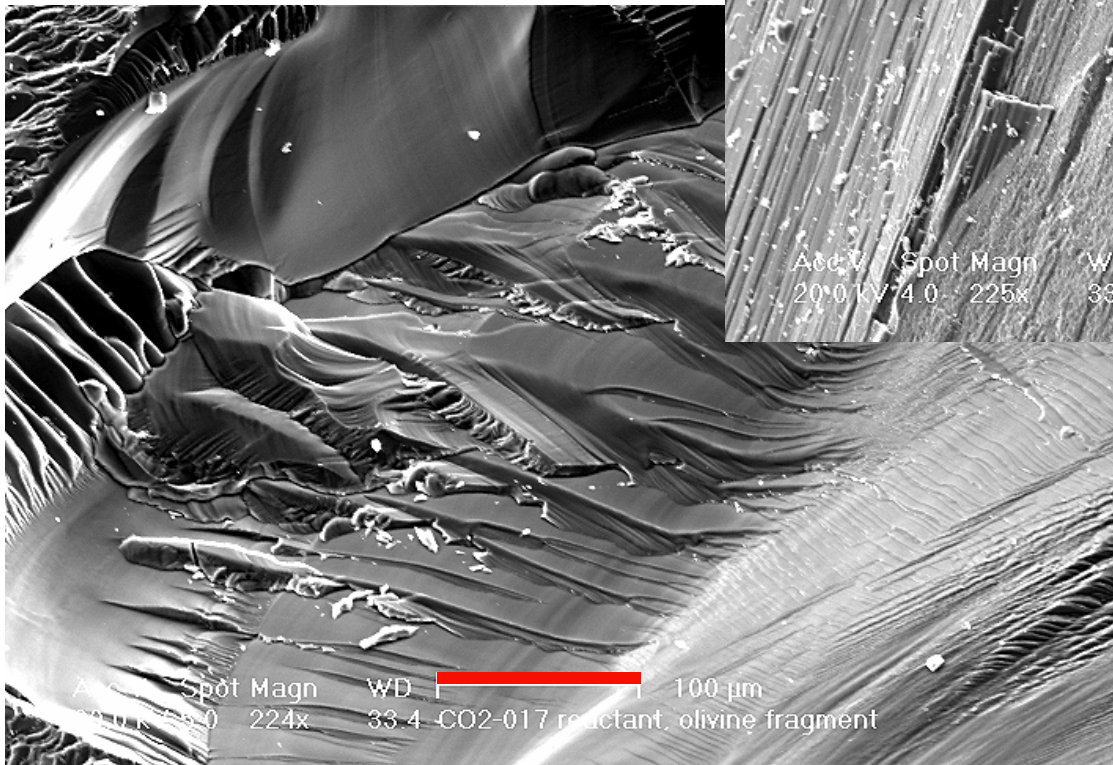


Powdered Peridotite as Reactant



Mineral Reactants (Fragments)

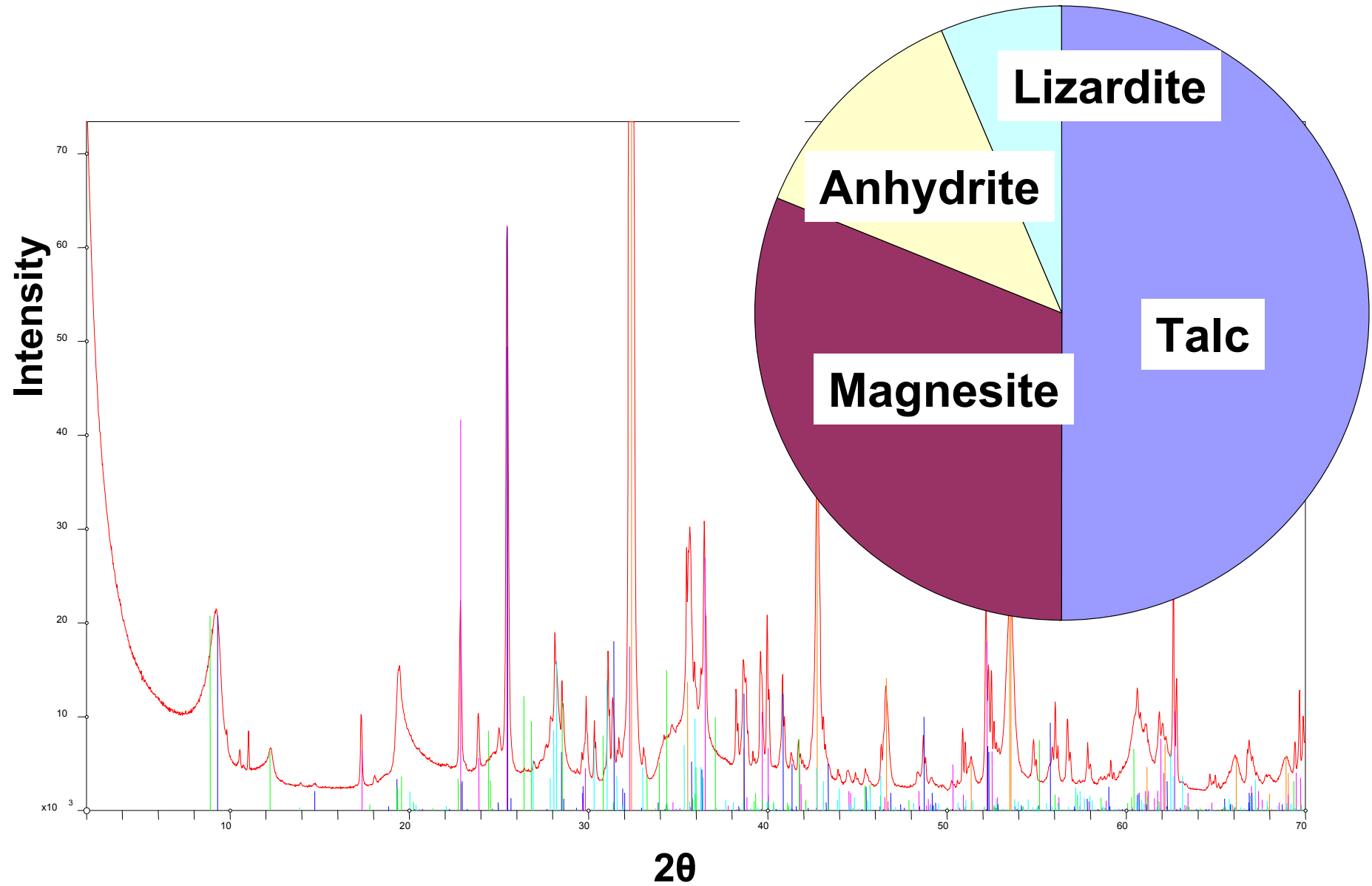
Olivine



Enstatite

Mineral Products

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Slide 10

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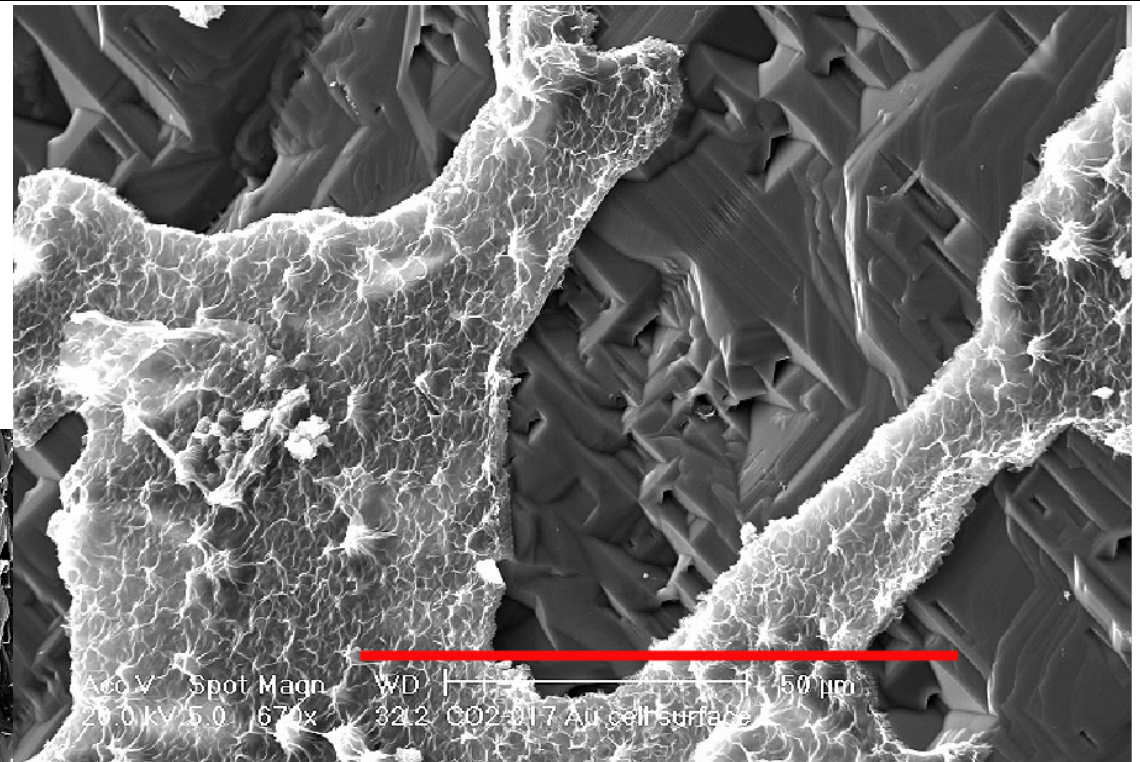
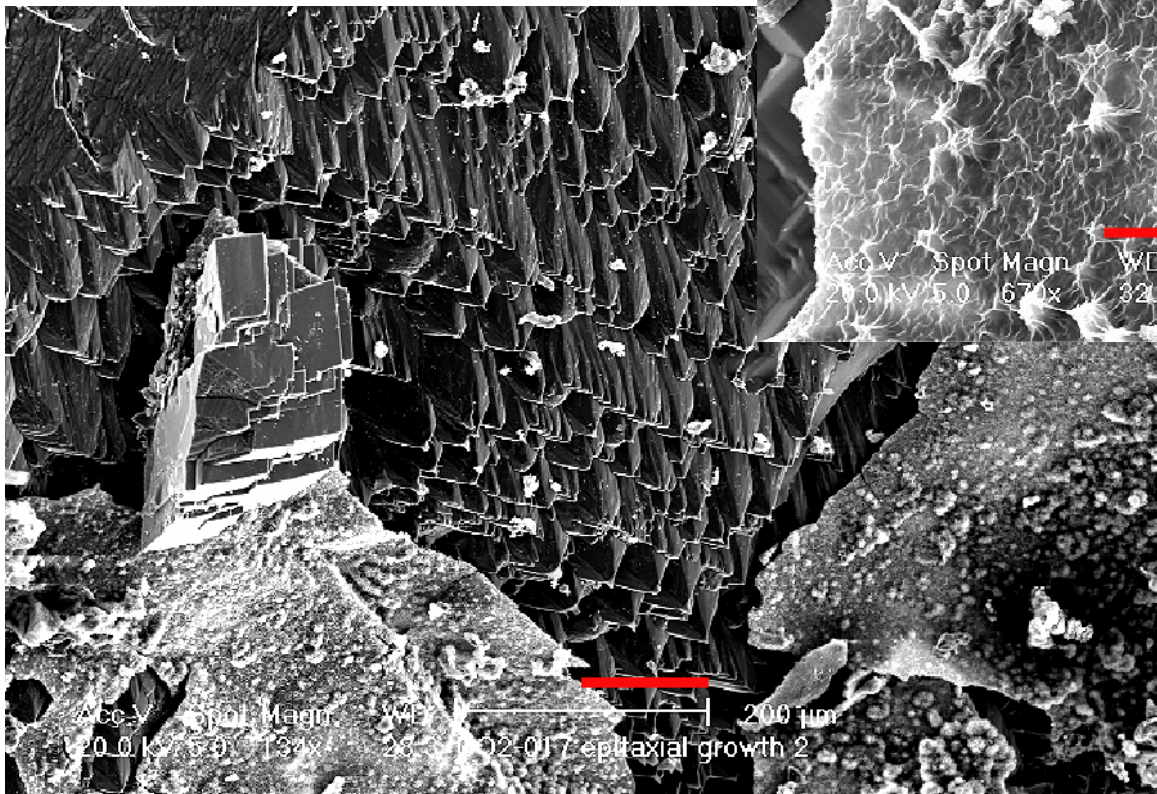
Do you want this slide?

what are your thoughts? If we keep it, would have to do some editing (cover text at upper right with blank text box; same with title on top).

JPK, 10/18/2006

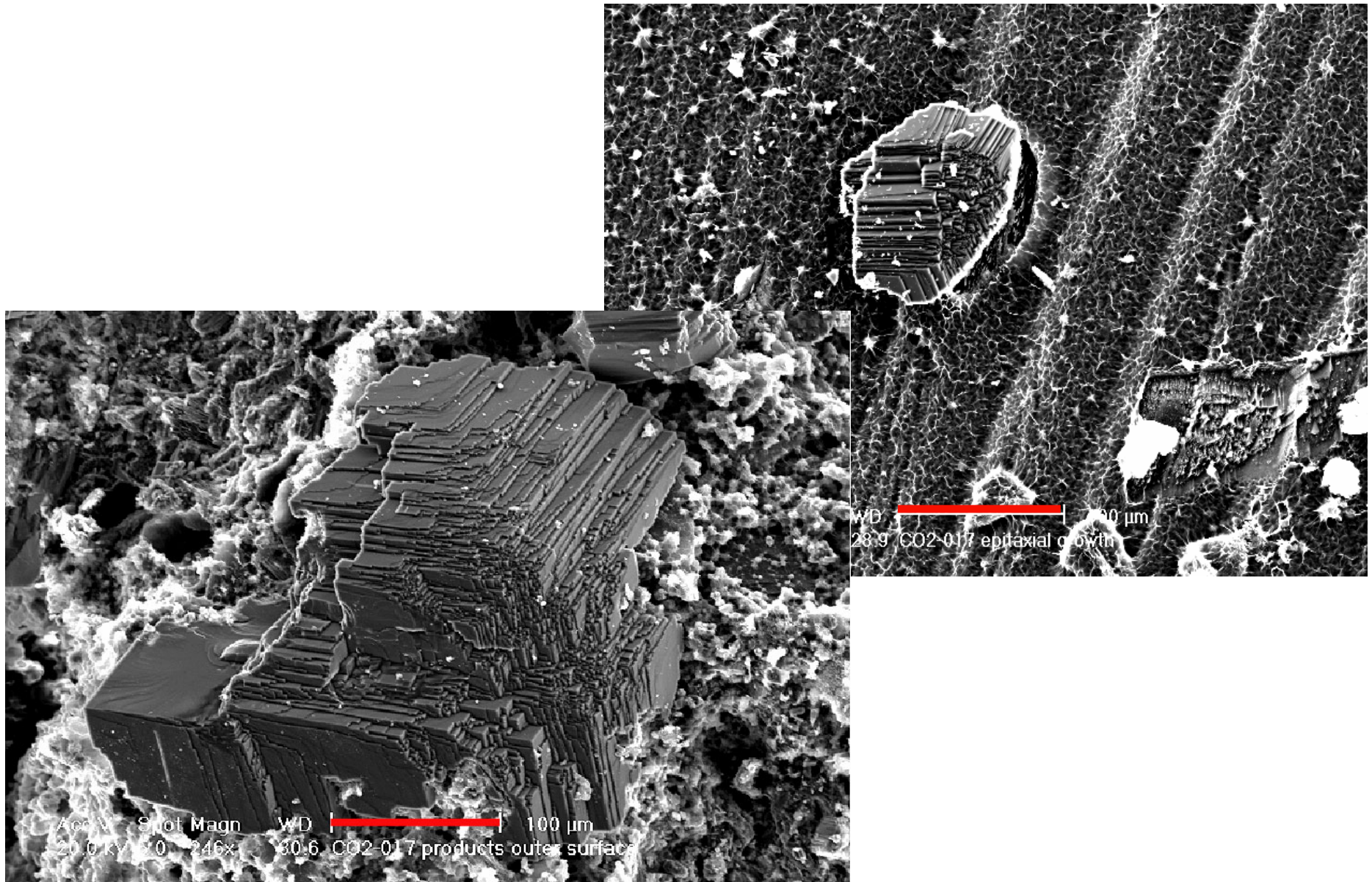
Reaction Textures (Dissolution/Precipitation)

Olivine

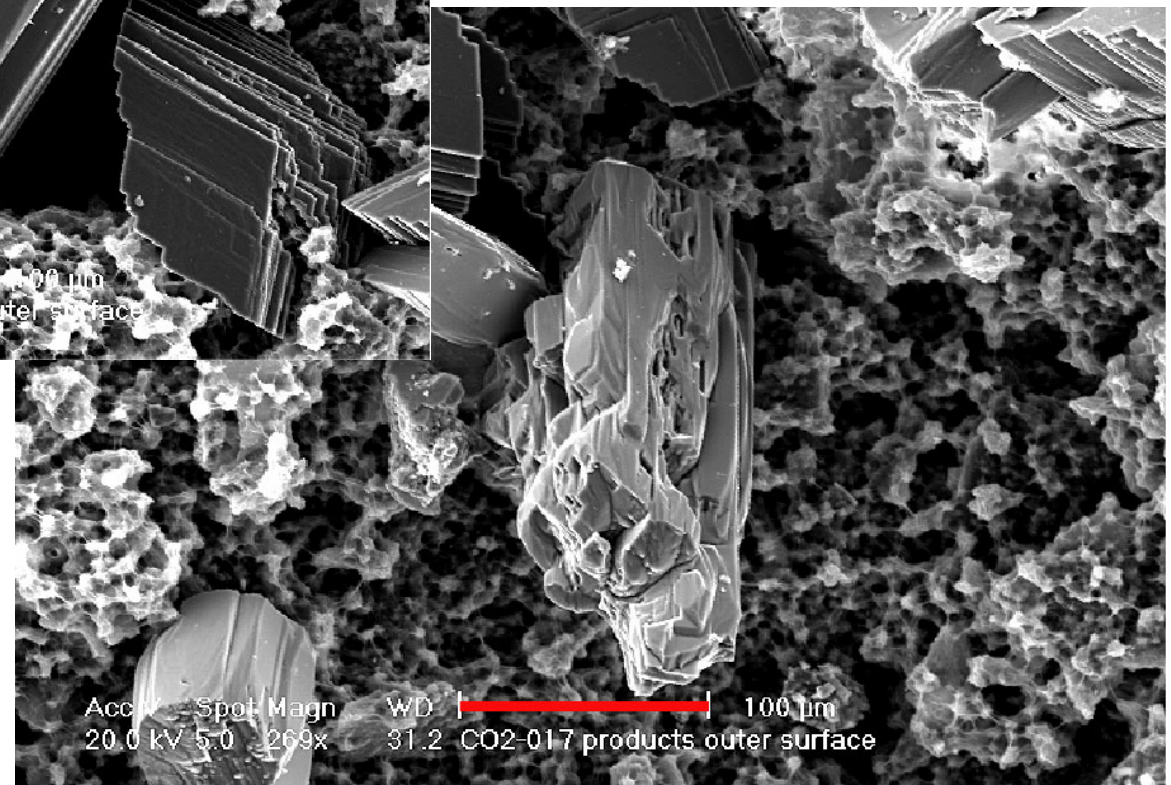
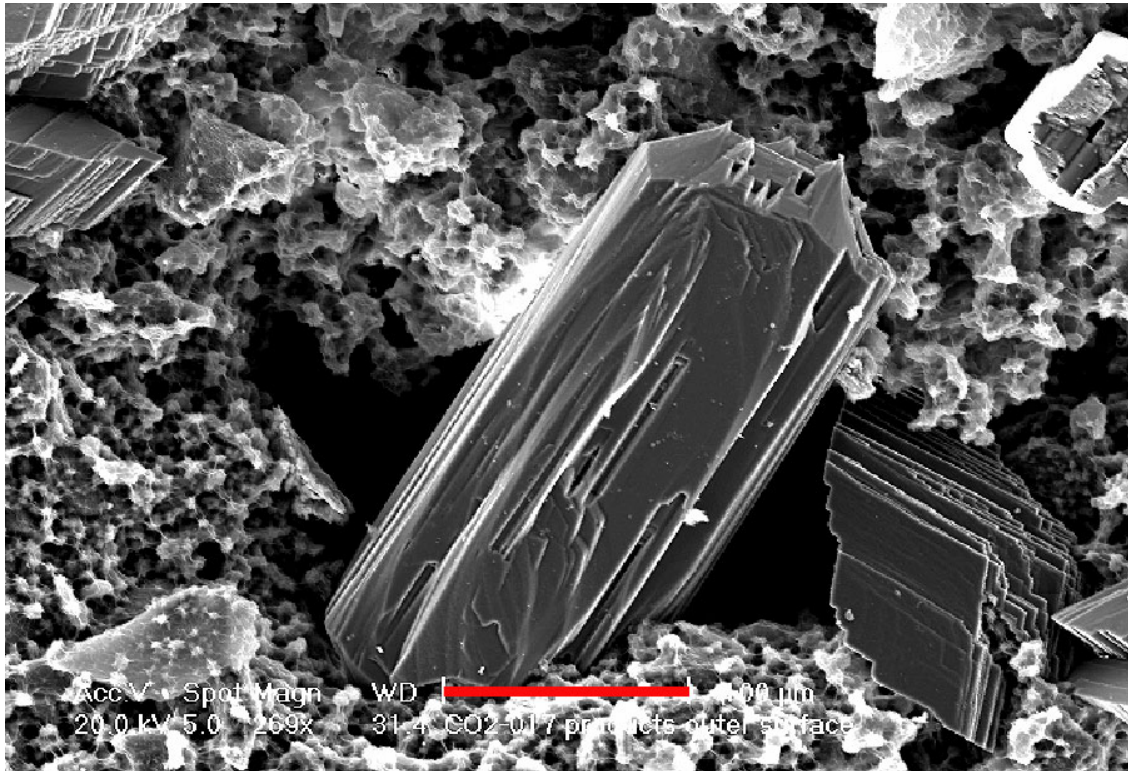


Enstatite

Euhedral Magnesite Precipitation

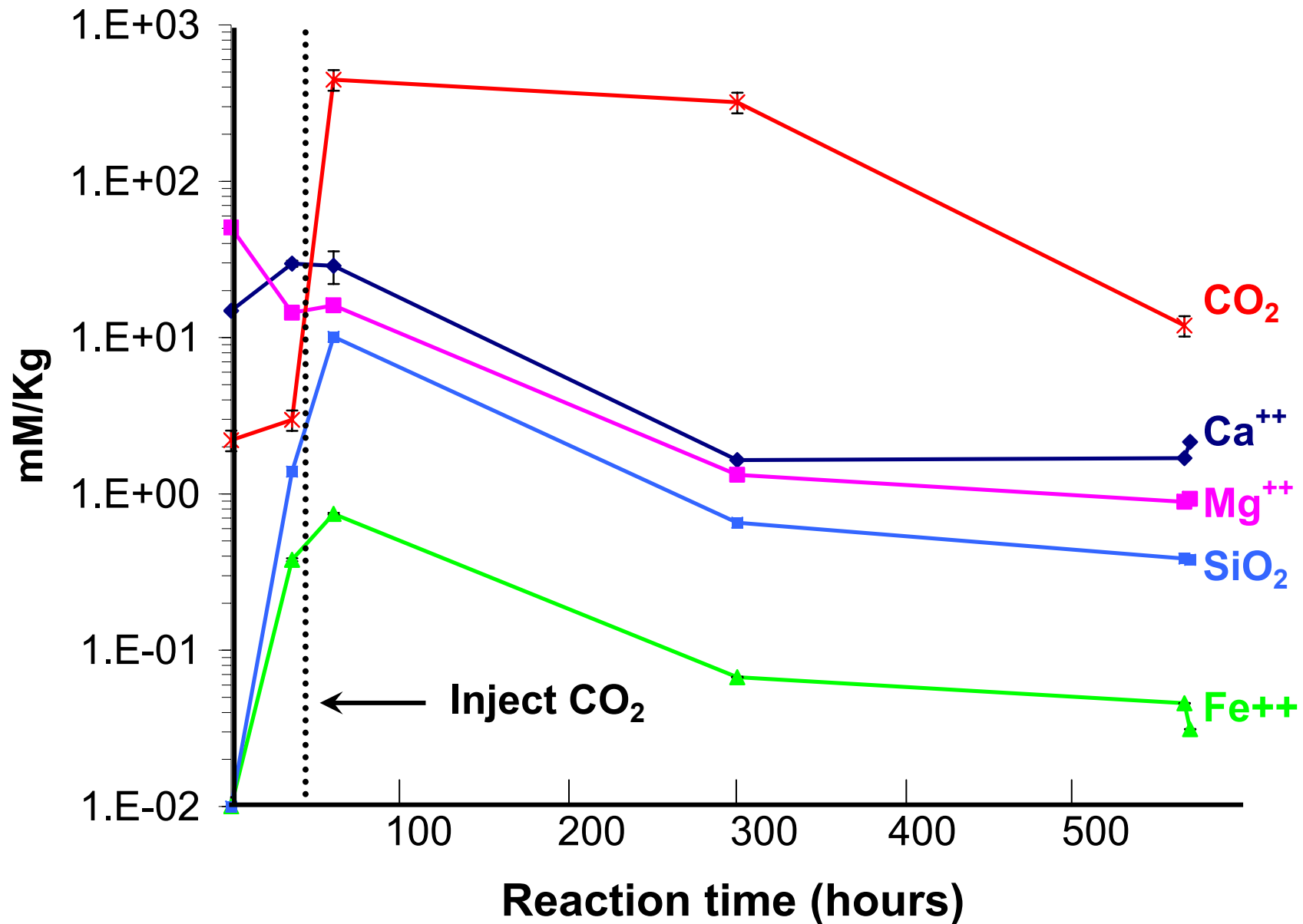


Euhedral Anhydrite Precipitation



Aqueous Fluid Chemistry – Cations and CO₂

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These seemed like the most suitable ions.

think about what you are trying to show...do these plots provide information. It's not a trick question, just want you to think about the data....

I hope it says something. It tells me that brine rock reaction generally increased the cation concentration of these fluids, then these ions were consumed by mineral precipitation after the CO₂ was injected. Mg is tricky tho. It is consumed during b-r reaction as well as b-rco₂.

In general, I think that b-r results in peridotite dissolution (the mg is masked by early talc formation?) and CO₂ injection provides suitable anion for ppt. (silicate precipitation would have resulted instead if not for CO₂ inj?)

I wasn't able to move the axis from the middle to the bottom of the chart. I will delete and draw one free hand if you don't know of any tricks.

go to format axis; go into scale tab; change value x axis crosses at from 0 to .001 or some small number.

I tried this before and after sending it to you and again after I changed the y-axis to exp format. I don't know why it doesn't work. So I just re-drew it free hand.

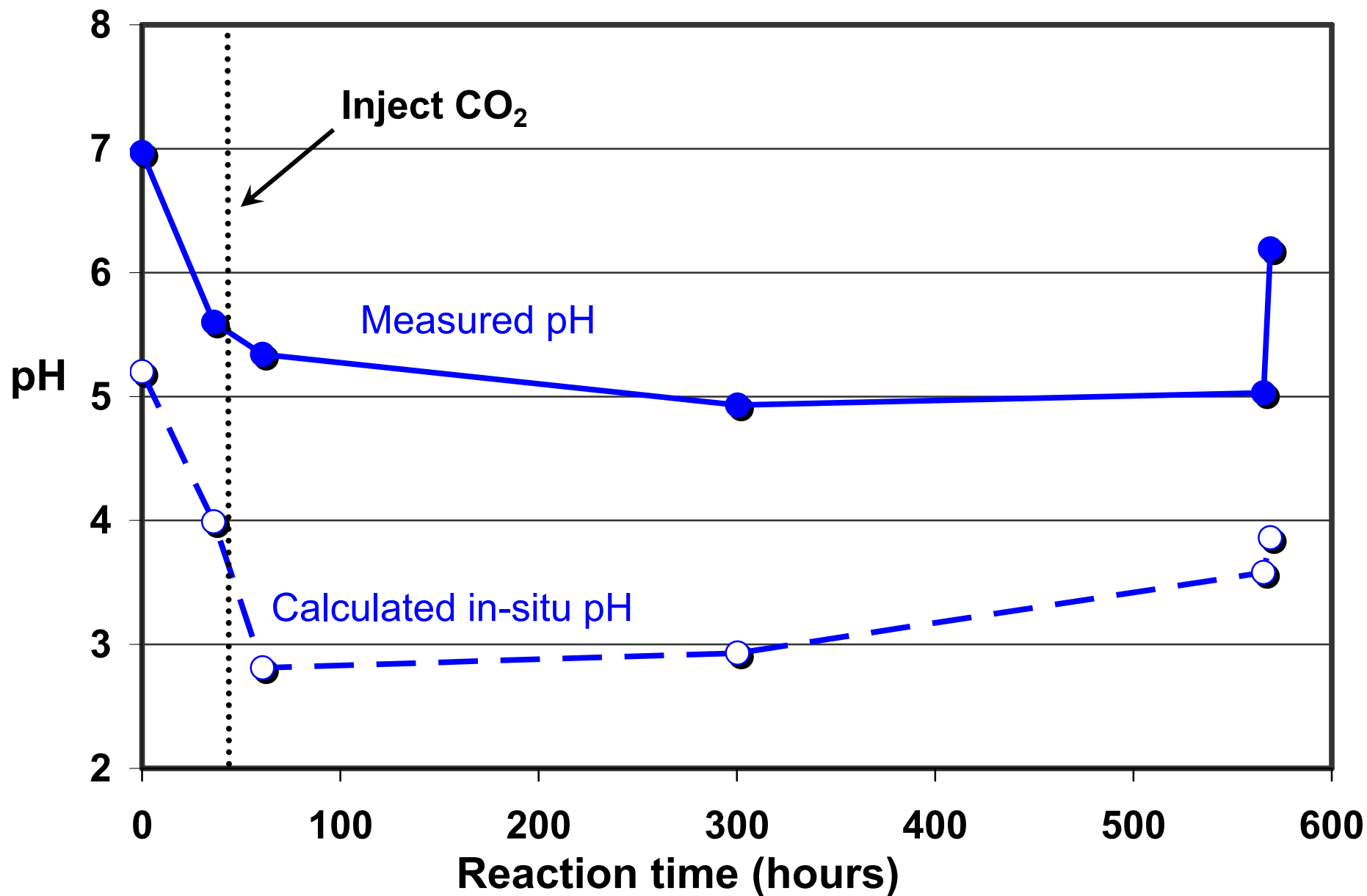
Also, with the log plot, I eliminated all the zeros in the data set, and yet I still get an error message from Excel that log plots cannot handle negative/zero numbers. So it plots everything less than one as zero, instead of 0.1, 0.01, etc. Sage advice?

it'll plot, you just need to change decimal places for number to a proper value, or use exponential format. Both options are in "number" tab for format axis

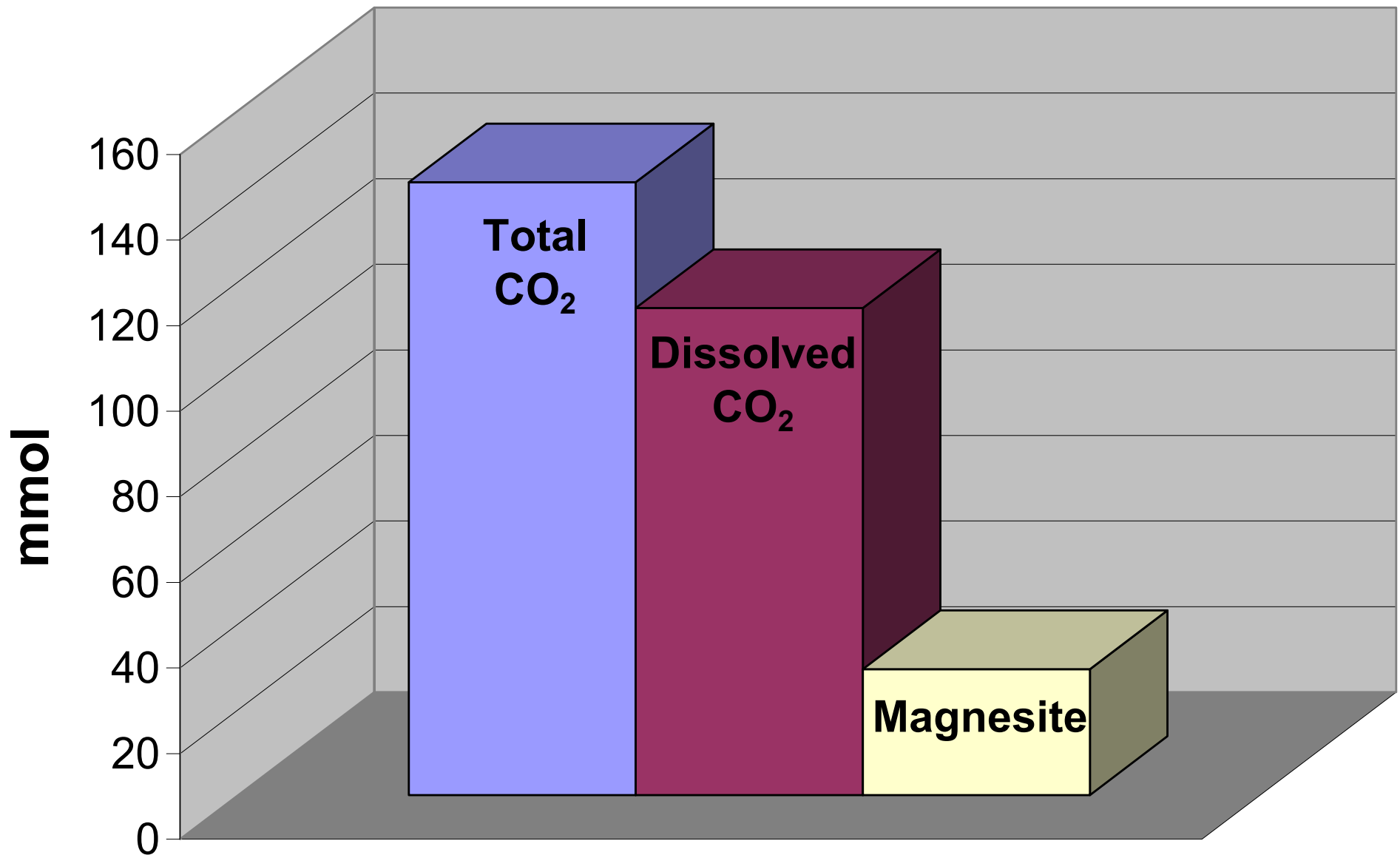
Seems to have worked.

JPK, 10/21/2006

Aqueous Fluid Chemistry – pH



Disposition of CO₂



Conclusions

- 1. Add supercritical CO₂ to ongoing seafloor-seawater reactions**
 - a) CO₂ pressure and aqueous CO₂ concentration decreases**
 - b) Magnesite (MgCO₃) crystallizes**
- 2. Supercritical CO₂ also produces reactive complexities**
 - a) Anhydrite (CaSO₄) crystallizes and subsequently dissolves**
 - b) Talc, not serpentine, is principal alteration product**
- 3. Ongoing calculations**
 - a) Mg vs SiO₂ activity (talc alteration rinds)**
 - b) Mass balance & sequestering reactions**

Acknowledgements

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Carbon Sequestration in Oceanic Crust: Preliminary Experimental Simulations

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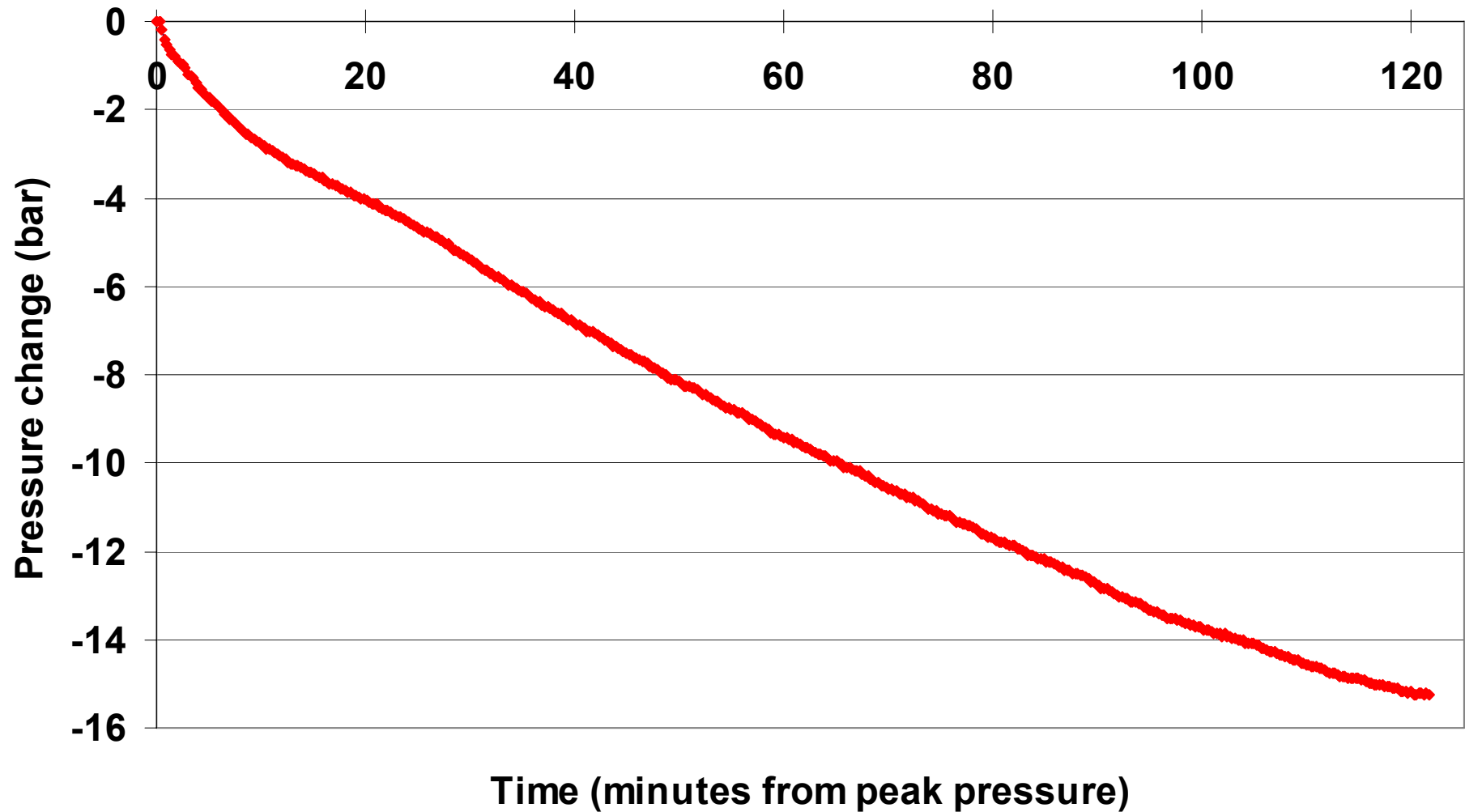
Direct injection of CO₂ into oceanic crust may be a viable means of sequestering anthropogenic carbon. To evaluate this hypothesis, experiments were conducted in flexible cell hydrothermal apparatus on seawater-lherzolite-CO₂ systems. These experiments simulate CO₂ injection and determine the extent of brine-rock reaction with CO₂. Synthetic lherzolite (71.4% forsteritic olivine, 18.4% diopside, 10.2% enstatite) was reacted at 300°C and 500 bar in synthetic seawater to approach steady state, then injected with supercritical CO₂ (2 to 4 mol percent) and reacted for ~550 hours.

Brine-rock reaction with CO₂ decreases pH from 7.4 to ~5, consumes ~50 mMol of aqueous magnesium and nearly all aqueous sodium and potassium. Calcium concentrations decrease (~1 to 2 mMol) following CO₂ injection, whereas magnesium concentrations rebound (~1 mMol), as do the silica concentrations (3 to 7 mMol), both likely a result of increased brine acidity. Significant dissolution of olivine and pyroxenes occurred as shown by pitting and etching of the mineral surfaces. Mineral powder reactants have been extensively reacted to talc and mineral fragments developed talc overgrowths. Extensive precipitation of rhombs of magnesium carbonate (magnesite) and needle-like laths of calcium sulfate (anhydrite) occurred on the mineral reactants and on the inner surfaces of the reaction cell. The experiments exhibited a gradual pressure decrease following CO₂ injection (27 bars) as a result of dissolution and mineralization of CO₂. CO₂ dissolution and concomitant formation of magnesite indicates that direct injection of CO₂ into oceanic crust may be a viable means of sequestering anthropogenic carbon.

Extra Slides



Change in Pressure after Injection of CO₂ TC11



Slide 21

TC11

Since this is only one phase, it makes me wonder about how long it takes to reach steady state as one phase. If you think the slide may be useful, I will fix it on Monday.

What do you think?

I think that this pressure drop is still representative of CO₂ dissolution of CO₂ into the fluid. What else would be causing it? Just because there will only be one phase at equilibrium, doesn't mean that there is one phase immediately upon CO₂ injection. There must be 2 phases for at least 120 minutes or so.

If we keep this slide, it will need to be improved as follows:

1. Time should be on bottom axis
2. larger font for axis labels

I'm not sure what the take home message will be. Let's look at the whole picture (i.e., one fluid phase at steady state, or two? mass fraction of CO₂ relative to H₂O? etc.) before we decide on whether to show the pressure history.

Mineral Compositions

Phase	Mass %	Composition
Olivine	71.4%	Forsterite 89%, Fayalite 11%
Enstatite	18.4%	wollasonite 4%, Enstatite 77%, Ferrosilite 19%
Diopside	10.2%	wollasonite 52%, Enstatite 45%, Ferrosilite 3%

*All compositional values represent the mean of five separate analyses



Reaction Textures (Dissolution)

