Geochemical effects of CO_2 sequestration on wellbore cements under simulated in-situ conditions

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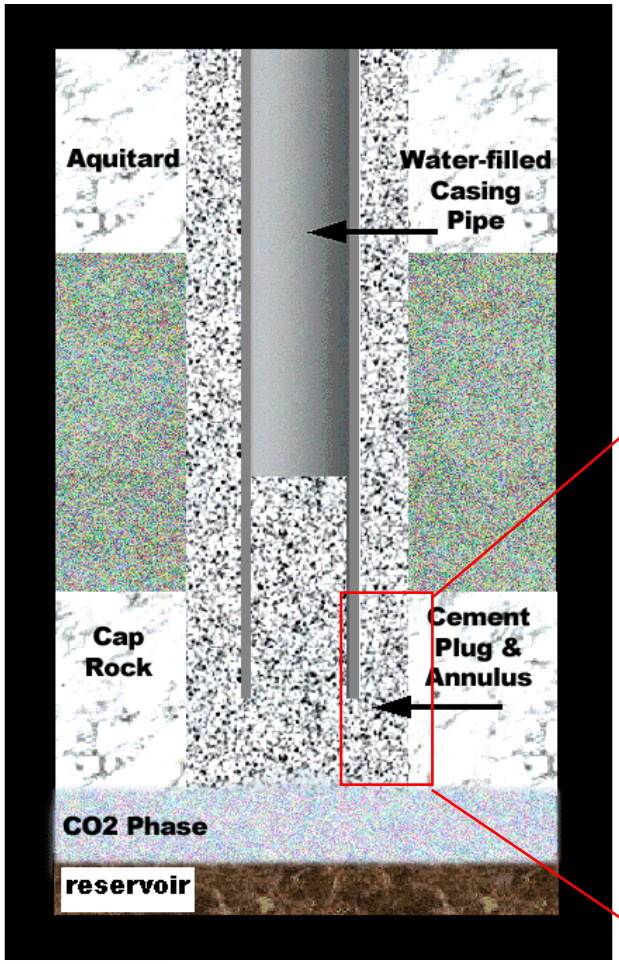
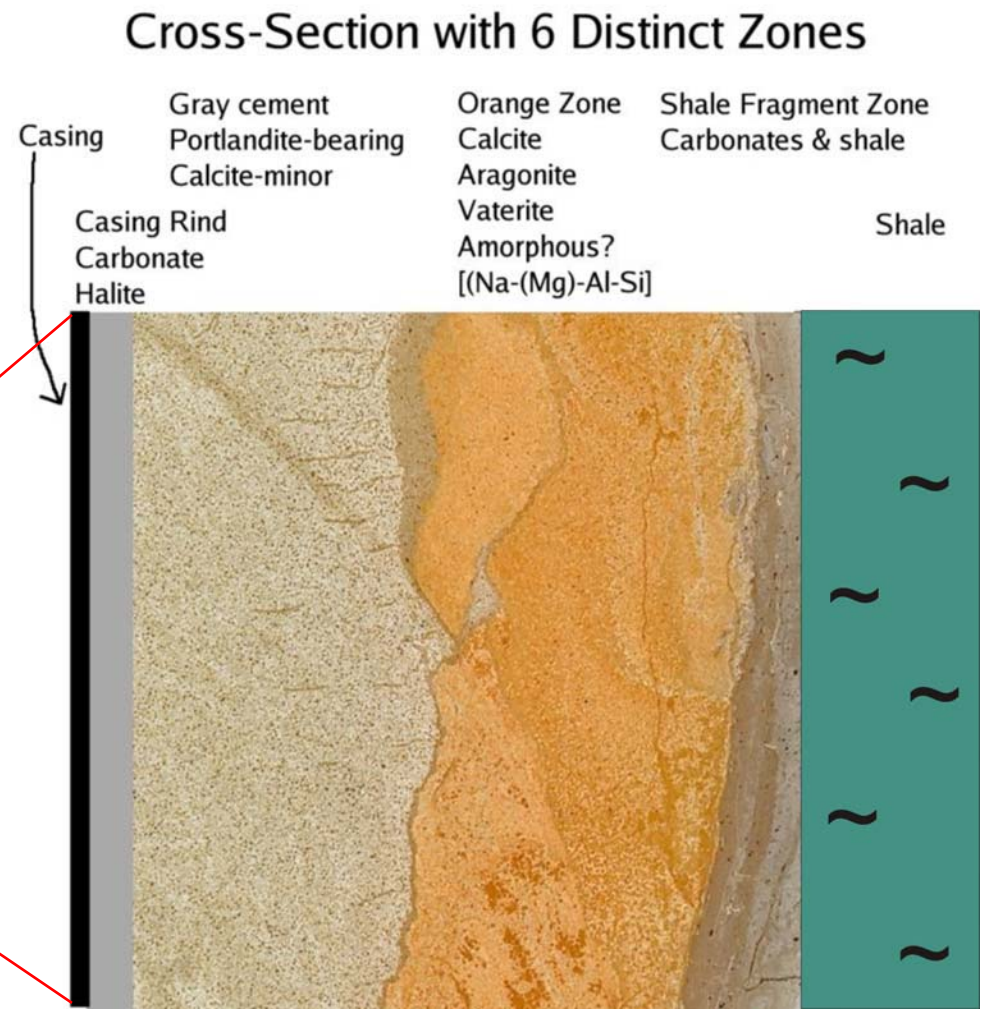
Wellbore integrity



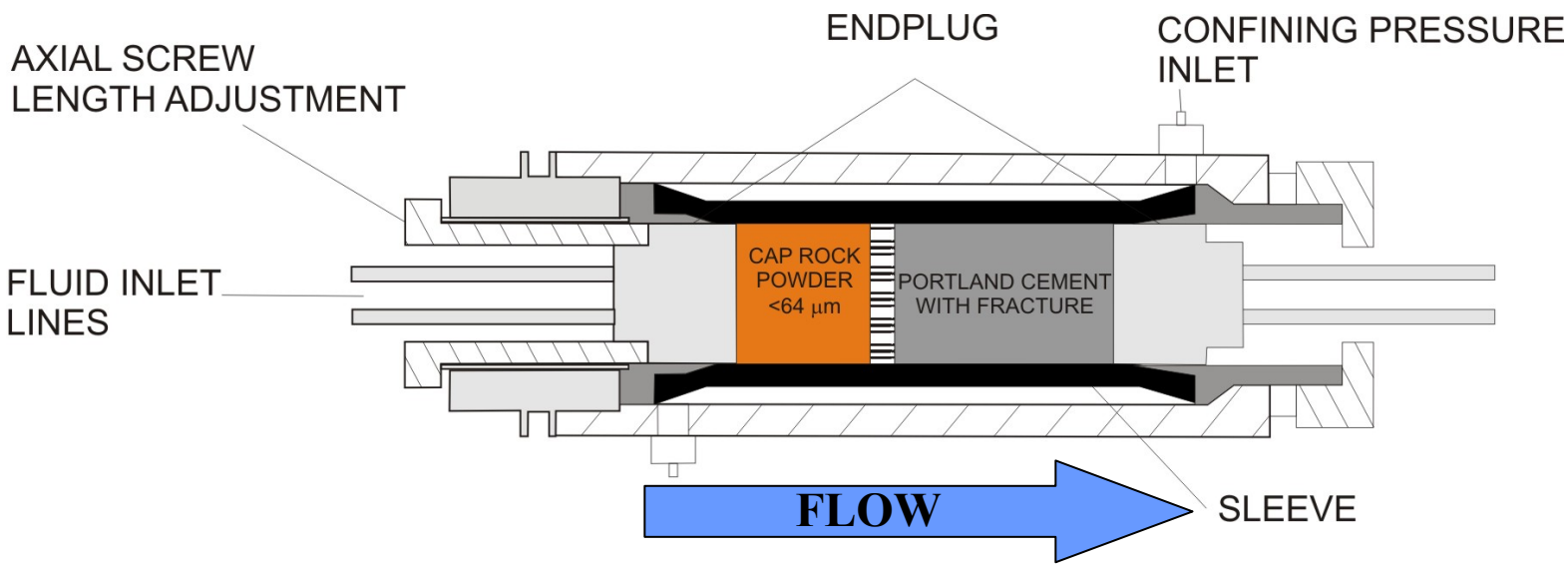
Wellbore image produced by F.B. Walton, LeNeveu Simulations Inc.



Objectives for this study

- Experimental study of the wellbore cement-cap rock-formation water-$SCCO_2$ system under in-situ reservoir conditions during carbon sequestration
- How the reaction with $SCCO_2$ does affect the geophysical properties of the cement (e.g. porosity and permeability)?
- How does fractured wellbore cement respond to a mixture of $SCCO_2$ and formation water?

Experimental setup



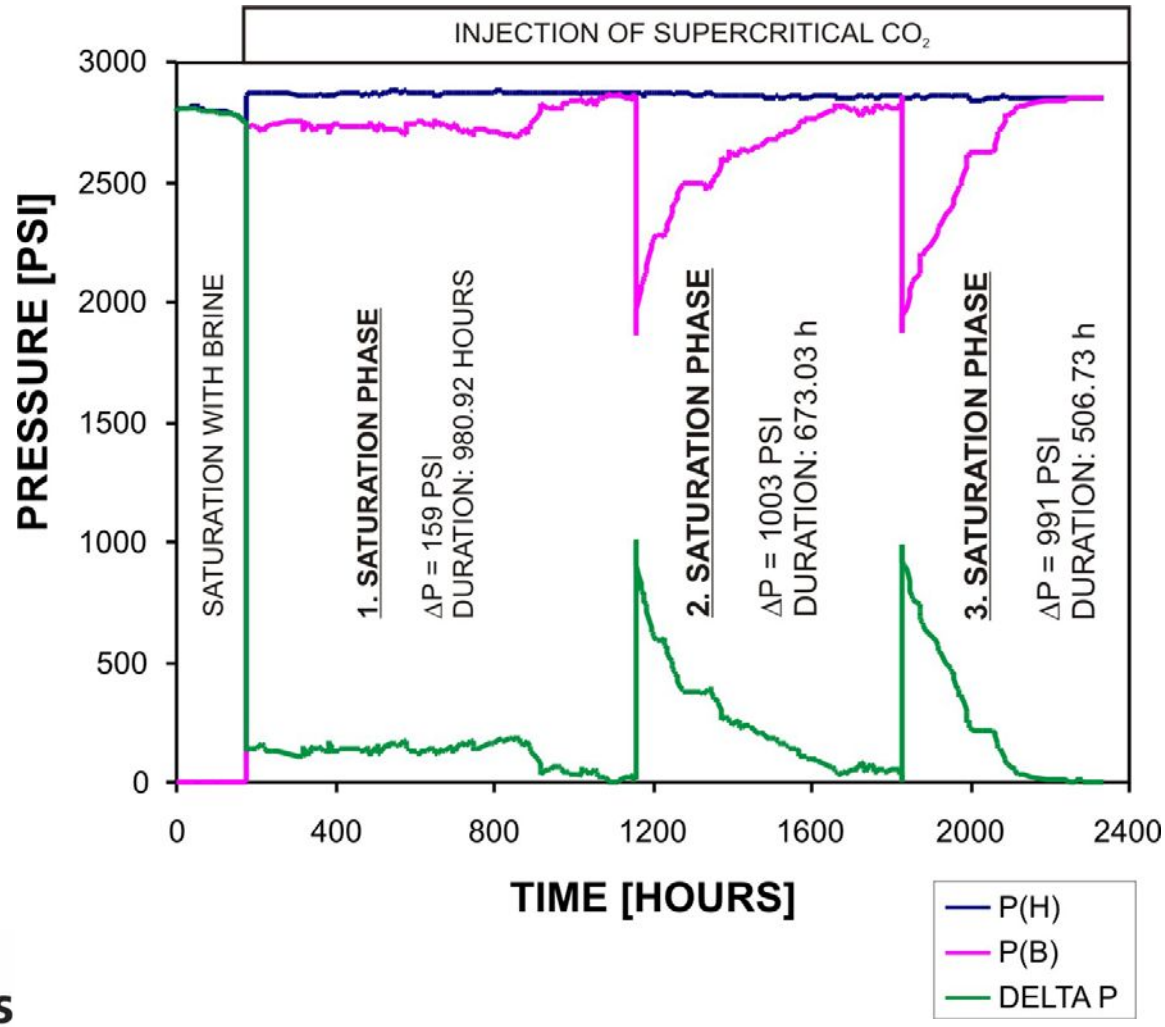
EXPERIMENTAL SETUP:

Hassler vessel
Pore pressure 2880 psi
Confining pressure 3800 psi
Temperature 54°C

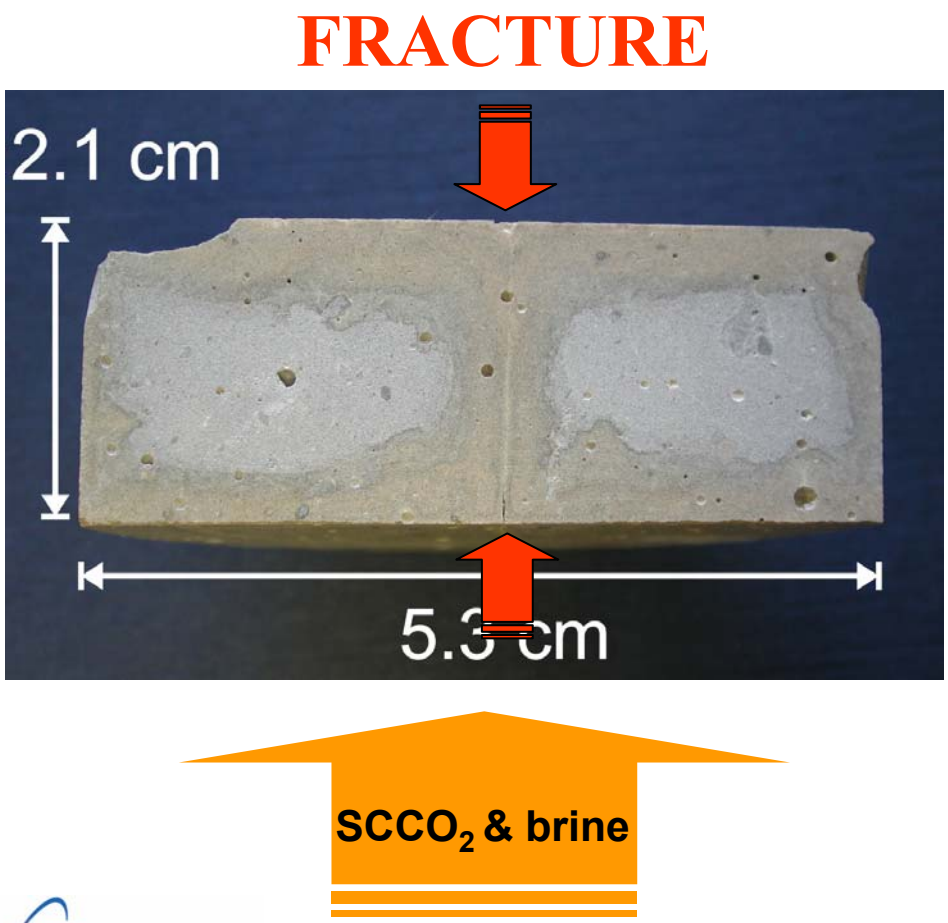
PROCEDURE

Saturation with 3 M brine over 174 hours
Injection of $SCCO_2$ over 2163 hours

Saturation and permeability evolution over time

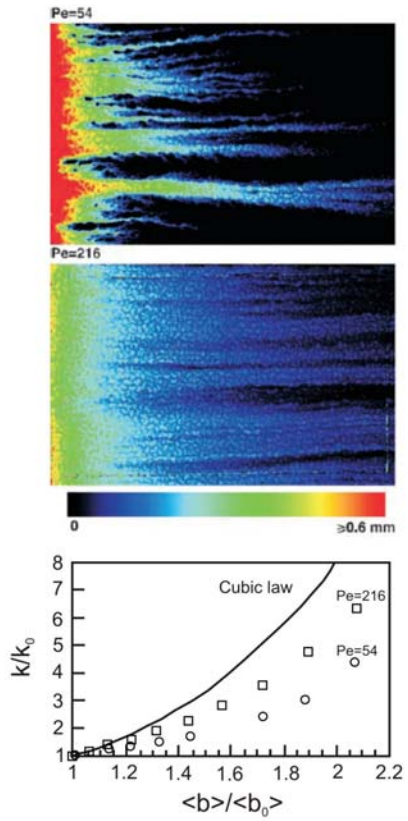


Observations after the experiment

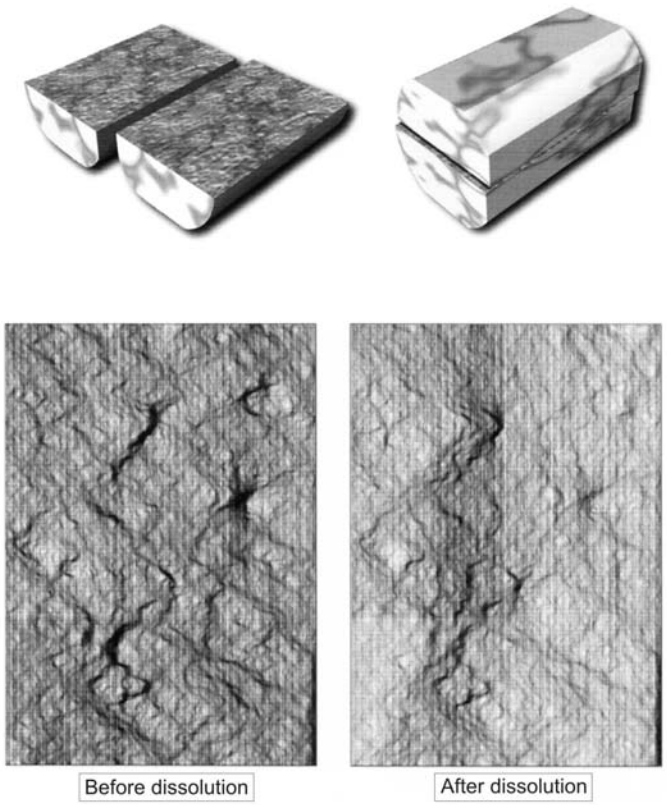


- Formation of an orange-colored and a gray-colored zone divided by a dense contact zone
- Fracture healed in parts during experiment but also opened due the reaction with $SCCO_2$ and brine

Surface phenomenon of channeling combined with dissolution in rock fractures



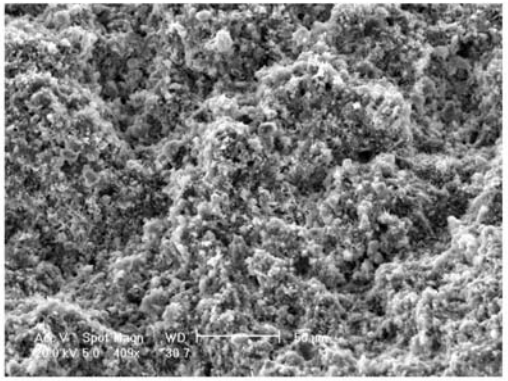
Dissolution as a result of flow along fractures (Detwiler et al., 2003)



Reactive flow along a single fracture (Durham et al., 2001)

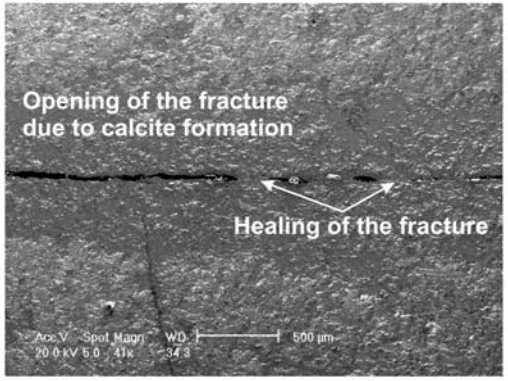
Geochemical reactions inside the fracture

Surface structure before experiment



Surface structure after experiment

Cross section of fracture after experiment



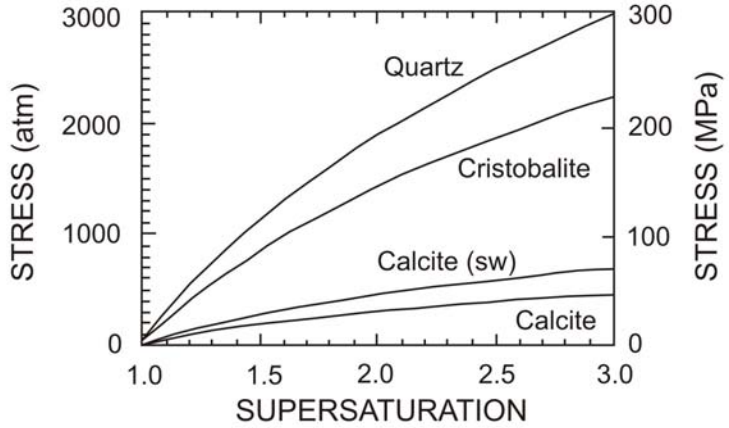
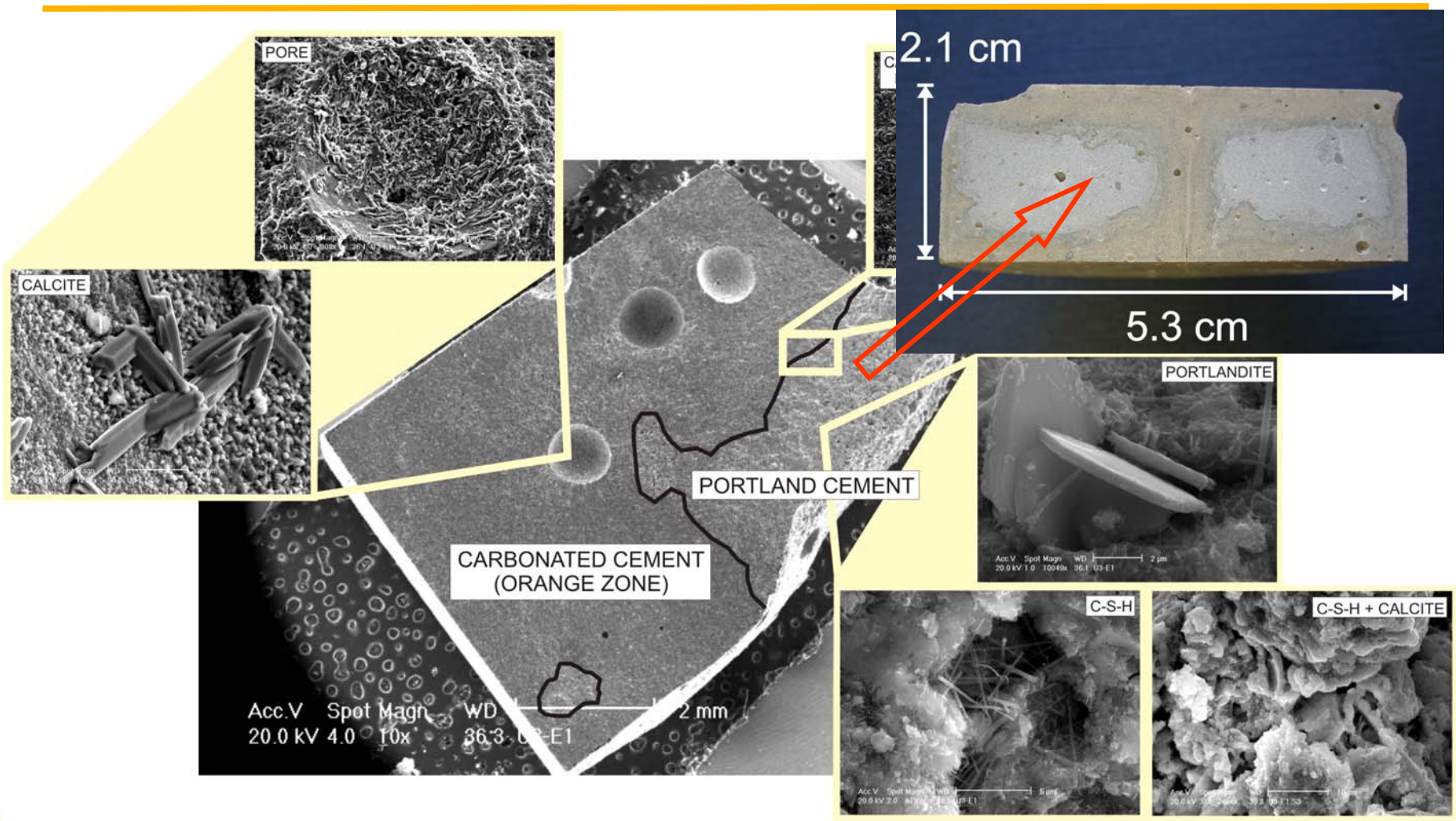
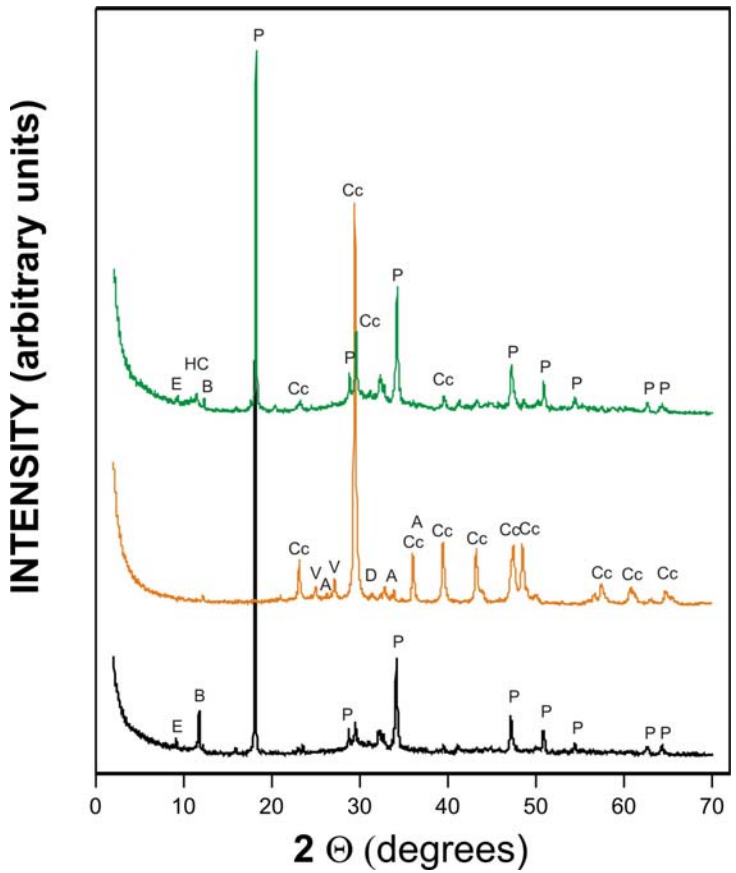


Diagram after Wiltschko & Morse (2001)

Geochemical reactions at the interface between cap rock and wellbore cement

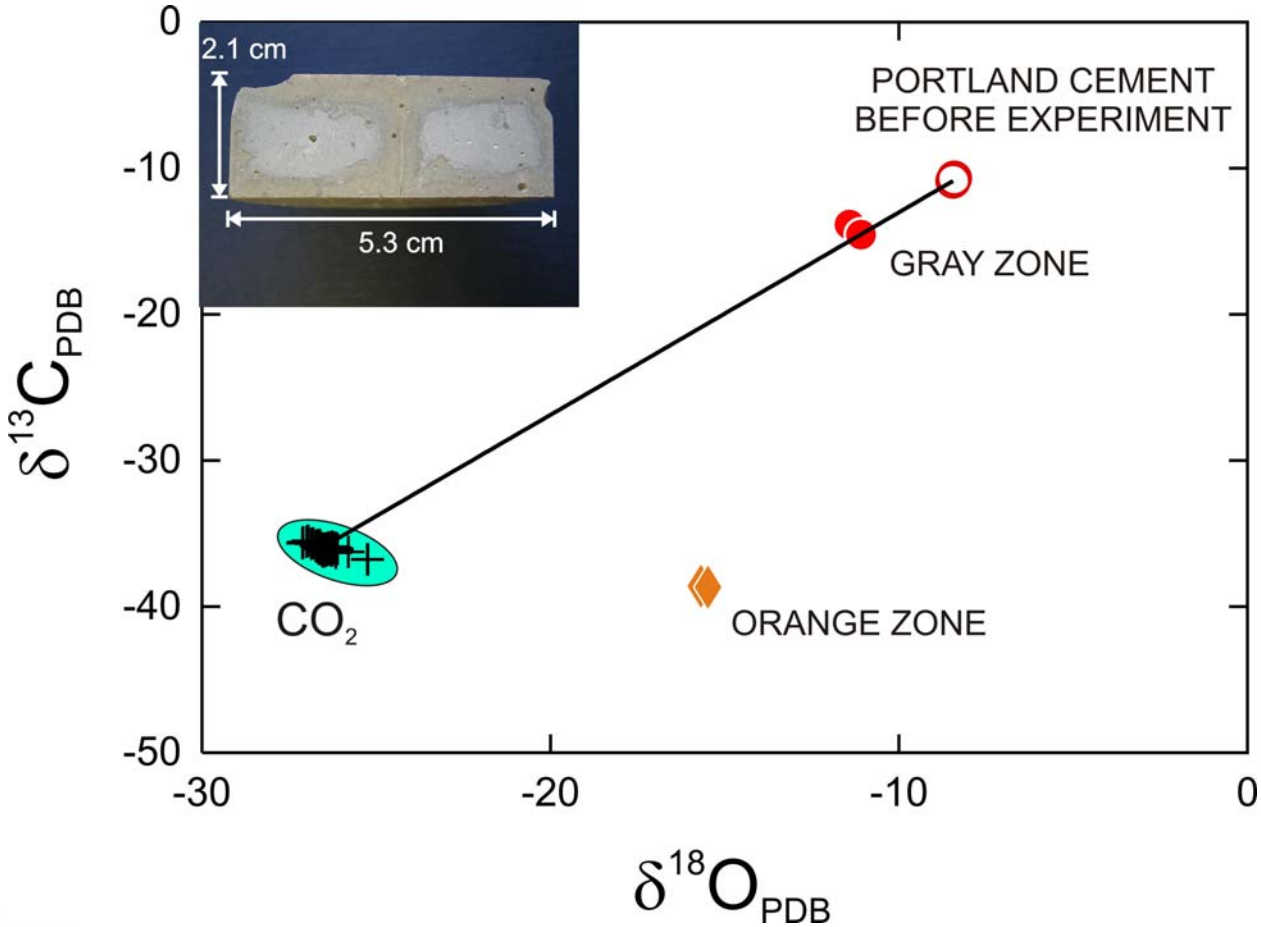


Changes in mineralogy of the cement



	PORTLAND CEMENT (before)	ORANGE ZONE	PORTLAND CEMENT (after)
Portlandite	X		X
C_2S	X		X
C_3S	X		
C_4AF	X	X	X
Ettringite	X		X
C_3AH_6			X
Hydrocalumite			X
Calcite		X	X
Vaterite		X	
Aragonite		X	
Dolomite		X	

Stable isotope geochemistry



Conclusions on cement degradation

- $SCCO_2$ reacts with the hydrated cement phases rapidly but carbonation of the wellbore cement results in a decrease in porosity and permeability
- Carbonated orange zone provides a low permeable barrier for the further intrusion of $SCCO_2$-saturated formation water into the cement
- Fractures in wellbore cement could be a potential risk because the opening of preexisting fractures due to carbonation results in an increase of the relative permeability

Acknowledgements

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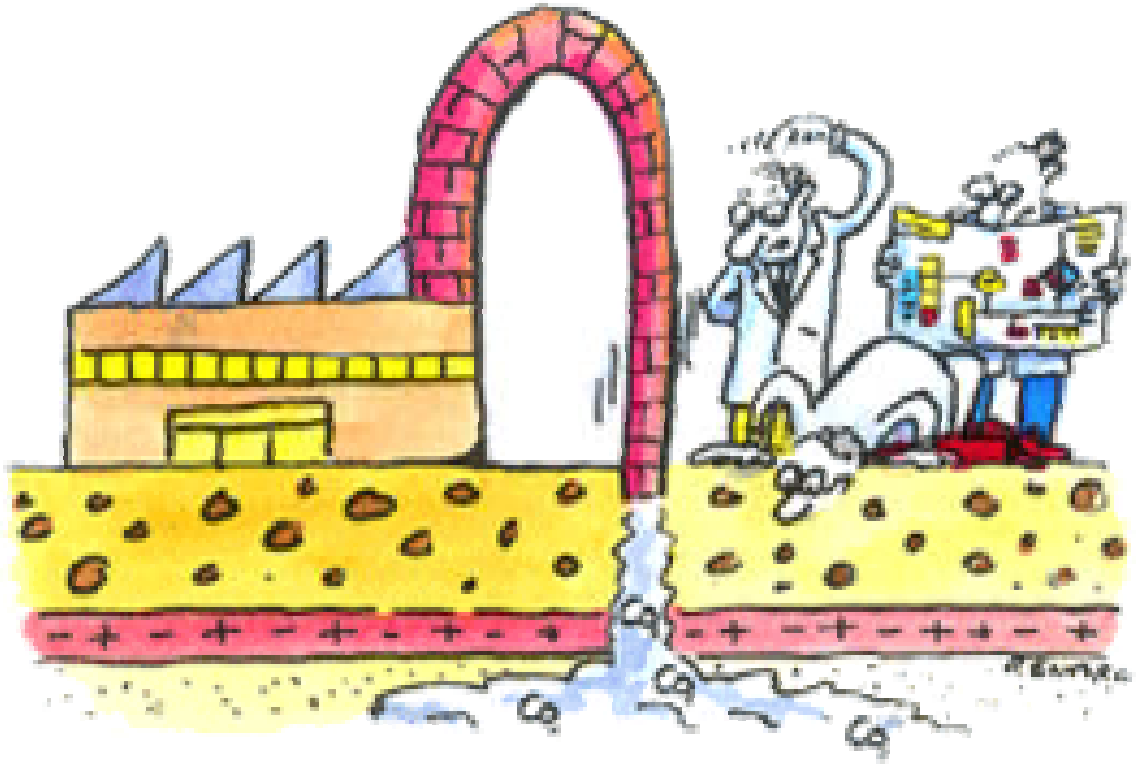

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Thank you very much for your attention!