Geochemical Model of CO2 impact at the Well-Caprock-Reservoir interfaces.

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Well – Reservoir – Cap rock INTERFACE

Modeling Cement CO_2-Alteration Mechanisms

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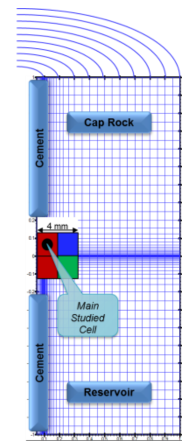
INTERFACE CO_2-Mechanisms - Agenda

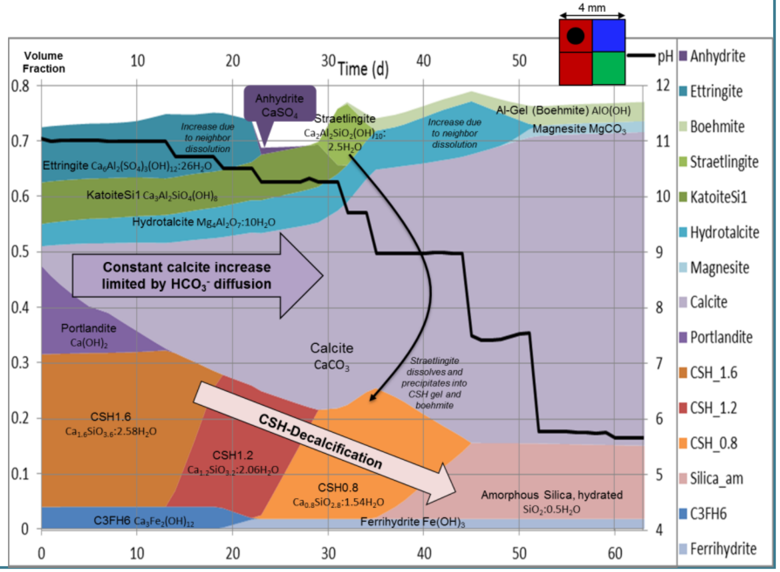
> Introduction
- Objectives

> Modeling Approach
- Considered Scenario
- Modeling tool
- Geometry and Gridding

> Results – Discussion
- Illustration Parisian Basin
- Cement Alteration Mechanisms

> Conclusions
- Limitations and Perspectives





INTERFACE CO_2-Mechanisms - Objectives

> ***Modeling*** *Geochemical interactions due to* CO_2 *injection at the Well-Reservoir-Caprock* ***INTERFACE***

- Characterization of reactions pathways
- Identification of new resulting minerals
- Chemical stability of cement-caprock interface
- Consequences in Porosity Evolution of the 3 zones

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Modeling Approach - Scenario

- Injection Well cement alteration due to ***acid brine only***
  - CO_2 Injection downhole => Reservoir Brine acidification
- **Diffusion only** of HCO_3^- and H^+ (from CO_{2aq}), *no flow, no gas phase*
  - Cement degradation due to brine contact
  - Cement leaching due to caprock contact
- Code Used : **ToughReact**
  - (finite volumes)
- 1m*2m-scale *axisymmetric* model
  - 2753 cells
  - $\Delta R = \Delta Z = 2$ mm at the interface
  - $\Delta t = 9$ sec for kinetic convergence reasons

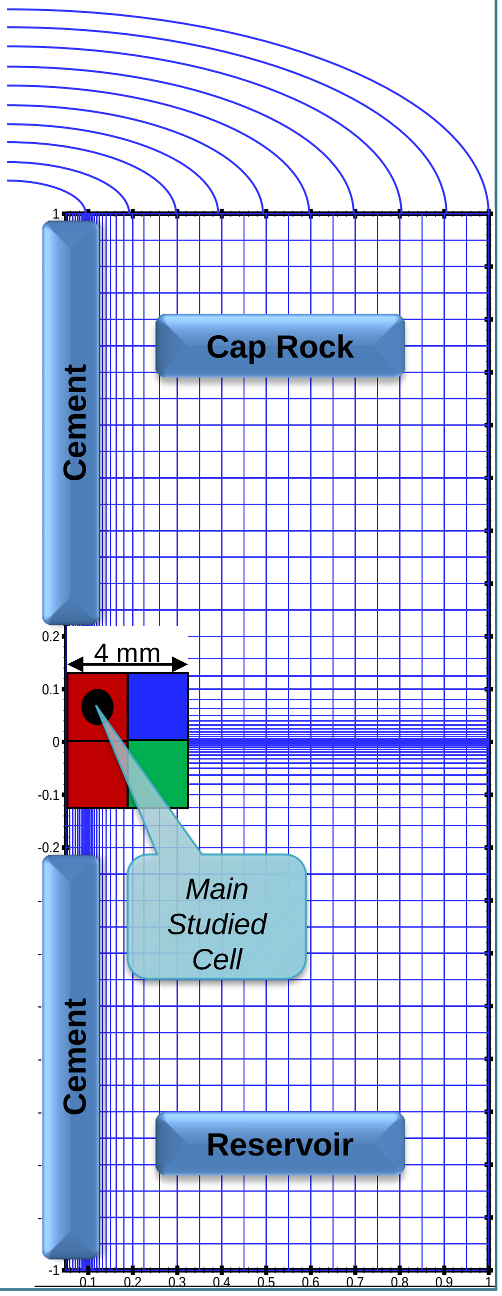


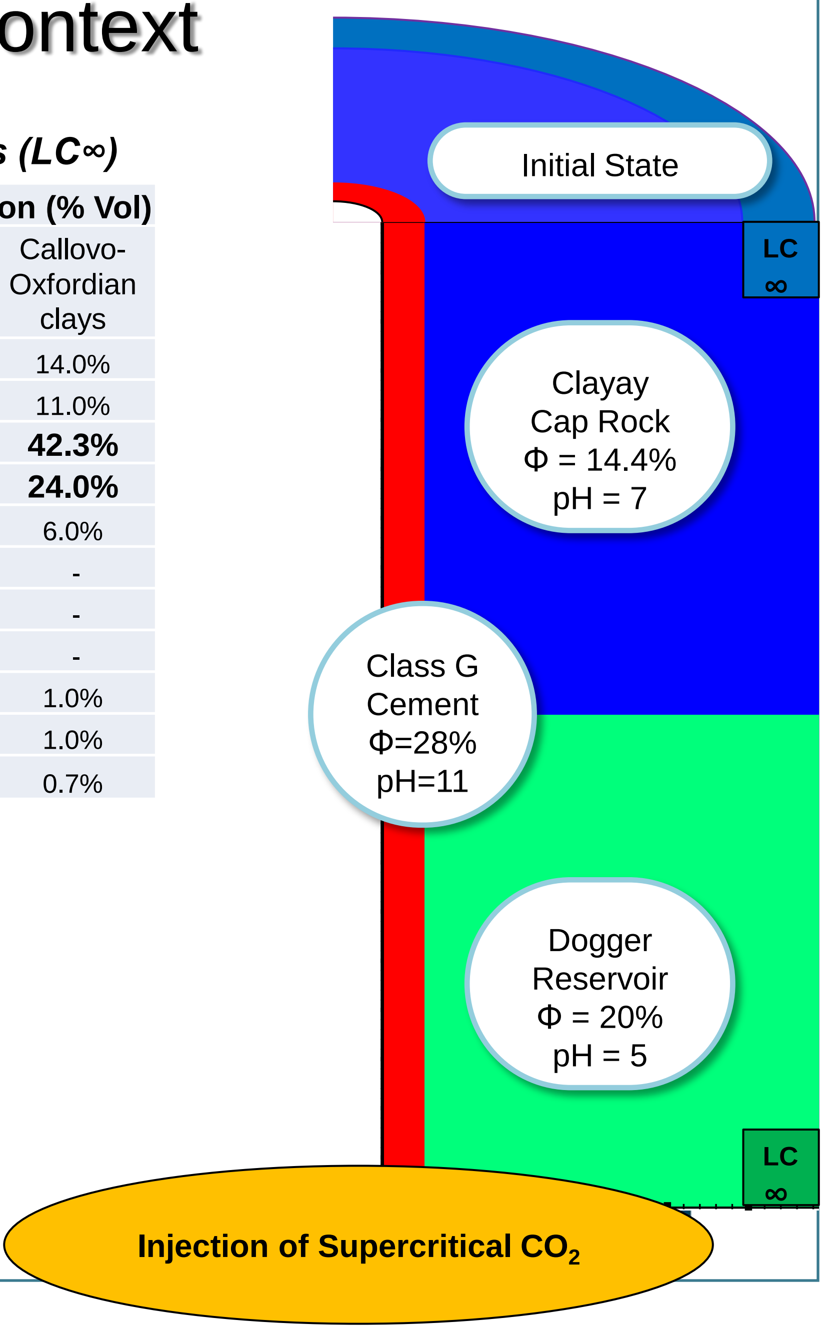
Illustration: Parisian Basin context

Initial state, equilibrated water
at t=0 and at the 2 Limit Conditions border-Cells (LC∞)

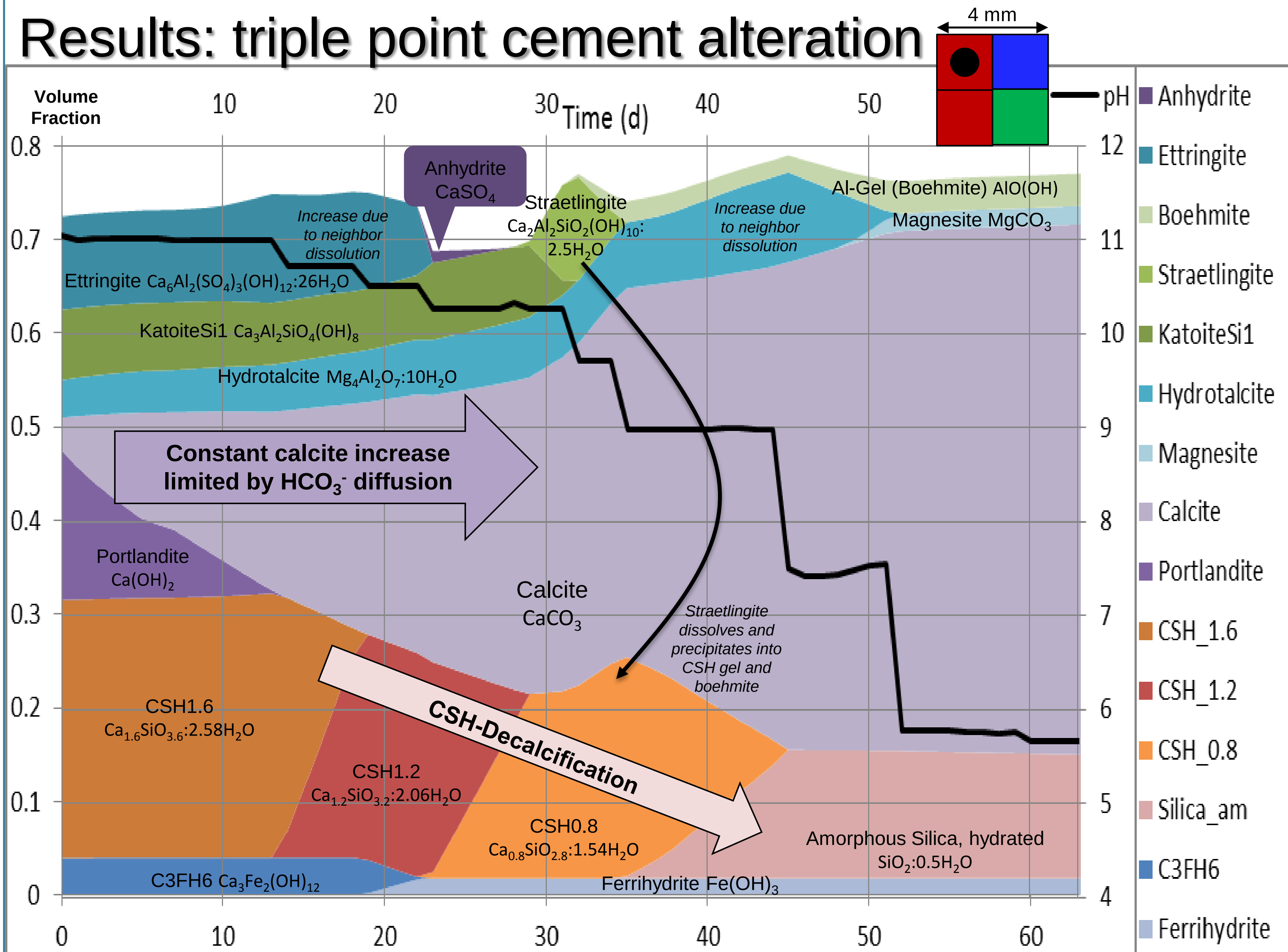
In-Situ Minerals	Formula	Composition (% Vol)	
		Dogger	Callovo-Oxfordian clays
Calcite	$CaCO_3$	**77.5%**	14.0%
Dolomite	$CaMg(CO_3)_2$	**10.2%**	11.0%
Illite-Mg	$K_{0.85}Mg_{0.25}Al_{2.35}Si_{3.4}O_{10}(OH)_2$	0.1%	**42.3%**
Quartz	SiO_2	-	**24.0%**
Mg-Montmorillonite-Na	$Na_{0.33}Mg_3Al_{0.33}Si_{3.67}O_{10}(OH)_2$	5.8%	6.0%
Siderite	$FeCO_3$	4.1%	-
Kaolinite	$Al_2Si_2O_5(OH)_4$	2.0%	-
Magnesite	$MgCO_3$	0.3%	-
Pyrite	FeS_2	-	1.0%
Chamosite	$Fe_5Al(AlSi_3)O_{10}(OH)_8$	-	1.0%
Celestite	$SrSO_4$	-	0.7%

Class_G Cement	Formula	Composition (% Vol)
CSH_1.6	$Ca_{1.6}SiO_{3.6}{:}2.58H_2O$	**38.1%**
Portlandite	$Ca(OH)_2$	**26.1%**
Ettringite	$Ca_6Al_2(SO_4)_3(OH)_{12}{:}26H_2O$	13.8%
Katoite_Si1	$Ca_3Al_2SiO_4(OH)_8$	10.5%
C3FH6	$Ca_3Fe_2(OH)_{12}$	5.5%
Hydrotalcite	$Mg_4Al_2O_7{:}10H_2O$	5.4%
Calcite	$CaCO_3$	0.6%

180 bar, 75°C, Salt = 25g/kg$_w$



Results: triple point cement alteration



Mechanisms Analysis - pH-Buffering and Volumes

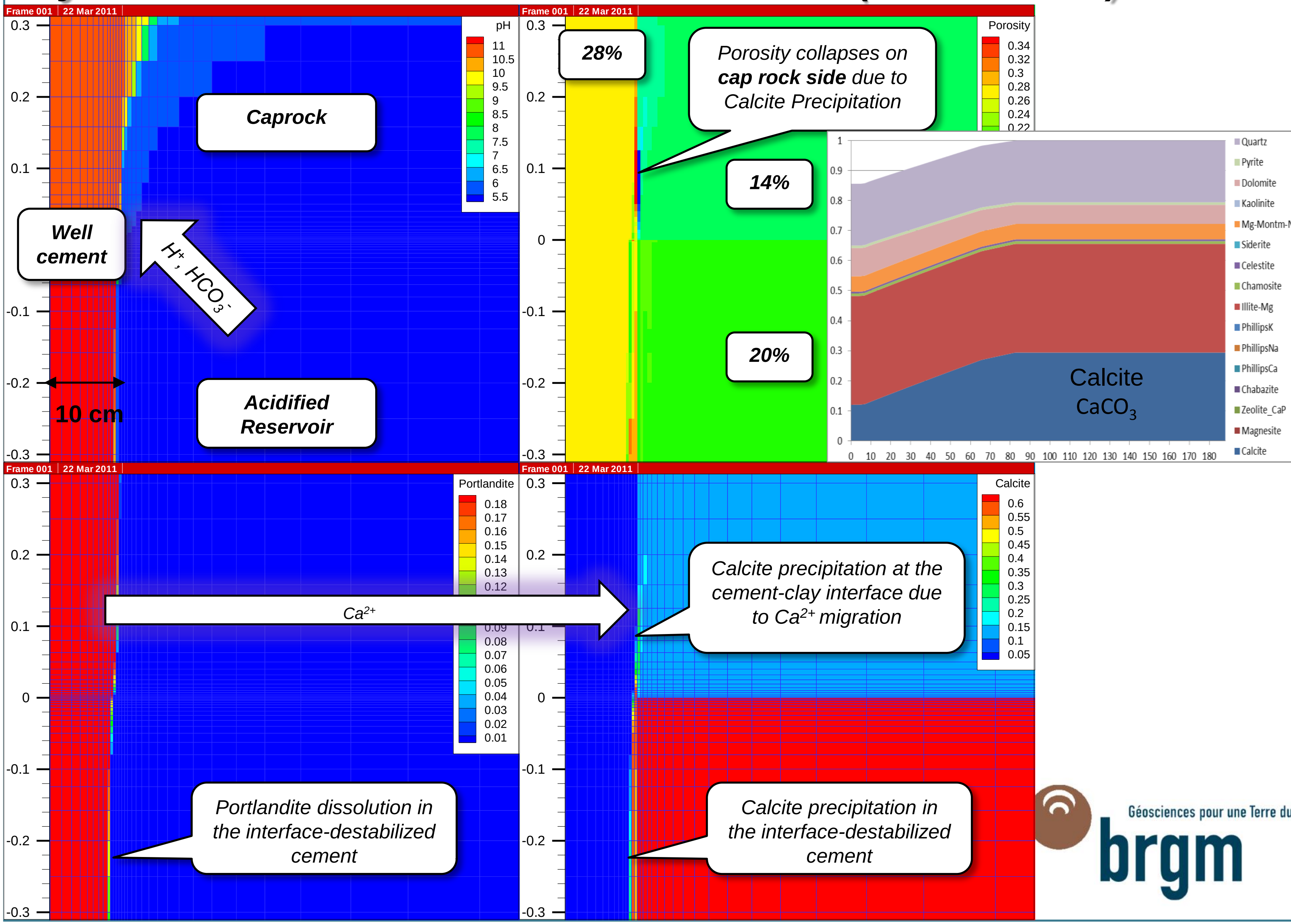
> **Simplified Reaction pathway:**

- H+ and HCO_3^- Diffusion is the limiting factor for the global cement degradation process
- pH is buffered successively by different mineral phases
- New created phases should occupy more Volume (%), but
- Liberated ions also migrate outside the cement

Time

Element\pH	11 (initial)	10.7	10.5	10.4	10.3	10.2	9.7	9	7.7	5.5 (final)
Ca	Portlandite	Calcite (+11.71%)								
Si	CSH1.6		CSH1.2 (+2.41%)			CSH0.8 (+2.93%)			Silica_am, hydrated (+13.92%)	
Fe	C3FH6			Ferrihydrite (+16.19%)						
S	Ettringite				(-66%)		Calcite			
Al	Katoite_Si1						Straetlingite (+93.27%)	Boehmite (+17.51%)		
Mg	Hydrotalcite									Magnesite (+3.11%)

System Evolution after 3 months (Ref Case)



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INTERFACE CO_2-Mechanisms - Conclusions

> ***Determination of conceptual reaction pathway***
- Possibility to extract simplified scheme to use it in a Poro-Mechanical study (part of the Project)

> ***Sensibility Analysis done on the cement tortuosity***
- *Variation of the Damkholer Number (here diffusion/kinetics)*

> ***Limitations of the model:***
- Cement carbonation produces a lot of H_2O (not considered in the mass/volume balance)
- Gas phase not considered (some experiments show a stronger effect of wet CO_2 than acidified brine)
- No heterogeneities

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