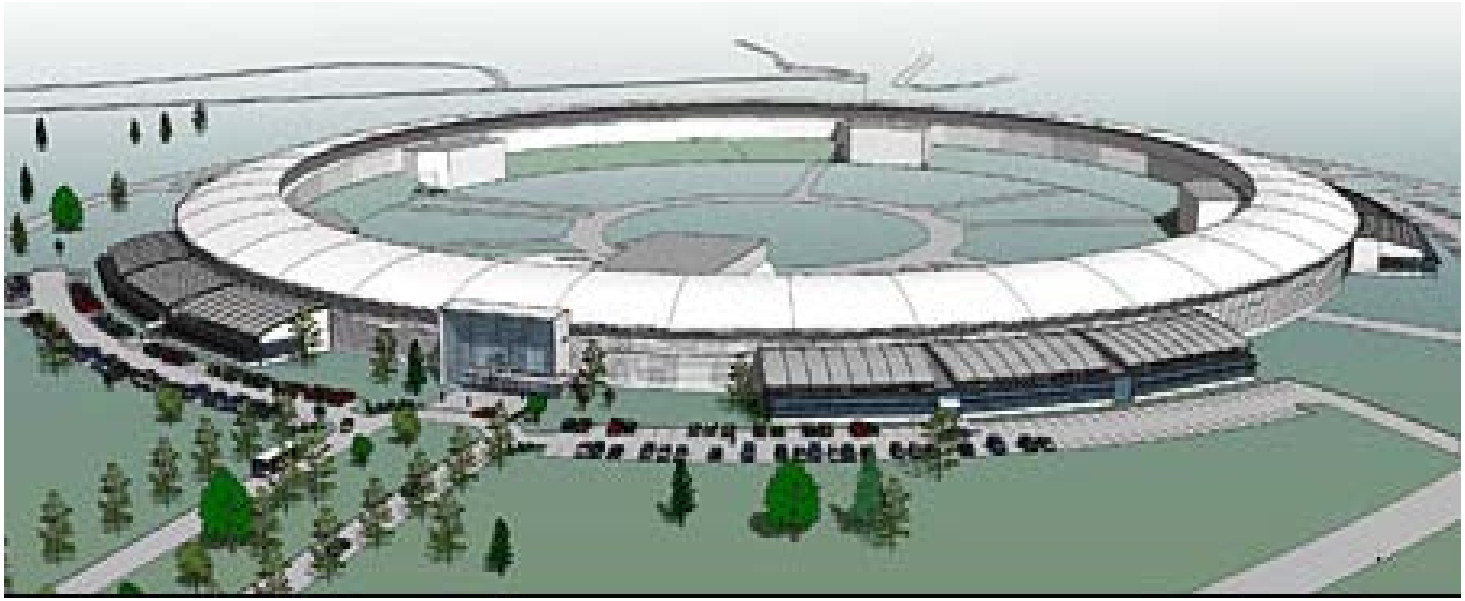

BNL National Synchrotron Light Source II

Carbonation Mechanism of Reservoir Rock by Supercritical Carbon Dioxide

May 19, 2010

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Presenter: Dr. Toshi Sugama
Co-presenter: Dr. Lynne Ecker
Brookhaven National Laboratory

Relevance/Impact of Research

Objectives: Elucidate comprehensively the carbonation reaction mechanisms between supercritical carbon dioxide ($scCO_2$) and reservoir rocks consisting of different mineralogical compositions in aqueous and non-aqueous environments at temperatures of up to 250ºC, and to develop chemical modeling of CO_2-reservior rock interactions.

Impact: The integration of all date obtained from this project will provide the following outcome;

- Whether $scCO_2$ possessing a great heat transmission and high flow rate can be applied to EGS at any or all geological locations as the working fluid.
- The offer of advanced and upgraded CO_2-sequestering technology at underground CO_2 storage sites.

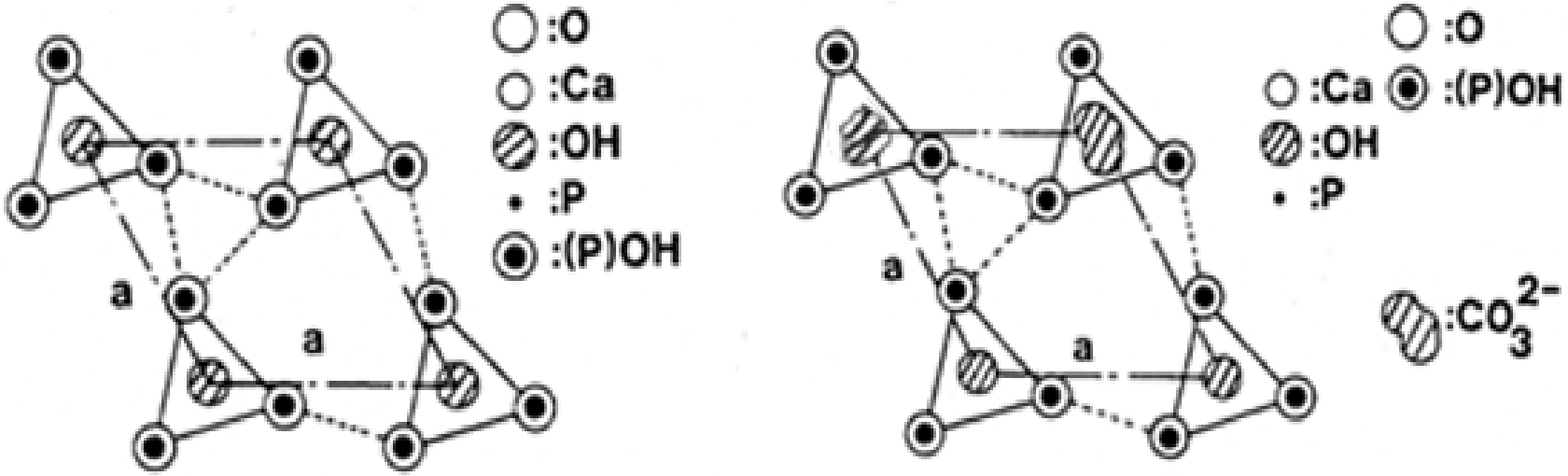
Scientific/Technical Approach

Background:

In 1997-2001, BNL with Halliburton and Unocal Corp succeeded in developing CO_2-resistant well casing cement called as calcium aluminate phosphate (CaP). Halliburton commercialized this patented CaP cement under the trade name “ThermaLock®” cement, and then this technology received the prestigious R&D 100 Award.

Background:

CO_2-resistant Mechanism of CaP Cement by Hydroxylapatite (HOAp) Phase



Replacement of OH Groups in HOAp by CO_2, sequestering CO_2

$$Ca_5(PO_4)_3(OH)_x \longrightarrow Ca_5(PO_4)_3(OH)_{x-y}(CO_3)_y$$

Background:

Carbonation of Conventional Cement (Ca_2O-SiO_2-H_2O System)

$$\text{C-S-H} + CO_2 + H_2O \longrightarrow \text{Silica gel} + CaCO_3$$

$$CaCO_3 + CO_2 + H_2O \longrightarrow Ca(HCO_3)_2$$

Water-soluble calcium bicarbonate

Scientific/Technical Approach

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Milestones

	FY2009	FY2010				FY2011			
	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
Task 1. Chemical analyses of pure rock and clay minerals as well as bore core samples taken from reservoir rock formation	■	■	30%*						
Task 2. Carbonation study of minerals			■	■	■	■	10%*		
Task 3. mechanical behaviors of carbonated minerals							■	■	
Table 4. Modeling of CO_2-resverior rock interactions									■

* Percent completion

Budget: FY09 $200,000. FY10 $134,000.

Partners: AltraRock Energy Corporation (cost-shear partner), Sandia National Laboratory (collaborator)

Scientific/Technical Approach

Approach

1. Mineralogical survey at Coso EGS Well
2. Identification of rock and clay minerals
3. Collection and chemical analysis of pure rock and clay minerals
4. $scCO_2$-exposure test and follow up analysis for pure minerals
5. Chemical analysis of bore core rock samples from EGS reservoir sites to obtain information on distribution and proportion of various different minerals
6. $scCO_2$-exposure test and follow up analysis for bore core samples
7. Integration of all data and establishment of modeling

Scientific/Technical Approach

Rock and Clay Mineral Formation at Coso EGS

Rock mineral	**Major**		**Minor**
	Granite	Na,K-based Albite	Diorite Quartz
		Na-based Albite	
		Quartz	
	Biotite mica		
	Hornblende		
Clay mineral	Illite		Kaolinite
	Smectite		

Experimental

Sample preparation for pure rock minerals:

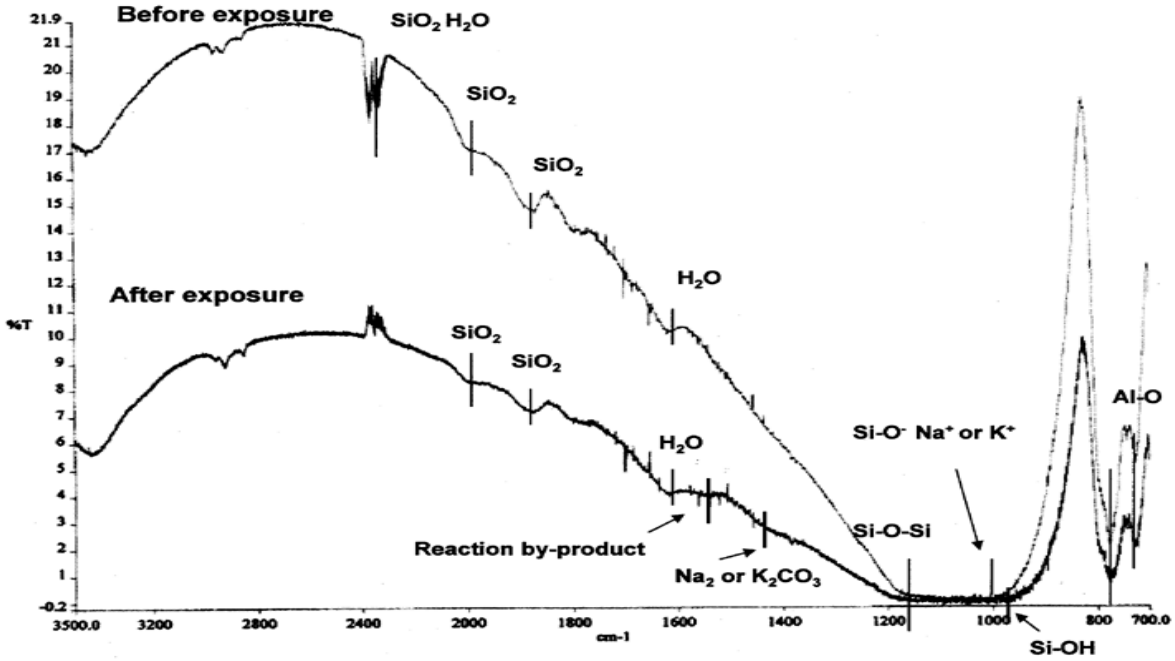
1. Crash and grind to make powder samples < 0.2mm particle size
2. Mix with water to make pastes

Short-term (3 days)-scCO_2 exposure test:
Temperature of 250ºC
Pressure of 2500 psi

Analysis:
X-ray powder diffraction (XRD) and Fourier transform infrared spectroscopy (FT-IR)

Scientific/Technical Approach

FT-IR result

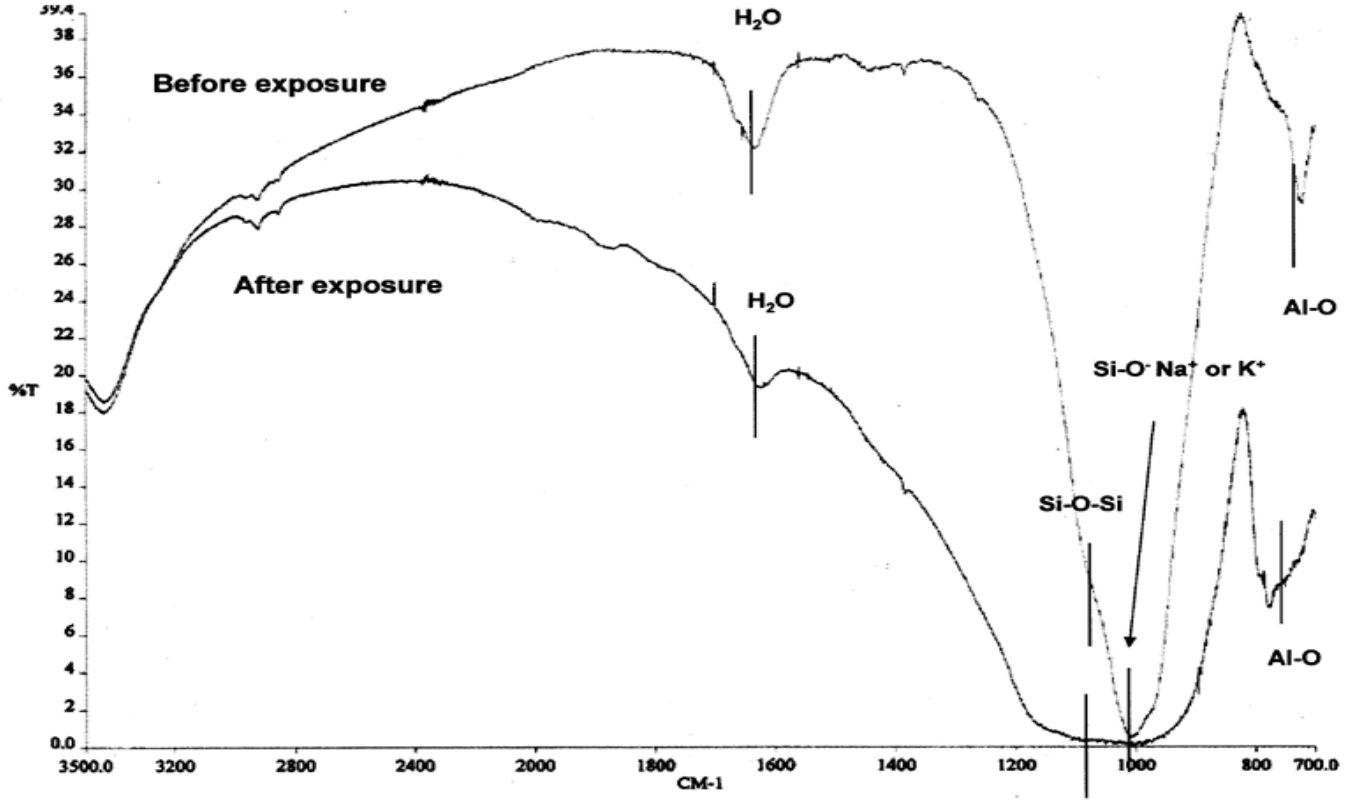


Granite (comprised of **Albite**,$(Na,K)AlSi_3O_6$, and **Quartz**, SiO_2)

Carbonation of Albite

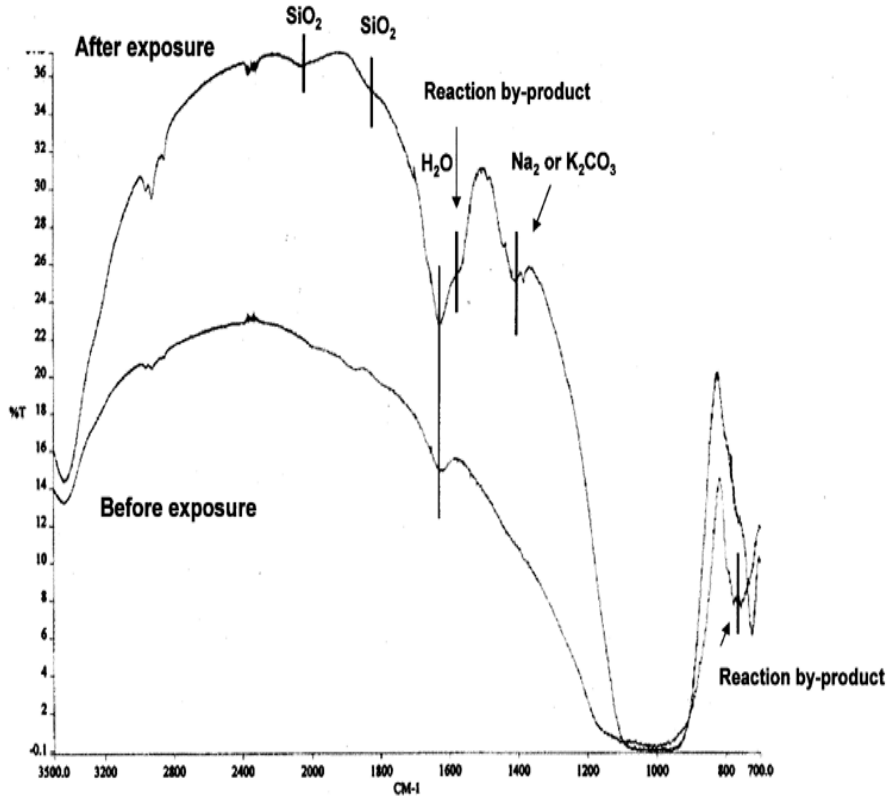
$(Na,K)AlSi_3O_6 + scCO_2 + water \rightarrow Na_2CO_3 + K_2CO_3 + Al_2Si_2O_5(OH)_4$

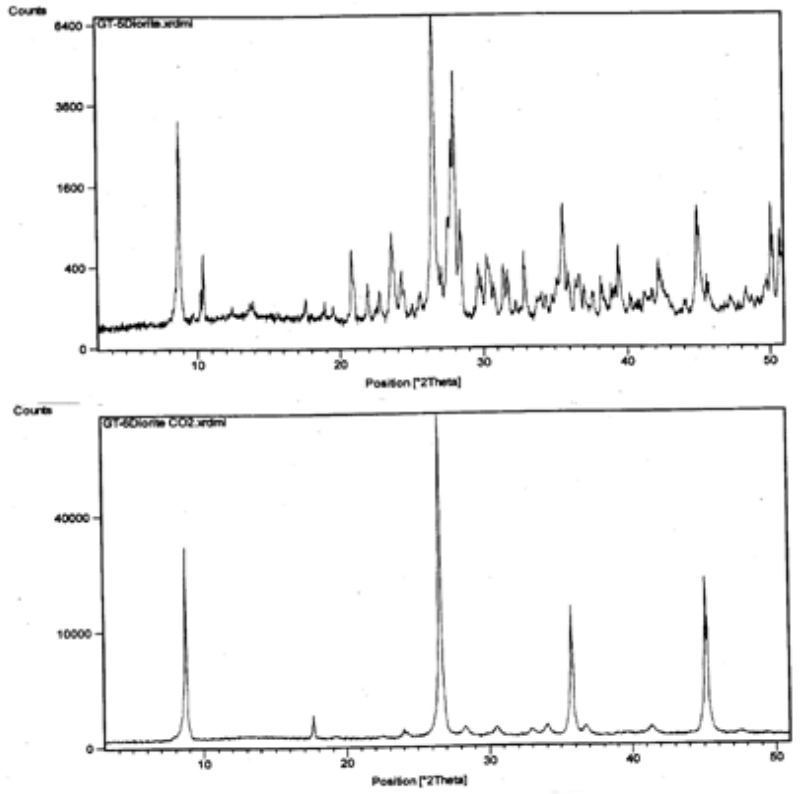
FT-IR result



Biotite mica, $NaAlSi_3O_8$-$CaAl_2Si_2O_8$

FT-IR and XRD results for **Diorite** known as volcanic mineral





Diorite [comprised of **Anorthite**, $(Ca,Na)(Si,Al)_4O_8$, and **Biotite**]

Before (top) and after exposure (bottom)

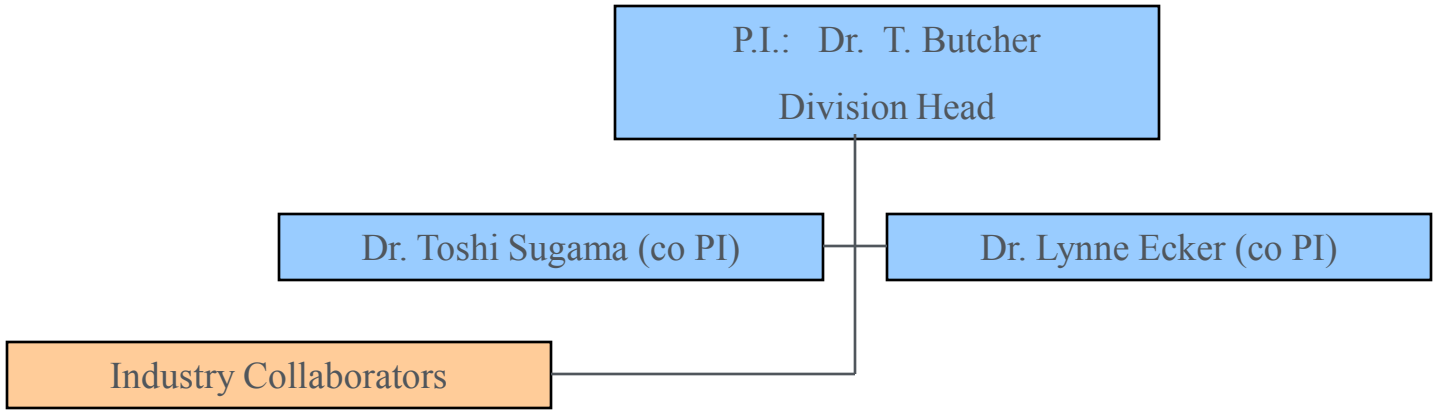
Finding:

Magnitude of susceptibility of minerals to reactions with $scCO_2$/water at 250ºC depended on their chemical configuration and constitution.

Ongoing work:

- Wet carbonation study of clay minerals.
- Identification of wet carbonation reaction-induced by-products of rock minerals.
- Dry carbonation study of both rock and clay minerals.
- Wet carbonation kinetics and quantitative analysis of rock and clay as a function of temperature and exposure time.

Project Management/Coordination



Services – as needed

- Laboratory Support
- Other BNL analytical tools
- Outside purchased services
- Outside Analytical Labs
- X-ray diffraction Lab and NSLS
- Students