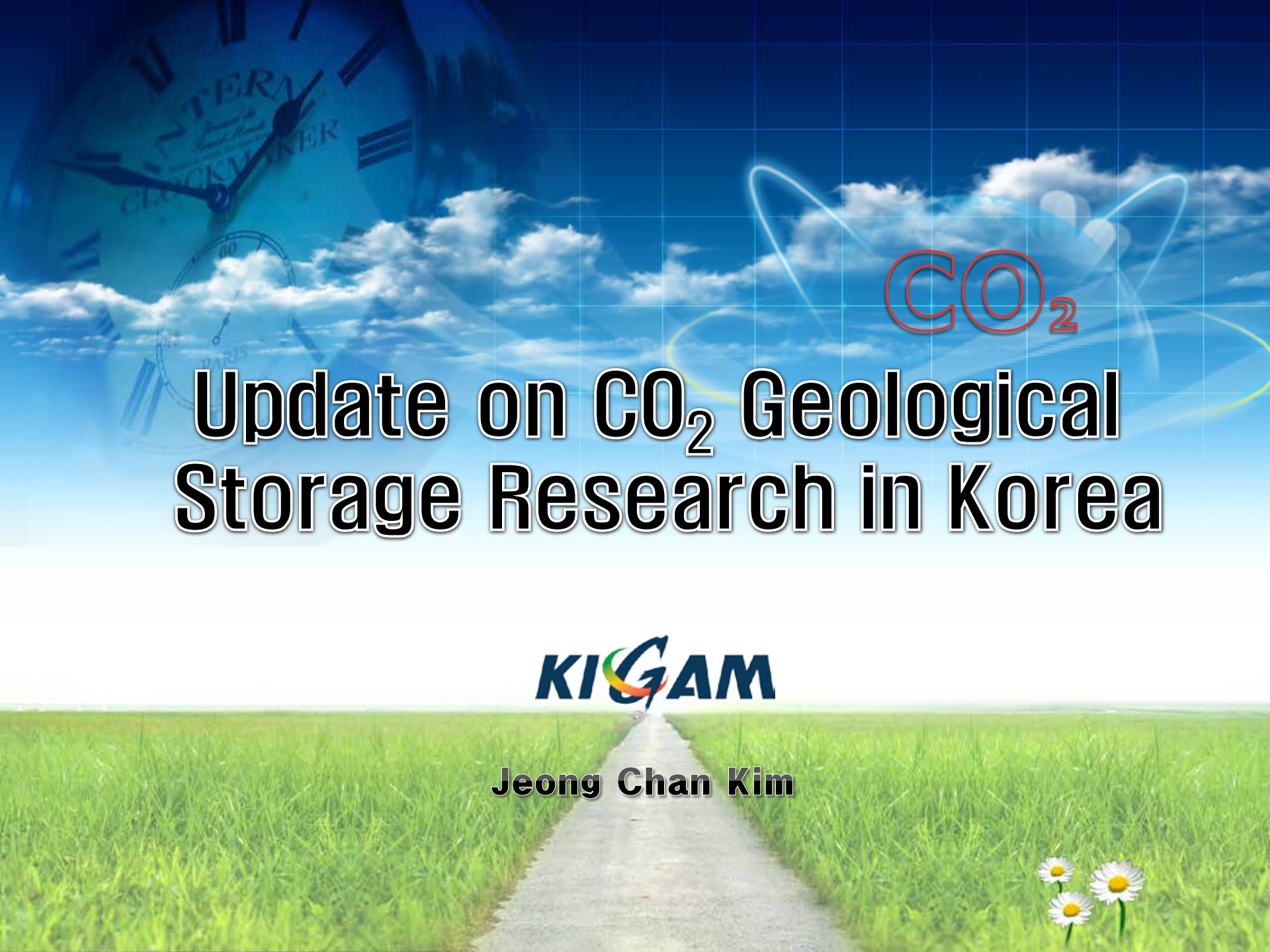
Update on CO_2 Geological Storage Research in Korea



KIGAM

Jeong Chan Kim

Introducing Remarks

- **In Korea, CCS is also an inevitable option for reducing CO_2 emission because of a huge amount of CO_2 emission and fossil fuel-consuming industrial structure.**
- **With regard to CO_2 capture, the government has continuously supported R&D, resulting in some success.**
- **On the other hand, the support for the CO_2 storage R&D has been delayed, due to uncertainties in storage site.**
- **However, for the integration of CCS technologies and the urgency of CCS deployment, the government has recently begun to support R&D regarding CO_2 storage.**

CO_2 Storage Research Categories

- **CO_2 storage site screening and geological characterization**
  - **Onshore/nearshore sedimentary basins**
  - **Offshore sedimentary basins**
- **CO_2 storage technology R&D**
  - **Development of CO_2 injection system**
  - **Monitoring of underground CO_2 behavior(flow and chemical reaction)**
- **International cooperation**
  - **CO2CRC Otway project**
  - **Canadian Aquistore project**
- **Mineral Carbonation**

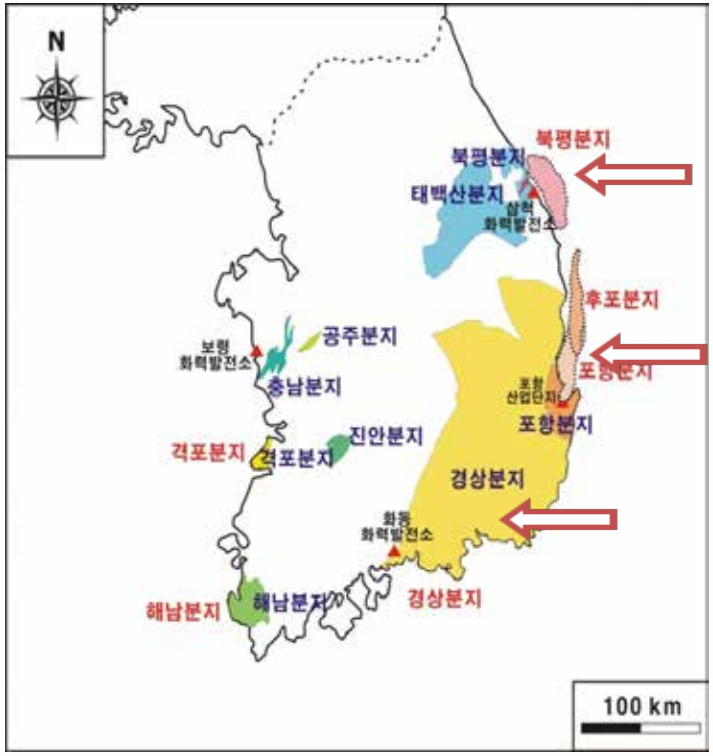
CO_2 Storage Site Screening & Geological Characterization

- **In Korea, the main challenge in the deployment of CCS is concerned with CO_2 storage site.**
- **There is no hydrocarbon basin having commercial value in both onshore and offshore region in Korea.**
- **The most important thing in CCS is to find the suitable CO_2 storage site and to characterize its storage potential.**
- **Recently, several site-screening and geological characterization projects have been launched.**

Site Screening

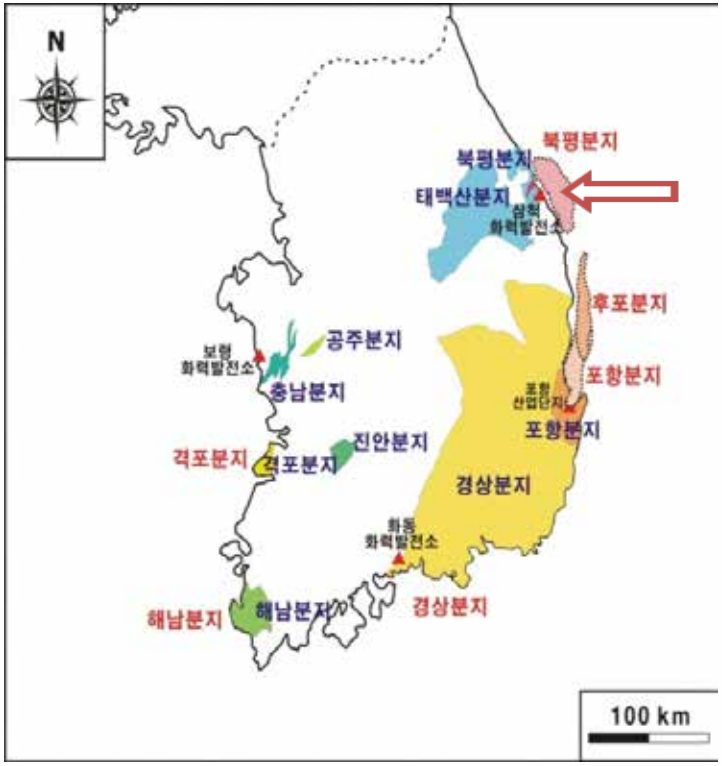
Site screening and characterization of onshore/nearshore sedimentary basins

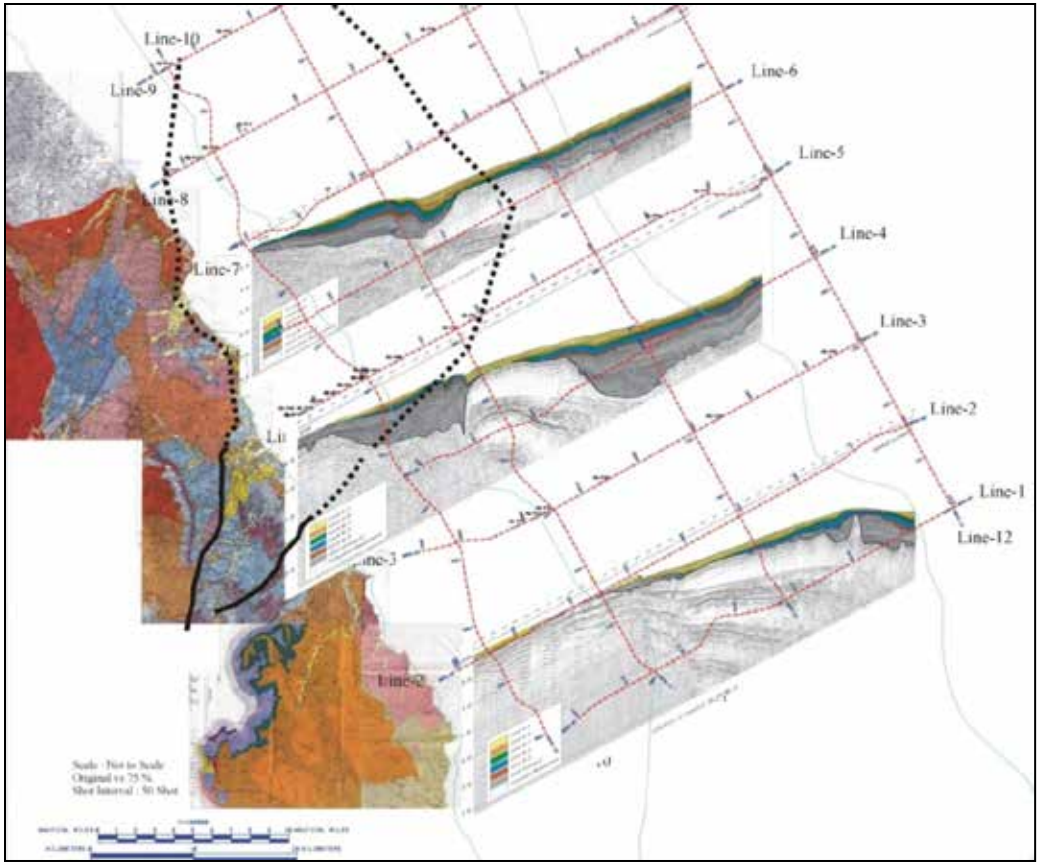
- ü **2 Projects: One was launched two years ago. The other has just begun.**
- ü **The former focuses on three sedimentary basins.**
- ü **Both projects are led by KIGAM with more than 15 partners (universities, institutes and small companies).**
- ü **For the Bukpyeong sedimentary Basin, we have just finished initial characterization.**



Bukpyeong Basin

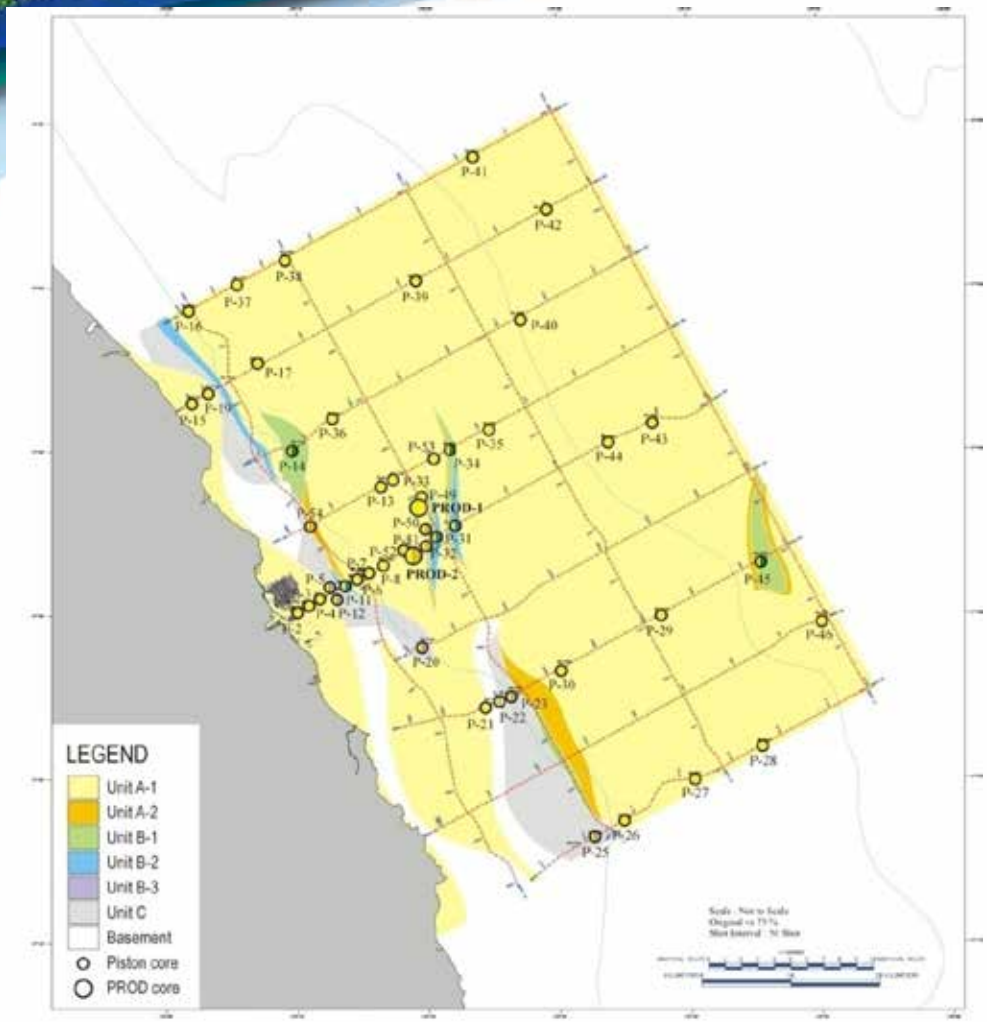
Bukpyeong Basin: Tertiary sedimentary basin continuing from land to ocean, filled with unconsolidated to semi-consolidated clastic sediments.





Bukpyeong Basin

Site Characterization



Locations of seismic exploration lines and ocean drilling

SEISMIC STRATIGRAPHIC UNIT			CORE
Unit Group A	Unit A-1	Subunit A-1a	PROD-1
		Subunit A-1b	PROD-2
		Subunit A-1c	PROD-2
	Unit A-2	Subunit A-2a	PROD-2
		Subunit A-2b	00ADP-50, 51, 52
Unit Group B	Unit B-1	Subunit B-1a	00ADP-14, 34, 45
		Subunit B-1b	
	Unit B-2	Subunit B-2a	00ADP-31, 32
		Subunit B-2b	
	Unit B-3		
Unit Group C	Unit C-1		00ADP-05,12, 20, 23, 25
	Unit C-2		
	Unit C-3		
	Unit C-4		

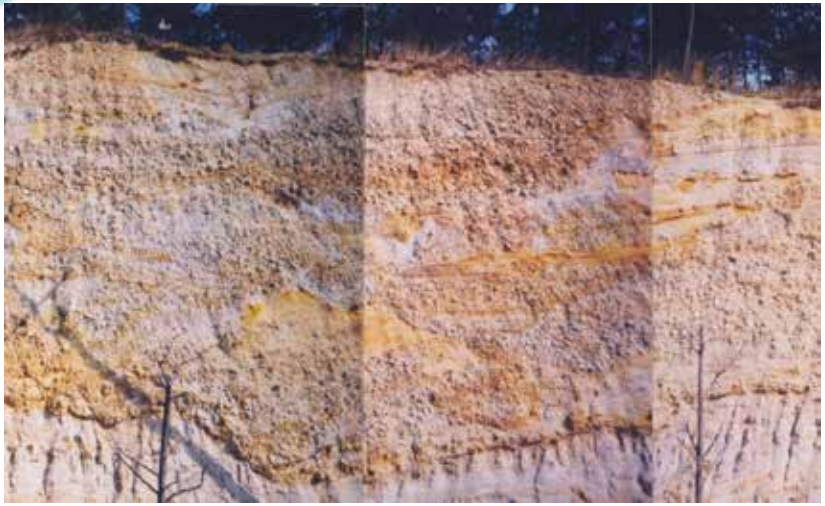
Seismic stratigraphic unit

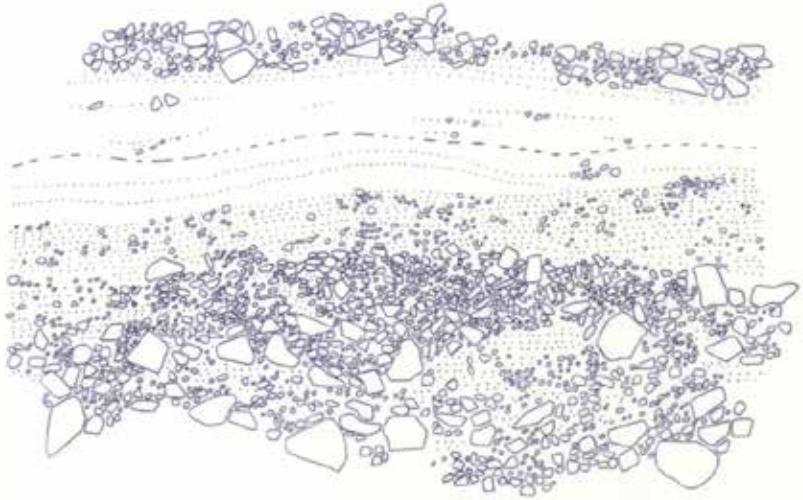
Tranformation of seismic stratigraphic unit into subbottom unit

AGE	SEISMIC STRATIGRAPHIC UNIT			PREDICTED LITHOLOGY	SUBBOTTOM UNIT	PREDICTED P-WAVE VELOCITY
Quaternary	Unit Group A	Unit A-1	Subunit A-1a	Mud	Unit a	1500
			Subunit A-1b	Sand	Unit b	1650
			Subunit A-1c	Sand/Mud		
		Unit A-2	Subunit A-2a	Sand/Mud		
			Subunit A-2b	Sand		
Tertiary	Unit Group B	Unit B-1	Subunit B-1a	Mud	Unit c	1550
			Subunit B-1b	Sand/Mud	Unit d	1650
		Unit B-2	Subunit B-2a	Sand/Mud		
			Subunit B-2b	Sand	Unit e	1700
		Unit B-3		Sand		
	Unit Group C	Unit C-1		Sand/Mud	Unit f	1800
		Unit C-2		Conglomerate/Sand		
		Unit C-3		Sand/Mud		
		Unit C-4		Conglomerate/Sand	Unit g	1900
Upper Paleozoic	Pyongan Group			Sand/Mud		4275
Lower Paleozoic	Choson Supergroup			Limestone/Shale		5925
Precambrian				Granitic gneiss		3750

Bukpyeong Basin

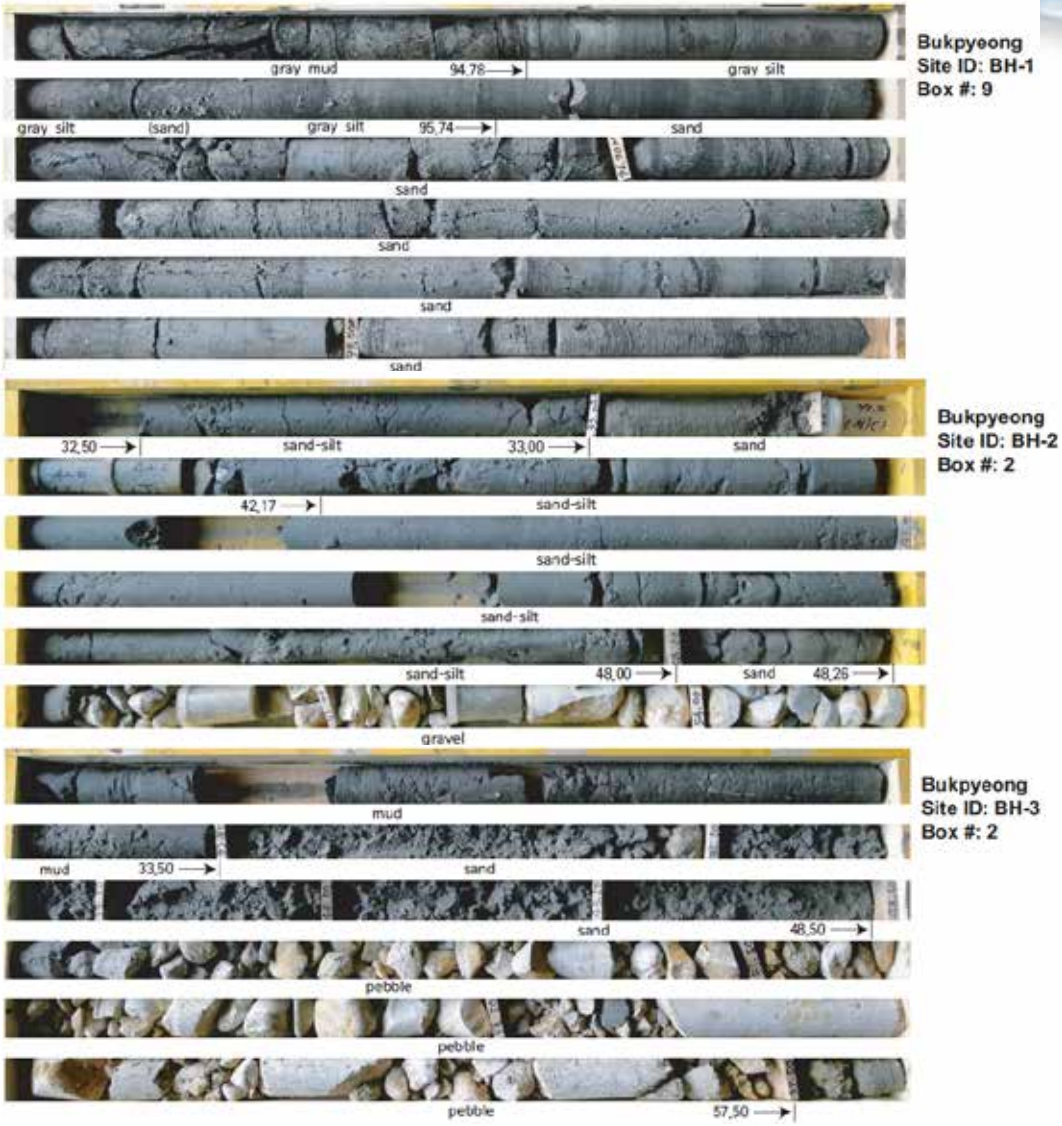
Semi-consolidated coarse-grained sediments, exposed on land- A potential CO_2 reservoir?



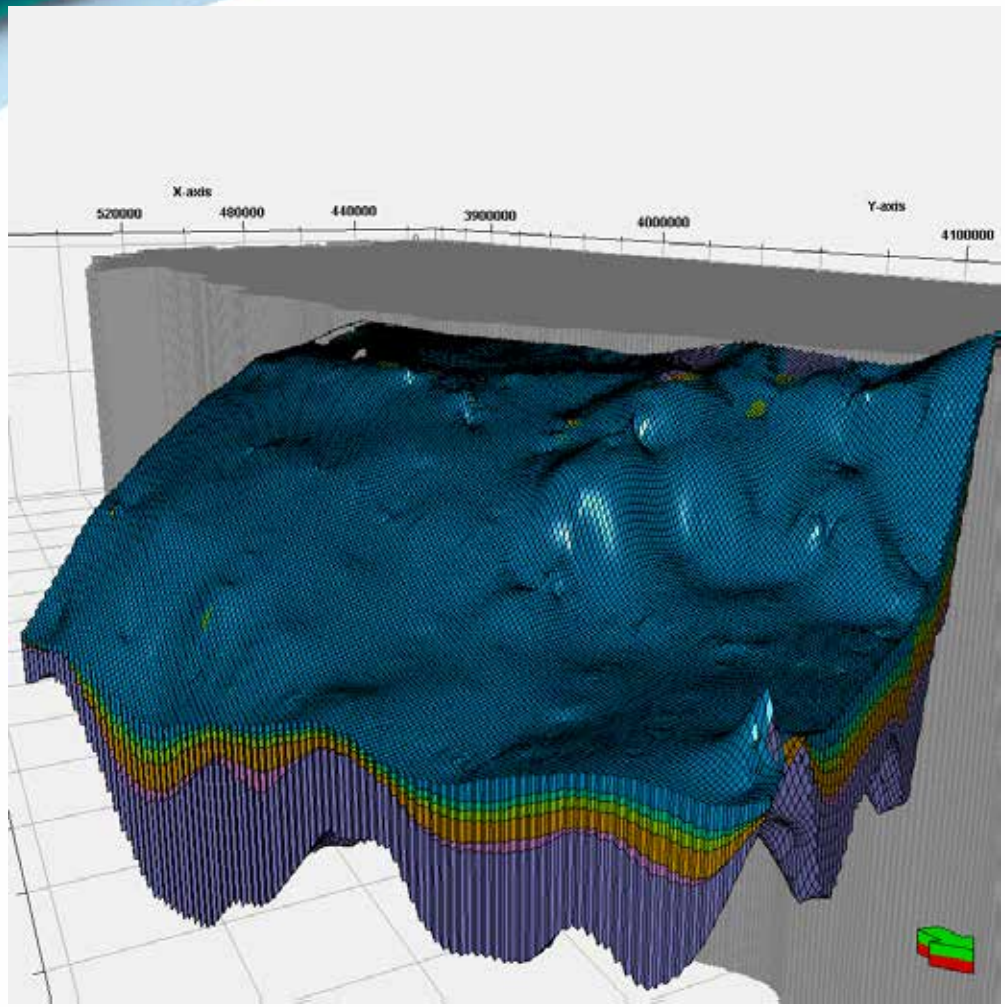


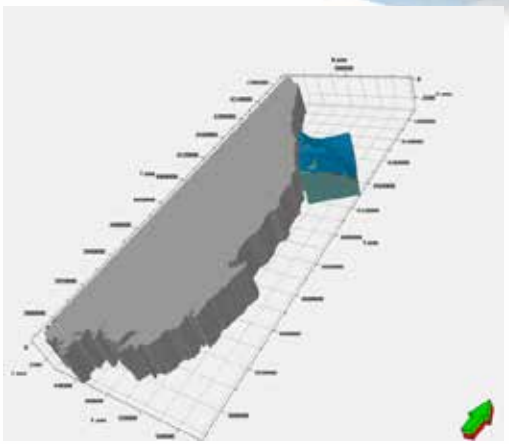
Bukpyeong Basin

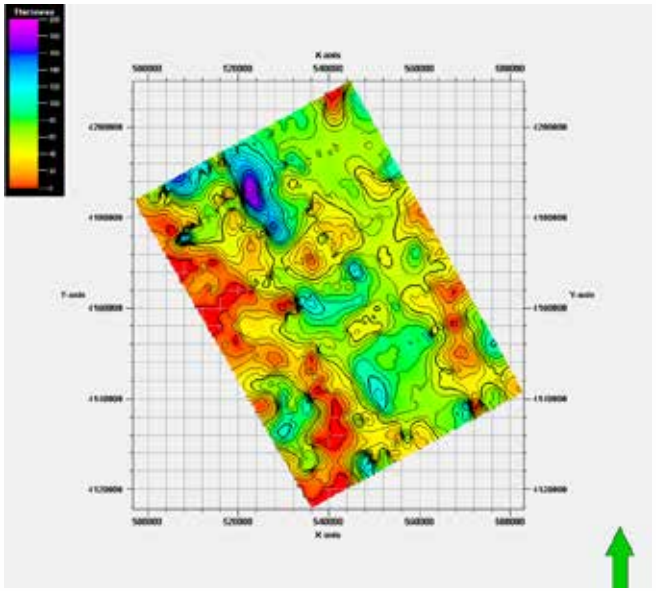
Site Characterization



A total of 300 m coring from three sites



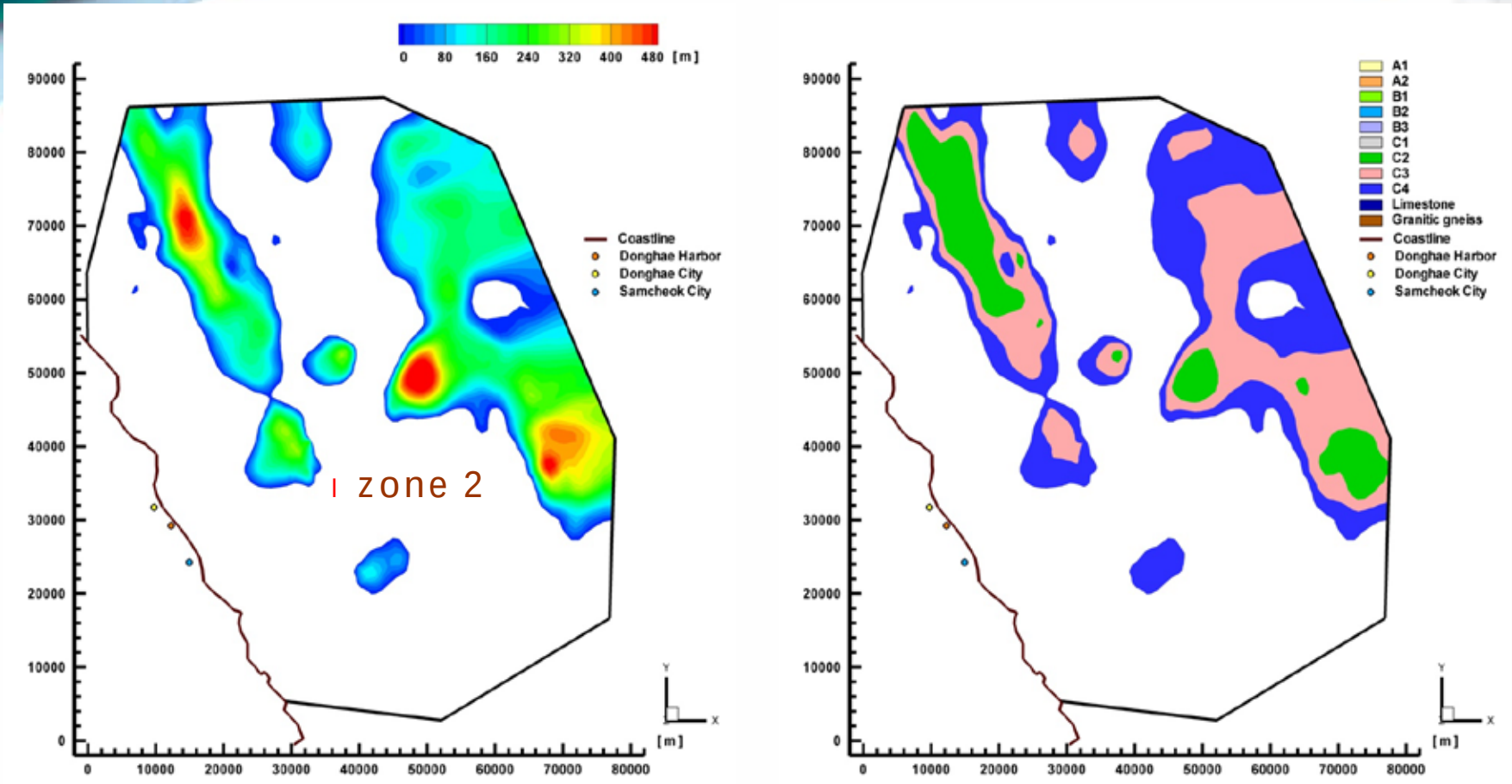




3 Dimensional Stratigraphic Model

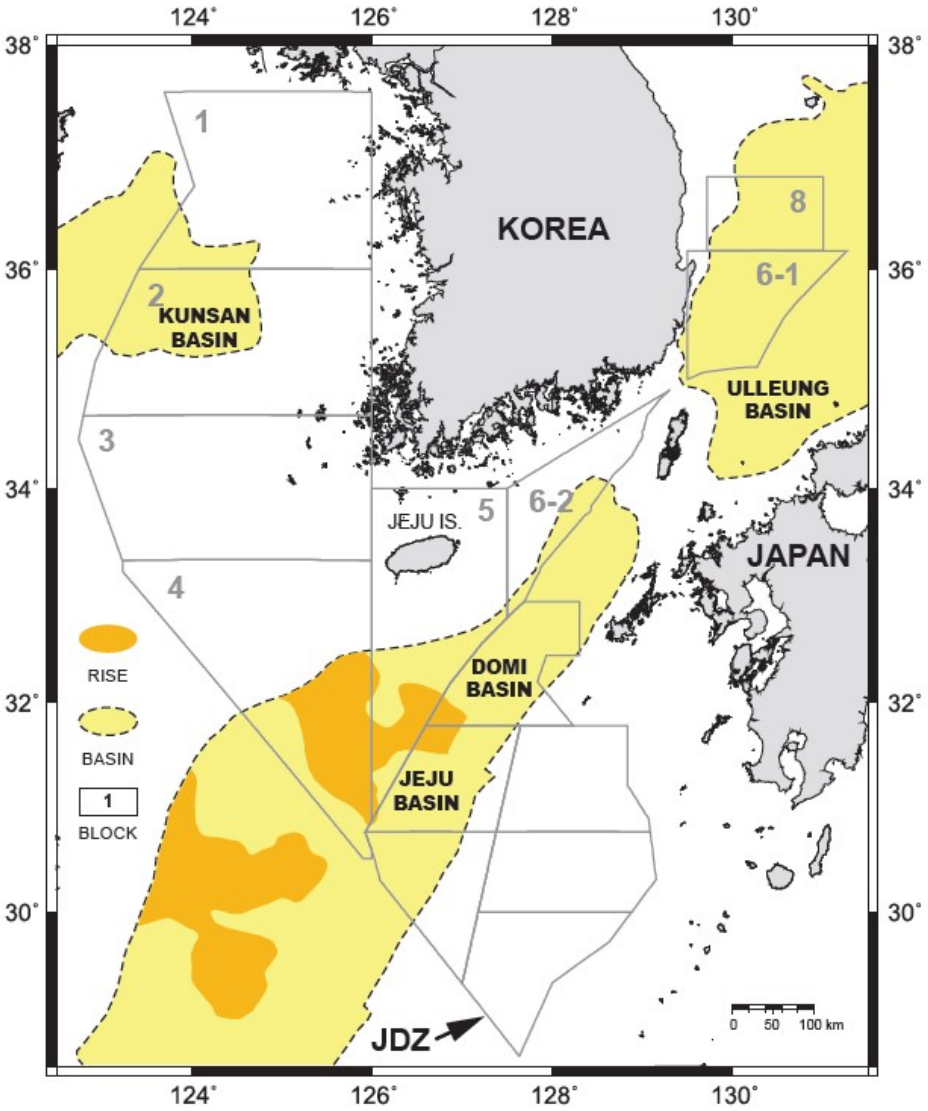
Bukpyeong Basin

Site Characterization

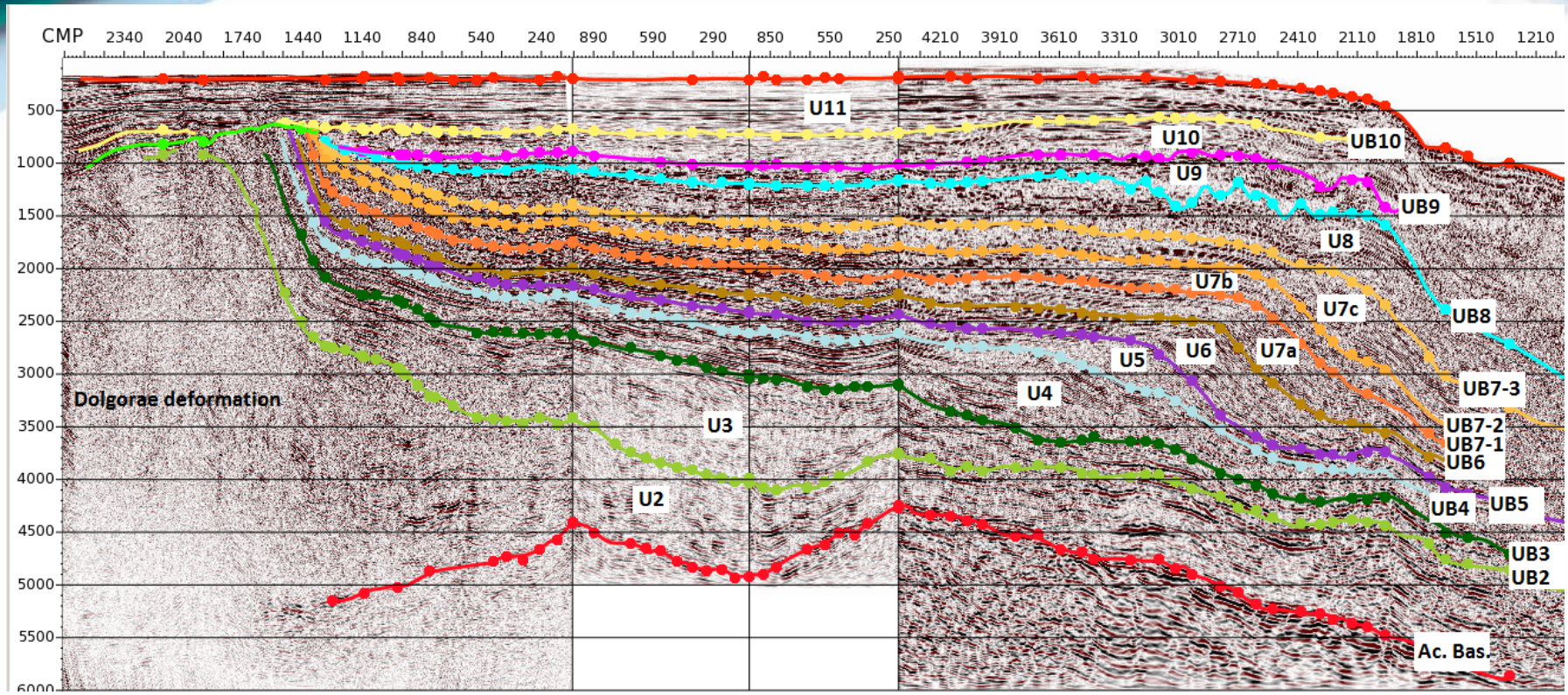


Potential CO_2 Storage Capacity: 140 Mt

compilation of seismic/well data



Interpretation of Seismic Data (Ulleung Basin)



CO_2 Storage Technology R&D

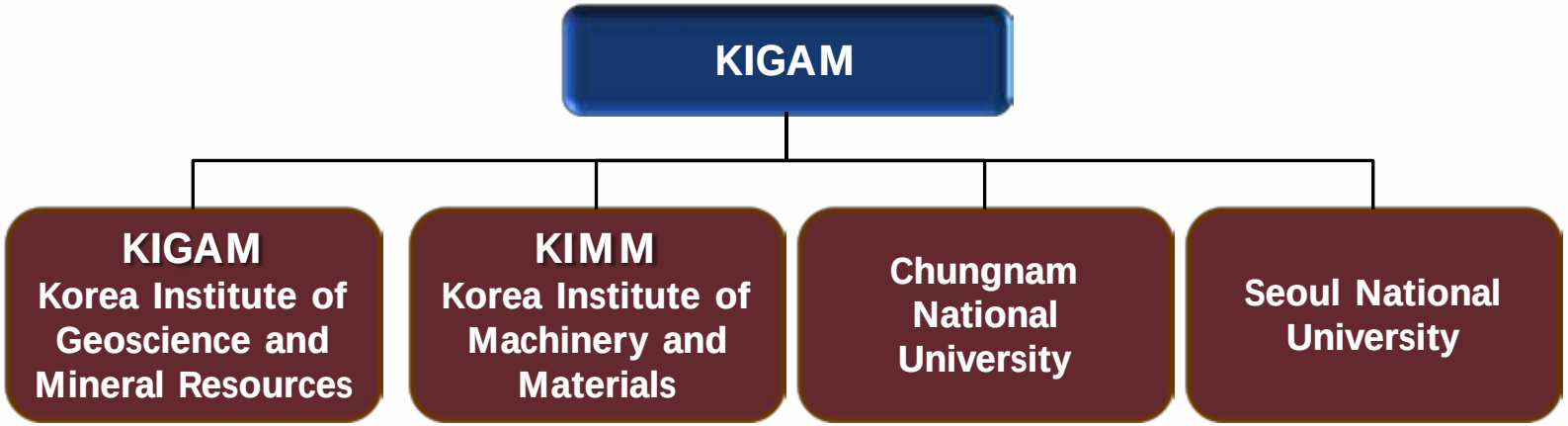
- **Development of CO_2 injection system**
- **Monitoring of underground CO_2 behavior(flow and chemical reaction)**

OUTLINE

Project Content

- Design of CO_2 injection pump and lab.-scale aboveground CO_2 injection facilities
- Design and installment of CO_2 injection well
- Planning of CO_2 injection well operation

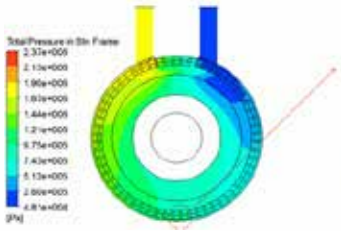
Project Team Organization

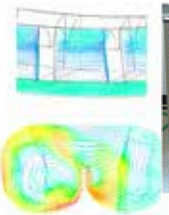


CO_2 injection facilities

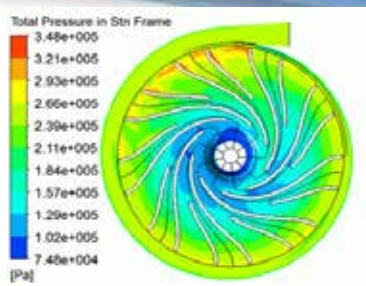
CO_2 Injection System

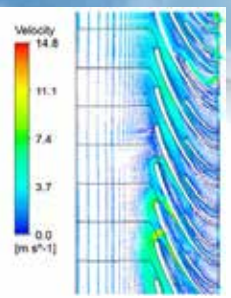
Pressuring pump





전체 시스템



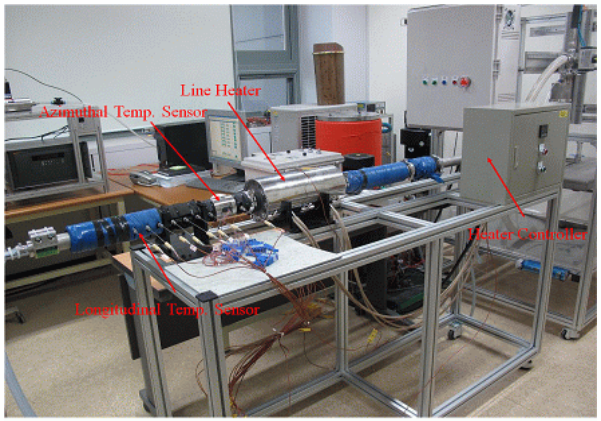


Booster pump

펌프 전력계

히터 전력계

10,000tCO_2/yr Pilot Injection System



Line Heater

Lab-scale Wellhead

- NPSH(Net Positive Suction Head, 유효흡입수두)

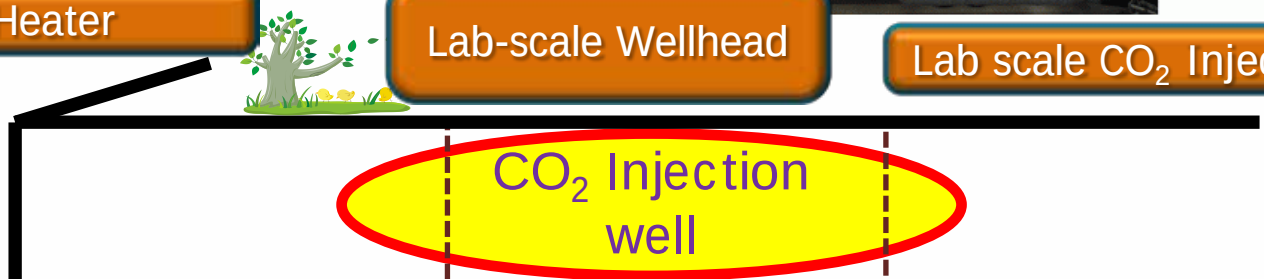
전압 = 동압 + 정압

$$P_t = \frac{1}{2}\rho v^2 + P_s$$

Ps > NPSH에 해당하는 압력

정압에 의한 수두가 NPSH를 상회하도록 탱크높이를 설계함

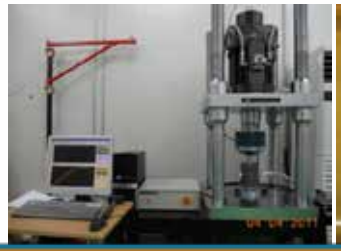
Lab scale CO_2 Injection system



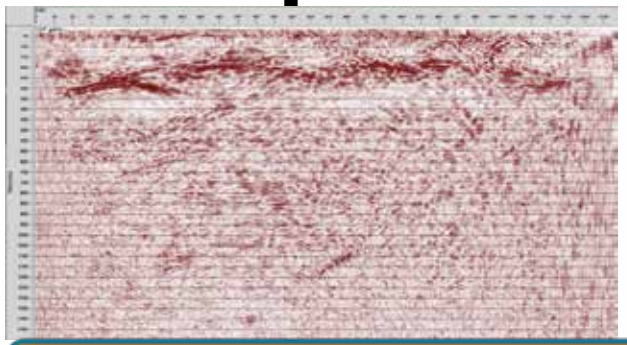
CO_2 Injection well

CO_2 injection well

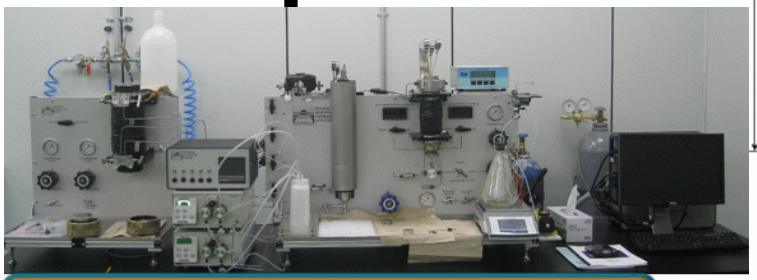
CO_2 Injection System



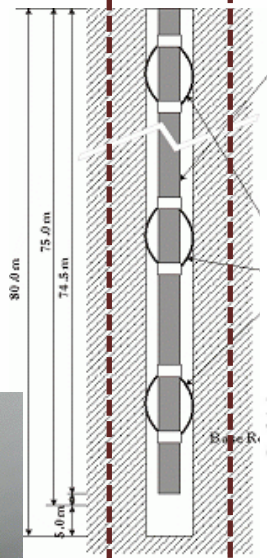
Evaluation of cement & grouting material

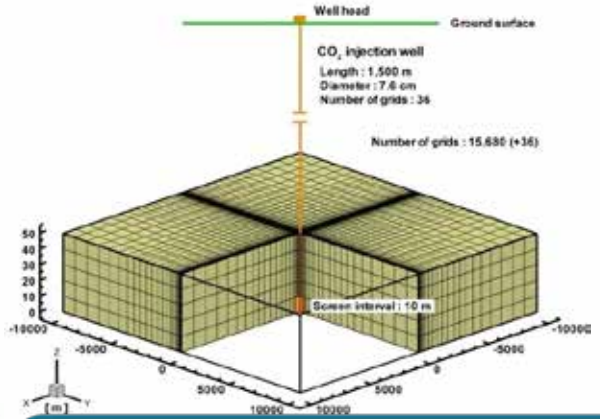


Seismic survey

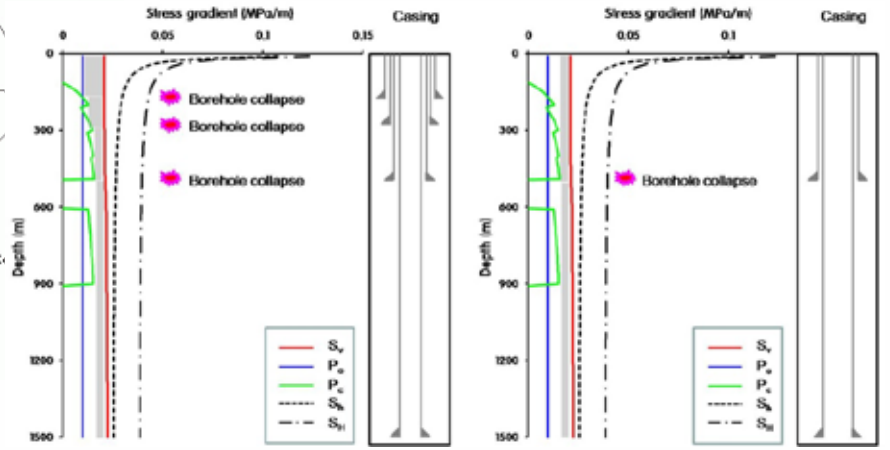


Test of multiphase fluid flow





TOUGHREACT(including ECO2N module)
T-H-C numerical modelling

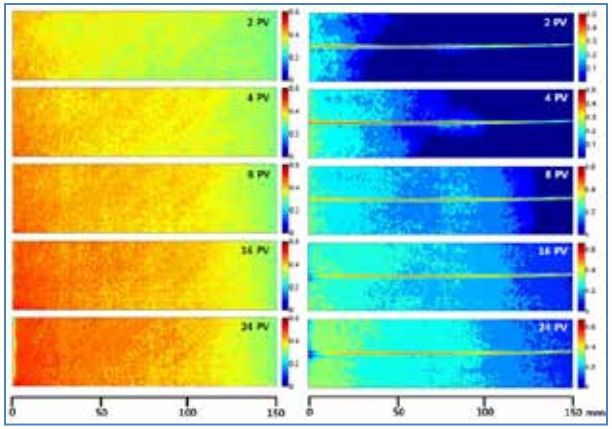


Determination of optimal drilling mud pressure

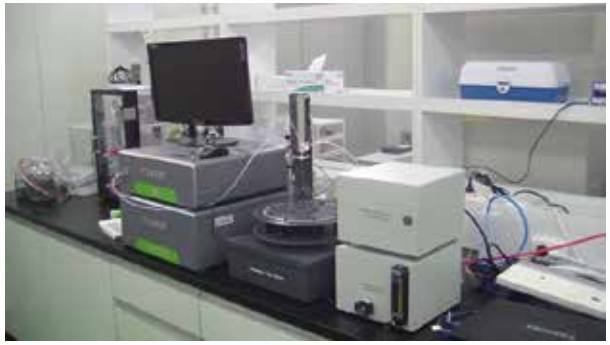
CO_2 Monitoring

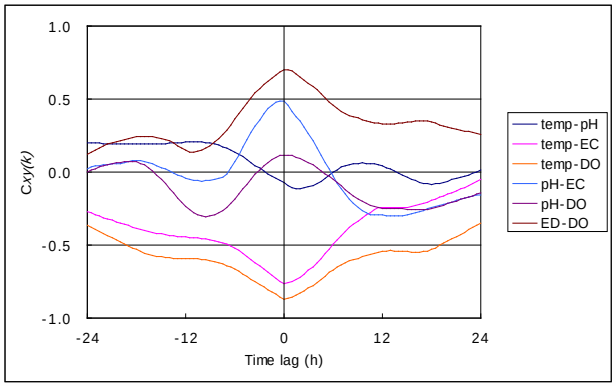
ü **New Project: Started this year as KIGAM's Basic Research Program**

1. Evaluation of underground CO_2 flow (based on X-ray core scanner measurement and numerical modeling)



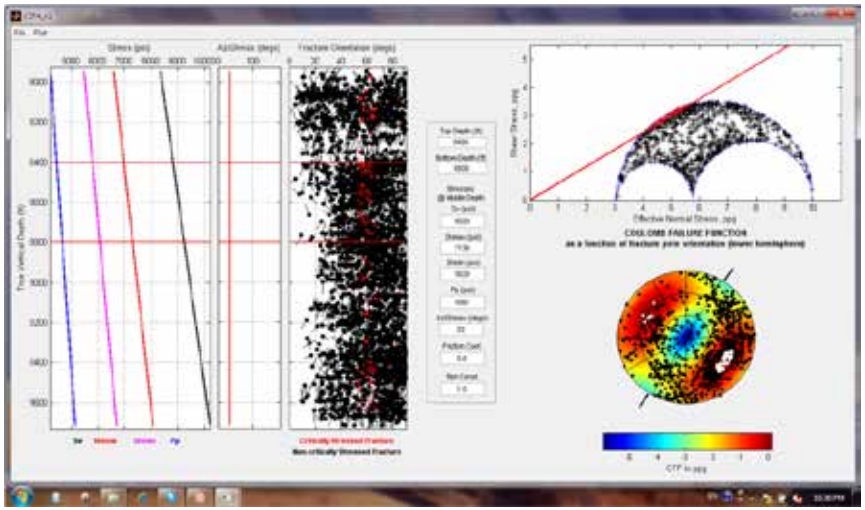
2. Geochemical monitoring: Analysis of carbon isotope and natural analogue study





3. Geophysical monitoring: Change of seismic wave(velocity, width) and reisistivity after CO_2 injection (Homotopy/viscoelastic modeling and Laboratory measurement)

4. Risk assessment through geomechanical study: Analysis of hydromechanical properties of fault rocks and evaluation of possibility of fault reactivation after CO_2 injection



International Cooperation

CO2CRC Otway Project
Canadian Aquistore Project

KIGAM Participates in Otway project as a International Cooperative Research Program

- Evaluation techniques of CO_2 storage site
- Geophysical CO_2 monitoring technique
- Modeling technique for CO_2 storage optimization
- Evaluation technique of injection well & storage system stability

Site evaluation

ü **Evaluating techniques of variable physical properties for CO_2 storage demonstration**

- Evaluation of CO_2 reservoir & cap rock
- Physical properties related with capacity, injectivity and containment

ü **Analysis of CRC- 2 core (February, 2010)**

- Porosity and void ratio
- Permeability
- Water content
- P and S wave velocity
- Electric conductivity
- Gamma density
- Magnetic susceptibility and its anisotropy
- Thermal conductivity
- Grain size distribution
- Rock texture
- Strain analysis
- Rock density
- XRD analysis for petro chemistry
- Pore-water analysis

Monitoring, modeling, operation

Otway Project

- ü **Geophysical Monitoring**
  - 4D seismic time-lapse CO_2 monitoring (acquisition/processing/interpretation)
- ü **CO_2 Storage Modeling**
  - Geological modeling for reservoir characterization
  - Reservoir simulation for injection optimization and monitoring
- ü **Management of whole CO_2 storage process (characterization-injection planning-operation, monitoring) using real field data**

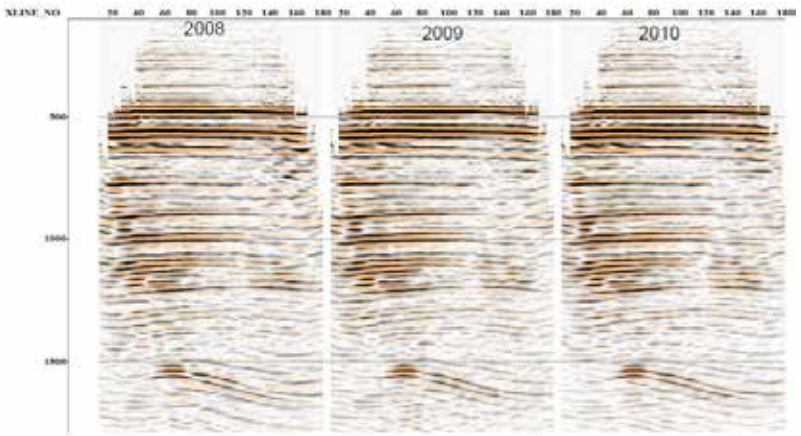
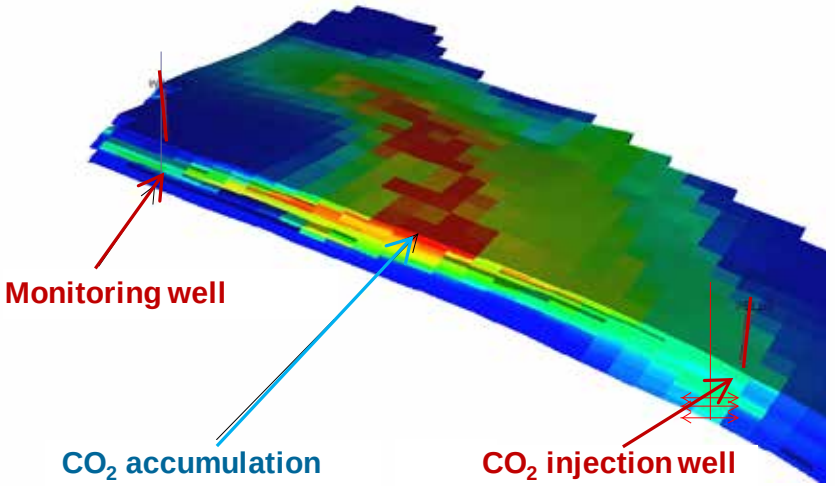


Figure 8: Baseline 2008, monitor I (2009) and II (2010) survey cross-equalised

Otway 4D Seismic Monitoring Data



J. Ennis-King

Participation of KIGAM

Otway Project

Geochemical monitoring

Geophysical monitoring

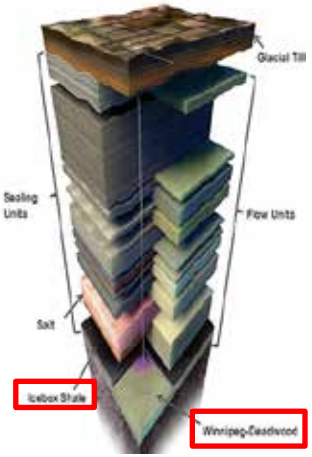
Coring

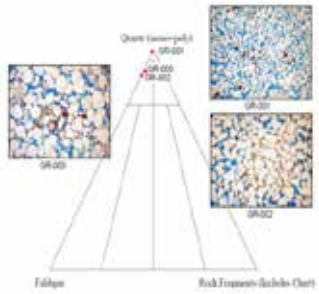
Residual saturation

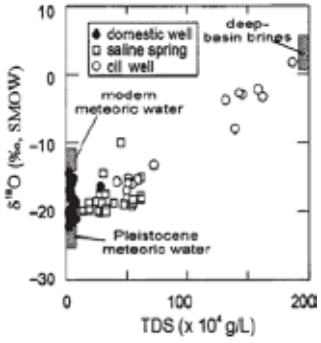
Outline

Aquistore Project

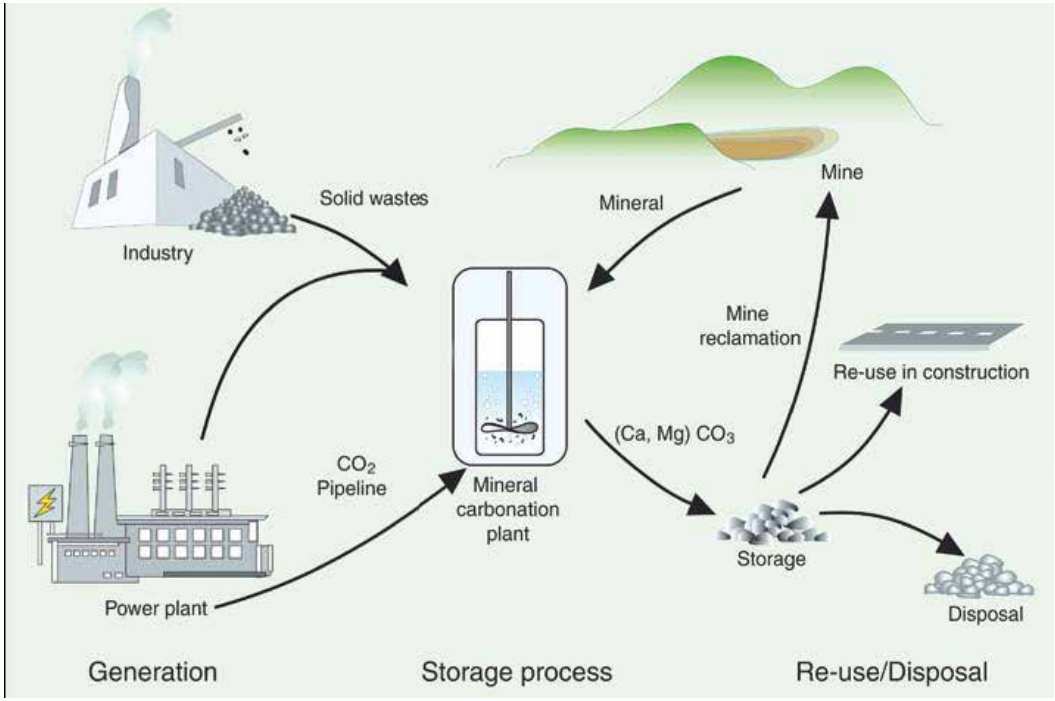
- ü **Integrated CCS Project managed by PTRC(Petroleum Technology Research Center), Canada**
- ü **The target basin is a Williston Basin at Saskatchewan, Canada.**
- ü **KNOC and KIGAM participate in this project**
  1. **3D geological modeling**
  2. **Petrographic analysis of core**
  3. **Seismic processing and interpretation**
  4. **Geochemical analysis of groundwater(background)**







Mineral Carbonation Using Industrial Wastes



CHARACTERISTICS

- Is safe and eternal, no monitoring is needed .
- Can reduce CO_2 and industrial wastes at the same time.
- May be economical if we can reutilize byproducts(carbonate and ammonium sulfate).

- Requires much energy, because carbonation occurs at high temperature.
- Is limited in amount of CO_2 reduction.
- May require large space for disposal if we fail to reutilize byproducts.

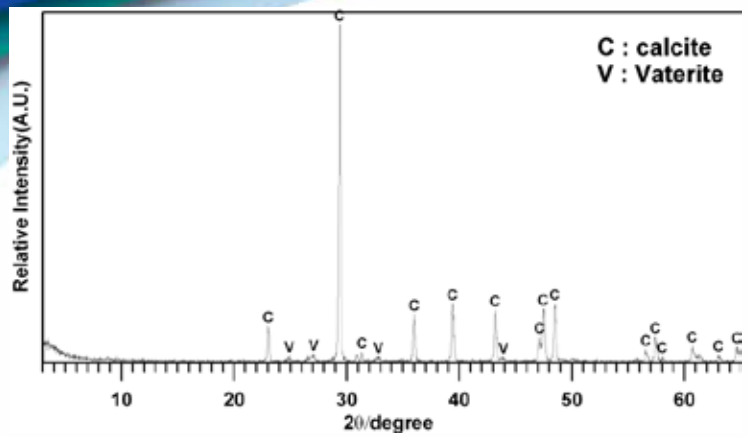
PRESENT STATE

Mineral carbonation

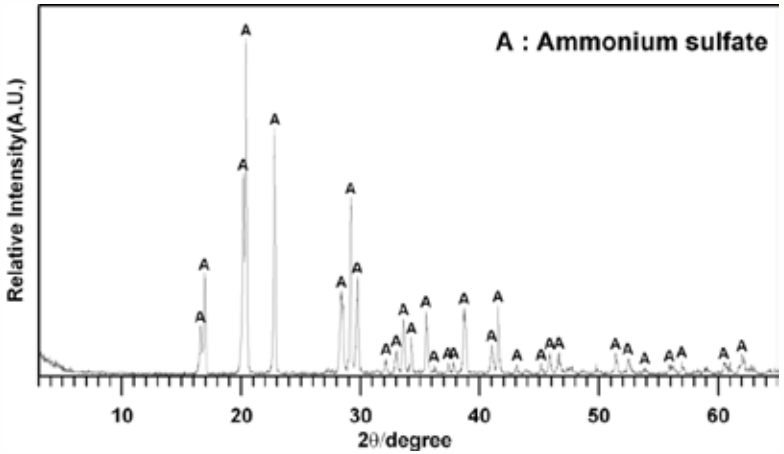
1. Optimization of mineral carbonation process using industrial wastes (gypsum, steel slag, cement and others)
2. Optimization of mineral carbonation process using natural rocks and minerals (serpentine, anorthosite and wollastonite)
3. Construction, operation, complementation of bench-scale mineral carbonation pilot plant
4. Reutilization of byproducts (calcite, ammonium sulfate)

Byproduct: calcite & ammonium sulfate

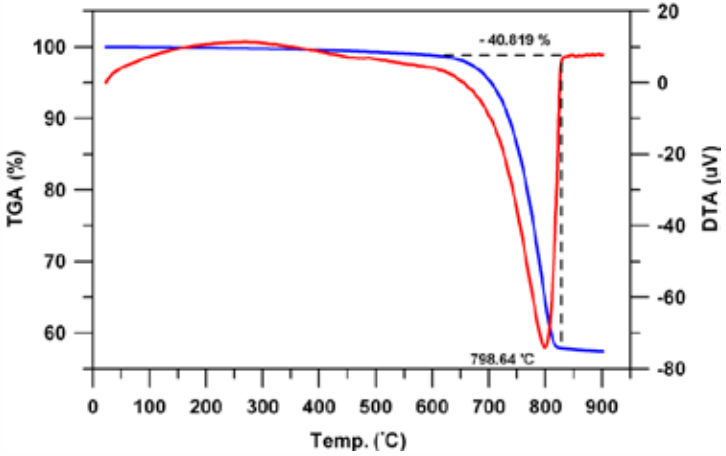
Mineral carbonation



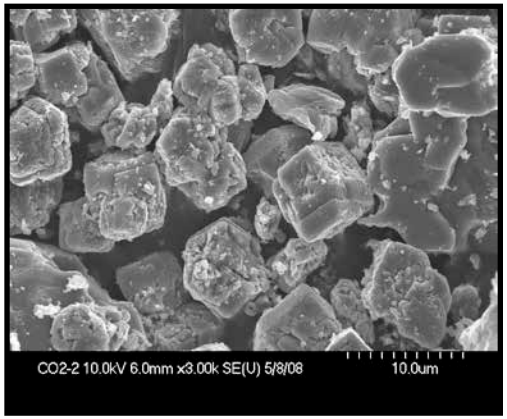
<XRD pattern of carbonation product>



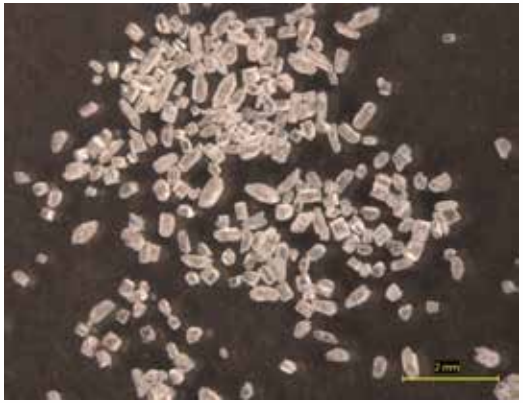
<XRD pattern of ammonium sulfate>



<TG-DTA result of carbonation product>
calcite purity: 93 %



calcite



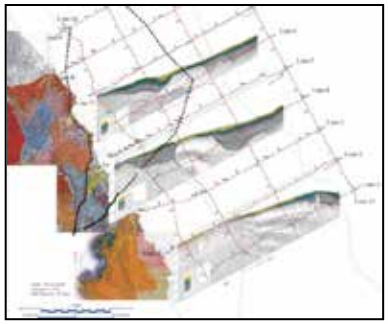
ammonium sulfate

Concluding Remark

MILESTONE

1. Pilot-scale demonstration of CO_2 storage until 2015
2. Commercial-scale demonstration of CO_2 storage until 2020
3. 10,000 ton-scale demonstration of carbonation until 2014

- ✓ Site screening and geological characterization
- ✓ CO_2 storage R&D (CO_2 injection and monitoring)
- ✓ International cooperation (Otway, Aquistore Projects)
- ✓ Mineral carbonation R&D



Thank You
For Your Attention!