Assessment of CO_2 Storage Capacity for Basalt Caprock - Sandstone Reservoir System in the northern East China Sea

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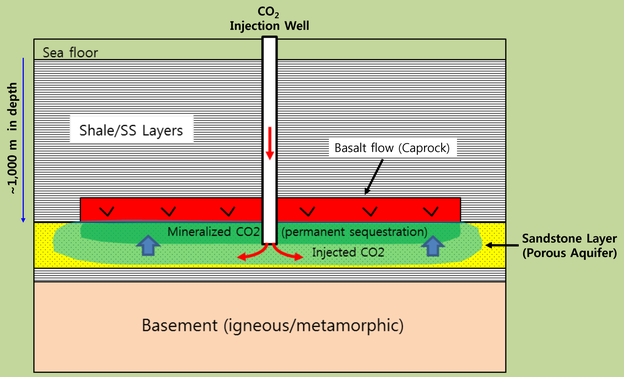
Moohee Kang (karl@kigam.re.kr), Jin Ho Kim, Kyong-O Kim, Snons Cheong, Young Jae Shinn
Korea Institute of Geoscience and Mineral Resources (KIGAM), Daejeon, South Korea

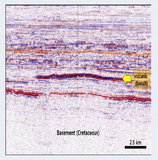
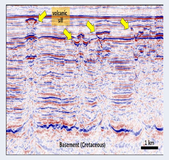
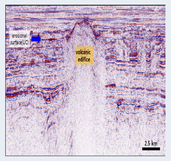
ABSTRACT

Estimation of carbon dioxide (CO_2) storage capacities in the northern East China Sea (ECS), which is one of the largest marginal seas in the world and divided into several deep sedimentary basins and basement highs, has been performed in basin scale using CO_2 storage efficiency. However, detailed studies on traps, caprocks and reservoirs, those are essential for the selection of CO_2 geological storage sites, are insufficient. We have identified a stratigraphic trap for potential CO_2 storage where sandstone reservoir is overlaid by basalt caprock on tectonically stable Cretaceous basement high of the northern ECS through analysis of 2D multichannel seismic and well data. The basalt formation forming anticlinal structure is located at about 1,000 m depth from the seafloor and distributes over about 84.9 km^2. Below the basalt formation, a high porous sandstone reservoir which is suitable for the efficient storage of CO_2 is developed with 60 ~ 100 m in thickness. 3D geological model is constructed for volume estimates of reservoir and reservoir property is derived from well-log evaluation. The estimated geologic CO_2 storage capacity for the potential sandstone reservoir covered by the basalt caprock ranges from 59.4 to 248.3 Mt of CO_2 with an average of 153.4 Mt of CO_2. Furthermore, we expect additional storage capacity for the basalt caprock-sandstone reservoir system because considerable amounts of CO_2 can be stored in basalt formation through mineral carbonization reactions as well as in conventional sandstone reservoir. A recent 2D seismic survey conducted in the northeastern part of ECS reveals that basaltic rocks are distributed in large area (~680 km^2). Therefore, the basaltic formations are expected to be utilized either as sealing caprocks or as permanent sequestration reservoirs by mineralization for CO_2 geological storage in this region.

Concept of CO_2 Sequestration at Basalt Caprock-Sandstone Reservoir System



Cartoon showing schematic of CO_2 sequestration at basalt caprock-sandstone reservoir system

Type	Volcanic(Basalt) Flow	Volcanic Sill	Volcanic Edifice
Shape	massive sheet	mound/bowl	massive stock
Seismic Profile			
CCS Potential	O	X	X

Typical forms of volcanic features developed in the northern East China Sea

REGIONAL GEOLOGY & STATIGRAPHY

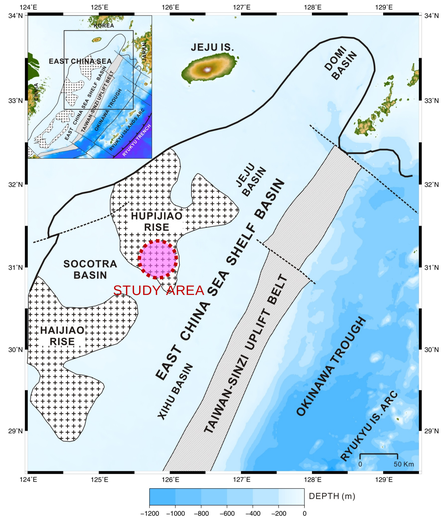


Figure 1. Structural and tectonic elements of the northern East China Sea (Zhou et al., 1989; Pigott et al., 2013)

Time Structure Map

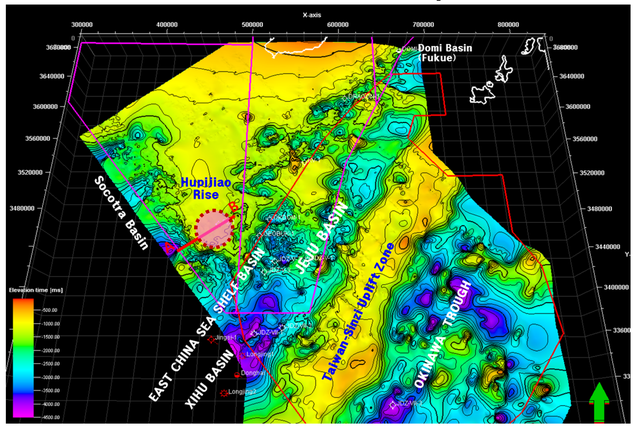


Figure 2. Time structure map of MB1(top of acoustic basement) in the northern East China Sea. The northern East China Sea is composed of several deep sedimentary basins and structural highs such as Okinawa Trough, Xihu, Jeju and Socotra basins, and Taiwan-Sinzi uplift belt, Haijiao and Hupijiao rises.

Table. Summary of stratigraphy and dominant lithology of the northern East China Sea.

Geologic Age \ Area		East China Sea Xihu Basin (West. Art/Core Labo., 1994)	N. East China Sea (Jeju Basin) KIGAM(1997)	This Study	Seismic Horizons (Megasequences)
PLEISTOCENE		Donghai G.	Mudstone Sandstone	Mudstone Sandstone	4
PLIOCENE		Santan F.			Orange Horizon (Top Miocene)
MIOCENE	LATE	Liulang F.			
	MIDDLE	Yuquan F.	Mudstone Sandstone (w / coals)	Mudstone Sandstone (w / coals)	3
	EARLY	Longjing F.	Mudstone Sandstone (w / coals)		Green Horizon (Top Oligocene)
OLIGOCENE		Huangang F.	Mudstone Sandstone Pyroclastics	Mudstone Sandstone (w / coals)	2
					Blue Horizon (Top Eocene)
EOCENE		Pinghu F.		Mudstone Sandstone Pyroclastics	1
PALEOCENE		?	?	?	
CRETACEOUS		Granite	Granite	Granite	Red Horizon (Top Basement)

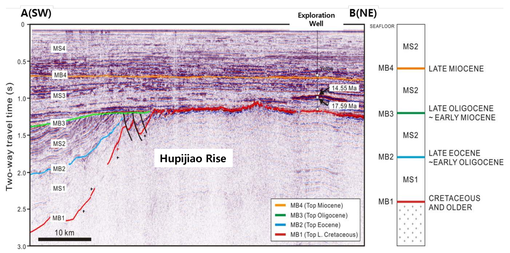


Figure 3. Seismic reflection profile showing major unconformities and megasequences of the northern East China Sea. See Figure 2 for location.

INTERPRETATION SEISMIC & WELL DATA

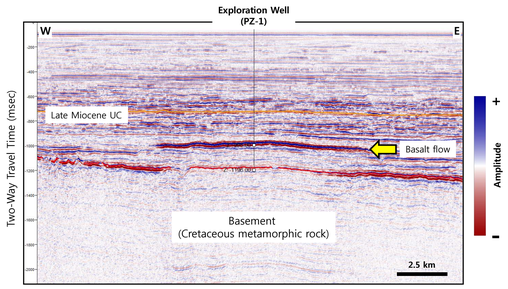


Figure 4. 2D seismic profile crossing PZ-1 exploration well on Hupijiao Rise of the northern East China Sea. Relatively high amplitude reflector in the middle of section is associated with basalt flow.

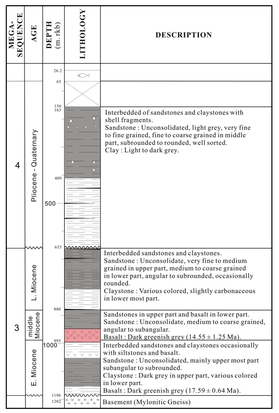


Figure 5. Geological summary of PZ-1 exploration well spudded in 1983.

Well Log Analysis

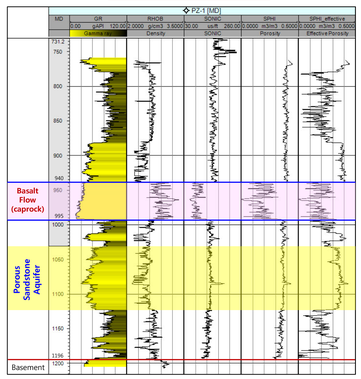


Figure 6. Well log analysis of PZ-1(gamma ray, density, Vp, total porosity derived from density log, and effective porosity corrected for shale effect).

Interval Velocity

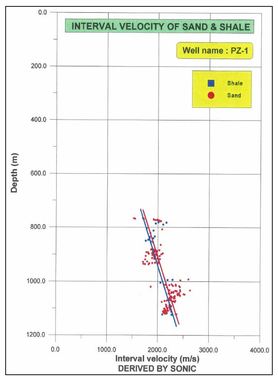


Figure 7. Interval velocity of sand/shale vs. depth plot of PZ-1 well (KIGAM, 1997).

Temperature & Pressure

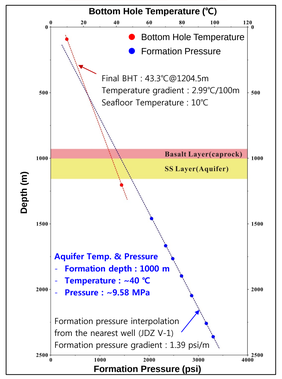
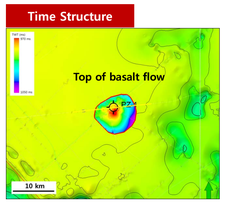


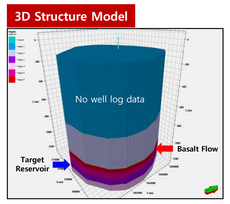
Figure 8. Interpolation of bottom hole temperature(BHT) and formation pressure of the SS layer (aquifer).

3D GEOLOGICAL MODEL & STORAGE CAPACITY ESTIMATION

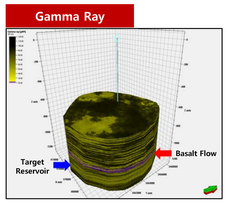
Time Structure



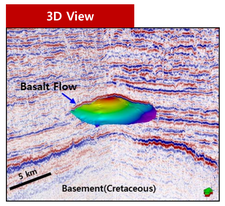
3D Structure Model



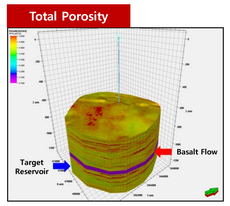
Gamma Ray



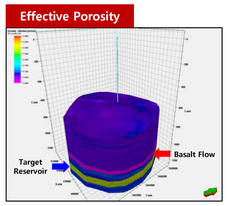
3D View



Total Porosity



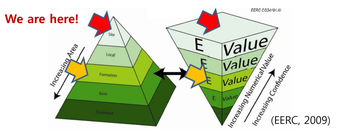
Effective Porosity



Estimating CO_2 Storage Capacity

Parameters	Site Specific Value
Reservoir Area with Caprock	~84,900,000 m^2 (84.9 km^2)
Storage Thickness	60~100 m
Storage Volume	~6,800,000,000 m^3
Storage Total Porosity	~40 %
Storage Effective Porosity	~29 %
Storage Pressure	~9.58 MPa
Storage Temperature	~40 ℃
Density of CO_2	700 kg/m^3
Storage coefficient*(EERC, 2009)	0.04~0.17
Min. Storage Capacity	~59.4 Mt CO_2
Max. Storage Capacity	~248.3 Mt CO_2
Storage Capacity (Average)	**153.4 Mt CO_2**

* Storage coefficient at Site-Specific level (EERC, 2009)



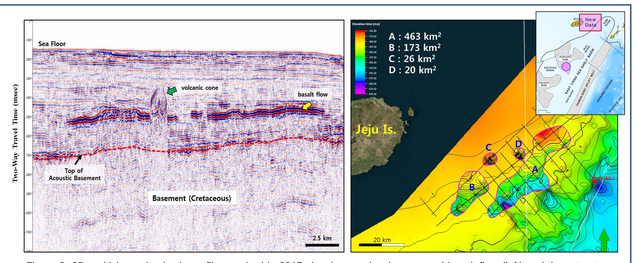


Figure 9. 2D multichannel seismic profile acquired in 2017 showing a volcanic cone and basalt flow (left) and time structure map of the top of basalt flow (right). The basalt flow distributes over ~680 km^2 in the northeastern part of East China Sea.

CONCLUSION

- **Through the analysis of 2D seismic and exploration well data, we identified a CO_2 storage potential stratigraphic trap where sandstone reservoir overlaid by basalt in the northern East China Sea. The estimated CO_2 storage capacity of the trap ranges from 59.4 to 248.3 Mt of CO_2 (average 153.4 Mt).**
- **New seismic data reveals that basalt covers large area (~680 km^2) in the northeastern part of ECS. Basalt formations are expected to be utilized either as sealing caprocks or as permanent sequestration reservoirs by mineralization for CO_2 storage in this region.**